H. T. HARVEY & ASSOCIATES
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Hawaiian Hoary Bat Research, Maui
Final Report 2019

Project #3978-01

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Abstract

This research project supports two of the goals presented by the Endangered Species Recovery Committee for the recovery of the federally and state endangered Hawaiian hoary bat (*Lasiurus semotus*): (1) conducting basic ecological research; and (2) identifying limiting factors to the population status of the species on Hawai‘i. In support of basic ecological research, we determined habitat preferences through long-term acoustic monitoring; measured the foraging range (FR), core-use area (CUA) as measurements of home ranges, assessed relative prey availability in habitats of the study area; and determined the diets of bats based on the DNA barcoding of insect fragments from guano. To assist with identifying limiting factors to the population status of this species in Hawaii, we identified habitats that contained relatively low bat activity. A better understanding of these habitat preferences, home ranges, and diet is critical in determining how to restore habitat to better promote the recovery of this species.

The study area encompassed 34,226 hectares on the north-facing and windward slopes of Haleakala on the island of Maui, Hawai‘i, and contained nine habitat types: agricultural vegetation, high-density developed, low-density developed, forest woodland low elevation, forest woodland upper elevation, grassland, gulch, shrubland, and sparse vegetation. From September 2017 through September 2018 we collected acoustic monitoring data with a sampling schematic utilizing nine bat detectors that were moved to new sites in the nine habitat types five times every other month. Thus, we installed bat detectors at 45 sites in the nine habitat types for a total of 315 deployments. We used the General Random Tessellation Stratified survey design to select the sites for acoustic monitoring across the nine habitat types. We determined the number of calls per night, the minutes with bat calls (call minutes), and the total number of feeding buzzes. After we finalized the habitat type definitions, we completed a trial power analysis of the first month's data and found differences in habitat use to be highly significant at a level of $\alpha = 0.05$ ($P < 0.0001$). This finding, which supported the alternative hypothesis of differences in habitat use by bats, gave us confidence to continue with our acoustic monitoring approach. We mist netted on 78 nights from June 2017 through September 2018 in three general areas: Haleakala National Park, Olinda Road, and Lower Kula to capture bats during summer and winter periods. Captured bats were radio-tracked using two or more handheld Yagi antennas to determine their locations through triangulation. Our team radio-tracked 16 bats on 109 nights during the mist netting period. We calculated the 95% kernel (FRs) and 50% kernel (CUAs) in R and determined mean ± SE 95% and 50% kernel areas for bats in our study. Additionally, we calculated the areas for the 95% and 50% kernel using the methods given in Bonaccorso et al. (2015) in order to attempt comparing the results of our kernel analysis of Maui bats and the bats from the Island of Hawaii. We sampled insects using extra tall blacklight traps in each of the nine habitat types for seven sampling periods from August 2017 through August 2018.

On the basis of the number of search calls and feeding buzzes in our acoustic data, bats spent more time foraging in gulch, low-density developed, and grassland habitats, although differences existed between months. Based on data from the 315 sites, we found habitat type to be highly significant at a level of $\alpha = 0.05$ ($P < 0.01$). The 50% kernel analysis determined the mean CUA was 3,991 hectares and the mean 95% kernel analysis found that the foraging range was 17,362 hectares. The majority of guano samples were collected from adult males

(n=7), followed by adult females (n=2) and subadult females (n=2). Bats ate primarily moths (68%), as well as flies (12%), termites (9%), crickets and katydids (5%), beetles (4%), and true bugs (2%). Insects eaten were both native and nonnative, and the dietary data suggest that bats were somewhat selective in prey species given the abundance of particular species found in the insect samples but not consumed. We found significant differences in the availability of prey based on the differences in the dry weights of insects collected in each of the habitat types from August 2017 through August 2018. The agricultural vegetation, grassland, and low-density developed habitats had the highest values for dry weight samples, followed by the gulch, shrubland, and sparse vesicular rock habitats. The lowest values for dry weight samples were from the forest woodland (low and upper elevation) and high-density developed habitats.

We identified a strong negative correlation between rainfall and the number of bat calls per night. To control for the effects of storm events we omitted nights when rainfall was greater than or equal to 5 millimeters from our dataset for the analysis. We found that bat activity was generally highest in gulch, low-density developed, and grassland habitats, and lowest in forest woodland habitats. Our findings contrast with the results of Hawaiian hoary bat studies on the island of Hawai'i, which found that bats foraged primarily in mature native and nonnative habitat, including macadamia nut (*Macadamia integrifolia*) orchards. Maui's forests comprised mostly monoculture nonnative forests (e.g., Monterey pine [*Pinus radiata*]) and only limited areas with native forest trees were present in our study area. We also found major differences between the CUAs and FRs for the bats we radio-tracked on Maui and the bats radio-tracked on the island of Hawaiʻi. Our mean CUA for bats on Maui was 3,700 hectares, and the CUA for bats on the island of Hawaiʻi was 25.5 hectares. Our data also suggest foraging flexibility in the species with the use of habitat types changing during different seasons.

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Section 1. Background

This research project supports two of the goals presented by the Endangered Species Recovery Committee for the recovery of the Hawaiian hoary bat (*Lasiurus semotus*): (1) conducting basic ecological research; and (2) identifying limiting factors to the population status of the species on Hawaiʻi. In support of basic ecological research, we measured the foraging range, core-use area (CUA), and long axis of home ranges in our primary study area (Figure 1), and compared those data with the measurements of home ranges determined by U.S. Geological Survey (USGS) studies on the island of Hawaiʻi (Bonaccorso et al. 2015), and H. T. Harvey & Associates studies on Oahu (H. T. Harvey & Associates 2014). We are now using the scientific name *Lasiurus semotus* in recognition of the Hawaiian hoary bat as a unique species based on recent work by Simmons and Cirranello (2020).

We studied some of the potential limiting factors that influence populations of the Hawaiian hoary bat, namely whether there is suitable habitat and available food. In addition to determining if bats foraged in habitats in our study area, we also determined whether bats spent different amounts of time in various habitats over the course of four seasons. We were not able to study predation risks because too many of the roosts were located in inaccessible sites such as some of the gulches. Our multifaceted study provides the means to identify between 100 and 200 species of prey that are available to bats, determine which insect species the bats consume, and determine whether populations of the Hawaiian hoary bat are indeed limited by food resources in at least parts of their range. We anticipated that in our study area the availability of prey would not be uniformly distributed over space and time and that we would find areas that had limited potential food resources for the Hawaiian hoary bat. In a study in rural Missouri, where bats' home ranges encompassed fragmented habitats, Womack et al. (2013) found that bats' home range sizes may be influenced by the distribution of prey. Habitat fragmentation occurs throughout much of the Hawaiian Islands, including in our study area, and we therefore expected similar results—that bats' CUAs will be influenced by the fragmented nature of the suitable habitats.

The results of our basic ecological research were intended to help guide and assist conservation efforts leading to the recovery of the Hawaiian hoary bat. This report provides a synthesis of our research from the first 2 years (2017 and 2018) of field work and the 2019 analyses of data and DNA barcoding of prey found in bats' guano. Thus, this report provides valuable information on which habitats are used by the species at different times of the year, the size and locations of CUAs, and a list of insects that the bats are eating. By better understanding these metrics, important habitats can be conserved and restoration areas can include host plants of insects known to be eaten by the Hawaiian hoary bat.

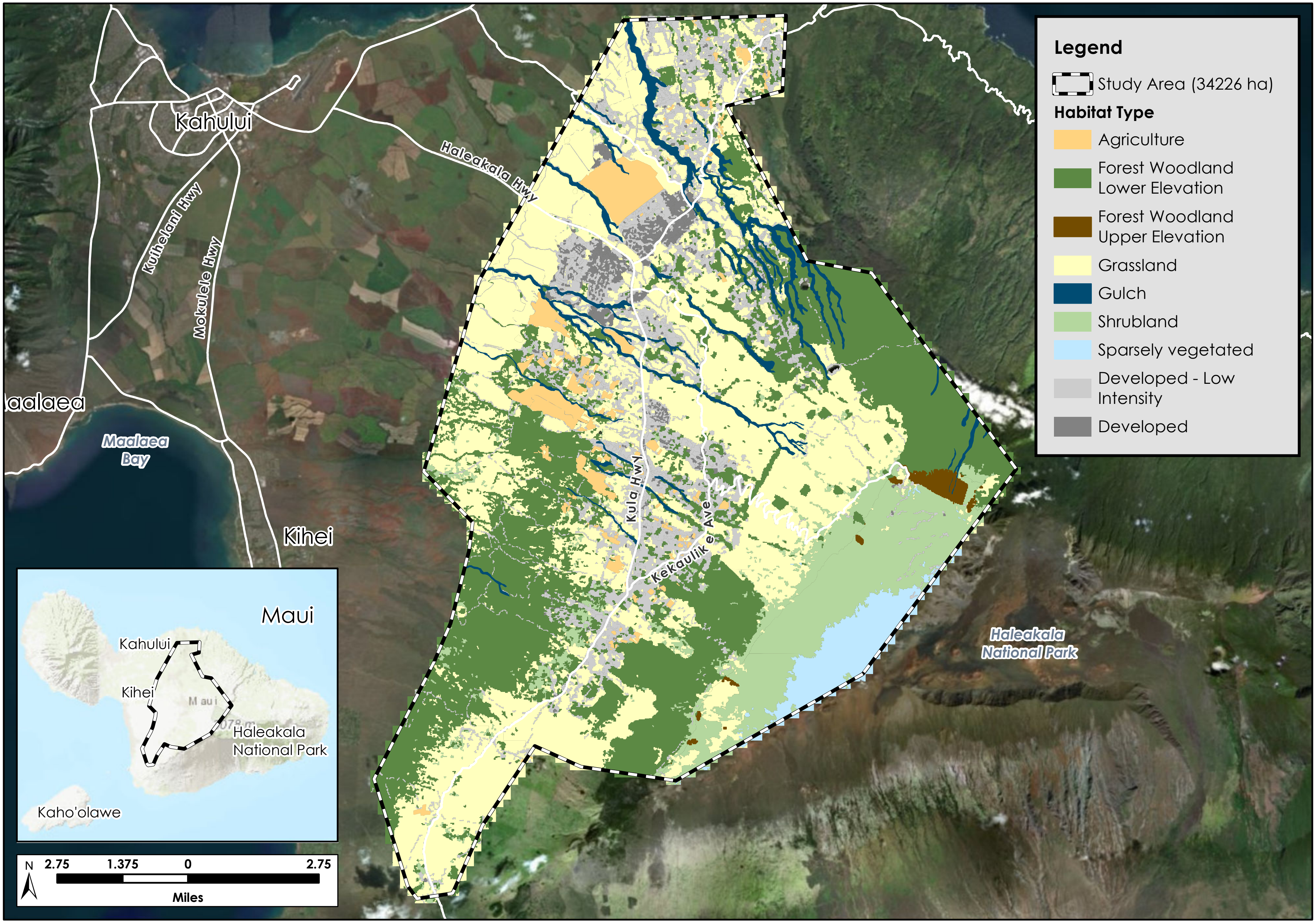

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Figure 1. Study Area and Habitats
Ecology of the Hawaiian Hoary Bat (3978-0
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Section 2. Methods

2.1 Study Area and Habitat Descriptions

The study area consists of 34,226 hectares on the north-facing leeward and windward slopes of Haleakala extending to the summit on the island of Maui, Hawaiʻi (Figure 1). This study area was chosen because of the general accessibility of many areas by vehicular roads and pedestrian trails, the reasonable density of known bat records, and the diversity of habitats that extend from about 200 meters North American Vertical Datum 88 NAVD88 in the valley up to the Haleakala Ridge at about 3,000 meters NAVD88. Included in the study area are a variety of land covers, and with the exception of the category Gulch, are based on the Hawaii Department of Agriculture land cover designations. Gulch habitat was added as a separate habitat when we realized that bats were often concentrating their foraging behavior in some gulches, which had not been designated as a land cover by the Hawaii Department of Agriculture.

Table 1. Habitat Descriptions

Habitat Abbreviation	Name	Notes about the Habitat
AV	Agricultural Vegetation	small- to large-scale farms containing at least some planted crops and/or fruit trees, but not animal agriculture
DevH	High Density Develop	Makawao, Pukalani, Haliimaile, and a few densely populated areas of Kula (including within the larger school campuses).
DevL	Low Density Develop	Rural with manicured landscapes and a greater density of buildings and artificial lighting.
Fwl	Forest Woodland Low	Forest woodland less than 2,000 meters asl
FWU	Forest Woodland Upper	Forest woodland greater than 2,000 meters asl
Grass	Grassland	Habitat dominated with open grasslands
Gulch	Gulch	Incised geographical features with $\geq$ 100% slope and $\geq$ 10 meters deep
Shrub	Shrubland	Mostly contiguous growth $\leq$ 2 meters high
SV	Sparse Vesicular rock	Areas comprising mostly lava flows

2.2 Habitat Descriptions and Definitions

The habitat type ISNV (introduced semi-natural vegetation) described nearly all forested habitat types but was not a useful distinction from FW (forested woodland). Intact Native Forest was considered as a habitat type. However, too few sites were accessible for sampling because of their distance to vehicular access and because these areas comprised only a very small percentage of the forested areas within our study area. Therefore, we divided the forested areas into two groups, and the lower forests (FWL) in our study area consisted of Makawao Forest Reserve, Waihou Spring Forest Reserve and the surrounding forested areas, Kula Forest Reserve, and

Polipoli Spring State Recreation Area. The upper forests (FWU) consisted of Waikamoi, Hosmer's Grove, the forest behind the Park RM building and the eucalyptus (Eucalyptus sp.) grove at approximately 8,500 feet asl in Haleakala National Park. Grassland areas in our study area were somewhat constrained because we did not have access to Haleakala Ranch and Kaonoulu Ranch lands. We did not make a distinction between grazed and ungrazed grasslands but because many "pastures" in Hawai'i include trees; however, we did decide that there should be no, or very few trees within a grassland to use it as a sample site. For gulches, we positioned detectors on the edge of the gulch facing in, not blocked by vegetation so that they would have a vantage point into the gulch. Gulches were typically 30 meters deep and to be mapped as a habitat, this feature was not less than 10 meters deep from the top of bank to the bottom at a given point and with a slope of at least 100%. Shrub sites in our study area generally occurred in Haleakala National Park from the entrance station to just below the eucalyptus grove elevation (after which open areas become SV), along the lower elevation areas of Skyline Trail, and along Waipoli Road. SV in our study area only occurred in Haleakala National Park at the elevation of the eucalyptus grove and above, and in the upper elevation area along Skyline Trail.

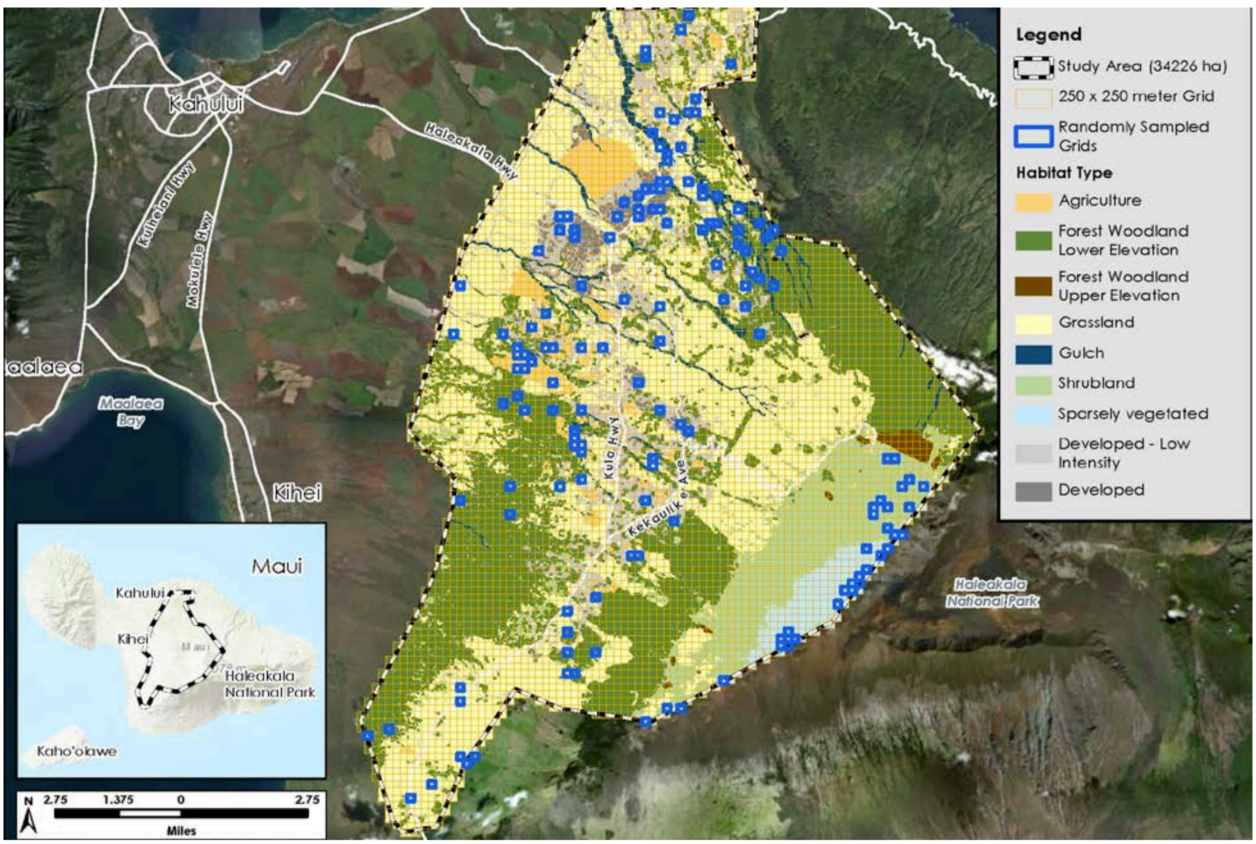


Figure 2. Study Area Showing Habitat Types, 250-meter Square Grid, and Randomly Sampled Sites.

2.3 Access to Private and Public Lands

Determining the land owners of 640 sample sites and gaining access to these sites was challenging. Many persons, especially Paul Conry of H. T. Harvey & Associates, Lance DeSilva of DOFAW, and Andrea Buckman of East Maui Watershed Collaborative. Through perseverance and a friendly approach we had great success working with agencies and private landowners. Additionally, staff have volunteered to do public outreach programs on the Hawaiian hoary bat through schools. This outreach has also helped with public perception and general acceptance of placing bat detectors on private lands. Thus, an enormous investment of non-billed time was made in the community to help gain access to private lands. Nonetheless, some large landowners chose not to allow access to non-conservation areas which limited our access to some portions of our study area.

2.4 Acoustic Monitoring and Modelling of Acoustic Data

From September 2017 through September 2018, we collected acoustic monitoring data with a sampling schematic utilizing nine bat detectors moved to new sites within each of the nine habitat types five times every other month. Bat detectors were left at each site for 3 nights. Thus, in each of the months of September and November 2017, and January, March, May, July, and September 2018, we deployed bat detectors at 45 sites in nine habitat types for a total of 315 deployments totaling 945 nights of bat detector data.

To control for temporal effects on bat activity, detectors in each habitat recorded simultaneously for 3 nights at each location from one hour before sunset until one hour after sunrise.

We used the General Random Tessellation Stratified survey design to select sites for acoustic monitoring across nine habitat types. A grid of 250-meter-square polygons were overlaid onto a map of habitats for the study area and sites were sampled based on a computer-generated random sampling (Figure 2). Accessible randomly selected sites were field-verified to determine that they met the criteria for each habitat type according to Table 1 before deploying acoustic monitoring equipment. In cases where sites did not meet these criteria or were inaccessible, the nearest accessible randomly selected sites meeting the habitat criteria were used.

Table 2. Criteria for Detector Deployment

Habitat	Minimum Criteria for Detector Deployment
AV	minimum of 100 square meters (m^2)of planted agriculture
DevH	minimum density of roads/buildings determined by GIS
DevL	maximum density of roads/buildings determined by GIS
FWL	forest and woodland low elevation/forest and woodland below 2,000 m elevation
FWU	forest and woodland upper elevation/forest and woodland above 2,000 m elevation
Grass	minimum of 100 m^2 of grazed or ungrazed pasture containing no/few trees/shrubs
Gulch	minimum of 10 m drop from edge to center of gulch
Shrub	minimum of 100 m^2 of landscape dominated by shrubs containing no/few trees
SV	minimum of 100 m^2 of bare or mostly bare rock

We used Song Meter SM4Bat FS (full spectrum) Bioacoustics Recorders (Wildlife Acoustics Inc., Maynard, Massachusetts, USA) bat detectors with SMM-U1 Ultrasonic Microphones. Audio recording settings were as follows: gain 12dB, 16 kiloHertz (kHz) high-pass filter off, sampling rate 256 kHz, minimum duration 1.5 milliseconds, no maximum duration, minimum trigger frequency 16 kHz, trigger level 12 dB, trigger window 3 seconds, max length 15 seconds. These settings differ from the recommended settings suggested by Gorresen et al. (2017) because many of the SM2Bat+ settings used in this reference are not available options on the newer SM4Bat models. Additionally, the SM4Bat FS equipped with the SMM-U1 microphone has superior sensitivity and signal-to-noise ratio compared with the older SM2Bat+ and SMX-US microphones. The 16 kHz high-pass filter was turned off because it actually cuts off calls at 20 kHz and social calls of the species are often below 16 kHz. The sampling rate was increased to 256 kHz because SD card capacity was not limiting, but increased fidelity of recordings would be of benefit for playback calls during mist netting. The max file duration was set to 15 seconds to be consistent with other recording protocols, including those using SD2 Anabat bat detectors (Titley Electronics, Australia).

All recorded files were manually analyzed in Avisoft Sound Analysis and Synthesis Laboratory (SASLab) Pro version 5.2 (Avisoft Bioacoustics, Berlin, DE). The settings used for analysis in SASLab were as follows: FFT Length 1024, frame 100%, Hamming window, and threshold intensity 50.

Recorded files were first analyzed for presence of bat echolocation pulses. To produce a standard, reliable method for quantifying bat activity without artificially increasing the importance of individual events containing many echolocation pulses, each file containing two or more bat echolocation pulses was classified as one bat call. Each file containing zero or one bat echolocation pulse was classified as no bat calls and removed from further analysis. Therefore we recorded the number of files (bat calls) containing two or more bat echolocation pulses. To further reduce inflation of activity caused by a single bat creating multiple bat calls within a short time frame, we removed duplicate calls timestamped with the same minute, so that each minute would either have one or zero calls. Thus, we also recorded the number of minutes with bat calls (call minutes). In addition to bat calls and call minutes, we also recorded the number of files with feeding buzzes (feeding buzzes). Because most bat acoustic studies in Hawai'i use the number of calls per night, we used this latter metric in our final statistical analyses of our data.

2.4.1 Statistical Analyses

With final definitions of our habitats we conducted a power analysis for the 250 x 250 meter squares to ensure that we would be able to compare habitat use among habitat types based on our sampling regime. With a sampling schematic utilizing 9 bat detectors moved to new sites within habitats over a 5-night period (a repeated measure), we found habitat to be highly significant at a significance level of $\alpha = 0.05$ ($P < 0.0001$). Utilizing generalized linear mixed model power simulation, our power to detect a difference between habitats with this sampling design was almost 100%, with a confidence interval of [99.63, 100] based on data from the month of July 2017 and the resulting 3,897 bat calls.

2.4.1.1 Dataset

Initially the 2017 dataset for acoustic dataset modelled well, but when the 2018 dataset was combined the model fell apart. To more efficiently proceed with the data analysis, we challenged some of our original assumptions that bat activity would not be adversely affected by precipitation events. In investigating the relationship between bat activity and precipitation, it became apparent that on nights when precipitation was high, bat activity was very low (Fig 3).

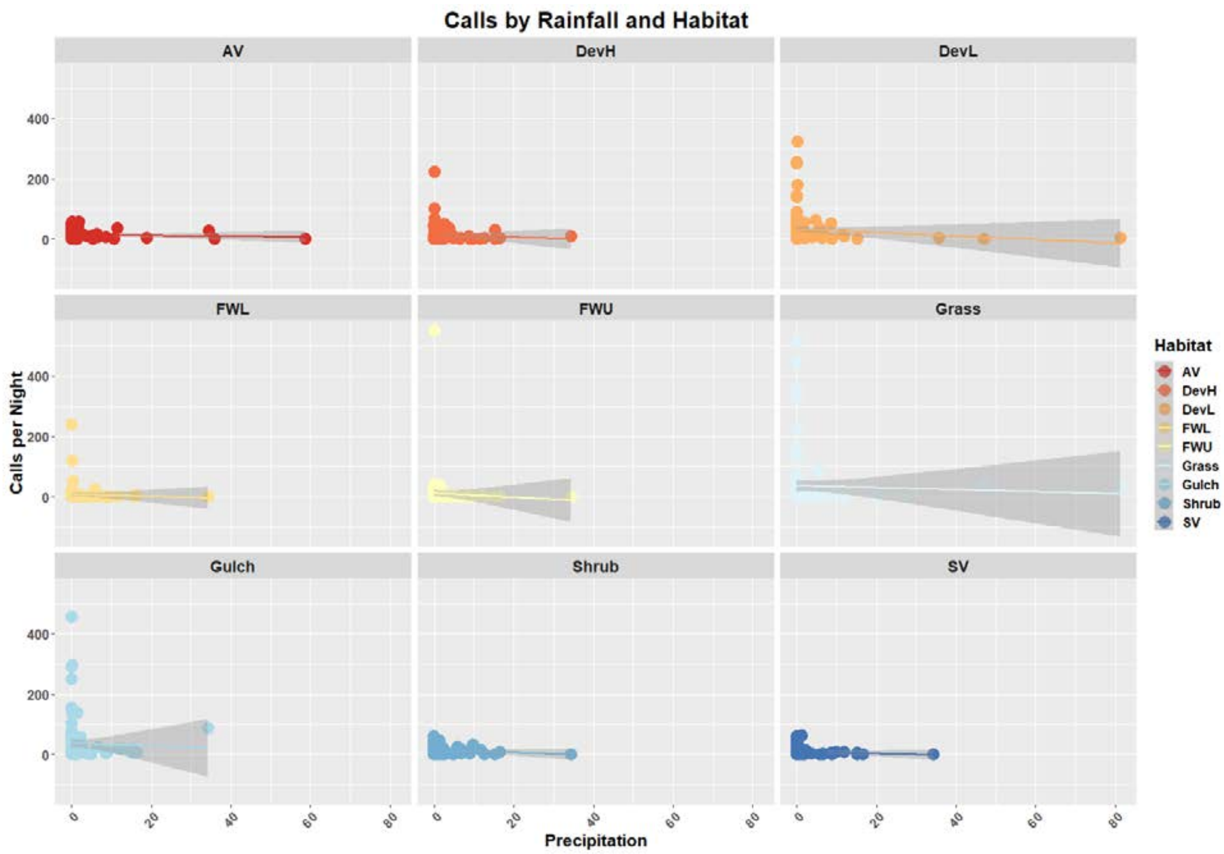


Figure 3. Relationship between Precipitation and the Nine Habitats in the Study Area.

Precipitation values in millimeters. Note that the number of calls/night drops to very low values after a few millimeters of precipitation.

Observations with any NA values were dropped from the analysis to encourage model convergence, and only the "max" values (the night with the highest number of bat call files out of the 3 nights of recording for each survey point) were retained in the final dataset, while any rows with precipitation higher than 5 millimeters were also removed. Original dataset contained 945 rows. The analysis dataset contained 283 rows. The resultant dataset had only 27 zeroes, as opposed to hundreds in the original dataset which was zero-inflated. The main issues in that dataset include non-normal distribution of the data, heterogeneity of variances among groups, potential for temporal autocorrelation, and an over dispersion in the response. The dataset is no longer zero-inflated.

When we removed data occurring when precipitation was greater than 5 millimeters, a better distribution of the points from left to right occurred, and we therefore removed the requirement to account for the effect of rainfall, at least when it is greater than 5 millimeters. Generally there are higher numbers of calls per night at lower precipitation levels, and the models worked better with this amount of spread in the data. Without removing nights with more than 5 millimeter of rainfall, the model resulted in a lack of model convergence or violations of modeling assumptions across a variety of modeling approaches.

We tested differences between the activity among the habitats by using a generalized linear model fit by maximum likelihood (LaPlace Approximation) with a negative binomial distribution (function glmer. nb, package lme 4; Bates et al. 2015), with date and site as random factors, and habitat as the fixed effect of interest. We added predictive parameters one at a time to the model, assessing the model fit and other model diagnostics after each run, including by checking patterns in the residuals overall and by predictor, testing normality of residual distribution and inspection of residual distribution plots, testing for collinearity among variables using variance inflation factors from the car package (Fox and Weisberg 2019) and by checking for model convergence and reasonable model estimates. To determine where significant differences existed across month and habitat combinations, we tested for differences between months within each habitat, and habitats within each month, using pairwise contrasts with a Tukey adjustment for comparing among estimates, by conditioning each factor type on the other (month on habitat, and habitat on month, respectively), with the emmeans package (Lenth 2016). Graphs and figures were generated using package ggplot2 (Wickham 2016).

2.5 Radio Tracking and Kernel Analysis

We mist netted for bat capture during summer 2017, winter 2017/2018, summer 2018, and winter 2018/2019. We used mist net sizes that varied from 2 meters by 3 meters (small) to 9 meters by 30 meters (macronets) that operate with a pulley system (Johnston 2000). At least three, and no more than five, mist nets were set. Additionally, a high definition acoustic lure (Ultra Sound Gate Player, Avisoft, Berlin, Germany) was used to help lure bats to nets. Each captured bat was weighed, the forearm length was measured, hair and tissue samples were taken, the sex, sexual condition, location, date of capture, and fur coloration were recorded. Each bat was outfitted with a BD-2T model radio-transmitter (Holohil Systems, Carp, Ontario, Canada). Fur between the shoulder blades was trimmed close to the skin and the transmitter was attached using Osto-Bond Skin Bond Latex Adhesive (Montreal Ostomy Inc., Vaudreuil-Dorion, Quebec, Canada). After allowing approximately 15 minutes for the adhesive to set, bats were released at the capture site. As radiotelemetry data on the night of capture would likely be influenced by the capture event, released bats were usually tracked for only a few minutes to obtain a bearing of disappearance or until roosting. This first night of data was not used to generate FRs and CUAs.

We used R-1000 Telemetry Receivers with hand-held 3- and 5-element Yagi antennas (Communications Specialists, Inc., Orange, California) to triangulate the locations of both roosting and moving bats. Triangulations were produced with two to three observers, each in a different GPS-recorded location, recording bearings in the direction of the strongest radiotelemetry signal strength using magnetic compasses. As Hawaiian hoary bats fly at high speeds and often change direction quickly, bearings used for each triangulation were always done simultaneously (within one second of each other). Single-bearing determinations of location (Bonaccorso et al. 2015) were not used in our study.

Bonaccorso et al. (2015) used single-bearing determinations by calibrating signal strength (attenuation) and stated that this method is generally similar in accuracy to triangulations until a distance of 300 meters from the tracked bat. We chose the Upcountry region of Maui for the telemetry study in part because of the reasonable access throughout the area by public roads. However, it was infeasible for us to always be within 300 meters of the bat due to the lack of road infrastructure in some outlying areas of our study area and because of the speed at which the bats travel. Because we did not use attenuation to determine distance of a bat with a transmitter, we tracked bats from several kilometers (maximum of about 8 kilometers) away from receivers as long as the angles of the two or more observers were greater than or equal to 15°. Data based on observers with receivers less than 15° were not used to determine FRs and CUAs.

Only one bat was tracked at a time, and the nightly tracking period was based on the habits of the bat being tracked. Bats were tracked for their first foraging bout, which was generally 1.5–3 hours between 5:00 p.m. and midnight. Only one position was obtained each time a bat roosted, either by honing on to the signal or by triangulation. While flying, triangulations were attempted at not less than 3-minute intervals following the methods of Bonaccorso et al. (2015) to prevent autocorrelation of the positional data.

We entered grouped GPS and azimuth data for triangulations into LOAS 4.0.3.8 software (Ecological Software Solutions, Urnäsh, Switzerland) to plot the triangulated positions of bats. Triangulated positions generated using three bearings were validated through agreement between bi-angulated positions. Triangulated positions generated using two bearings were validated if the positions did not change markedly if either bearing were increased or decreased by 1° and verified using signal strength data recorded by the observers when available. Triangulated positions not meeting the validation criteria were eliminated from the dataset and not used in the kernel analysis. Bats with fewer than 25 qualifying fixes were not used for kernel analyses. Fixes determined by antennae with angles less than 15 degrees from each other were also not used for kernel analyses. We used the kernel UD function of the adehabitat HR package in R (Calenge 2006) to calculate the 95% kernel (FRs) and 50% kernel (CUAs). The smoothing parameter was set to "href" for this adehabitat HR package and a complete set of parameters is provided in Appendix A.

Because FRs and CUAs generated from our data were substantially larger than those determined for Hawaiian hoary bats on the island of Hawai'i, we also calculated these values using the same methods for kernel analysis used by Bonaccorso et al. 2015. Home ranges were assessed using Home Range Tools for ArcGIS 10 software. A least squares cross-validation was used to determine a smoothing parameter with minimum estimated error for fixed-kernel estimates (Rodgers et al. 2015). From these data we calculated minimum area probabilities for foraging range as the 95% fixed kernel. CUAs were defined by the 50% fixed kernel. A complete set of parameters is provided in Appendix A. Flight positions only (not roosting) were used to calculate foraging range and CUA. Bat locations were transposed on a map of Hawai'i using ArcGIS 10.7.1 software (Environmental Systems Research Institute, Redlands, California). Habitat types for bats' radio telemetry coordinates within the FRs and CUAs were determined from base habitat maps.

2.6 Insect Sampling

We sampled insects using extra tall blacklight traps (BIOQUIP model 2805) at nine sites (one in each of the nine habitat types) for seven sampling periods: August and October/November 2017, and January, February/March, May, June/July, and August/September 2018.

In each sampling period, insect traps were deployed for one week, suspended approximately 2 meters above the ground. A 40% ethanol killing agent was used and each trap was powered by a 12-volt deep cycle marine battery. A photosensor switch was used to automatically turn insect traps on at night and off in the daytime to collect prey available to the Hawaiian hoary bat. Because little light penetrates the canopy in forest sites during the day, FWL and FWU insect traps were equipped with timer switches set for sunset and sunrise. On the third or fourth day after deployment, insects were strained and collected in ethanol, ethanol in light traps was replaced, and marine batteries were swapped out. After traps had run for 7 nights, insects were strained and collected in ethanol again, and traps retrieved.

2.6.1 Insect Identification and Quantifying Dry Weight

Because our primary purpose for collecting insects was to help identify which species the bats had foraged on, and we had collected tens of thousands of insects (i.e., too many to fully sort and identify), we gave priority to samples from habitats with the most bat activity for a given month. To obtain a representative set of insect species identifications at each high-priority sampling location, 50 insects were chosen randomly from each vial by drawing a line along the side of a closed vial with a marker, and then taking a vertical sample of the first 50 insects along that line. The sampled insects were placed into glass dishes and sorted under a microscope. Insects were identified to lowest taxonomic order, which was usually family for non-Lepidoptera. For Lepidoptera, identification to genus or species was only carried out for males, whose genitalia allow for easier identification (wing pattern, labial palps, and other generic characters were destroyed during specimen collection). Dissections of male Lepidoptera were undertaken by first immersing specimens for 1 hour in simmering 10% potassium hydroxide, then subsequently soaking them in 50% ethanol, chlorozol black stain, 100% ethanol, and water, and mounting them on slides using polyvinyl alcohol fixative. Figure 4 is an example of one of the many prepared slides of male genitalia used to identify moths collected. This nonnative species, *Darna pallivitta,* was recently introduced to Hawaii.

Figure 4. Slide preparation of Male Genitalia of *Darna pallivitta* Used to Identify the Species.

To obtain the dry weights of the insect samples, the vial lids were unscrewed and the vials were set in a fume hood for one week, being gently stirred each day. The mass of each vial was recorded after 1 week, and its tare value (i.e., mass of an empty vial) was subtracted from the scale reading to calculate the dry weight of the samples.

2.6.2 Statistical Analysis of Dry Weights of Insect Samples per Habitat

We tested for temporal autocorrelation between months for the dry weights of insect samples using the Breusch-Godfrey test for serial correlation in software package ecm (Bansal 2019) and by inspecting the auto correlation function (acf) plot of model residuals in package and by inspecting the acf plot of model residuals in software package nlme (Pinheiro et al. 2018), but no patterns emerged and we failed to reject the null hypothesis that temporal autocorrelation does not exist in these data. We fit a negative binomial generalized linear model with a log link function from the MASS package (Venables and Ripley 2002) to accommodate overdispersion in the data and analyzed the impact of habitat and month on total dry weight of insect samples collected. The final model was selected based on model fit, satisfaction of model assumptions, and comparison of AIC (Akaike's Information Criterion) values between different models, with the model having the significantly lowest AIC score being the "best" model. The final model included both habitat and month, but no interaction of the two factors, as not 100% of habitats were successfully sampled in all months due to inclement weather.

We assessed model fit and other model diagnostics by checking patterns in the residuals (overall and by predictor), testing normality of residual distribution and inspection of residual distribution plots, testing for collinearity among variables using variance inflation factors from the car software package (Fox and Weisberg 2011) and by checking for model convergence and reasonable model estimates. The final model residuals were randomly distributed, and fitted estimates were positively correlated with the raw data, indicating good model fit.

To obtain model estimates of insect weight, we used the estimated marginal means (emmeans) (Searle et al. 1980) function from the emmeans software package in R (Lenth 2009) to generate estimated means for each group, adjusted for other factors in the model. To determine where significant differences existed across month and habitat combinations, we tested for differences between months and habitats using pairwise contrasts with a Tukey adjustment (Lenth 2009). Graphs and figures were generated using package ggplot2 (Wickham 2016).

2.7 DNA Extraction, Polymerase Chain Reaction, Library Prep and Sequencing:

Fecal samples were rinsed of storage media using sterile water and approximately half of the fecal material, was subjected to DNA extraction with QIAamp PowerFecal DNA kit (Qiagen) following manufacturer's protocol. For four fecal samples that were unsuccessfully extracted, a second extraction was performed, rinsing the fecal samples more thoroughly and increasing the two 4°C incubation steps from 5 minutes to 30 minutes. DNA was extracted with the QIAamp PowerFecal DNA kit according to the manufacturer's protocol.

DNA from all 11 extracts was amplified at two loci using two technical replicates for a total of 44 amplifications. We targeted the CO1 region with ZBJ-ArtF1c and ZBJ-ArtR2c primers (Zeale et al. 2010) and the 16S region with Coleop_16Sc and Coleop_16Sd (Epp et al. 2012) modified with adapters on the 5' end for the Illumina MiSeq platform (Illumina Corporation, San Diego, CA, USA). Conditions for PCR were 25 microliter (μL) reactions of 1X PCR gold buffer, 2.5 millimolar MgCl2, 0.8 millimolar deoxyribonucleotide triphosphate blend, 0.125 μL AmpliTaq Gold (Applied Biosystems, Foster City, CA, USA), 5g BSA (Sigma-Aldrich, St. Louis, MI, USA), 5 micromolar each primer (Integrated DNA Technologies, Coralville, IA, USA), and 3 μL of fecal DNA. PCR cycling parameters were: denaturation at 95°C for 10 minutes, followed by 35 cycles of 95°C for 30 seconds, 52°C for 30 seconds, and 72°C for 30 seconds, with a final elongation step of 10 minutes at 72°C. Amplification success was confirmed by running 5 μL of each sample on a 2% agarose gel (Sigma-Aldrich, St. Louis, MI, USA).

Initial PCR products with Illumina adapters were cleaned of unincorporated nucleotides with Agencourt AMPure XP beads (Beckman Coulter, Indianapolis, IN, USA). The cleaned products were labeled with unique combinations of forward and reverse indexes using a 50 μL second-step PCR, consisting of 25 μL KAPA HiFi HotStart taq (KAPA Biosystems, Wilmington, MA, USA), 5 μL each of Nextera XT v2 index forward and reverse primers (Illumina Corporation, San Diego, CA, USA), and 5 μL of initial PCR product. Cycling parameters were: denaturation at 95°C for 3 minutes, followed by 8 cycles of 95°C for 30 seconds, 55°C for 30 seconds, and 72°C for 30 seconds, with a final elongation step of 5 minutes at 72°C.

The indexed PCR products pooled to approximately equal molarities. Each pool was visualized and quantified on a Bioanalyzer (Agilent Technologies, Santa Clara, CA, USA) to ensure proper size and to calculate final loading concentration. Samples were diluted to 4 parts per million and combined with PhiX control DNA (Illumina Corporation, San Diego, CA, USA) at a ratio of 10% PhiX and then loaded onto a MiSeq Reagent Kit v2 500-cycle flow cell reading 175 bases paired-end, for sequencing at the University of Tennessee Genomics Core (Knoxville, TN, USA).

COI data analysis: The sequenced COI region was merged using custom scripts and the USEARCH method (Edgar 2010). Merged reads were uploaded to the mBRAVE platform (http://www.mbrave.net/). Length trimming was set at 30bp from the front end and 23bp from the reverse end to remove primers. We then filtered any read that was greater than 600bp. Primer masking was left off. We set the quality filters at MinQV=0, Min Length=90bp, Max Bases with Low QV (<20)=75%, Max Bases with Ultra Low QV (<10)=75%. The pre-clustering threshold was set to none and the ID distance threshold was set at 2%. We compared all reads to three established reference collections derived from the BOLD database:

- System reference library for insects consisting of 663,781 sequences representing 491,902 BINs (a cluster of related reference sequences which equates to a species) and 199,009 species designations.
- System reference library for non-arthropod invertebrates consisting of 69,983 sequences representing 42,990 BINs and 29,624 species designations.
- System reference library for non-insect arthropods consisting of 76,769 sequences representing 58,227 BINs and 23,254 species designations.

Data from the two technical replicates were pooled for analysis.

16S data analysis: The amplified 16S region was also merged using custom scripts and the USEARCH method (Edgar 2010). The merged reads were then analyzed using the QIIME2 platform, following the standard protocol for 16S sequence data (Bolyen et al. 2019). This involved quality control and filtering before generating a frequency table of unique sequences detected within each sample, using DADA2 (Callahan et al. 2016). The raw 50849 sequences were reduced to 8344 sequence variants at this step. Sequence variants are equivalent to 100% OTUs produced using other methods. These unique sequences were then identified by comparison to the reference data in NCBI GenBank using BLAST (Altschul et al. 1990).

Section 3. Results

3.1 Habitat Use Based on Acoustic Data

We recorded 17,408 bat calls, (15,382 calls per night and 12,650 call-minutes), 734 feeding buzzes, and 146 social calls between the dates of September 1, 2017 and September 30, 2018 located in nine habitats found on the study area. The conversion of total calls to number of calls per night is useful for long-term studies and is often used in acoustic studies of the Hawaiian hoary bat. The conversion of total calls to call-minutes is used to buffer the number of recordings of a single bat made in a short period of time because within one minute, calls are most frequently generated by a single bat (Miller 2001).

3.1.1 Modelling of bat calls per night

Based on the number of bat calls per night for all habitats over the course of the study, bats used Gulch, DevL, and Grass habitats more than other habitats overall (Figure 5). There is also more variance in Gulch, Grass, and DevL habitats. The higher the mean, the greater the variance. Moreover, we have different variances per group (Figure 5). By month, there is a general decrease in in calls per night from September 2017 to January 2018, and then increasing call minutes from March through September 2018 (Figure 6). Although that does not necessarily mean that there is an annual trend with only one year of data, September 2017 and September 2018 both had the highest calls per night and this is the expected trend based on other acoustic studies of the Hawaiian hoary bat (Bonaccorso et al. 2015, Gorreson et al. 2013) although we have only one year of data. September 2017 and 2018 were more alike in that they had the highest calls per night, but September 2017 had lower mean calls per night than September 2018. Using habitats as categories we found an interaction with month; and therefore, found habitat to be highly significant between habitats for specific months of the year (Figure 5, see Appendix B for estimates of means and standard errors, and Appendix C for a table of significant differences between habitats within each month). Table 3 provides examples of pairwise comparisons between habitat types showing significant, or near significant, bat use of some habitat types over others during different times of the year. In summary, the results (contrasts with Tukey adjustment, 0.95 confidence level; significance level of alpha=0.05) indicate that it is reasonable to conclude that there are significant differences between some habitats in some months, when rainfall is less than 5 millimeters. Appendix C shows a summary of significant differences between habitats over time.

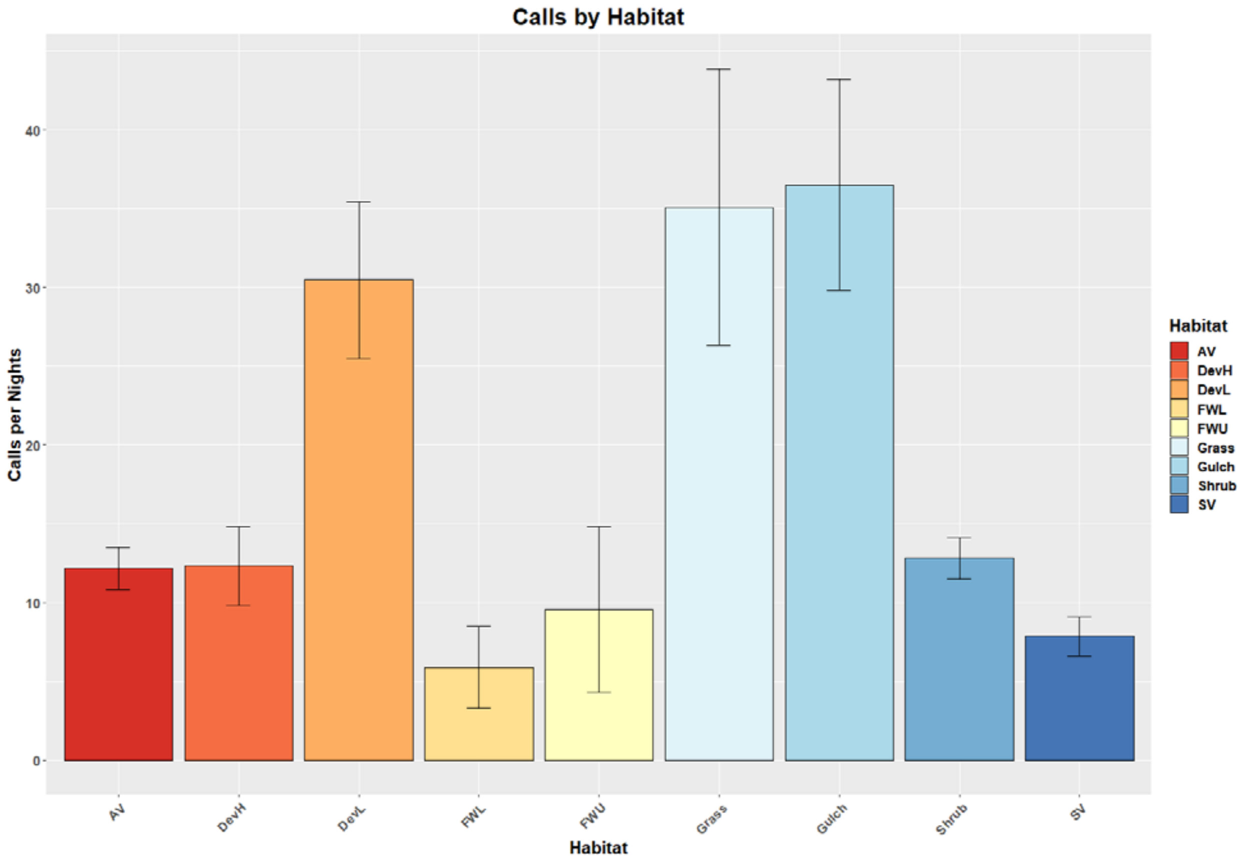


Figure 5. Differences in Bat Activity among Habitats within the Project Site Based on Raw Data

Bars show means and whiskers are one standard error of the mean. Gulch, Grassland, and Low Density Developed habitats had more bat calls/night overall than other habitats. Bat activity was least in the low and upper forested areas. Acronyms are as follows: AV = Agricultural Vegetation, DevH = High Density Developed, DevL = Low Density Developed, FWL = Forest Woodland Lower elevation (< 2000 meters above sea level), FWU = Forest Woodland Upper ($\geq$ 2,000 meters above sea level), Grass = Grasslands, Gulch = Gulches, Shrub = Shrub lands, SV = Sparse Vesicular Rock.

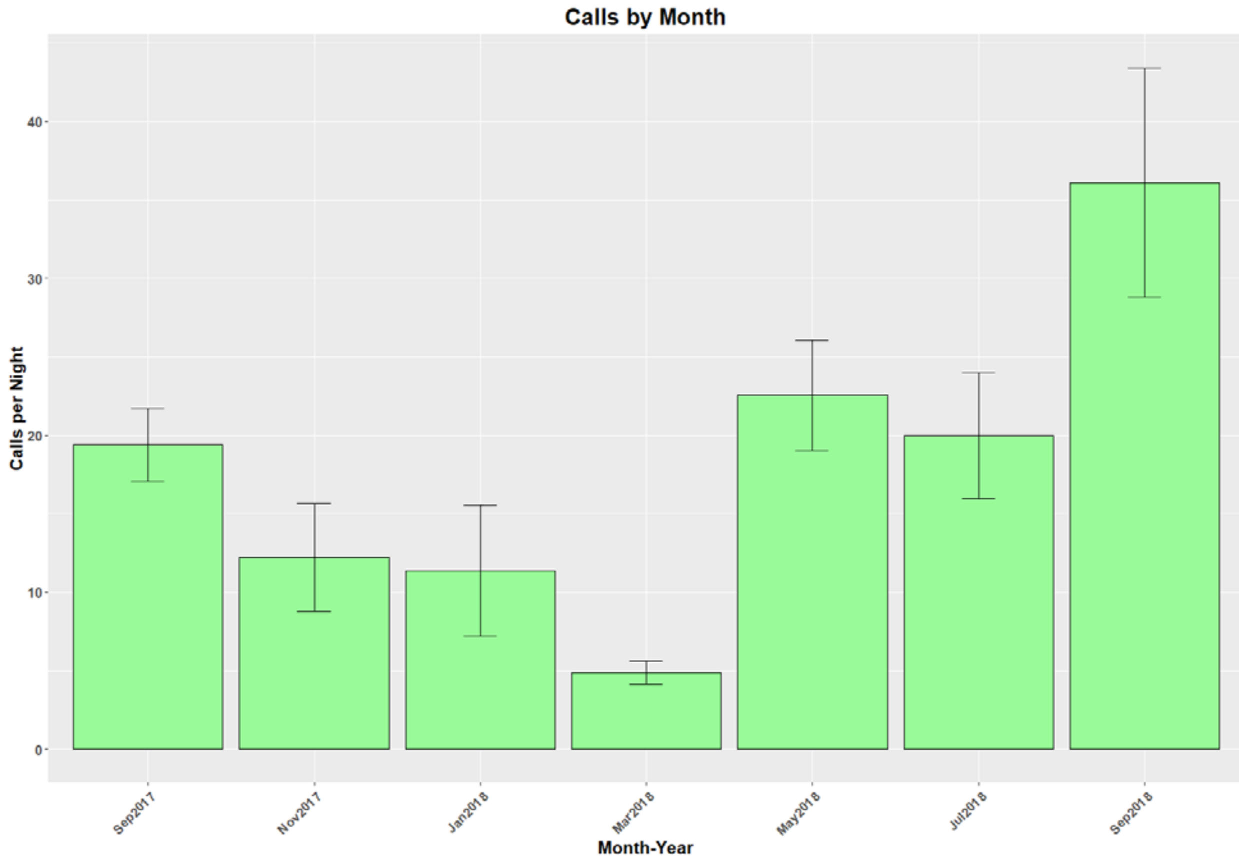


Figure 6. Differences in Bat Activity among Months Based on Raw Data.

Bars show means and whiskers are one standard error of the mean.

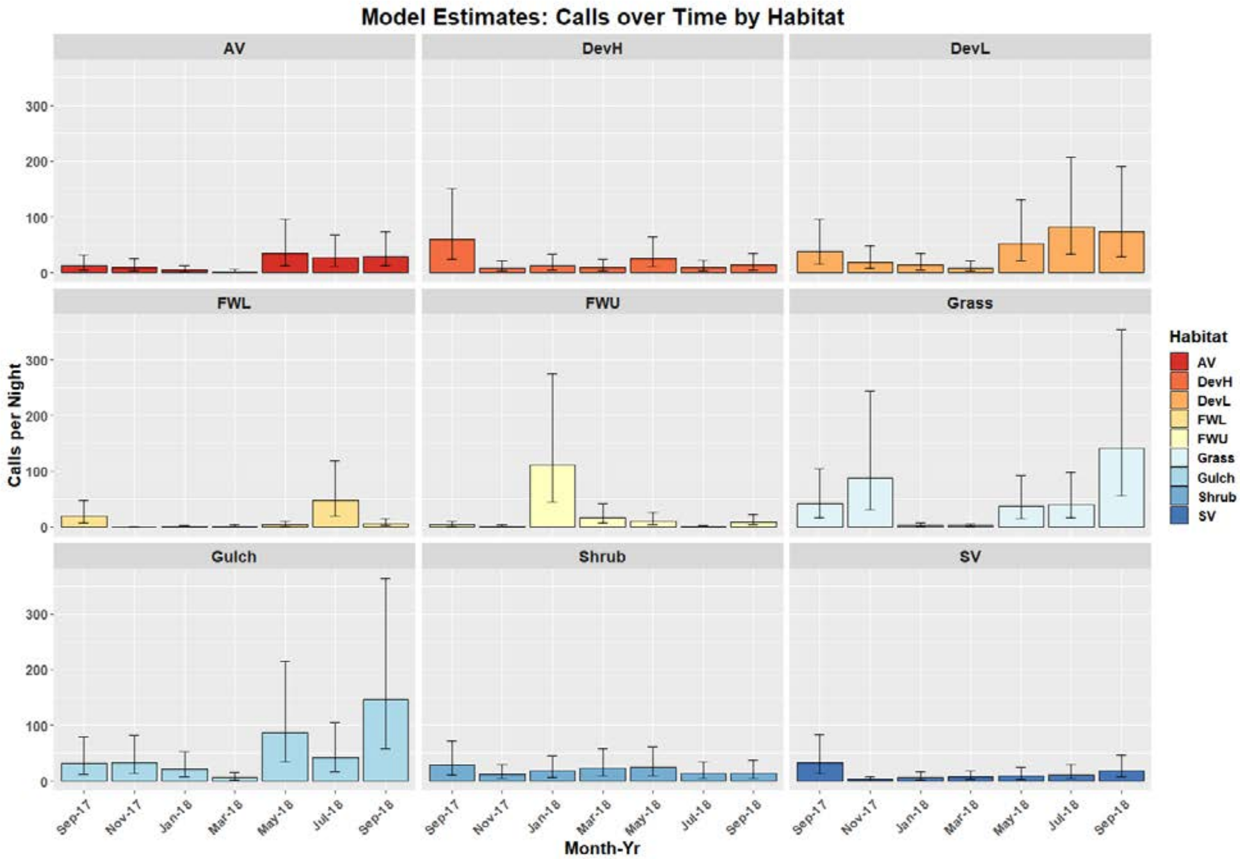


Figure 7. Differences in Bat Activity among Months Based on Raw Data.

Bars show means and whiskers are one standard error of the mean.

DevL, Gulch, and Grass show trends of greater activity during summer months. Higher values also show greater standard error. For all habitats during January, the highest amount of activity occurred in the FWU (forested areas above 2,000 meters). During summer months, FWL was little used although it was greater than the FWU.

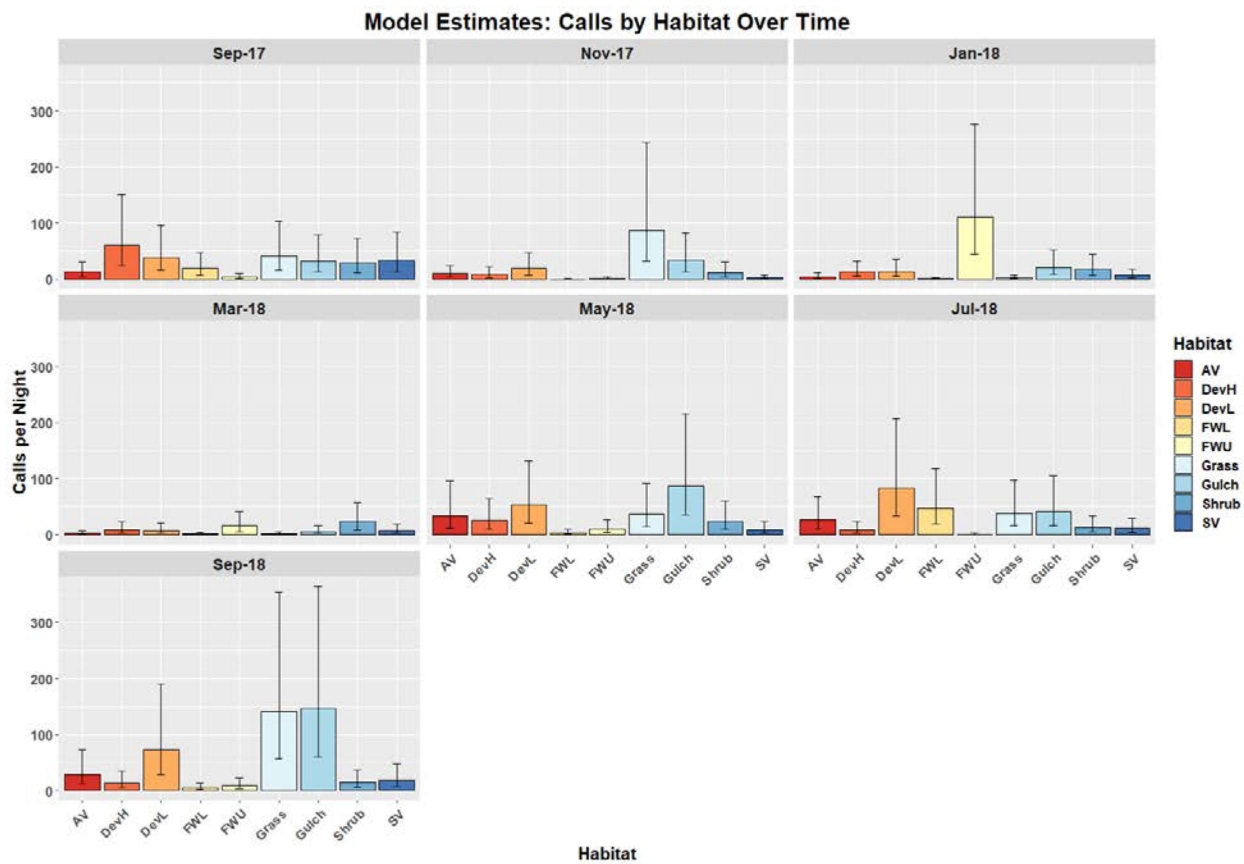


Figure 8. Model Estimates: Calls by Month, within Habitat.

Bars show means and whiskers are one standard error of the mean.

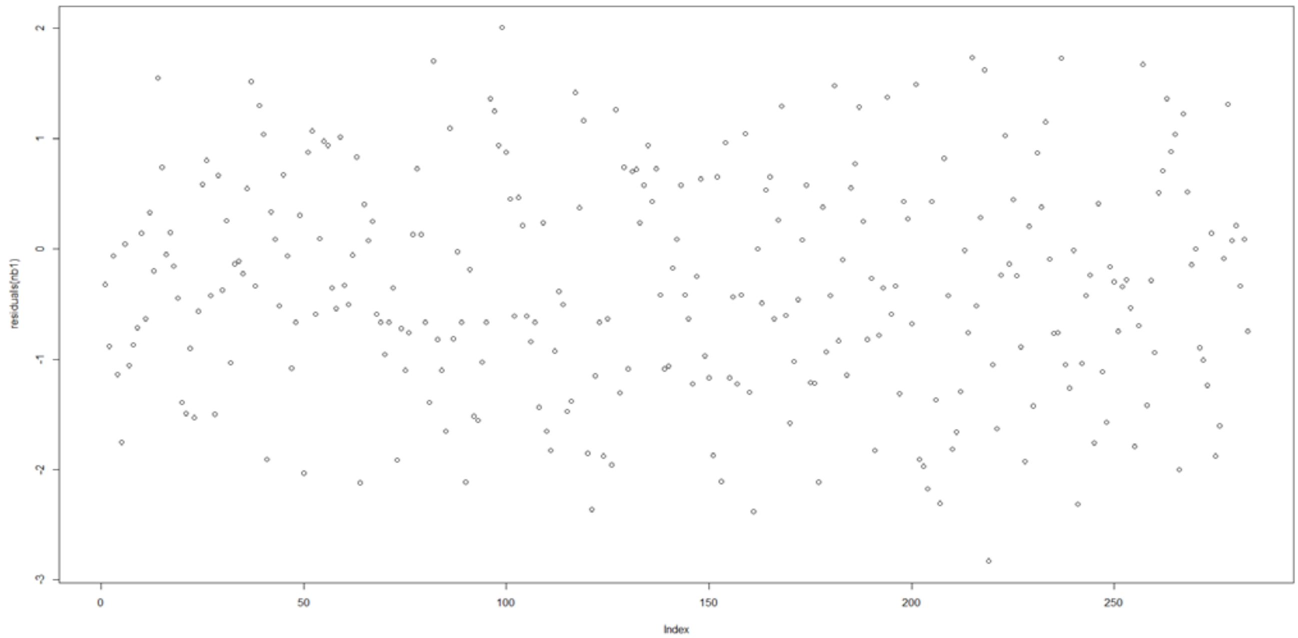
Table 3. Pairwise Comparisons of Habitat Types at Alpha = 0.05.[1]

Acoustic Monitoring Sample Month	Habitat(s) with Significantly Greater Amount of Activity	Habitat(s) with Significantly Less Amount of Activity
September 2017	DevL, DevH, Grass, Gulch, and SV	FWU
November 2017	Grass	DevH, FWL, FWU, and SV
	Gulch	FWL, FWU, and SV
	DevL	FWL and FWU
	AV, DevH, and Shrub	FWL
March 2018	FWU and Shrub	FWL
	Shrub	AV and Grass
May 2018	AV, DevL, Grass, and Gulch	FWL
	Gulch	FWU and SV
July 2018	AV, DevL, FWL, Grass, Gulch, Shrub, and SV	FWU
	DevL	DevH
September 2018	DevL, Grass, and Gulch	FWL
	Grass and Gulch	FWU
	Grass and Gulch	DevH
	Grass and Gulch	Shrub
	Gulch	SV

[1] Detailed statistics provided in Appendix C.

3.1.2 Model Diagnostics

We used a negative binomial distribution to model these data. A Shapiro test was applied to test for normality of the model residuals, and the results indicate that the residuals are normally distributed (W = 0.99) with no patterns emerging [Figure 9 (top)]. When the fitted values (model estimates) are plotted by the raw (actual) data there is a strong, positive relationship, indicating a good agreement between the model estimates and the actual data [Figure 9 (bottom)].



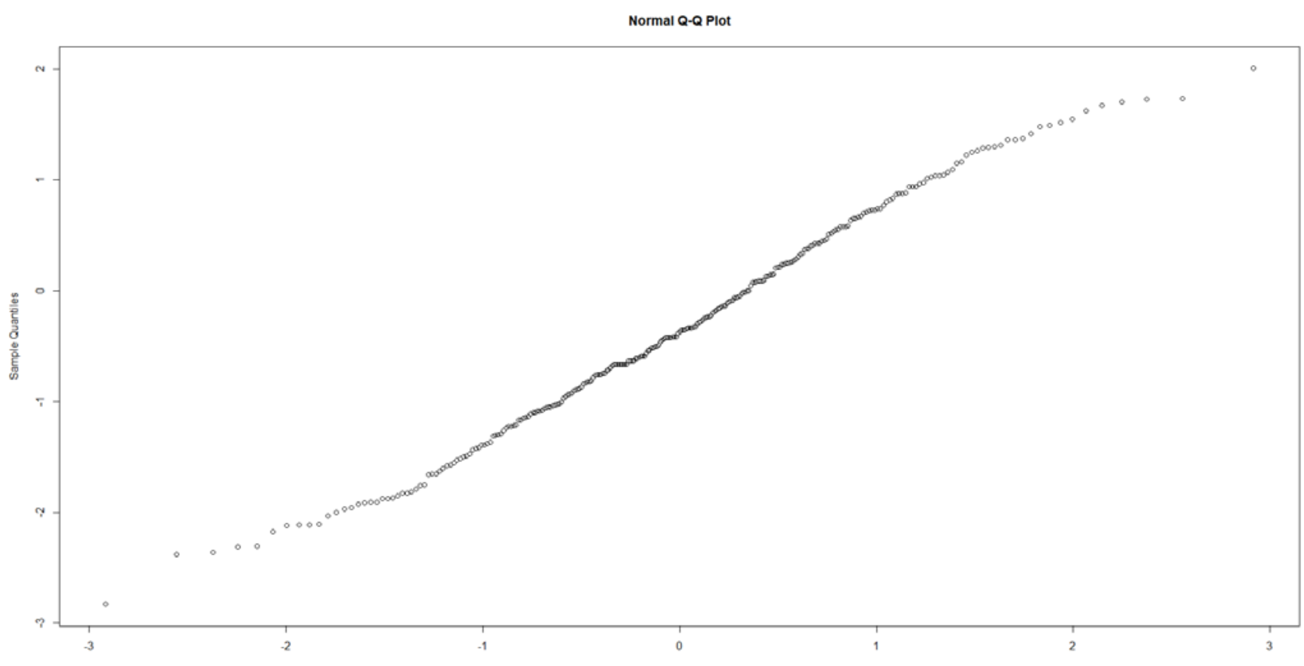


Figure 9. Distribution of Model Residuals (Shapiro Test, W = 0.99). (Top) Model Qqnorm Plots. Showing a Strong Positive Relationship. (Bottom)

3.1.3 Spatial Distribution of calls each night

Spatially these data are fairly well distributed. Figure 10 provides each night of data, including all 3 days of each deployment; and therefore, showing quite a bit of variation from one night to the next for the 3 nights. Areas without any acoustic monitoring are the result of a few large land owners who did not feel comfortable hosting the collection of bat acoustic data. The spatial distribution for calls each night for individual habitat types are provided in Appendix D.

Figure 10. Spatial Distribution of Bat Calls Based on 315 Locations among Nine Habitat Types from September 2017 through September 2018.

3.2 Results: Radio-tracking and Core Use Areas

Our capture success increased over time (Figure 11) possibly because of our increase in use of acoustic lures with locally recorded social calls. We mist netted on 78 nights from June 2017 through September 2018 (Figure 12). We initially used mainland hoary bat social calls and switched to Maui-specific Hawaiian hoary bat social calls and feeding buzzes as we recorded them during our acoustic surveys. The local social calls appeared to be much more effective as lures. Acoustic lures were most effective in September and October. Note that equal sampling effort did not occur in each month because after a bat was captured our nighttime hours were dedicated to radio-tracking that individual. Our mist netting effort was also biased during summer months partly because the rainy and windy weather during winter months prevented regular mist netting (Figure 12).

The mist netting areas consisted of 13 total capture sites in three broad regions: Haleakala National Park (summit district [n=3, Resource Management Office, 12-mile pool, Hosmer Grove]); Lower Kula–Na'alae Road (n=2, a native plant nursery and rural property); Olinda/Pi'iholo Roads (n=9, Maui Forest Bird Recovery Project Office, Maui Forest Bird Recovery Project Cottage, Waihou Springs Reserve, five private residences, and Kamehameha Schools in Makawao). In total, we caught twenty bats composed of two subadult females, two subadult males, two adult females and sixteen adult males (Figure 13). Subadults are individuals that can fly but are less than one year old.

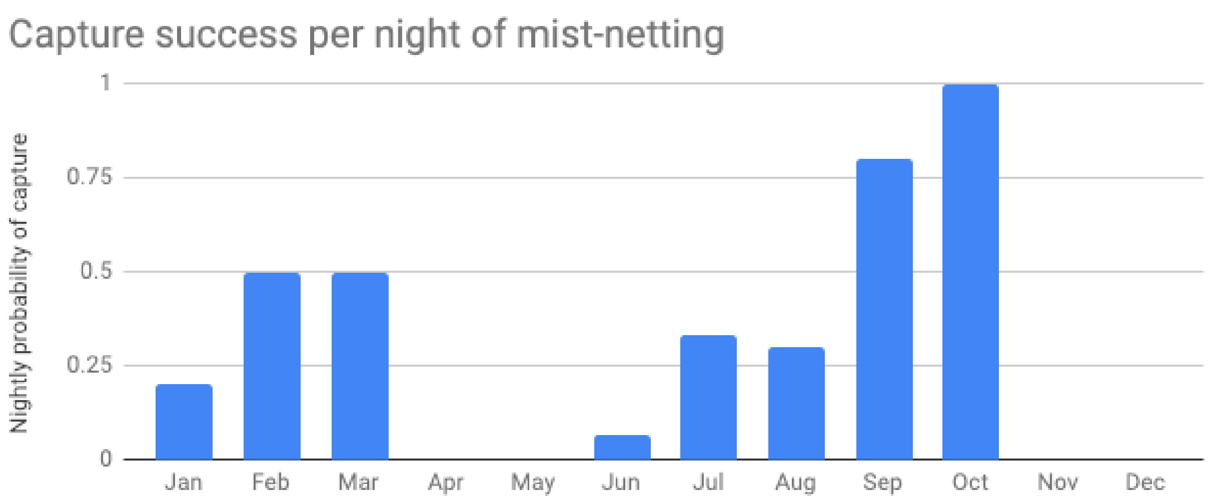


Figure 11. Probability of Capture Success per Night of Mist-netting Effort

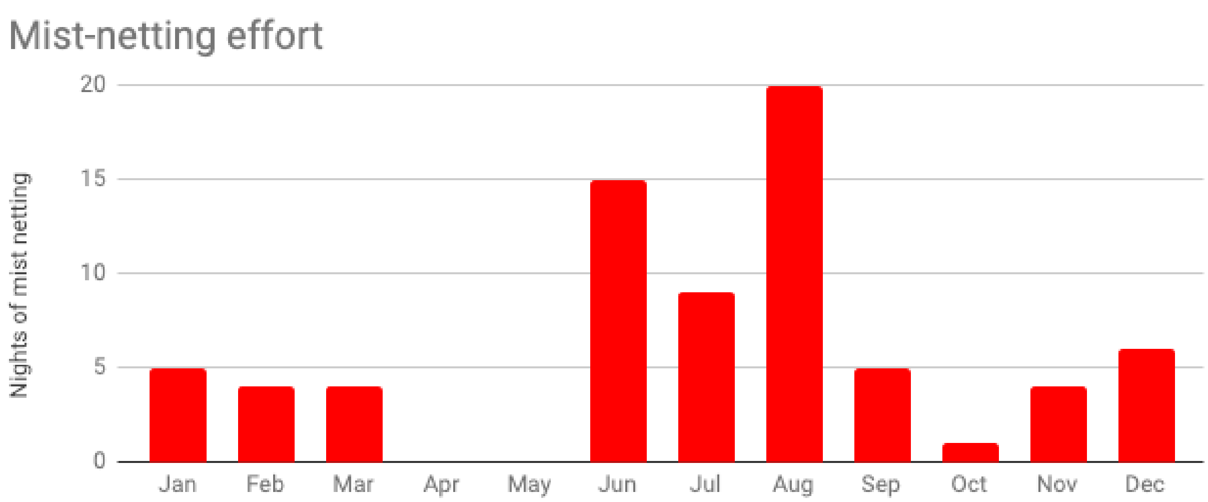


Figure 12. Mist Netting Effort for 2018.

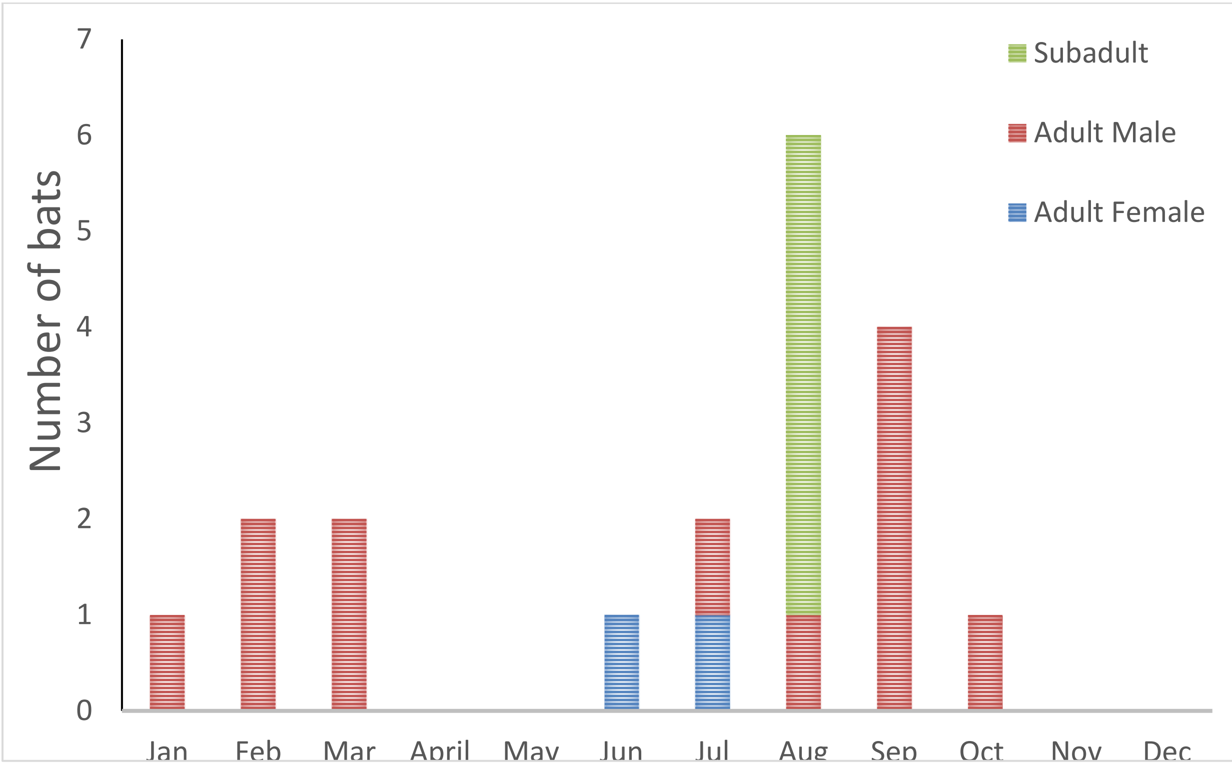


Figure 13. Pooled Data Showing the Distribution of Age Class and Sex from Mist Netting Effort

Seventy-eight nights of mist netting yielded 20 bat captures

Table 4. Summary of Mist Netting Effort

Season	Dates	Number of Valid Netting Nights	Hours * Net Meters²	Total Bats Captured	Bats Captured with Use of Playback	Nights of Mist Netting to Capture Bat
Summer 2017	Jun 5 – Oct 2	30	12,052	7	4	4.3
Winter 2017/2018	Dec 29 – Mar 21	14	4,073	5	4	2.8
Summer 2018	Jun 4 – Sept 20	26	1,679	8	8	3.3
Winter 2018/2018	Nov 24 – Jan 8	8	569	0	0	N/A
	Total	**78**	**18,373**	**20**	**16**	**3.9**

Radiotelemetry. We radio-tagged a total of 16 bats and were able to sufficiently track the movements of 11 of these bats to map home range and CUAs. Table 6 provides data for the number of nights tracked, number of fixes, and other pertinent data for each bat tracked. Data for five bats were too limited to determine home range and another four bats were not fitted with radio-transmitters because of a late delivery of transmitters. We spent 109 nights tracking the movements of tagged bats. Of the 11 bats whose home ranges we mapped, the mean 50% kernel CUA based on our kernel analysis methods was 2,914.39 hectares and 2,192.53 hectares based on methods used in the USGS studies (Figures 14 and 15) and the mean 95% kernel foraging range was 12,905.38 hectares based on our kernel analysis methods and 9,943.73 hectares based on the USGS studies (Figure 15). Because of huge differences in values for the CUAs and FRs, the standard deviations were 5,730 hectares and 23, 556 hectares, respectively, using our study methods. The mean longest length measurement based on our study methods is 6.86 kilometers and 15.1 kilometers for the CUAs and FRs, respectively. As seen in Table 5, we observed a high level of variability between individuals.

Table 5. Results for Kernel Analysis Based on H. T. Harvey & Associates and USGS Methods for Core Use Areas and Foraging Ranges

ID	%	Gender	Age	Length in km HTH	Hectare_ HTH	Month	Year	Hectare_ USGS	Difference for 50% kernel	Difference for 95% kernel
2	50	Male	Juv	1.77	235.80	Aug	2017	257.00	-21.20	
2	95	Male	Juv	5.56	1,263.30	Aug	2017	1,372.56		-109.26
3	50	Female	Juv	13.26	6,508.06	Aug	2017	231.93	6276.13	
3	95	Female	Juv	24.84	26,064.76	Aug	2017	1,185.83		24,878.93
4	50	Male	Ad	8.78	3,430.13	Sept	2017	2,106.94	1,323.19	
4	95	Male	Ad	22.48	18,503.88	Sept	2017	11,849.19		6,654.69
5	50	Male	Ad	3.72	574.57	Sept	2017	406.22	168.35	
5	95	Male	Ad	10.13	3,612.36	Sept	2017	2,694.69		917.66
6	50	Male	Ad	4.85	793.64	Oct	2017	743.61	50.04	
6	95	Male	Ad	10.06	3,706.85	Oct	2017	3,638.68		68.16
7	50	Male	Ad	3.8	842.21	Jan	2018	1,088.48	-246.27	
7	95	Male	Ad	8.27	3,519.08	Jan	2018	4,508.76		-989.68
9	50	Male	Ad	11.05	3,531.15	Feb	2018	4,865.20	-1,334.06	
9	95	Male	Ad	16.51	12,398.30	Feb	2018	18,417.52		-6,019.21

ID	%	Gender	Age	Length in km HTH	Hectare_ HTH	Month	Year	Hectare_ USGS	Difference for 50% kernel	Difference for 95% kernel
10	50	Male	Ad	0.2	2.76	Mar	2018	1.63	1.14	
10	95	Male	Ad	0.62	14.63	Mar	2018	8.03		6.59
11	50	Male	Ad	3.76	970.67	Mar	2018	699.79	270.88	
11	95	Male	Ad	11.5	5,208.64	Mar	2018	4,083.70		1,124.94
12	50	Female	Ad	7.1	4,264.57	June	2018	4,275.03	-10.47	
12	95	Female	Ad	24.55	23,359.50	June	2018	23,306.52		52.98
20	50	Male	Ad	17.17	10,904.68	Sept	2018	9,441.99	1,462.70	
20	95	Male	Ad	31.1	44,307.91	Sept	2018	38,315.52		5,992.39

Notes: HTH = H. T. Harvey & Associates; USGS = U.S. Geological Survey; Ad = adult; Juv = juvenile

See Appendix E for individually mapped CUAs and foraging ranges based on H. T. Harvey & Associates and USGS kernel analysis methods, and Appendix F for detailed accounts of the movements of each radio-tagged bat.

Table 6. Summary of Tracking Success

Bat	Dates	Number of Tracking Nights	Number of Triangulated Fixes Used	Number of Day Roost Observations (Locations)	Number of Night Roost Observations (Locations)
1	Jul 16 – 19, 2017	2	3	0 (0)	0 (0)
2	Jul 27 – Aug 8, 2017	16	63	3 (1)	1 (1)
3	Aug 14 – 22, 2017	6	31	0 (0)	0 (0)
4	Sep 7 – 19, 2017	13	112	2 (1)	8 (4)
5	Sep 22 – Oct 1, 2017	10	128	2 (2)	6 (4)
6	Oct 2 – 8, 2017	7	65	2 (1)	3 (1)
7	Jan 10 – 18, 2018	7	59	2 (1)	1 (1)
9	Feb 20 – Mar 5, 2018	8	76	0 (0)	1 (1)
10	Mar 7 – 12, 2018	5	84	1 (1)	3 (1)
11	Mar 21 – Apr 1, 2018	5	52	1 (1)	2 (2)
12	Jun 19 – 25, 2018	6	54	1 (1)	0 (0)
20	Sep 18 – Oct 4, 2018	7	28	0 (0)	0 (0)
	Total	**92**	**755**	**14 (9)**	**25 (15)**

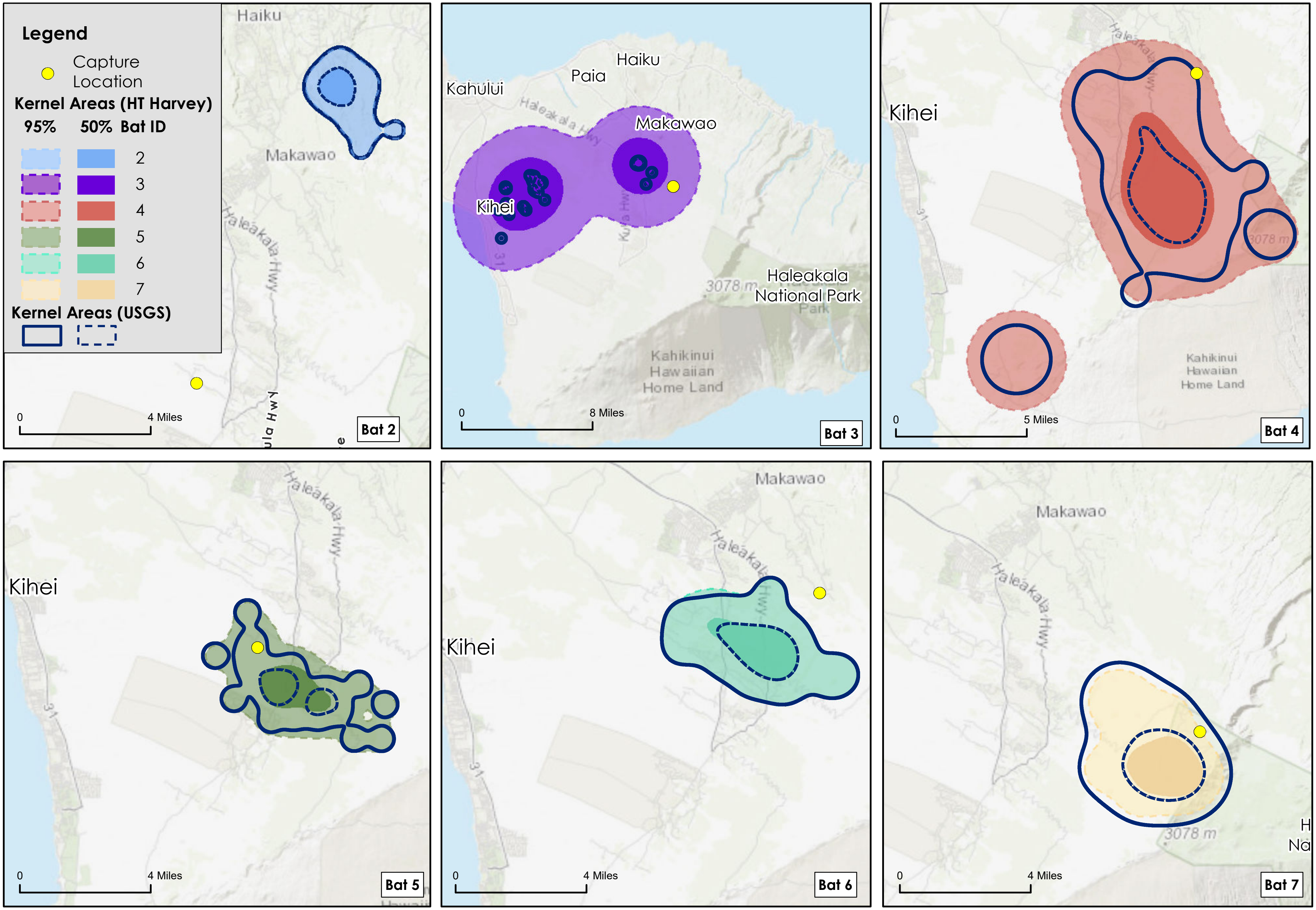


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Figure 14. 95% and 50% Kernel Foraging and Core Areas per Individual Bat Using HT Harvey and USGS Methodology

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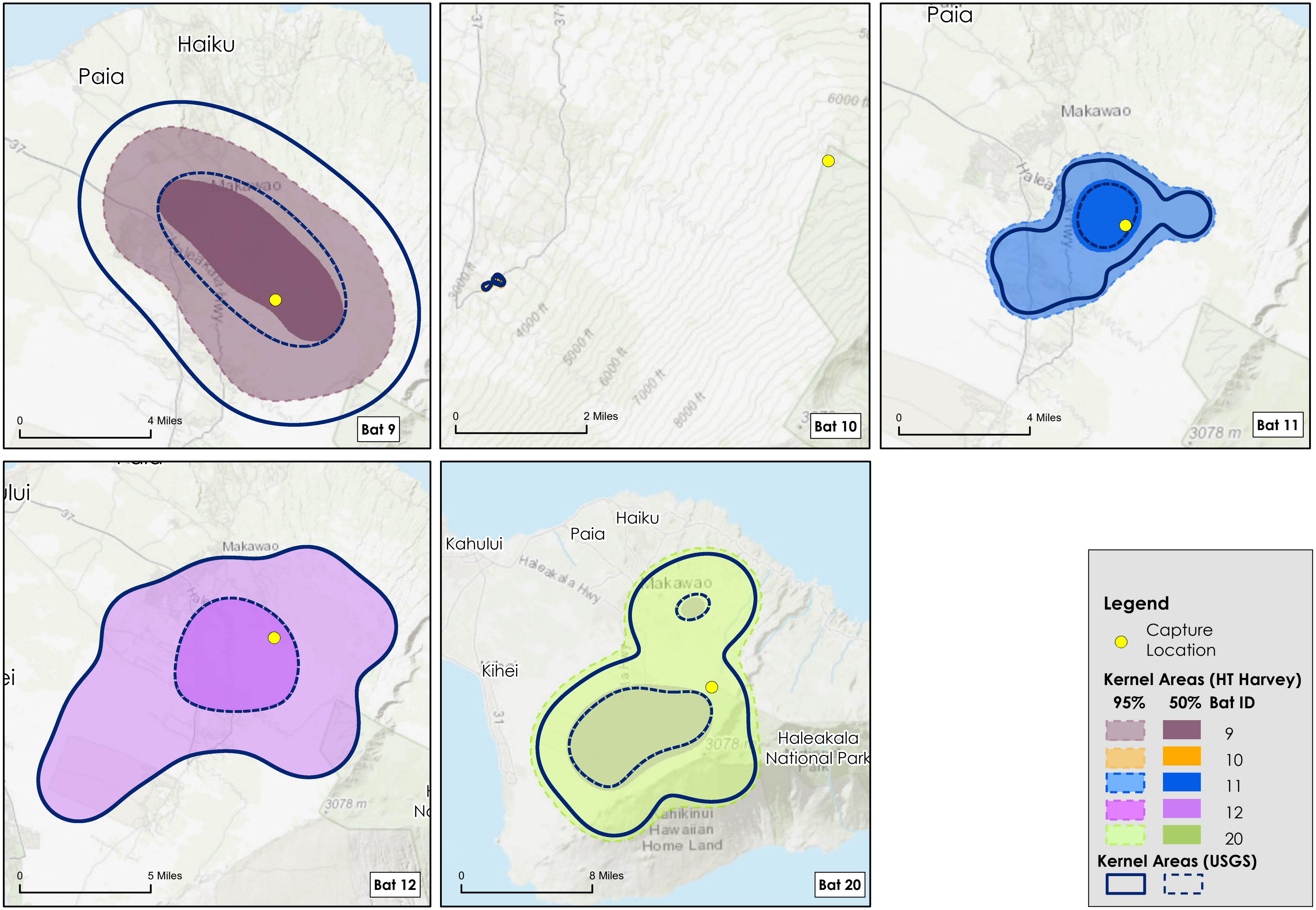

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Figure 15. 95% and 50% Kernel Foraging and Core Areas per Individual Bat Using HT Harvey and USGS Methodology

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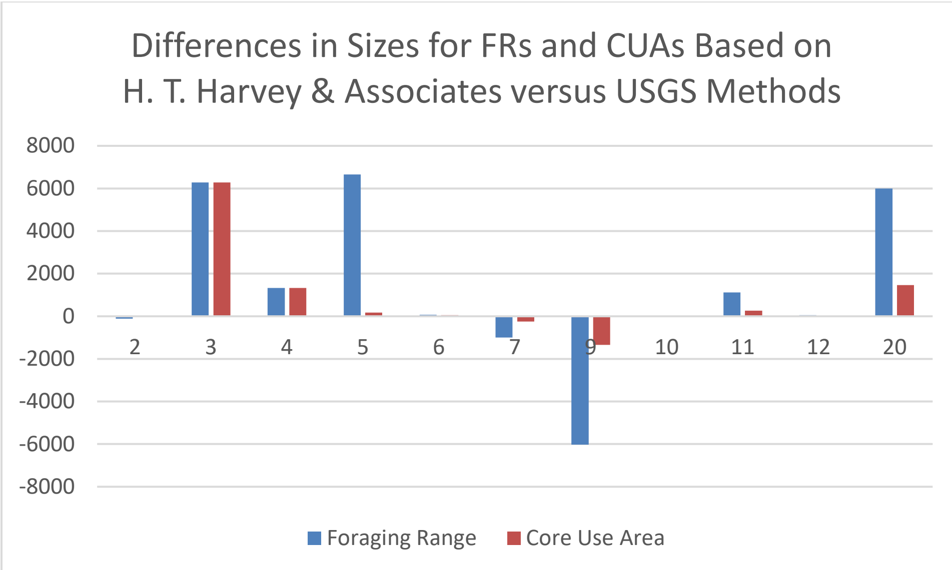

Figure 16. Size Differences in the CUAs (50% kernel) and FRs (95% kernel) based on H. T. Harvey & Associates methods versus USGS methods.

Although the mean sizes for the CUAs and FRs are larger when applying our study methods, the changes in size are dependent upon the individual bat. For example, Bat 3's FR is over 6,000 hectares larger when using our study methods compared with those in the USGS studies. Conversely, Bat 9's FA is over 6,000 hectares smaller when applying our study methods than it would be if the USGS methods were applied. The variation is likely attributable to different degrees of smoothing. The USGS methods tend to make smaller clusters of occupied space as opposed to our study methods, which tend to group small clusters of fixes. For example, Bat 3 shows a large FR and CUA based on our study methods whereas the USGS methods tend to make separate polygons of smaller areas resulting in a smaller FR and CUA (Figure 14).

On average, bats were tracked for 8 nights, thus the number of nights we collected data was quite small to be representative of the full range of their movements, even within a single season. Yet, even in these brief monitoring periods, we detected numerous long-range movements of approximately 16 kilometers. Based on our study methods, the mean long axis for the CUA was 6.86 kilometers (4.26 miles) and the mean foraging range long axis was 15.06 kilometers (9.36 miles).

In addition to measuring the number of bat calls in the nine habitat types to determine habitat use, we also looked at the distribution of habitat use based on the telemetry coordinates of location fixes. After pooling habitat data from the radiotelemetry fixes, we found that bats occurred in some habitats more than others. The data presented in Figure 17 suggest that at a confidence interval of 0.95 (alpha = 0.05) bats spent more time over low-density developed, forest woodland low elevation, and grassland habitat types. Although the bat calls/night data varied somewhat among these habitats for different months, the acoustic data imply that bats tend to spend more time in low-density developed, grassland, and gulch habitats, but not the forest woodland low elevation habitat. Interestingly, the gulch habitat type had only a single fix data point despite the acoustic data suggesting that it is an important habitat for the Hawaiian hoary bat. We found that the bats were typically undetectable with the radiotelemetry receiver when they were inside these deep gulches; however, individuals were detectable when they reemerged and flew over the forest and woodland low elevation habitat between gulches. Most of the radiotelemetry fixes in the forest and woodland low elevation habitat were situated at the edges of gulches and between gulches that were relatively close together.

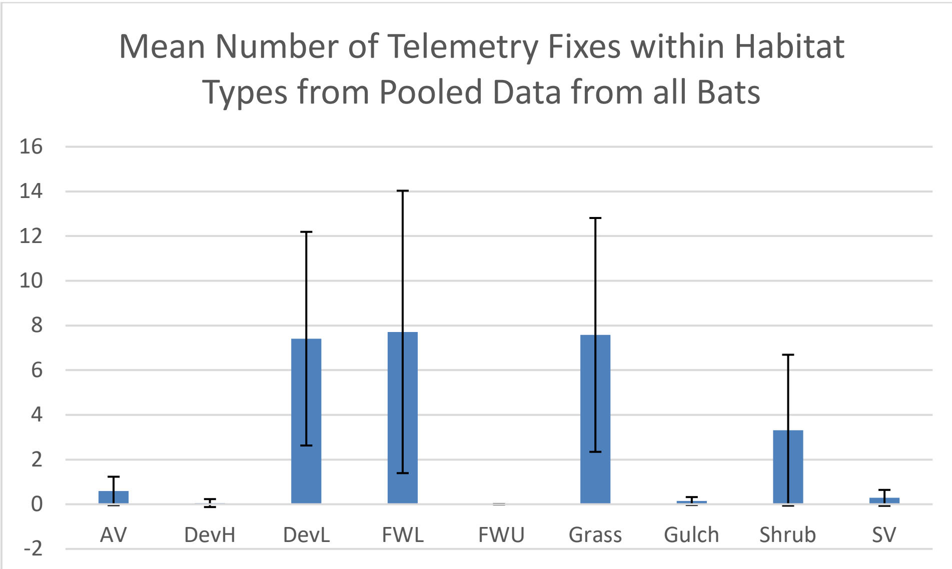

Figure 17. Habitat Use Based on Pooled Data from Radiotelemetry Fixes for 11 Bats.

Bars are mean estimates, and whiskers are 95% confidence intervals: AV (0.59), DevH (0.052), DevL (7.41), FWL (7.71), Grass (7.58), Gulch (0.14), Shrub (3.31) and SV (0.29). Acronyms are as follows: AV = Agricultural Vegetation, DevH = High Density Developed, DevL = Low Density Developed, FWL = Forest Woodland Lower elevation (< 2,000 meters above sea level), FWU = Forest Woodland Upper (≥ 2,000 meters above sea level), Grass = Grasslands, Gulch = Gulches, Shrub = Shrub lands, SV = Sparse Vesicular Rock.

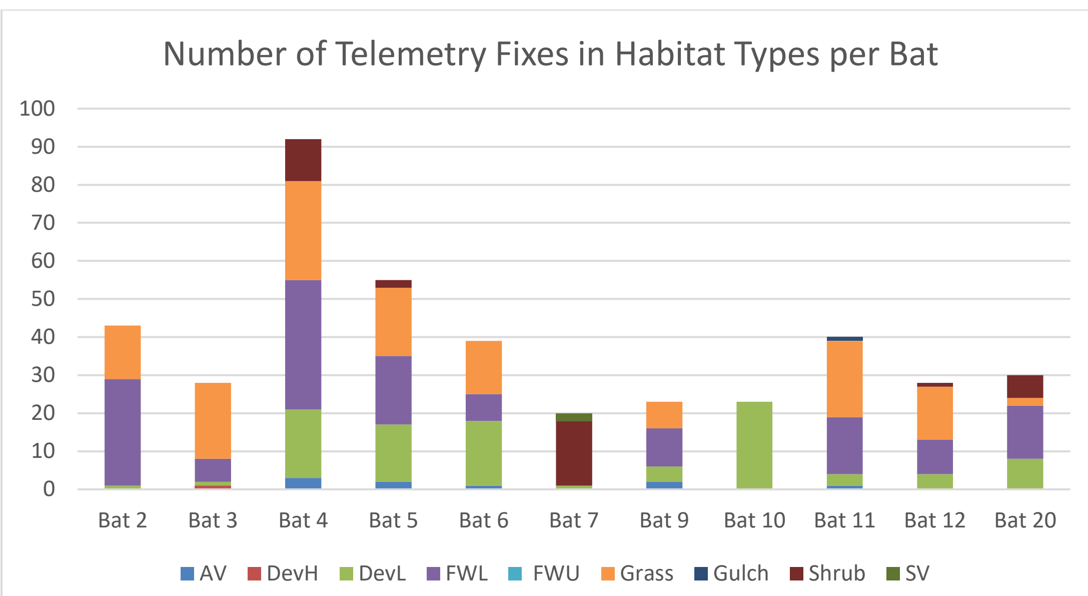

Figure 18. Number of Telemetry Fixes within Habitat Types per Bat.

Bats 2 (tracked in July) and 3 (tracked in August) spent most of their time in grasslands and forest woodland low elevation (which we believe represents gulches). Their CUAs do not overlap, but their FRs intersect. Bats 4 and 5 (both tracked in September) and Bat 6 (tracked in early October) show similar habitat use with forest woodland low elevation, grassland, and low-density developed as their primary habitats. Bat 7 was tracked in January and almost exclusively spent time in shrubland habitat found at high elevations (greater than 2,000 meters). Bat 9 was tracked in February and based on field observations and locations of fixes, spent most of its time in gulches; however, the fixes indicate the edges of the forest and woodland low elevation habitat. Bats 10, 11, and 12 were tracked in March but Bat 10 (tracked in early March) flew almost exclusively in low-density developed. Bats 11 and 12 were tracked in mid-March and late March, respectively, and foraged primarily in grassland, forest woodland low elevation (gulches) with less time foraging in low-density developed habitat. Bat 20 was tracked in September and used mostly forest woodland low elevation (gulches), low-density developed, and shrubland habitats. Statistical analyses were not attempted because of the relatively low number of nights each bat was tracked in each habitat on each night. Appendix G provides the FR and CUA for each radio-tracked bat showing the distribution of fixes superimposed on the habitat map.

On October 1, 2017 between 6:02 p.m. and 6:06 p.m. a foraging bat that was about 25 meters above ground and presumed to be Bat 5, dive-bombed another bat three separate times as the second bat was commuting through the airspace. Physical contact between the two bats was not observed, although that same evening several bats were observed simultaneously within the same small area. The transmitter had just fallen off of Bat 5, so we could not determine whether both bats were males. However, the edges of the foraging ranges for Bat 5 and Bat 6 were close to the site of the observation and they were caught just 10 days apart. Both foraging ranges represent mostly low-density developed habitat. The two males had enlarged testis and well-developed spines on their penises, which are indicators of sexual maturity. The bats' FAs were from 0 to 0.89 kilometers apart for a distance of 11.4 kilometers, which suggested they may have been defending territories. This behavior was also mentioned in the telemetry study of hoary bats on the island of Hawaiʻi (Bonaccorso et al. 2015). The FAs for females and other males overlap considerably and do not suggest any separation of CUAs.

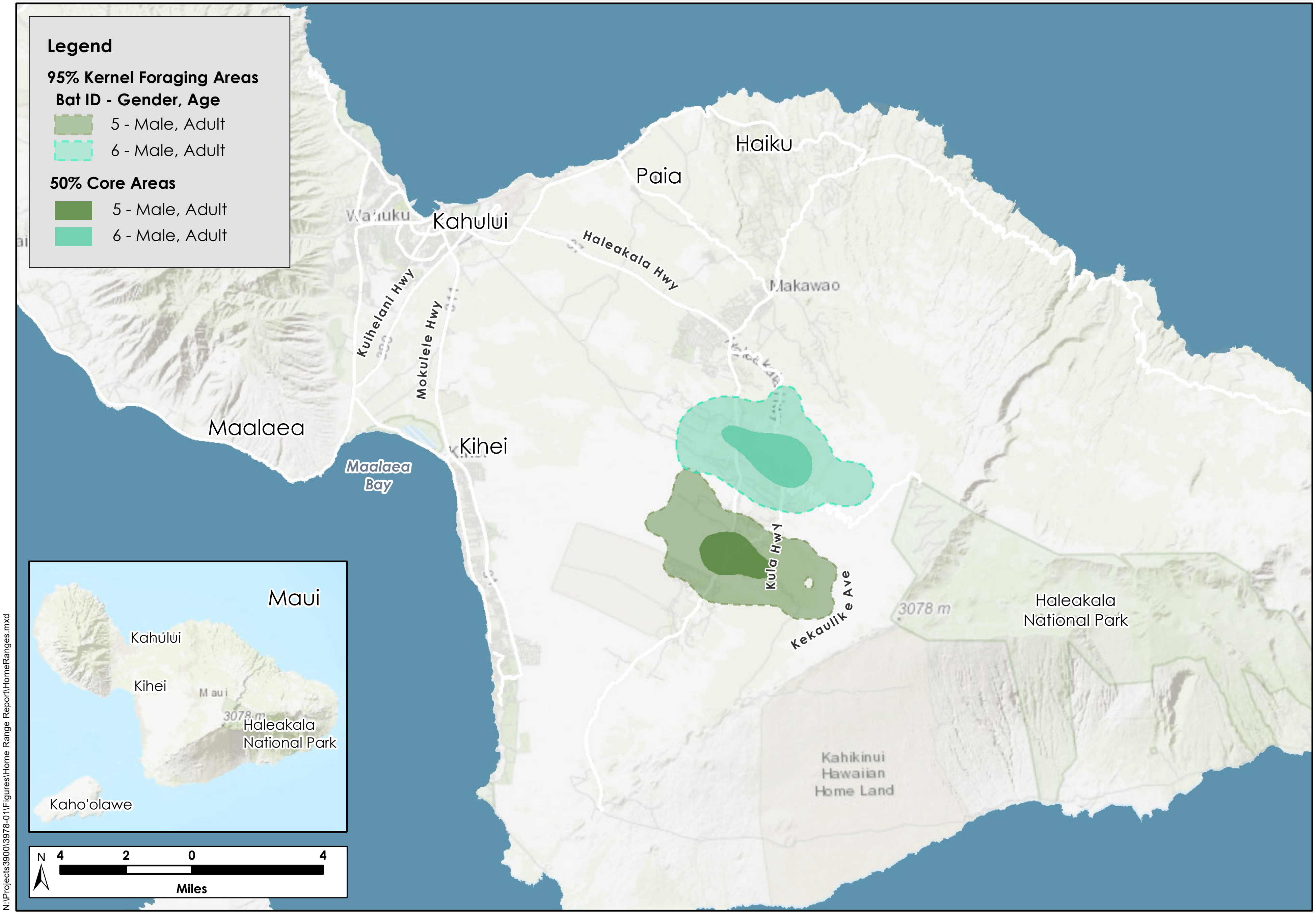

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Figure 16. Bat 5 and 6 at 95% and 50% Kernel Areas

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February 2020

3.3 Diet: Insect Sampling, DNA Extraction from Guano Samples, and DNA Barcoding

During the 2017 and 2018 period of acoustic monitoring and radio telemetry, a total of 63 samples (9 habitats sampled every other month over a fourteen-month period) of insects were collected from within the study area. Additionally, guano samples were collected from approximately half of the bats captured (summer = 9, winter = 2). The majority of guano samples were collected from adult males (n=7), followed by adult females (n=2) and subadult females (n=2). Bats ate primarily moths although a small percentage of Orthopterans, coleaopterans, and isoterans were also eaten (Figure 17). The identification of insects in samples from habitats and the DNA barcoding of prey fragments found in guano samples was conducted in 2019.

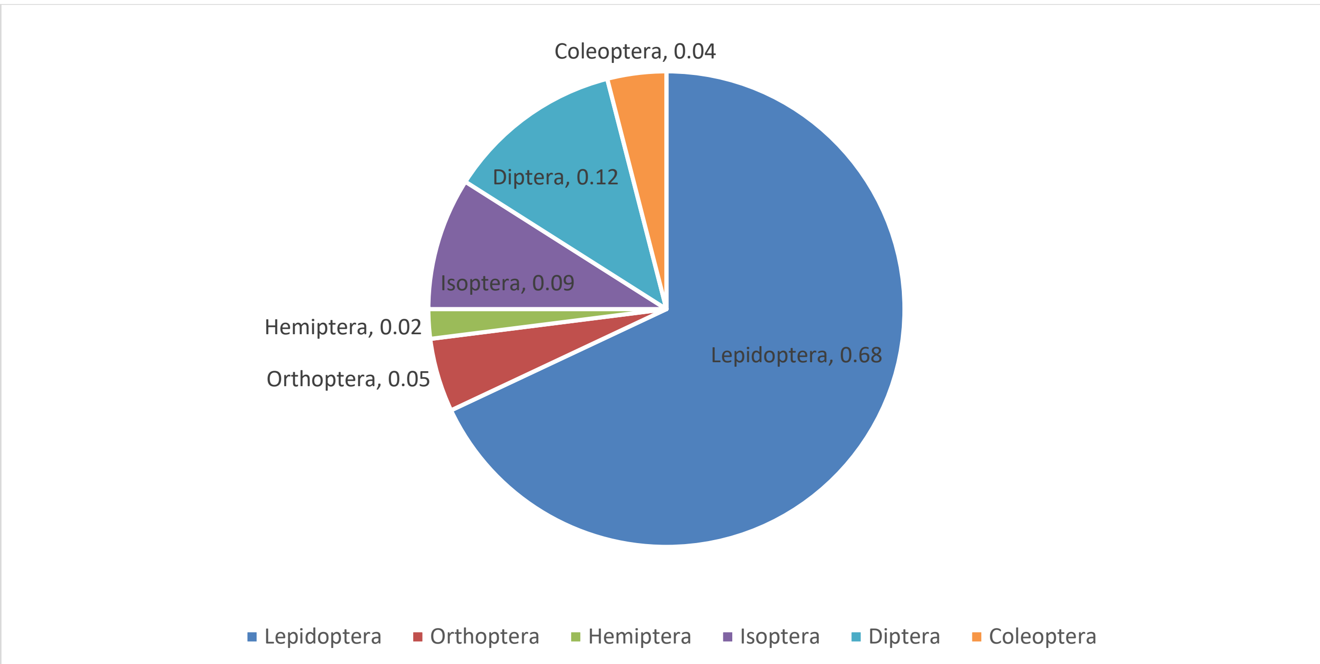

Figure 20. Percentage of Prey Items by Order for 11 Bats.

3.3.1 Species based on DNA Extraction from guano samples

COI Data. We recovered sequences from 22 PCR reactions and pooled these to correspond to 11 fecal samples (Table 5). Negative PCR controls contained less than 200 reads and any identification was made with fewer than 30 assigned reads. Positive controls (mock communities) were analyzed and in these known mixes any identification with less than 200 reads was flagged as generating a false positive. Based on negative and positive controls we retained identifications with more than 200 assigned reads for further consideration and excluded those which did not meet these criteria (insufficient data). The vast majority of insects were moths including *Athetis thoracica, Peridroma saucia* and *Perpetogramma licarsisalis* that were identified in five of the eleven guano samples while *Melipotis indomita* and *Mythimna unipucta* were found in three of the guano samples.

16S Data. The 16S reference data was very limited. As a consequence sequence identification was limited and made at a variety of taxonomic levels including a few noctuid and crambid moths. However, the 16S data identified other insect orders that were not identifie d by the COI data, namely Diptera including short palped crane flies (Limoniinae), blow flies (Calliphoridae), Isoptera including the termites Zootermopsis and Neotermes, and Orthoptera including field crickets (Gryllus) and katydids (Tettigoniidae). The introduced dung beetle (Digitonthophagus gazella) was also identified only in the 16s data.

Table 6. A summary of the Recovered COI and 16S Data from 11 Fecal Samples.

Sample	Reads[1] COI Data	Taxa Order	Taxa Identified	Geographic Agreement	Element or Vegetation
Bat 1	310000	Lepidoptera	*Herpetogramma licarsisalis*	Yes	grasses
		Lepidoptera	*Omiodes continuatalis*	Yes	grasses
		Lepidoptera	*Melipotis (indomita)*	Yes	*Prosopis*
		Lepidoptera	*Athetis (thoracica)*	Yes	generalist
		Lepidoptera	*Elaphria (nucicolora)*	Yes	generalist
		Lepidoptera	*Peridroma saucia*	Yes	generalist
		Orthoptera	*Trigonidomorpha sjostedti*	Yes	generalist
		Diptera	Tipulidae, Limoniinae*	Yes	freshwater detritus
		Isoptera	Neotermes*	Yes	wood
		Orthoptera	Tettigoniidae*	Yes	generalist
Bat 4	333900	Lepidoptera	*Herpetogramma licarsisalis*	Yes	grasses
		Lepidoptera	*Athetis (thoracica)*	Yes	generalist
		Lepidoptera	*Cryptophlebia illepida*	Yes	generalist
		Orthoptera	*Trigonidomorpha sjostedti*	Yes	many, incl. *Acacia koa*
		Diptera	Tipulidae, Limoniinae*	Yes	freshwater detritus
		Isoptera	*Zootermopsis**	Yes	wood
Bat 5	228394	Lepidoptera	*Herpetogramma licarsisalis*	Yes	grasses
		Lepidoptera	*Melipotis*	Yes	*Prosopis*
		Lepidoptera	*Peridroma saucia*	Yes	generalist
		Orthoptera	*Gryllus*	Yes	generalist
Bat 6	493882	Lepidoptera	*Herpetogramma licarsisalis*	Yes	grasses
		Lepidoptera	*Athetis (thoracica)*	Yes	generalist
		Lepidoptera	*Mythimna unipuncta*	Yes	generalist
		Diptera	Calliphoridae*	Yes	carrion and/or dung
		Diptera	Tipulidae, Limoniinae*	Yes	freshwater detritus
Bat 10	437496	Lepidoptera	*Hadenine*	Yes	generalist
		Lepidoptera	*Mythimna unipuncta*	Yes	
		Lepidoptera	*Peridroma saucia*	Yes	generalist
		Diptera	Calliphoridae*	Yes	carrion and/or dung
Bat 11	324361	Lepidoptera	*Hadenine*	Yes	

Sample	Reads[1] COI Data	Taxa Order	Taxa Identified	Geographic Agreement	Element or Vegetation
		Lepidoptera	*Mythimna unipuncta*	Yes	generalist
		Crambidae	*Spoladea (recurvalis)**	Yes	generalist
Bat 12	249839	Coleoptera		Yes	
		Lepidoptera	*Herpetogramma licarsisalis*	Yes	grasses
		Lepidoptera	*Athetis (thoracica)*	Yes	generalist
		Hemiptera	*Nezara viridula*	Yes	generalist, esp. legumes
		Lepidoptera	*Opogona sacchari*	Yes	generalist
		Lepidoptera	*Cryptophlebia illepida*	Yes	many, incl. *Acacia koa*
		Orthoptera	*Trigonidomorpha sjostedti*	Yes	generalist
		Coleoptera	*Digitonthophagus gazella**	Yes	dung
		Hemiptera	*Nezara viridula**	Yes	generalist
		Isoptera	*Neotermes**	Yes	wood
		Orthoptera	Oedipodinae*	Yes	generalist
		Orthoptera	*Gryllus**	Yes	
Bat 15	252774	Lepidoptera	*Herpetogramma licarsisalis*	Yes	grasses
		Lepidoptera	*Melipotis*	Yes	*Prosopis*
		Lepidoptera	*Mompha*	Yes	Melastomataceae (expected)
		Lepidoptera	*Athetis*	Yes	generalist
		Orthoptera	*Chrysodeixis (eriosoma)*	Yes	generalist
		Orthoptera	*Euconocephalus**	Yes	generalist
		Orthoptera	*Trigonidomorpha sjostedti**	Yes	generalist
		Isoptera	*Neotermes**	Yes	wood
		Orthoptera	Tettigoniidae*	Yes	generalist
Bat 17		Diptera	Limoniinae*	Yes	freshwater detritus
		Isoptera	Neotermes*	Yes	wood
Bat 18	264369	Lepidoptera	*Cryptophlebia illepida*	Yes	many, incl. *Acacia koa*
		Diptera	Limoniinae*	Yes	freshwater detritus
		Isoptera	*Neotermes**	Yes	wood
Bat 20	311665	Hemiptera	*Gyponana*	Yes	plant sap
		Lepidoptera	*Peridroma saucia*	Yes	generalist

[1] Reads refers to the number of sequences retained for analysis, taxa identified is the genera and species identified by strict match to reference collections. Geographic agreement is a refinement based on which taxa are likely to be found in the sample area. Species determined by DNA barcoding but not known to occur in Hawai'i (e.g., *Pleuroprucha*, *Agrotis infusa*) were omitted. Species with an asterisk were determined by 16S; all others were determined by CO1. Species names in parentheses are the only Hawaiian representative of genera determined by DNA barcoding; thus, these species were not determined by DNA barcoding but rather, are provided here as the only known geographic representative of these genera.

3.3.2 Availability of Prey – Modelling of Dry Weights of Insect Samples by Habitat and Month

Differences among habitats. Raw data from the dry weights of insect samples suggest significant differences among habitats for the samples collected from August 2017 through August 2018 (Figure 21).

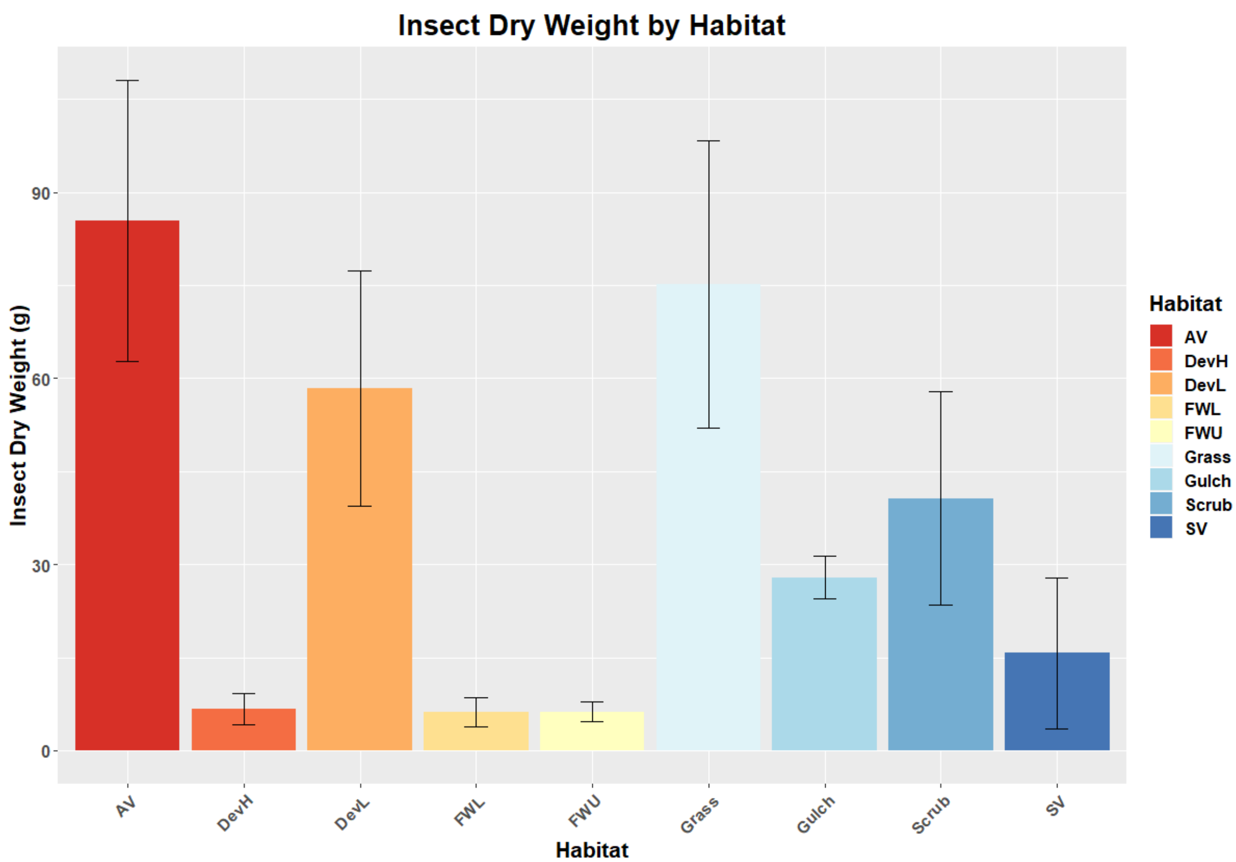

Figure 21. Raw Data for the Dry Weights of Insect Samples in Nine Habitats from August 2017 through August 2018.

Bars show means and whiskers are one standard error of each mean. AV = Agricultural Vegetation, DevH = High Density Developed, DevL = Low Density Developed, FWL = Lower Forest Woodland, FWU = Upper forest Woodland, Grass = Grassland, Scrub = Scrubland, and SV = Sparse Vesicular Rock.

These values are different from model estimates shown in the below Figure 22 which has adjusted for the mean estimates based on the variance in the model and accounting for overdispersion in the dataset. The difference being that Model Estimates (Figure 22) are back-transformed from the log scale because the negative binomial regression (glm.nb) uses a log function, so the estimates on the response (i.e., measured) scale, have to be back-transformed while the statistical analyses are run on logged responses.

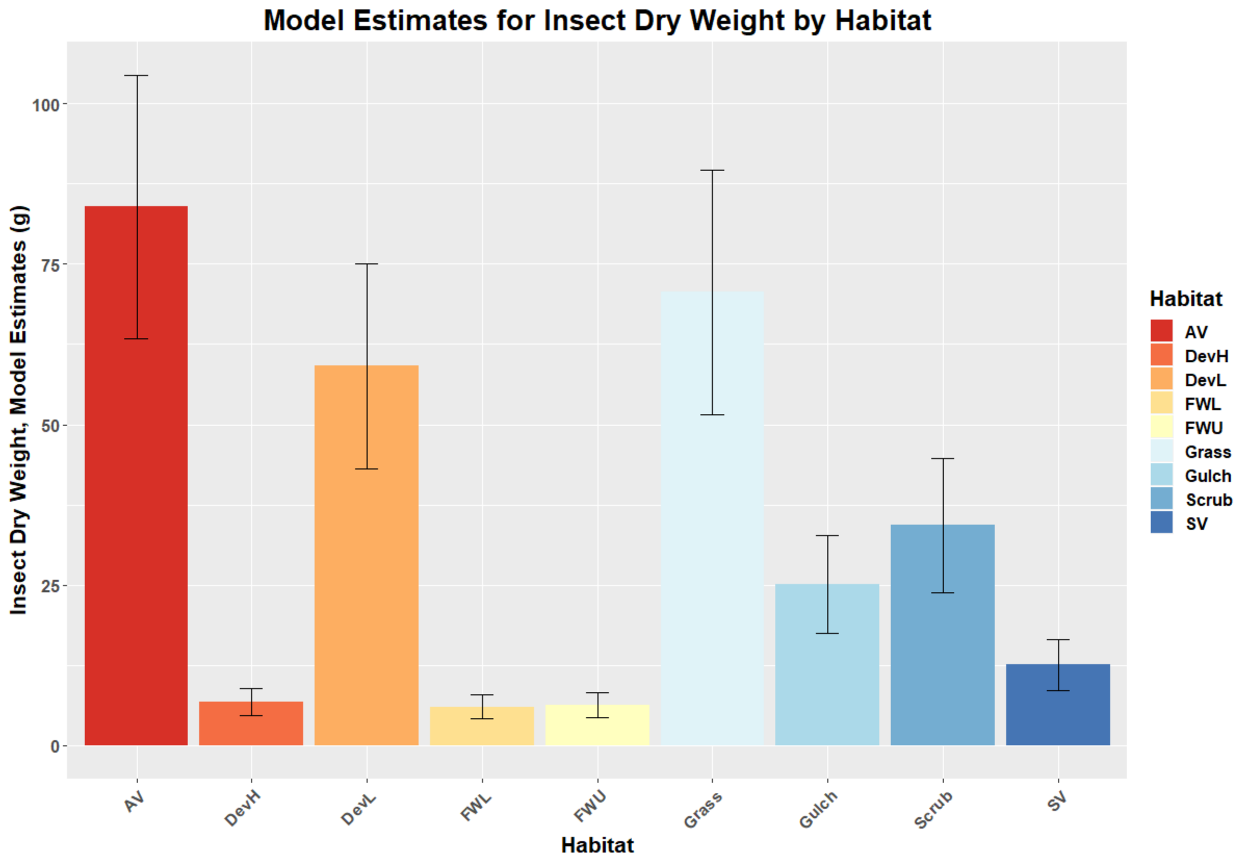

Figure 22. Model Dry Weights of Insect Samples by Habitat.

Bars are mean estimates, and whiskers are 95% confidence intervals generated from contrasts. AV = Agricultural Vegetation, DevH = High Density Developed, DevL = Low Density Developed, FWL = Lower Forest Woodland, FWU = Upper forest Woodland, Grass = Grassland, Gulch = Gulch, Scrub = Scrubland, and SV = Sparse Vesicular Rock.

Modelling results (Tukey, 0.95 confidence; $\alpha = 0.05$ significance level) indicate that it is reasonable to conclude that there are significant differences between some habitat types (Table 7).

Table 7. Pairwise Comparisons of Habitat Types at Alpha = 0.05.

Habitat Types with Significantly Greater Dry Weights of Insects	Habitat Type(s) with Significantly Less Dry Weight of Insects
DevL, Grass, AV, Gulch, and Scrub	FWL and FWU
Scrub, DevL, Grass, and AV	DevH
DevL, Grass, and AV	SV

AV = Agricultural Vegetation, DevH = High Density Developed, DevL = Low Density Developed, FWL = Lower Forest Woodland, FWU = Upper forest Woodland, Grass = Grassland, Gulch = Gulch, Scrub = Scrubland, and SV = Sparse Vesicular Rock.

Differences among months. We could not detect significant differences between months sampled for the dry weights of insect samples. This is not to say that there are not differences between months. However, because of a few missing data, relatively small differences in the raw data, large variances, along with small sample size (maximum of one sample per month collected in each habitat type), it is likely impossible to discern differences.

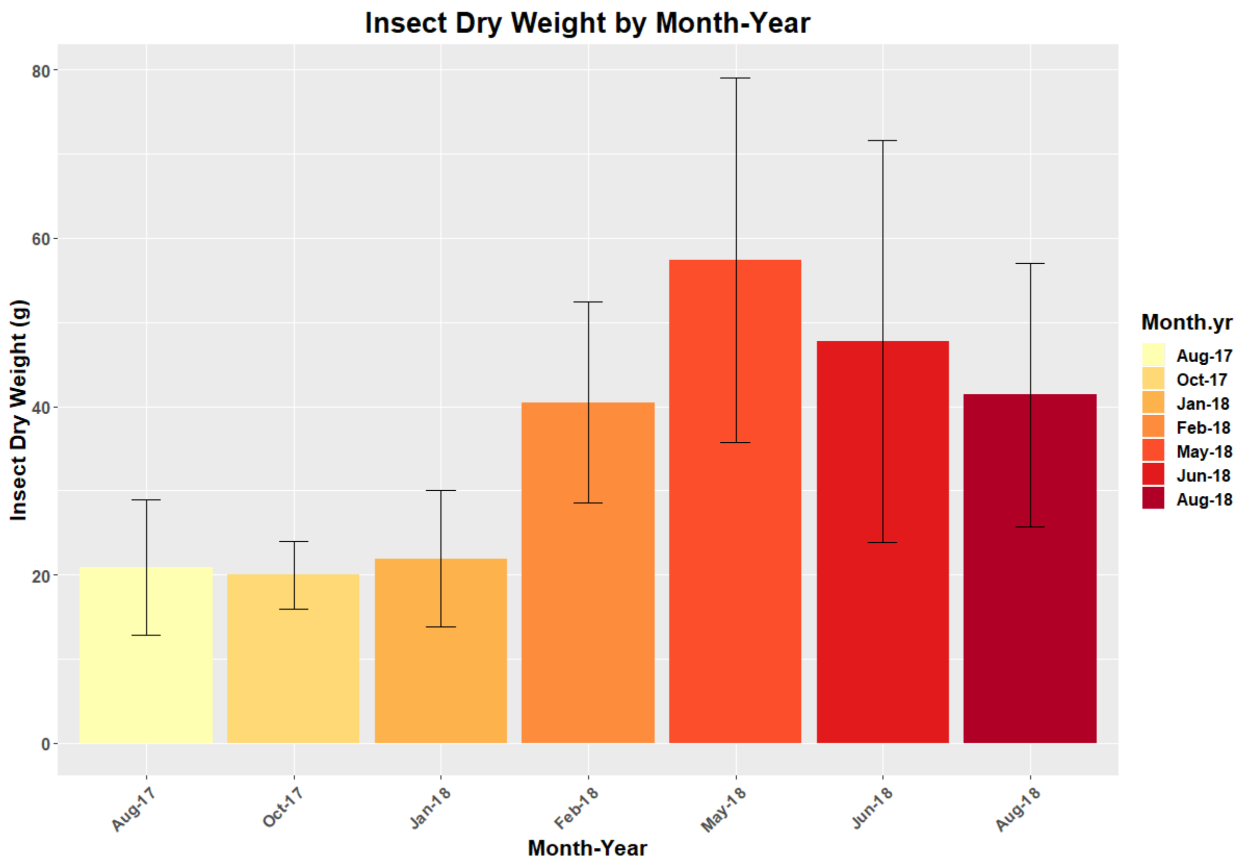

Figure 23. Raw Data for Dry Weights of Insect Samples during Seven sampling Months from Nine Habitat Types.

Bars show means and whiskers are one standard error of each mean.

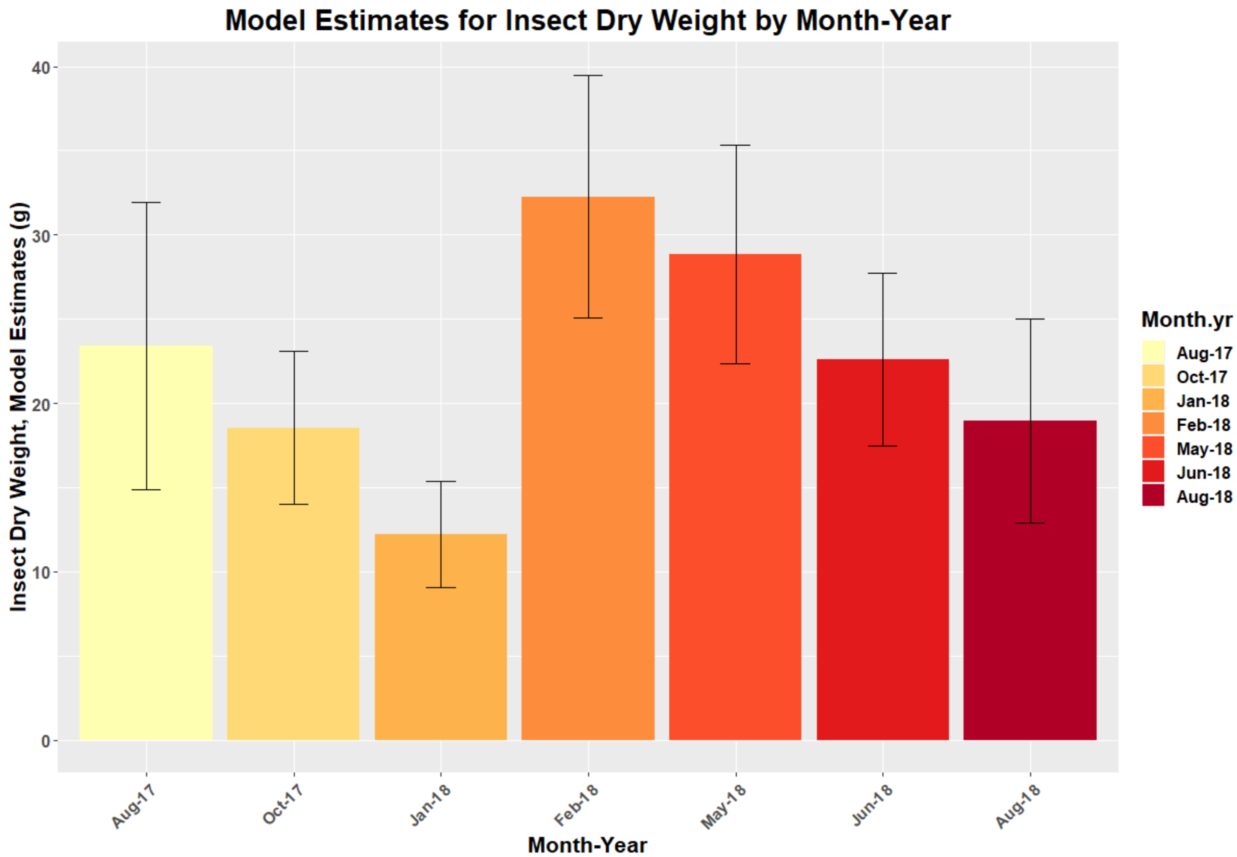

Figure 24. Modelled Dry Weights of Insect Samples by Month.

Values are adjusted based on the model, which calculates mean estimates on the basis of variance and other factors in the model and accounts for overdispersion in the dataset. Bars are mean estimates, and whiskers are 95% confidence intervals generated from contrasts.

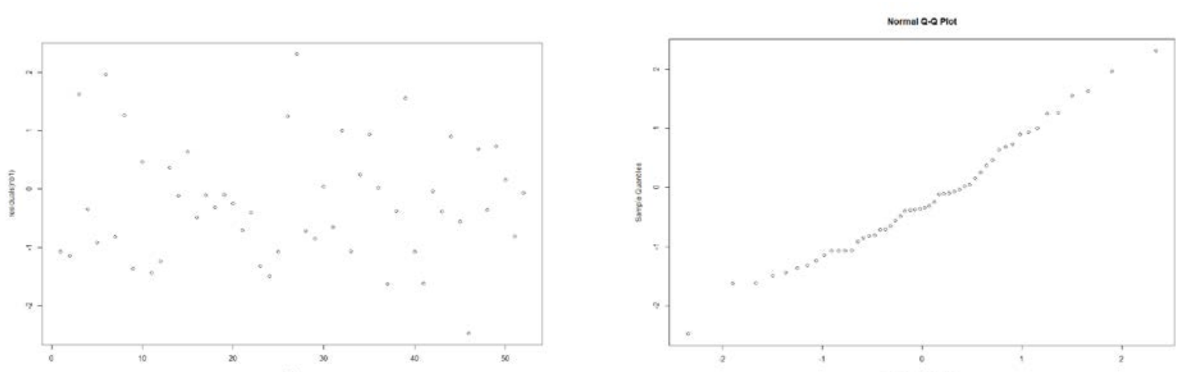

Figure 25. Distribution of Model residuals (Shapiro test, W = 0.99) (Left)
Model Qqnorm Plots Showing a Strong Positive Relationship. (Right)

We inspected the residuals factor (i.e., month and habitat type) and no evident patterns emerged, suggesting a valid model. When investigating residuals by habitat type and month, the residual spread is now much more homogeneous, which is an assumption of this model approach. A Shapiro test was applied to test for normality of the model residuals, and the results indicate that the residuals are normally distributed (W = 0.98, assumed normal because this value is greater than 0.95). The residuals appear to be sufficient and the fitted values plot looks good with no evident patterns. This finding is important because the residuals from the model fits should not be changing systematically in relation to a predictor in the model (this would be a violation of model assumptions). The fitted values (model estimates) plotted by the raw (actual) data have a strong, positive relationship, indicating good agreement between the model estimates and the actual data; this is also important for ensuring adequate model fit.

Appendix H provides the model output, model estimates (mean, standard error, and confidence interval), and the significant differences in dry insect weights between habitats and months.

Appendix I provides a list of species identified from samples

Correlation between Bat Activity and Dry Weights of Insect Samples. We could not examine interactions between bat activity per habitat and dry weights of insect samples per habitat because we collected only a single sample of insects in each habitat for each sample month. Further, several samples were missing because of collection difficulties due to storm events.

Section 4. Discussion

Bats primarily used gulches, grassland, and low density developed habitats. Gulches as a habitat for the Hawaiian hoary bat were unrecognized before this study as an important habitat feature for foraging although acoustic studies at Kawailoa Wind Farm on Oahu suggested that bats use gulches along with surrounding habitats (H. T. Harvey & Associates 2015). Because trade winds typically blow perpendicular to the gulches in our study area, these areas provide flying insects protection from the wind. We believe the concentration of bat activity and foraging in gulches is therefore likely because of the concentration of flying insects that find refuge from the wind, such as described by Verboom and Huitema (1997). Pooled habitat data from the radiotelemetry fixes suggests that bats spent significantly more time over low-density developed, forest woodland low elevation, and grassland habitat types. Although the bat calls/night data varied somewhat among these habitats for different months, the acoustic data imply that bats tend to spend more time in low-density developed, grassland, and gulch habitats, but not the forest woodland low elevation habitat. Interestingly, the gulch habitat type had only a single fix data point despite the acoustic data suggesting that it is an important habitat for the Hawaiian hoary bat. We found that the bats were typically undetectable with the radiotelemetry receiver when they were inside these deep gulches; however, individuals were detectable when they reemerged and flew over the forest woodland low elevation habitat between gulches. Most of the radiotelemetry fixes in the forest woodland low elevation habitat were situated at the edges of gulches and between gulches that were relatively close together. Further, gulches produced significantly more insects based on the dry weights of insects sampled at these habitats. Because gulches appear to provide an important habitat for the Hawaiian hoary bat on Maui, and because gulches tend to be less developable because of their steep terrain, we believe this habitat could play an important role in the conservation of habitats for this species.

Based on the acoustic and telemetry data, bats also spent significantly more time in grasslands, especially during the months of May through September, than most other habitats. Additionally, Bats 1, 2, 3, 4, 5, 6, 12, and 15 had all consumed the tropical webworm, *Herpotogramma licarsisalis*, an introduced moth specialized on grasses as their host species. Other bats, Bats 7, 8, 10, 11, and 12, were all caught early in the year (January through March) and did not have any evidence of this moth in their fecal pellets, presumably because their capture time was before this moth matured as an adult making it unavailable as prey. Although we did not have enough samples of pastures to treat these as a subset of the grasslands, many pastures had high levels of bat activity based on acoustic data. In this study for Bat 12 and in Pinzari et al. (2019) the introduced African dung beetle (*Digitonthophagus gazella*) was also identified as a prey type and is found in active pastures throughout much of Hawaii. Additionally, the blow flies (Calliphoridae) that we found in guano from bats 6 and 10 may have also come from dung in pastures.

Low density development had significantly higher levels of bat activity based on our acoustic and telemetry data. Bats 4, 5, and 6 were caught in September and October and all show large portions of their time in low density development. We also found that these low density development habitats in the semi-rural communities surrounding Makawao and Kula had the second highest levels of insect mass based on our insect sampling.

These areas were generally open and had a high diversity of nonnative plants and invertebrates likely providing ample prey bases. Schlaepfer (2018) suggested that some areas of nonnative introduced plants and animals, particulary in areas with cultivated landscapes, often have a richer species diversity than neighboring native habitats. We are not suggesting that the low density developed areas had higher biodiversities of native areas of Hawaii, but we are suggesting this habitat is rich in biodiversity; bats appear to take advantage of this habitat within our study area.

We found that bats spent significantly less time in forested habitats (forest woodland low and forest woodland upper) than any of the other seven habitats based on our robust acoustic study with 35 separate bat detection sites in each of the nine habitat types. We did not separate native forests from non-native forest because there were too few locations of native forest habitat where we could install bat detectors. Both forest habitat types (forest woodland lower and forest woodland upper) in our study area were composed of mostly nonnative forests. Nonetheless, native forests occurred and bats used native forests more than expected given the scant percentage of native forests. Of the telemetry data, 81% of detections were over non-native forest lands as opposed to the 19% of detections over native forest lands while less than 10% of the forest habitat areas were native. Additionally, low density development, grassland, agricultural vegetation, gulch, and scrubland habitats all had significantly higher amounts of dry weights of insects compared to the forest habitats, and we observed very few moths and other flying insects in these nonnative forests while mist netting there. We occasionally observed bats flying over forests, but these bats did not typically forage based on the limited circling behavior observed.

Shrubland, occurring primarily at altitudes greater than 2,000 meters, appears to be an important habitat during winter months based on the acoustic data and telemetry data for habitat use. Bat 7 used these high altitude shrublands almost exclusively in February and forest woodland upper, also above 2,000 feet, had significantly higher acoustic activity in January. Thus, based on our acoustic and telemetry data, the importance of a specific habitat appears to change through seasons. Any management plan for the Hawaiian hoary bat needs to take these complex relationships with habitats into consideration.

We totaled 92 nights of radio-tracking and had a total of 755 triangulated fixes to determine kernel analyses for home range sizes. Many fixes were not used when the timing of the bearings did not occur within one second of each other, could not be verified, or were from bats with less than 25 fixes. Although our location data are fairly accurate, the number of nights we collected data on bats was quite small to be representative of the full range of their movements, even within a single season. Yet, even in this very brief monitoring period, we detected numerous long-range movements of approximately 16 kilometers. A limitation of using only two observers for bats that can fly fast (likely 60 miles per hour or more [Swartz pers. comm. 2019]) and use large home ranges is that it's often difficult to always have both observers at different wide angles to the bats to ensure accuracy. However, angles between observers less than 15 degrees were not used because fixes lose accuracy as bearings begin to converge. In such cases we did not include fixes and the lack of fixes in those instances would underestimate our home ranges. When compared to CUAs determined on the island of Hawaiʻi (Bonaccoso et al. 2015) our kernel analysis for Maui bats suggests CUAs averaged many times the size. Because of huge differences in mean sizes for the FRs and CUAs, we reanalyzed our data using the same parameters and smoothing values used for the telemetry data in the Bonaccorso et al. 2015 paper. As indicated in our results, and through this second analysis of our data, our kernel analyses averages of the Maui bats were slightly smaller but not consistently so. The telemetry study on Hawaiʻi was designed to require only one observer to collect data, and was also designed to limit the potential distance from the observer to the bat at 300 meters at which an error could occur. This limitation may have introduced a bias toward underestimating the distance between observer and bat and made it impossible to obtain a point on a bat further away than the maximum calibration distance of 300 meters.

However, we believe this difference in mean sizes for FRs and CUAs could be due largely because the habitats bats used on the island of Hawaiʻi are quite different; the habitats for the Bonaccorso et al. (2015) study included more native vegetation and bats there may have foraged on higher densities of insects. This would reduce the amount of time and space needed for bats to forage. Several other studies suggest bats' foraging ranges and core use areas vary enormously between different geographic areas. For example, the core use areas for the Indiana bat (*Myotis sodalis*) was 145 hectares in Illinois (Menzel et al. 2005) and 1,137 hectares in Missouri (Womack et al. 2013). A sister taxon to hoary bats, the eastern red bat (*Lasiurus borealis*), had a mean core use area of 94 hectares in Mississippi (Elmore et al. 2005) and 1,357 hectares in Missouri (Amelon et al. 2014), a factor of over 14 times the size.

We found that the Hawaiian hoary bat ate both native and nonnative insects. We also found that bats on Maui ate primarily moths, and rarely beetles, in contrast to bats on the Island of Hawaii that appeared to rely more on beetles at middle and lower elevations (Todd 2012). Many very common species of moths found in our insect samples were not observed in the diets of bats. Although this suggests bats were selective in their feeding habits, our sample size of guano was comparatively small, and more samples should be analyzed for species contents before determining if bats showed preferences for prey species. The changes in habitat use over time, the differences in home range sizes, and diets of bats between different Hawaiian Islands strongly suggests foraging flexibility in this species.

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Appendix A. Parameters and Documentation for Kernel Analysis Method

1. Kernel Density Analysis (as per methods in Bonaccorso et al. 2015 p)

Start Time: 2/12/2020 3:37:43 PM
Input Data: CombinedFlyBats2020
Unique ID Field: Bat_id
Independence of observation indices:
System.Windows.Forms.ComboBox, Items.Count: 3, Count, Schoener, Swihart_Slade
2, 45, 0.5895, 0.25481
3, 28, 0.21031, 2.07054
4, 92, 0.53101, 2.48472
5, 55, 0.79848, 0.46162
6, 40, 1.18853, 0.51884
7, 25, 2.22128, -0.04386
9, 23, 0.87042, -0.0744
10, 23, 1.45613, 0.47087
12, 28, 0.73153, 1.77266
20, 32, 1.05162, 1.7071

Variances of x and y coordinates:
System.Windows.Forms.ComboBox, Items.Count: 3, Count, StdDev_X, StdDev_Y, Ratio(x:y)
2, 45, 707.68, 867.07, 0.82
3, 28, 5830.01, 1959.62, 2.98
4, 92, 2898.63, 3703.53, 0.78
5, 55, 1703.09, 1047.46, 1.63
6, 40, 1673.64, 922.23, 1.81
7, 25, 1265.22, 1390.46, 0.91
9, 23, 2752.8, 2530.32, 1.09
10, 23, 120.51, 66.54, 1.81
12, 28, 3893.36, 2604.4, 1.49
20, 32, 4311.18, 5567.71, 0.77

Kernel Settings
Kernel type: fixed
Bandwidth estimator: LSCV
Output Folder: N:\Projects3900\3978-01\shapefiles\Homerange\Telemetry_HRT_outputs
Raster Prefix name: kde
Raster Cell Size: 10
Scaling Factor: 10
Extent Setting: Full
Isopleths: 95, 50 (lines polygons donuts)/n/nCase specific settings
Unique ID: 2
Sample Size: 45
Bandwidth: 462.843011245185

HREF (for reference): 419.621950358283
Bandwidth represents minimized LSCV
Columns, Rows:4208, 4755
Origin of the Raster (lower left x,y): 756076.7633, 2275647.189
Raster name: kde0
Kernel calculated successfully.
Volume: 9.99882822764607/10
Unique ID: 3
Sample Size: 28
Bandwidth: 222.123753795937
HREF (for reference): 2495.7725145611
Bandwidth represents minimized LSCV
Columns, Rows:4208, 4755
Origin of the Raster (lower left x,y): 756076.7633, 2275647.189
Raster name: kde1
Kernel calculated successfully.
Volume: 9.99876343723856/10
Unique ID: 4
Sample Size: 92
Bandwidth: 1009.14433185872
HREF (for reference): 1565.17151121943
Bandwidth represents minimized LSCV
Columns, Rows:4208, 4755
Origin of the Raster (lower left x,y): 756076.7633, 2275647.189
Raster name: kde2
Kernel calculated successfully.
Volume: 9.99875092294746/10
Unique ID: 5
Sample Size: 55
Bandwidth: 410.884557797558
HREF (for reference): 724.983780851449
Bandwidth represents minimized LSCV
Columns, Rows:4208, 4755
Origin of the Raster (lower left x,y): 756076.7633, 2275647.189
Raster name: kde3
Kernel calculated successfully.
Volume: 9.99881358658858/10
Unique ID: 6
Sample Size: 40
Bandwidth: 734.678314602725
HREF (for reference): 730.659686327921
Bandwidth represents minimized LSCV
Columns, Rows:4208, 4755
Origin of the Raster (lower left x,y): 756076.7633, 2275647.189
Raster name: kde4
Kernel calculated successfully.
Volume: 9.99874190209491/10
Unique ID: 7
Sample Size: 25
Bandwidth: 1016.6272740778
HREF (for reference): 777.386560181841
Bandwidth represents minimized LSCV

Columns, Rows:4208, 4755
Origin of the Raster (lower left x,y): 756076.7633, 2275647.189
Raster name: kde5
Kernel calculated successfully.
Volume: 9.99875121053928/10
Unique ID: 9
Sample Size: 23
Bandwidth: 2249.01245292563
HREF (for reference): 1567.80233734794
Bandwidth represents minimized LSCV
Columns, Rows:4208, 4755
Origin of the Raster (lower left x,y): 756076.7633, 2275647.189
Raster name: kde6
Kernel calculated successfully.
Volume: 9.99874252152107/10
Unique ID: 10
Sample Size: 23
Bandwidth: 37.2154834100862
HREF (for reference): 57.7207962932706
Bandwidth represents minimized LSCV
Columns, Rows:4208, 4755
Origin of the Raster (lower left x,y): 756076.7633, 2275647.189
Raster name: kde7
Kernel calculated successfully.
Volume: 9.99874878761319/10
Unique ID: 12
Sample Size: 28
Bandwidth: 1900.7367737047
HREF (for reference): 1900.7367737047
Bandwidth represents minimized LSCV
Columns, Rows:4208, 4755
Origin of the Raster (lower left x,y): 756076.7633, 2275647.189
Raster name: kde8
Kernel calculated successfully.
Volume: 9.99875282550947/10
Unique ID: 20
Sample Size: 32
Bandwidth: 2401.17823517117
HREF (for reference): 2794.50478344041
Bandwidth represents minimized LSCV
Columns, Rows:4208, 4755
Origin of the Raster (lower left x,y): 756076.7633, 2275647.189
Raster name: kde9
Kernel calculated successfully.
Volume: 9.99874486446701/10
Finish Time: 2/12/2020 4:27:14 PM
Processing Complete
[RESCALE]
False
[kernel]
True
[form]

Gaussian (bivariate normal)
[lscv]
True
[bcv]
[href]
False
[manual]
False
[outfolder]
N:\Projects3900\3978-01\shapefiles\Homerange\Telemetry_HRT_outputs
[prefix]
kde
[cellsize]
10
[scaling]
10
[verbose]
True
[extent]
full
9781
[iso]
True
95, 50
True
True
True
[silent]
False

2. Kernel Density Analysis (as per original methods in R for this study)

```
# Analysis visualizing the kernel homerange distribution
library(readr)
library(sp)
library(adehabitatHR)
library(maptools)
library(rgdal)
library(raster)
library(ggplot2)
library(rworldmap)
library(mapproj)
library(ggmap)
library(Rmisc)
library(ggthemes)
library(leaflet)
library(ggsn)
library(g.data)
library(grid)
```

```
#________________GET THE DATA
IN_______________________________________________________________________________
setwd("C:/Users/kjonasson/Desktop/Telemetry Data/Fixes/")
# Get the files names
files = list.files(path="C:/Users/kjonasson/Desktop/Telemetry Data/Fixes/", pattern="*.csv")
# First apply read.csv, then rbind
data = do.call(rbind, lapply(files, function(x) read.csv(x, stringsAsFactors = FALSE)))
# X&Y Estimates are UTMs (Output from the LOAS program)
addinfo <- subset(data[, c(3,4)])
i= 7
# Get capture data
setwd("C:/Users/kjonasson/Desktop/")
capture <- read.csv("capture.csv")
capture <- capture[i,]
#capture <- read.csv("G:/Work Products/Active Projects/3978, HI Hoary Bat Research/01,
Maui/FieldData/MistNetting/CaptureData.csv")

# quick plot of the points
plot(data$X_Estimate, data$Y_Estimate, asp = 1)


#________________GET THE DATA IN SPATIAL DATA FRAME
__________________________________________________________________


prj <- '+proj=utm +zone=4 +datum=WGS84' #need for next step, don't delete
sp <- SpatialPointsDataFrame(coordinates(cbind(data$X_Estimate, data$Y_Estimate)), data = addinfo,
                             proj4string = CRS(prj))

#plot the mean center of the data
mc <- apply(sp, 2, mean)


# Note: if you want more information, like animal id, you'll need to make this into a SpatialPonitsDataFrame
# another quick plot
plot(sp, pch = 19, cex = .5, axes=TRUE)


kd <- kernelUD(sp[,"Bat_id" ], h="href", grid=150) # the "Bat_id" is super important to pull out thee bats
image(kd)

#________________ CREATING THE SPATIAL POLYGONS DATA FRAME
___________________________________________________________
kd_names <- c("Bat 2", "Bat 3", "Bat 4", "Bat 5", "Bat 6", "Bat 9", "Bat 10", "Bat 12", "Bat 16")
ud_50 <- lapply (kd, function(x) try(getverticeshr(x,50)))
# This code dpesn't work, but it's OK because the row names are appropriate

sapply(1:length(ud_50), function(i){
  row.names(ud_50[[i]]) <<- kd_names[i] # two arrows because it's a superassignment ... inside [[]]
  })
```

```
sdf_poly <- Reduce(rbind,ud_50)
sdf_poly

df <- fortify (sdf_poly)
g <- ggplot(df, aes(x=long, y=lat, fill = id, group=group))+
  geom_polygon(alpha=0.4)+
  coord_equal()+
  theme_void()
g



#________________ VISUALIZE IN GGPLOT
________________________________________________________________________

# first convert to longitude and latitude
sp2 <- spTransform(sp, CRS('+proj=longlat'))
plot(sp2, axes=TRUE)
sp3 <- as.data.frame(sp2) # this has fly and roost
sp3$Bat_id <- as.character(sp3$Bat_id)
colnames(sp3) <- c("Bat_id", "FlyRoost", "lon", "lat")
fly <- subset(sp3, FlyRoost=="Fly")
roost <- subset(sp3, FlyRoost=="Roost")


sdf_poly_latlong <- spTransform(sdf_poly, CRS('+proj=longlat +datum=WGS84'))a
plot(sdf_poly_latlong, axes=TRUE)
sdf_poly_latlong<- fortify(sdf_poly_latlong)

# Work around for mapping
HImap.df <- ggmap(get_stamenmap(rbind(as.numeric(paste(geocode_OSM("Maui")$bbox))), zoom = 12))

bb <- attr(HImap.df, "bb")
bb2 <- data.frame(long=unlist(bb[c(2,4)]), lat=unlist(bb[c(1,3)]))
scale <- data.frame(lat= c(-156.25,-156.4), lon=c(20.625,20.625))

scalebar = function(x,y,w,n,d, units="km"){
  # x,y = lower left coordinate of bar
  # w = width of bar
  # n = number of divisions on bar
  # d = distance along each division

  bar = data.frame(
    xmin = seq(0.0, n*d, by=d) + x,
    xmax = seq(0.0, n*d, by=d) + x + d,
    ymin = y,
    ymax = y+w,
    z = rep(c(1,0),n)[1:(n+1)],
    fill.col = rep(c("black","white"),n)[1:(n+1)])

  labs = data.frame(
    xlab = c(seq(0.0, (n+1)*d, by=d) + x, x),
```

```
    ylab = c(rep(y-w*1.5, n+2), y-3*w),
    text = c("0","5","10","15","20","25 km", "")
  )
  list(bar, labs)
}

sb = scalebar(-156.5, 20.625, 0.005, 4, 0.048092, "km" )

# Mapping
HImap.df <- get_map(location = c(long = -156.33, lat= 20.79),
                    maptype="satellite",
                    source="google",
                    zoom=11,
                    color="color")

bb <- attr(HImap.df, "bb")
bb2 <- data.frame(long=unlist(bb[c(2,4)]), lat=unlist(bb[c(1,3)]))
scale <- data.frame(lat= c(-156.25,-156.4), lon=c(20.625,20.625))

scalebar = function(x,y,w,n,d, units="km"){
  # x,y = lower left coordinate of bar
  # w = width of bar
  # n = number of divisions on bar
  # d = distance along each division

  bar = data.frame(
    xmin = seq(0.0, n*d, by=d) + x,
    xmax = seq(0.0, n*d, by=d) + x + d,
    ymin = y,
    ymax = y+w,
    z = rep(c(1,0),n)[1:(n+1)],
    fill.col = rep(c("black","white"),n)[1:(n+1)])

  labs = data.frame(
    xlab = c(seq(0.0, (n+1)*d, by=d) + x, x),
    ylab = c(rep(y-w*1.5, n+2), y-3*w),
    text = c("0","5","10","15","20","25 km", "")
  )
  list(bar, labs)
}

sb = scalebar(-156.5, 20.625, 0.005, 4, 0.048092, "km" )



# Pulling out the areas of these polygons is a shit ton of work
ud_95[[5]] # give the home range in ha (look up mcp that will tell units in and out of the function)
# The below no longer works with the type of object i have :(
# hr2 <- round( ud_95[[2]], digits=2)
```

```
# Plot with  no fixes
p1 <- ggmap(HImap.df, extent="panel")+
  geom_polygon(data=sdf_poly_latlong, aes(x = long, y = lat, group=group, fill = id), alpha=0.6)+ # need
group=group so the polygons make sense

  geom_rect(data=sb[[1]], aes(xmin=xmin, xmax=xmax, ymin=ymin, ymax=ymax, fill=z), inherit.aes=F,
            show.legend = F,  color = "black", fill = sb[[1]]$fill.col) +
  geom_text(data=sb[[2]], aes(x=xlab, y=ylab, label=text), inherit.aes=F, show.legend = F, size=3,
color="white")+
  labs(title = "Homeranges of bats tracked from Jul 28 - Oct 7, 2017", x="Longitude", y="Latitude")+
  theme(plot.margin = margin(1, 1, 1, 1, "cm"), legend.position = "bottom", legend.justification = "left")+
  scale_fill_discrete(name="95% Kernel ", labels= c("Bat 2  1,263.30 ha","Bat 3  26,064.76 ha","Bat 4
19,213.87 ha","Bat 5  4,000.17 ha","Bat 6  3,706.85 ha" ))+
  guides(fill=guide_legend(nrow=5,byrow=TRUE, title.position = "top"))+
  coord_cartesian()+
  north(data=bb2, location="topright", symbol = 10)

p1

pdf(paste("C:/Users/kjonasson/Desktop/Telemetry Data/HomerangePlots/AllBats.pdf", sep=""),
     width=7, height=9, paper = "letter")
 p1
dev.off()

#i <- i+1 # increase the counter so you go to the next bat

#}

# Plot with fixes

g_legend<-function(a.gplot){
  tmp <- ggplot_gtable(ggplot_build(a.gplot))
  leg <- which(sapply(tmp$grobs, function(x) x$name) == "guide-box")
  legend <- tmp$grobs[[leg]]
  legend
}

legends <- list(g_legend(p2 + geom_point(data=fly, aes(color = "black" ))),
                g_legend(p2 + geom_point(data=roost, aes(lon, lat, shape="FlyRoost"), pch=19, color="red",
show.legend = TRUE)
                         +  scale_fill_discrete(name="  ") +
                          guides(fill=guide_legend(nrow=5,byrow=TRUE, title.position = "top"))

                         )
                         )


library(gridExtra)
grid.arrange(p2  + guides(color = 'none'),
             do.call(arrangeGrob, legends), nrow = 1, widths = c(0.8, 0.2))
```

```
# Just the map
p2 <- ggmap(HImap.df, extent="panel")+
  geom_blank()+
  #geom_polygon(data=sdf_poly_latlong, aes(x = long, y = lat, group=group, fill = id), alpha=0.6,
show.legend = F)+ # need group=group so the polygons make sense
  #geom_point(data=fly, aes(lon, lat), col="black", show.legend=F)+
  #geom_point(data=roost, aes(lon, lat), col="red")+
  #geom_point(data=capture, aes(Long, Lat), col="black", pch=23, fill="white", size=2)+
  geom_rect(data=sb[[1]], aes(xmin=xmin, xmax=xmax, ymin=ymin, ymax=ymax, fill=z), inherit.aes=F,
           show.legend = F,  color = "black", fill = sb[[1]]$fill.col) +
  geom_text(data=sb[[2]], aes(x=xlab, y=ylab, label=text), inherit.aes=F, show.legend = F, size=3,
color="white")+
  labs(title = "Homeranges of bats tracked from Jul 28 - Oct 7, 2017", x="Longitude", y="Latitude")+
  theme(plot.margin = margin(1, 1, 1, 1, "cm"), legend.position = "bottom", legend.justification = "left")+
  scale_fill_discrete(name="95% Kernel ", labels= c("Bat 2  1,263.30 ha","Bat 3  26,064.76 ha","Bat 4
19,213.87 ha","Bat 5  4,000.17 ha","Bat 6  3,706.85 ha" ))+
  guides(fill=guide_legend(nrow=5,byrow=TRUE, title.position = "top"))+
  coord_cartesian()+
  north(data=bb2, location="topright", symbol = 10)

p2

# Just the homerange
p_hr <- ggmap(HImap.df, extent="panel")+
  geom_polygon(data=sdf_poly_latlong, aes(x = long, y = lat, group=group, fill = id), alpha=0.6,
show.legend = T)+ # need group=group so the polygons make sense
  scale_fill_discrete(name="95% Kernel ", labels= c("Bat 2  1,263.30 ha","Bat 3  26,064.76 ha","Bat 4
19,213.87 ha","Bat 5  4,000.17 ha","Bat 6  3,706.85 ha" ))+
  guides(fill=guide_legend(nrow=5,byrow=TRUE, title.position = "top"))+
  theme(legend.position = "bottom")
p_hr

# Just the fly
p_fly <- ggmap(HImap.df, extent="panel")+
  geom_point(data=fly, aes(x=lon, y=lat, shape=FlyRoost), col="black")+
  scale_shape_manual(values=19, guide = guide_legend(nrow=1, title.position = "top")) +
  theme(legend.position = "bottom", legend.title=element_blank(), legend.key = element_rect(colour =
"transparent", fill = "white"))
p_fly

# Just the roost
p_roost <- ggmap(HImap.df, extent="panel")+
  geom_point(data=roost, aes(x=lon, y=lat, shape=FlyRoost), col="red")+
  scale_shape_manual(values=19, guide = guide_legend(nrow=1, title.position = "top")) +
  theme(legend.position = "bottom", legend.title=element_blank(), legend.key = element_rect(colour =
"transparent", fill = "white"))
p_roost

# Just the capture site
p_cap <- ggmap(HImap.df, extent="panel")+
  geom_point(data=capture, aes(x=Long, y=Lat, shape=LED), col="black", fill="white", size=2)+
  scale_shape_manual(values=23, guide = guide_legend(nrow=1, title.position = "top")) +
```

```
  theme(legend.position = "bottom", legend.title=element_blank(), legend.key = element_rect(colour =
"transparent", fill = "white"))
p_cap

pdf(paste("C:/Users/kjonasson/Desktop/Telemetry Data/HomerangePlots/AllBats_fixes.pdf", sep=""),
    width=7, height=9, paper = "letter")
p2
dev.off()
```

Appendix B. Contrast Estimates by Habitat and Month

```
> emmeans(nb1, pairwise ~ Month | Habitat, type = "response")
$emmeans
Habitat = AV:
 Month    response     SE  df asymp.LCL asymp.UCL
 Jan2018     4.508  2.284 Inf    1.6701     12.17
 Jul2018    26.865 12.679 Inf   10.6523     67.75
 Mar2018     2.270  1.265 Inf    0.7612      6.77
 May2018    34.344 18.024 Inf   12.2777     96.07
 Nov2017     9.760  4.731 Inf    3.7743     25.24
 Sep2017    12.209  5.860 Inf    4.7657     31.28
 Sep2018    28.966 13.630 Inf   11.5172     72.85

Habitat = DevH:
 Month    response     SE  df asymp.LCL asymp.UCL
 Jan2018    12.744  6.122 Inf    4.9705     32.67
 Jul2018     8.965  4.358 Inf    3.4580     23.24
 Mar2018     9.174  4.501 Inf    3.5070     24.00
 May2018    25.545 12.046 Inf   10.1376     64.37
 Nov2017     8.310  4.051 Inf    3.1964     21.61
 Sep2017    60.479 28.243 Inf   24.2163    151.04
 Sep2018    13.208  6.325 Inf    5.1667     33.77

Habitat = DevL:
 Month    response     SE  df asymp.LCL asymp.UCL
 Jan2018    13.523  6.469 Inf    5.2951     34.54
 Jul2018    82.830 38.606 Inf   33.2242    206.50
 Mar2018     7.896  3.945 Inf    2.9656     21.02
 May2018    52.675 24.620 Inf   21.0747    131.66
 Nov2017    18.813  8.923 Inf    7.4257     47.66
 Sep2017    38.128 17.880 Inf   15.2087     95.59
 Sep2018    72.843 35.656 Inf   27.9084    190.12

Habitat = FWL:
 Month    response     SE  df asymp.LCL asymp.UCL
 Jan2018     0.419  0.350 Inf    0.0814      2.15
 Jul2018    47.184 22.094 Inf   18.8459    118.14
 Mar2018     1.032  0.670 Inf    0.2889      3.68
 May2018     3.425  1.789 Inf    1.2300      9.54
 Nov2017     0.194  0.215 Inf    0.0223      1.70
 Sep2017    18.713  8.879 Inf    7.3832     47.43
 Sep2018     5.145  2.655 Inf    1.8711     14.15

Habitat = FWU:
 Month    response     SE  df asymp.LCL asymp.UCL
 Jan2018   110.793 51.556 Inf   44.5057    275.81
 Jul2018     0.598  0.448 Inf    0.1377      2.59
 Mar2018    16.341  7.776 Inf    6.4298     41.53
 May2018    10.134  4.904 Inf    3.9252     26.16
 Nov2017     1.514  0.883 Inf    0.4832      4.75
 Sep2017     3.569  1.846 Inf    1.2947      9.84
 Sep2018     8.685  4.226 Inf    3.3470     22.54

Habitat = Grass:
 Month    response     SE  df asymp.LCL asymp.UCL
 Jan2018     2.273  1.243 Inf    0.7783      6.64
 Jul2018    39.109 18.332 Inf   15.6060     98.01
 Mar2018     1.976  1.126 Inf    0.6471      6.04
 May2018    36.422 17.086 Inf   14.5228     91.34
 Nov2017    87.604 45.625 Inf   31.5656    243.13
```

```
 Sep2017   41.327 19.362 Inf   16.4981    103.52
 Sep2018  140.576 66.313 Inf   55.7672    354.36

Habitat = Gulch:
 Month   response     SE  df asymp.LCL asymp.UCL
 Jan2018   20.572  9.739 Inf    8.1345     52.03
 Jul2018   41.721 19.569 Inf   16.6378    104.62
 Mar2018    5.994  2.986 Inf    2.2583     15.91
 May2018   86.492 40.295 Inf   34.7068    215.54
 Nov2017   33.057 15.528 Inf   13.1651     83.00
 Sep2017   31.865 14.974 Inf   12.6857     80.04
 Sep2018  146.166 67.959 Inf   58.7602    363.59

Habitat = Shrub:
 Month   response     SE  df asymp.LCL asymp.UCL
 Jan2018   17.567  8.346 Inf    6.9236     44.57
 Jul2018   13.523  6.495 Inf    5.2752     34.67
 Mar2018   22.937 10.835 Inf    9.0871     57.89
 May2018   24.133 11.394 Inf    9.5657     60.88
 Nov2017   11.806  5.678 Inf    4.5994     30.30
 Sep2017   28.721 13.516 Inf   11.4191     72.24
 Sep2018   14.435  7.016 Inf    5.5679     37.42

Habitat = SV:
 Month   response     SE  df asymp.LCL asymp.UCL
 Jan2018    6.428  3.180 Inf    2.4379     16.95
 Jul2018   11.489  5.549 Inf    4.4587     29.61
 Mar2018    7.194  3.544 Inf    2.7392     18.89
 May2018    9.218  4.481 Inf    3.5548     23.90
 Nov2017    2.668  1.426 Inf    0.9356      7.61
 Sep2017   33.231 15.606 Inf   13.2373     83.42
 Sep2018   18.595  8.822 Inf    7.3377     47.12

Confidence level used: 0.95
Intervals are back-transformed from the log scale
```

Contrast Tests for Significant Differences
Differences between Habitats within a Month-Yr

```
$contrasts
Month = Jan2018:
 contrast          ratio       SE  df z.ratio p.value
 AV / DevH      3.54e-01 2.47e-01 Inf -1.488  0.8614
 AV / DevL      3.33e-01 2.32e-01 Inf -1.578  0.8172
 AV / FWL       1.08e+01 1.05e+01 Inf  2.433  0.2660
 AV / FWU       4.07e-02 2.80e-02 Inf -4.657  0.0001
 AV / Grass     1.98e+00 1.48e+00 Inf  0.919  0.9920
 AV / Gulch     2.19e-01 1.52e-01 Inf -2.191  0.4117
 AV / Shrub     2.57e-01 1.78e-01 Inf -1.960  0.5718
 AV / SV        7.01e-01 4.96e-01 Inf -0.501  0.9999
 DevH / DevL    9.42e-01 6.39e-01 Inf -0.088  1.0000
 DevH / FWL     3.04e+01 2.93e+01 Inf  3.545  0.0118
 DevH / FWU     1.15e-01 7.69e-02 Inf -3.233  0.0334
 DevH / Grass   5.61e+00 4.08e+00 Inf  2.368  0.3015
 DevH / Gulch   6.19e-01 4.18e-01 Inf -0.710  0.9987
 DevH / Shrub   7.25e-01 4.90e-01 Inf -0.475  0.9999
 DevH / SV      1.98e+00 1.37e+00 Inf  0.992  0.9867
 DevL / FWL     3.23e+01 3.11e+01 Inf  3.610  0.0093
 DevL / FWU     1.22e-01 8.14e-02 Inf -3.153  0.0428
 DevL / Grass   5.95e+00 4.32e+00 Inf  2.456  0.2540
 DevL / Gulch   6.57e-01 4.42e-01 Inf -0.624  0.9995
 DevL / Shrub   7.70e-01 5.19e-01 Inf -0.388  1.0000
 DevL / SV      2.10e+00 1.45e+00 Inf  1.081  0.9770
 FWL / FWU      3.78e-03 3.61e-03 Inf -5.834  <.0001
 FWL / Grass    1.84e-01 1.84e-01 Inf -1.695  0.7501
 FWL / Gulch    2.04e-02 1.95e-02 Inf -4.056  0.0016
 FWL / Shrub    2.38e-02 2.29e-02 Inf -3.889  0.0032
 FWL / SV       6.51e-02 6.32e-02 Inf -2.814  0.1113
 FWU / Grass    4.87e+01 3.50e+01 Inf  5.415  <.0001
 FWU / Gulch    5.39e+00 3.57e+00 Inf  2.538  0.2139
 FWU / Shrub    6.31e+00 4.19e+00 Inf  2.771  0.1241
 FWU / SV       1.72e+01 1.17e+01 Inf  4.194  0.0009
 Grass / Gulch  1.10e-01 7.99e-02 Inf -3.047  0.0588
 Grass / Shrub  1.29e-01 9.37e-02 Inf -2.824  0.1083
 Grass / SV     3.54e-01 2.61e-01 Inf -1.410  0.8943
 Gulch / Shrub  1.17e+00 7.85e-01 Inf  0.236  1.0000
 Gulch / SV     3.20e+00 2.19e+00 Inf  1.700  0.7471
 Shrub / SV     2.73e+00 1.87e+00 Inf  1.466  0.8712

Month = Jul2018:
 contrast          ratio       SE  df z.ratio p.value
 AV / DevH      3.00e+00 2.03e+00 Inf  1.619  0.7945
 AV / DevL      3.24e-01 2.15e-01 Inf -1.696  0.7490
 AV / FWL       5.69e-01 3.78e-01 Inf -0.848  0.9954
 AV / FWU       4.50e+01 3.98e+01 Inf  4.299  0.0006
 AV / Grass     6.87e-01 4.57e-01 Inf -0.564  0.9998
 AV / Gulch     6.44e-01 4.28e-01 Inf -0.662  0.9992
 AV / Shrub     1.99e+00 1.34e+00 Inf  1.020  0.9841
 AV / SV        2.34e+00 1.58e+00 Inf  1.258  0.9431
 DevH / DevL    1.08e-01 7.29e-02 Inf -3.303  0.0267
 DevH / FWL     1.90e-01 1.28e-01 Inf -2.460  0.2518
 DevH / FWU     1.50e+01 1.34e+01 Inf  3.033  0.0612
 DevH / Grass   2.29e-01 1.55e-01 Inf -2.182  0.4173
 DevH / Gulch   2.15e-01 1.45e-01 Inf -2.276  0.3570
 DevH / Shrub   6.63e-01 4.53e-01 Inf -0.601  0.9996
 DevH / SV      7.80e-01 5.35e-01 Inf -0.362  1.0000
 DevL / FWL     1.76e+00 1.16e+00 Inf  0.851  0.9952
 DevL / FWU     1.39e+02 1.22e+02 Inf  5.590  <.0001
 DevL / Grass   2.12e+00 1.40e+00 Inf  1.136  0.9688
```

contrast	ratio	SE	df	z.ratio	p.value
DevL / Gulch	1.99e+00	1.31e+00	Inf	1.036	0.9824
DevL / Shrub	6.13e+00	4.10e+00	Inf	2.706	0.1453
DevL / SV	7.21e+00	4.84e+00	Inf	2.942	0.0791
FWL / FWU	7.90e+01	6.97e+01	Inf	4.946	<.0001
FWL / Grass	1.21e+00	8.00e-01	Inf	0.283	1.0000
FWL / Gulch	1.13e+00	7.49e-01	Inf	0.186	1.0000
FWL / Shrub	3.49e+00	2.34e+00	Inf	1.864	0.6390
FWL / SV	4.11e+00	2.76e+00	Inf	2.101	0.4728
FWU / Grass	1.53e-02	1.35e-02	Inf	-4.732	0.0001
FWU / Gulch	1.43e-02	1.27e-02	Inf	-4.805	0.0001
FWU / Shrub	4.42e-02	3.93e-02	Inf	-3.506	0.0135
FWU / SV	5.20e-02	4.64e-02	Inf	-3.317	0.0255
Grass / Gulch	9.37e-01	6.22e-01	Inf	-0.097	1.0000
Grass / Shrub	2.89e+00	1.94e+00	Inf	1.582	0.8151
Grass / SV	3.40e+00	2.29e+00	Inf	1.819	0.6693
Gulch / Shrub	3.09e+00	2.07e+00	Inf	1.679	0.7597
Gulch / SV	3.63e+00	2.44e+00	Inf	1.916	0.6024
Shrub / SV	1.18e+00	8.01e-01	Inf	0.239	1.0000

Month = Mar2018:

contrast	ratio	SE	df	z.ratio	p.value
AV / DevH	2.47e-01	1.84e-01	Inf	-1.883	0.6258
AV / DevL	2.87e-01	2.15e-01	Inf	-1.667	0.7666
AV / FWL	2.20e+00	1.88e+00	Inf	0.922	0.9918
AV / FWU	1.39e-01	1.02e-01	Inf	-2.692	0.1505
AV / Grass	1.15e+00	9.15e-01	Inf	0.174	1.0000
AV / Gulch	3.79e-01	2.83e-01	Inf	-1.299	0.9319
AV / Shrub	9.90e-02	7.23e-02	Inf	-3.164	0.0414
AV / SV	3.16e-01	2.35e-01	Inf	-1.551	0.8313
DevH / DevL	1.16e+00	8.11e-01	Inf	0.215	1.0000
DevH / FWL	8.89e+00	7.23e+00	Inf	2.687	0.1523
DevH / FWU	5.61e-01	3.84e-01	Inf	-0.843	0.9955
DevH / Grass	4.64e+00	3.49e+00	Inf	2.044	0.5126
DevH / Gulch	1.53e+00	1.07e+00	Inf	0.609	0.9996
DevH / Shrub	4.00e-01	2.73e-01	Inf	-1.344	0.9182
DevH / SV	1.28e+00	8.87e-01	Inf	0.350	1.0000
DevL / FWL	7.65e+00	6.26e+00	Inf	2.486	0.2385
DevL / FWU	4.83e-01	3.34e-01	Inf	-1.052	0.9806
DevL / Grass	4.00e+00	3.02e+00	Inf	1.830	0.6623
DevL / Gulch	1.32e+00	9.29e-01	Inf	0.390	1.0000
DevL / Shrub	3.44e-01	2.37e-01	Inf	-1.548	0.8324
DevL / SV	1.10e+00	7.70e-01	Inf	0.133	1.0000
FWL / FWU	6.31e-02	5.09e-02	Inf	-3.429	0.0176
FWL / Grass	5.22e-01	4.51e-01	Inf	-0.753	0.9980
FWL / Gulch	1.72e-01	1.41e-01	Inf	-2.150	0.4391
FWL / Shrub	4.50e-02	3.61e-02	Inf	-3.860	0.0036
FWL / SV	1.43e-01	1.17e-01	Inf	-2.382	0.2935
FWU / Grass	8.27e+00	6.14e+00	Inf	2.844	0.1027
FWU / Gulch	2.73e+00	1.88e+00	Inf	1.456	0.8757
FWU / Shrub	7.12e-01	4.77e-01	Inf	-0.506	0.9999
FWU / SV	2.27e+00	1.56e+00	Inf	1.198	0.9572
Grass / Gulch	3.30e-01	2.49e-01	Inf	-1.466	0.8713
Grass / Shrub	8.62e-02	6.38e-02	Inf	-3.311	0.0261
Grass / SV	2.75e-01	2.07e-01	Inf	-1.715	0.7372
Gulch / Shrub	2.61e-01	1.79e-01	Inf	-1.955	0.5751
Gulch / SV	8.33e-01	5.84e-01	Inf	-0.260	1.0000
Shrub / SV	3.19e+00	2.18e+00	Inf	1.699	0.7475

Month = May2018:

contrast	ratio	SE	df	z.ratio	p.value
AV / DevH	1.34e+00	9.48e-01	Inf	0.420	1.0000
AV / DevL	6.52e-01	4.58e-01	Inf	-0.609	0.9996
AV / FWL	1.00e+01	7.43e+00	Inf	3.113	0.0483
AV / FWU	3.39e+00	2.42e+00	Inf	1.710	0.7408

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 AV / Grass    9.43e-01 6.64e-01 Inf -0.083  1.0000
 AV / Gulch    3.97e-01 2.79e-01 Inf -1.316  0.9268
 AV / Shrub    1.42e+00 1.00e+00 Inf  0.500  0.9999
 AV / SV       3.73e+00 2.67e+00 Inf  1.839  0.6562
 DevH / DevL   4.85e-01 3.22e-01 Inf -1.090  0.9758
 DevH / FWL    7.46e+00 5.25e+00 Inf  2.855  0.0999
 DevH / FWU    2.52e+00 1.70e+00 Inf  1.368  0.9098
 DevH / Grass  7.01e-01 4.66e-01 Inf -0.533  0.9998
 DevH / Gulch  2.95e-01 1.96e-01 Inf -1.840  0.6551
 DevH / Shrub  1.06e+00 7.06e-01 Inf  0.085  1.0000
 DevH / SV     2.77e+00 1.88e+00 Inf  1.505  0.8536
 DevL / FWL    1.54e+01 1.08e+01 Inf  3.899  0.0031
 DevL / FWU    5.20e+00 3.50e+00 Inf  2.450  0.2568
 DevL / Grass  1.45e+00 9.57e-01 Inf  0.557  0.9998
 DevL / Gulch  6.09e-01 4.02e-01 Inf -0.752  0.9980
 DevL / Shrub  2.18e+00 1.45e+00 Inf  1.175  0.9618
 DevL / SV     5.71e+00 3.85e+00 Inf  2.585  0.1929
 FWL / FWU     3.38e-01 2.41e-01 Inf -1.523  0.8449
 FWL / Grass   9.40e-02 6.60e-02 Inf -3.367  0.0217
 FWL / Gulch   3.96e-02 2.77e-02 Inf -4.613  0.0001
 FWL / Shrub   1.42e-01 9.99e-02 Inf -2.773  0.1235
 FWL / SV      3.72e-01 2.65e-01 Inf -1.387  0.9030
 FWU / Grass   2.78e-01 1.88e-01 Inf -1.898  0.6150
 FWU / Gulch   1.17e-01 7.87e-02 Inf -3.192  0.0380
 FWU / Shrub   4.20e-01 2.84e-01 Inf -1.283  0.9364
 FWU / SV      1.10e+00 7.54e-01 Inf  0.138  1.0000
 Grass / Gulch 4.21e-01 2.78e-01 Inf -1.309  0.9291
 Grass / Shrub 1.51e+00 1.00e+00 Inf  0.618  0.9995
 Grass / SV    3.95e+00 2.67e+00 Inf  2.034  0.5194
 Gulch / Shrub 3.58e+00 2.38e+00 Inf  1.925  0.5966
 Gulch / SV    9.38e+00 6.32e+00 Inf  3.325  0.0249
 Shrub / SV    2.62e+00 1.77e+00 Inf  1.420  0.8904

Month = Nov2017:
 contrast         ratio       SE  df z.ratio p.value
 AV / DevH     1.17e+00 8.07e-01 Inf  0.234  1.0000
 AV / DevL     5.19e-01 3.52e-01 Inf -0.968  0.9887
 AV / FWL      5.02e+01 6.06e+01 Inf  3.244  0.0323
 AV / FWU      6.44e+00 4.89e+00 Inf  2.458  0.2528
 AV / Grass    1.11e-01 7.93e-02 Inf -3.085  0.0526
 AV / Gulch    2.95e-01 1.99e-01 Inf -1.808  0.6772
 AV / Shrub    8.27e-01 5.64e-01 Inf -0.279  1.0000
 AV / SV       3.66e+00 2.64e+00 Inf  1.798  0.6840
 DevH / DevL   4.42e-01 3.00e-01 Inf -1.202  0.9563
 DevH / FWL    4.27e+01 5.16e+01 Inf  3.108  0.0490
 DevH / FWU    5.49e+00 4.17e+00 Inf  2.242  0.3785
 DevH / Grass  9.49e-02 6.76e-02 Inf -3.303  0.0267
 DevH / Gulch  2.51e-01 1.70e-01 Inf -2.041  0.5145
 DevH / Shrub  7.04e-01 4.82e-01 Inf -0.513  0.9999
 DevH / SV     3.12e+00 2.25e+00 Inf  1.571  0.8206
 DevL / FWL    9.68e+01 1.16e+02 Inf  3.801  0.0046
 DevL / FWU    1.24e+01 9.33e+00 Inf  3.354  0.0226
 DevL / Grass  2.15e-01 1.51e-01 Inf -2.185  0.4154
 DevL / Gulch  5.69e-01 3.80e-01 Inf -0.845  0.9955
 DevL / Shrub  1.59e+00 1.08e+00 Inf  0.690  0.9989
 DevL / SV     7.05e+00 5.04e+00 Inf  2.735  0.1357
 FWL / FWU     1.28e-01 1.60e-01 Inf -1.643  0.7812
 FWL / Grass   2.22e-03 2.71e-03 Inf -5.001  <.0001
 FWL / Gulch   5.88e-03 7.06e-03 Inf -4.276  0.0006
 FWL / Shrub   1.65e-02 1.99e-02 Inf -3.406  0.0190
 FWL / SV      7.29e-02 8.95e-02 Inf -2.133  0.4506
 FWU / Grass   1.73e-02 1.35e-02 Inf -5.193  <.0001
 FWU / Gulch   4.58e-02 3.43e-02 Inf -4.121  0.0013
 FWU / Shrub   1.28e-01 9.69e-02 Inf -2.718  0.1414
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FWU / SV	5.68e-01	4.49e-01	Inf	-0.716	0.9986
Grass / Gulch	2.65e+00	1.86e+00	Inf	1.390	0.9018
Grass / Shrub	7.42e+00	5.26e+00	Inf	2.828	0.1073
Grass / SV	3.28e+01	2.45e+01	Inf	4.681	0.0001
Gulch / Shrub	2.80e+00	1.88e+00	Inf	1.532	0.8407
Gulch / SV	1.24e+01	8.81e+00	Inf	3.539	0.0120
Shrub / SV	4.43e+00	3.18e+00	Inf	2.069	0.4950

Month = Sep2017:

contrast	ratio	SE	df	z.ratio	p.value
AV / DevH	2.02e-01	1.35e-01	Inf	-2.391	0.2885
AV / DevL	3.20e-01	2.15e-01	Inf	-1.699	0.7477
AV / FWL	6.52e-01	4.40e-01	Inf	-0.633	0.9994
AV / FWU	3.42e+00	2.41e+00	Inf	1.744	0.7189
AV / Grass	2.95e-01	1.98e-01	Inf	-1.819	0.6693
AV / Gulch	3.83e-01	2.57e-01	Inf	-1.429	0.8868
AV / Shrub	4.25e-01	2.86e-01	Inf	-1.273	0.9391
AV / SV	3.67e-01	2.47e-01	Inf	-1.492	0.8597
DevH / DevL	1.59e+00	1.05e+00	Inf	0.698	0.9988
DevH / FWL	3.23e+00	2.15e+00	Inf	1.763	0.7071
DevH / FWU	1.69e+01	1.18e+01	Inf	4.064	0.0016
DevH / Grass	1.46e+00	9.67e-01	Inf	0.576	0.9997
DevH / Gulch	1.90e+00	1.26e+00	Inf	0.968	0.9887
DevH / Shrub	2.11e+00	1.40e+00	Inf	1.124	0.9708
DevH / SV	1.82e+00	1.20e+00	Inf	0.905	0.9928
DevL / FWL	2.04e+00	1.36e+00	Inf	1.067	0.9788
DevL / FWU	1.07e+01	7.45e+00	Inf	3.395	0.0197
DevL / Grass	9.23e-01	6.11e-01	Inf	-0.122	1.0000
DevL / Gulch	1.20e+00	7.94e-01	Inf	0.270	1.0000
DevL / Shrub	1.33e+00	8.81e-01	Inf	0.427	1.0000
DevL / SV	1.15e+00	7.61e-01	Inf	0.207	1.0000
FWL / FWU	5.24e+00	3.68e+00	Inf	2.361	0.3056
FWL / Grass	4.53e-01	3.02e-01	Inf	-1.188	0.9591
FWL / Gulch	5.87e-01	3.92e-01	Inf	-0.797	0.9970
FWL / Shrub	6.52e-01	4.35e-01	Inf	-0.641	0.9994
FWL / SV	5.63e-01	3.76e-01	Inf	-0.860	0.9949
FWU / Grass	8.63e-02	6.02e-02	Inf	-3.512	0.0132
FWU / Gulch	1.12e-01	7.82e-02	Inf	-3.135	0.0453
FWU / Shrub	1.24e-01	8.68e-02	Inf	-2.983	0.0704
FWU / SV	1.07e-01	7.50e-02	Inf	-3.195	0.0377
Grass / Gulch	1.30e+00	8.60e-01	Inf	0.392	1.0000
Grass / Shrub	1.44e+00	9.55e-01	Inf	0.548	0.9998
Grass / SV	1.24e+00	8.25e-01	Inf	0.329	1.0000
Gulch / Shrub	1.11e+00	7.38e-01	Inf	0.156	1.0000
Gulch / SV	9.59e-01	6.37e-01	Inf	-0.063	1.0000
Shrub / SV	8.64e-01	5.74e-01	Inf	-0.219	1.0000

Month = Sep2018:

contrast	ratio	SE	df	z.ratio	p.value
AV / DevH	2.19e+00	1.47e+00	Inf	1.170	0.9628
AV / DevL	3.98e-01	2.71e-01	Inf	-1.352	0.9153
AV / FWL	5.63e+00	3.94e+00	Inf	2.471	0.2462
AV / FWU	3.34e+00	2.26e+00	Inf	1.781	0.6952
AV / Grass	2.06e-01	1.38e-01	Inf	-2.364	0.3038
AV / Gulch	1.98e-01	1.31e-01	Inf	-2.448	0.2578
AV / Shrub	2.01e+00	1.36e+00	Inf	1.028	0.9833
AV / SV	1.56e+00	1.04e+00	Inf	0.664	0.9992
DevH / DevL	1.81e-01	1.25e-01	Inf	-2.486	0.2386
DevH / FWL	2.57e+00	1.81e+00	Inf	1.338	0.9200
DevH / FWU	1.52e+00	1.04e+00	Inf	0.614	0.9995
DevH / Grass	9.40e-02	6.33e-02	Inf	-3.512	0.0132
DevH / Gulch	9.04e-02	6.03e-02	Inf	-3.603	0.0096
DevH / Shrub	9.15e-01	6.25e-01	Inf	-0.130	1.0000
DevH / SV	7.10e-01	4.79e-01	Inf	-0.508	0.9999

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 DevL / FWL    1.42e+01 9.96e+00 Inf  3.765  0.0052
 DevL / FWU    8.39e+00 5.81e+00 Inf  3.068  0.0552
 DevL / Grass  5.18e-01 3.45e-01 Inf -0.987  0.9871
 DevL / Gulch  4.98e-01 3.38e-01 Inf -1.027  0.9834
 DevL / Shrub  5.05e+00 3.43e+00 Inf  2.381  0.2944
 DevL / SV     3.92e+00 2.68e+00 Inf  1.993  0.5483
 FWL / FWU     5.92e-01 4.21e-01 Inf -0.737  0.9983
 FWL / Grass   3.66e-02 2.54e-02 Inf -4.761  0.0001
 FWL / Gulch   3.52e-02 2.45e-02 Inf -4.811  0.0001
 FWL / Shrub   3.56e-01 2.52e-01 Inf -1.462  0.8732
 FWL / SV      2.77e-01 1.94e-01 Inf -1.830  0.6621
 FWU / Grass   6.18e-02 4.20e-02 Inf -4.098  0.0014
 FWU / Gulch   5.94e-02 4.00e-02 Inf -4.198  0.0009
 FWU / Shrub   6.02e-01 4.15e-01 Inf -0.737  0.9983
 FWU / SV      4.67e-01 3.17e-01 Inf -1.121  0.9713
 Grass / Gulch 9.62e-01 6.39e-01 Inf -0.059  1.0000
 Grass / Shrub 9.74e+00 6.54e+00 Inf  3.390  0.0200
 Grass / SV    7.56e+00 5.07e+00 Inf  3.014  0.0645
 Gulch / Shrub 1.01e+01 6.82e+00 Inf  3.435  0.0172
 Gulch / SV    7.86e+00 5.22e+00 Inf  3.106  0.0493
 Shrub / SV    7.76e-01 5.28e-01 Inf -0.372  1.0000

P value adjustment: tukey method for comparing a family of 9 estimates
Tests are performed on the log scale
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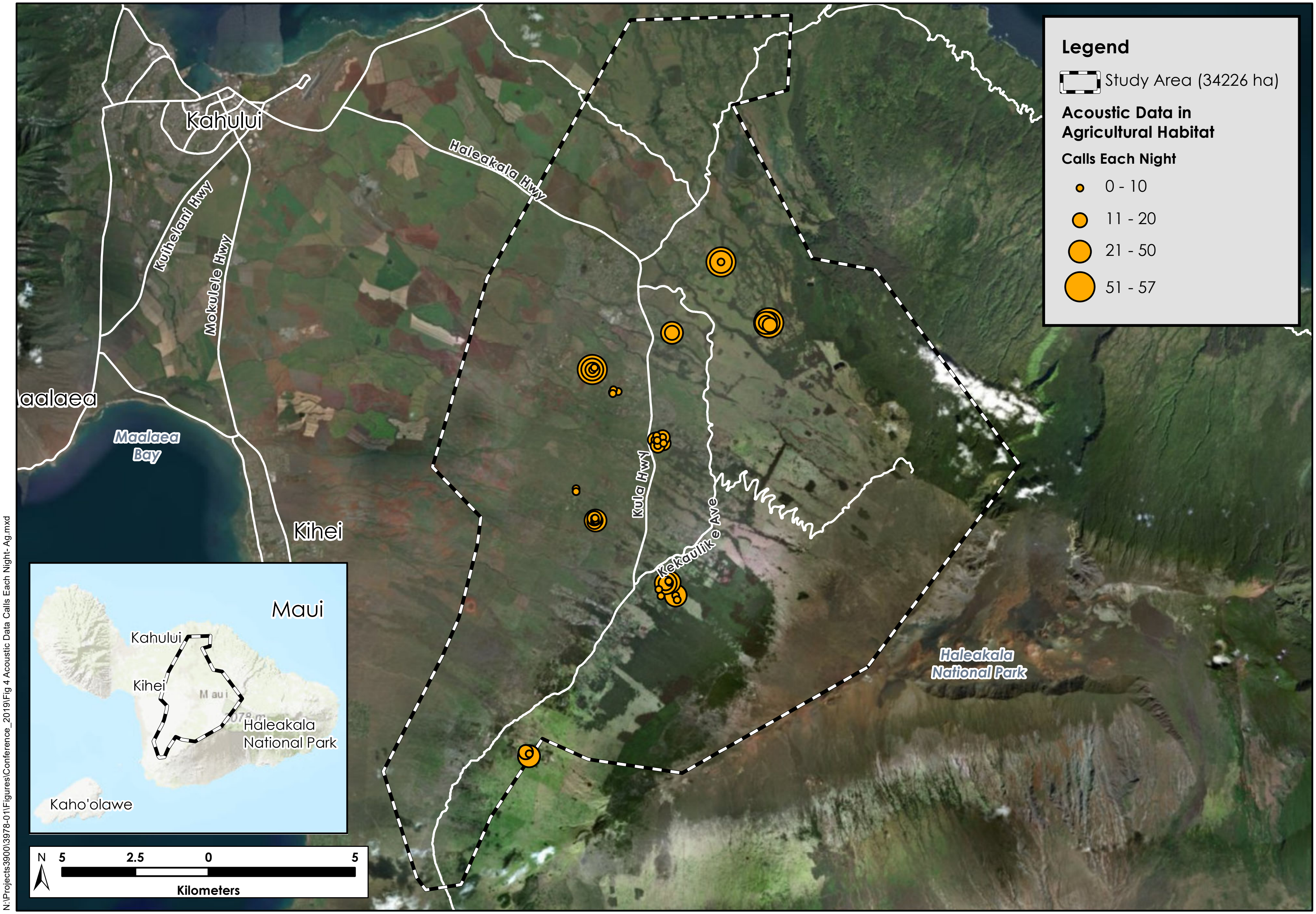
Appendix C. Significant Differences between Habitats by Month

Month	Habitat 1					Habitat 2					Significance and Test Statistics				
	Type	***Mean est***	***SE***	***LCL***	***UCL***	***Type***	***Mean est***	***SE***	***LCL***	***UCL***	***Sign. Difference***	***ratio***	***SE***	***z.ratio***	***p.value***
Sep-17	DevH	60.48	28.24	24.22	151.04	FWU	3.57	1.85	1.29	9.84	DevH > FWU	16.90	11.80	4.06	0.0016
	FWU	3.57	1.85	1.29	9.84	Grass	41.33	19.36	16.50	103.52	Grass > FWU	0.09	0.06	-3.51	0.0132
	DevL	38.13	17.88	15.21	95.59	FWU	3.57	1.85	1.29	9.84	DevL > FWU	10.70	7.45	3.40	0.0197
	FWU	3.57	1.85	1.29	9.84	SV	33.23	15.61	13.24	83.42	SV > FWU	0.11	0.08	-3.20	0.0377
	FWU	3.57	1.85	1.29	9.84	Gulch	31.87	14.97	12.69	80.04	Gulch > FWU	0.11	0.08	-3.14	0.0453
Nov-17	FWL	0.19	0.22	0.02	1.70	Grass	87.60	45.63	31.57	243.13	Grass > FWL	0.00	0.00	-5.00	<.0001
	FWU	1.51	0.88	0.48	4.75	Grass	87.60	45.63	31.57	243.13	Grass > FWU	0.02	0.01	-5.19	<.0001
	Grass	87.60	45.63	31.57	243.13	SV	2.67	1.43	0.94	7.61	Grass > SV	32.80	24.50	4.68	0.0001
	FWL	0.19	0.22	0.02	1.70	Gulch	33.06	15.53	13.17	83.00	Gulch > FWL	0.01	0.01	-4.28	0.0006
	FWU	1.51	0.88	0.48	4.75	Gulch	33.06	15.53	13.17	83.00	Gulch > FWU	0.05	0.03	-4.12	0.0013
	DevL	18.81	8.92	7.43	47.66	FWL	0.19	0.22	0.02	1.70	DevL > FWL	96.80	116.00	3.80	0.0046
	Gulch	33.06	15.53	13.17	83.00	SV	2.67	1.43	0.94	7.61	Gulch > SV	12.40	8.81	3.54	0.012
	FWL	0.19	0.22	0.02	1.70	Shrub	11.81	5.68	4.60	30.30	Shrub > FWL	0.02	0.02	-3.41	0.019
	DevL	18.81	8.92	7.43	47.66	FWU	1.51	0.88	0.48	4.75	DevL > FWU	12.40	9.33	3.35	0.0226
	DevH	8.31	4.05	3.20	21.61	Grass	87.60	45.63	31.57	243.13	Grass > DevH	0.09	0.07	-3.30	0.0267
	AV	9.76	4.73	3.77	25.24	FWL	0.19	0.22	0.02	1.70	AV > FWL	50.20	60.60	3.24	0.0323
	DevH	8.31	4.05	3.20	21.61	FWL	0.19	0.22	0.02	1.70	DevH > FWL	42.70	51.60	3.11	0.049
Jan-18	FWL	0.42	0.35	0.08	2.15	FWU	110.79	51.56	44.51	275.81	FWU > FWL	0.00	0.00	-5.83	<.0001
	FWU	110.79	51.56	44.51	275.81	Grass	2.27	1.24	0.78	6.64	FWU > Grass	48.70	35.00	5.42	<.0001
	AV	4.51	2.28	1.67	12.17	FWU	110.79	51.56	44.51	275.81	FWU > AV	0.04	0.03	-4.66	0.0001
	FWU	110.79	51.56	44.51	275.81	SV	6.43	3.18	2.44	16.95	FWU > SV	17.20	11.70	4.19	0.0009
	FWL	0.42	0.35	0.08	2.15	Gulch	20.57	9.74	8.13	52.03	Gulch > FWL	0.02	0.02	-4.06	0.0016
	FWL	0.42	0.35	0.08	2.15	Shrub	17.57	8.35	6.92	44.57	Shrub > FWL	0.02	0.02	-3.89	0.0032
	DevL	13.52	6.47	5.30	34.54	FWL	0.42	0.35	0.08	2.15	DevL > FWL	32.30	31.10	3.61	0.0093
	DevH	12.74	6.12	4.97	32.67	FWL	0.42	0.35	0.08	2.15	DevH > FWL	30.40	29.30	3.55	0.0118

Month	Habitat 1					Habitat 2					Significance and Test Statistics				
	Type	*Mean est*	*SE*	*LCL*	*UCL*	*Type*	*Mean est*	*SE*	*LCL*	*UCL*	*Sign. Difference*	*ratio*	*SE*	*z.ratio*	*p.value*
	DevH	12.74	6.12	4.97	32.67	FWU	110.79	51.56	44.51	275.81	FWU > DevH	0.12	0.08	-3.23	0.0334
	DevL	13.52	6.47	5.30	34.54	FWU	110.79	51.56	44.51	275.81	FWU > DevL	0.12	0.08	-3.15	0.0428
Mar-18	FWL	1.03	0.67	0.29	3.68	Shrub	22.94	10.84	9.09	57.89	Shrub > FWL	0.05	0.04	-3.86	0.0036
	FWL	1.03	0.67	0.29	3.68	FWU	16.34	7.78	6.43	41.53	FWU > FWL	0.06	0.05	-3.43	0.0176
	Grass	1.98	1.13	0.65	6.04	Shrub	22.94	10.84	9.09	57.89	Shrub > Grass	0.09	0.06	-3.31	0.0261
	AV	2.27	1.27	0.76	6.77	Shrub	22.94	10.84	9.09	57.89	Shrub > AV	0.10	0.07	-3.16	0.0414
May-18	FWL	3.43	1.79	1.23	9.54	Gulch	86.49	40.30	34.71	215.54	Gulch > FWL	0.04	0.03	-4.61	0.0001
	DevL	52.68	24.62	21.07	131.66	FWL	3.43	1.79	1.23	9.54	DevL > FWL	15.40	10.80	3.90	0.0031
	FWL	3.43	1.79	1.23	9.54	Grass	36.42	17.09	14.52	91.34	Grass > FWL	0.09	0.07	-3.37	0.0217
	Gulch	86.49	40.30	34.71	215.54	SV	9.22	4.48	3.55	23.90	Gulch > SV	9.38	6.32	3.33	0.0249
	FWU	10.13	4.90	3.93	26.16	Gulch	86.49	40.30	34.71	215.54	Gulch > FWU	0.12	0.08	-3.19	0.038
	AV	34.34	18.02	12.28	96.07	FWL	3.43	1.79	1.23	9.54	AV > FWL	10.00	7.43	3.11	0.0483
Jul-18	DevL	82.83	38.61	33.22	206.50	FWU	0.60	0.45	0.14	2.59	DevL > FWU	139.00	122.00	5.59	<.0001
	FWL	47.18	22.09	18.85	118.14	FWU	0.60	0.45	0.14	2.59	FWL > FWU	79.00	69.70	4.95	<.0001
	FWU	0.60	0.45	0.14	2.59	Grass	39.11	18.33	15.61	98.01	Grass > FWU	0.02	0.01	-4.73	0.0001
	FWU	0.60	0.45	0.14	2.59	Gulch	41.72	19.57	16.64	104.62	Gulch > FWU	0.01	0.01	-4.81	0.0001
	AV	26.87	12.68	10.65	67.75	FWU	0.60	0.45	0.14	2.59	AV > FWU	45.00	39.80	4.30	0.0006
	FWU	0.60	0.45	0.14	2.59	Shrub	13.52	6.50	5.28	34.67	Shrub > FWU	0.04	0.04	-3.51	0.0135
	FWU	0.60	0.45	0.14	2.59	SV	11.49	5.55	4.46	29.61	SV > FWU	0.05	0.05	-3.32	0.0255
	DevH	8.97	4.36	3.46	23.24	DevL	82.83	38.61	33.22	206.50	DevL > DevH	0.11	0.07	-3.30	0.0267
Sep-18	FWL	5.15	2.66	1.87	14.15	Grass	140.58	66.31	55.77	354.36	Grass > FWL	0.04	0.03	-4.76	0.0001
	FWL	5.15	2.66	1.87	14.15	Gulch	146.17	67.96	58.76	363.59	Gulch > FWL	0.04	0.02	-4.81	0.0001
	FWU	8.69	4.23	3.35	22.54	Gulch	146.17	67.96	58.76	363.59	Gulch > FWU	0.06	0.04	-4.20	0.0009
	FWU	8.69	4.23	3.35	22.54	Grass	140.58	66.31	55.77	354.36	Grass > FWU	0.06	0.04	-4.10	0.0014
	DevL	72.84	35.66	27.91	190.12	FWL	5.15	2.66	1.87	14.15	DevL > FWL	14.20	9.96	3.77	0.0052
	DevH	13.21	6.33	5.17	33.77	Gulch	146.17	67.96	58.76	363.59	Gulch > DevH	0.09	0.06	-3.60	0.0096

Month	Habitat 1					Habitat 2					Significance and Test Statistics				
	Type	*Mean est*	*SE*	*LCL*	*UCL*	*Type*	*Mean est*	*SE*	*LCL*	*UCL*	*Sign. Difference*	*ratio*	*SE*	*z.ratio*	*p.value*
	DevH	13.21	6.33	5.17	33.77	Grass	140.58	66.31	55.77	354.36	Grass > DevH	0.09	0.06	-3.51	0.0132
	Gulch	146.17	67.96	58.76	363.59	Shrub	14.44	7.02	5.57	37.42	Gulch > Shrub	10.10	6.82	3.44	0.0172
	Grass	140.58	66.31	55.77	354.36	Shrub	14.44	7.02	5.57	37.42	Grass > Shrub	9.74	6.54	3.39	0.02
	Gulch	146.17	67.96	58.76	363.59	SV	18.60	8.82	7.34	47.12	Gulch > SV	7.86	5.22	3.11	0.0493

Appendix D. GIS Spatial relationships of calls each night for acoustic monitoring.



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Appendix D. Acoustic Data in Agricultural Habitat

Ecology of the Hawaiian Hoary Bat (3978-01)
December 2019

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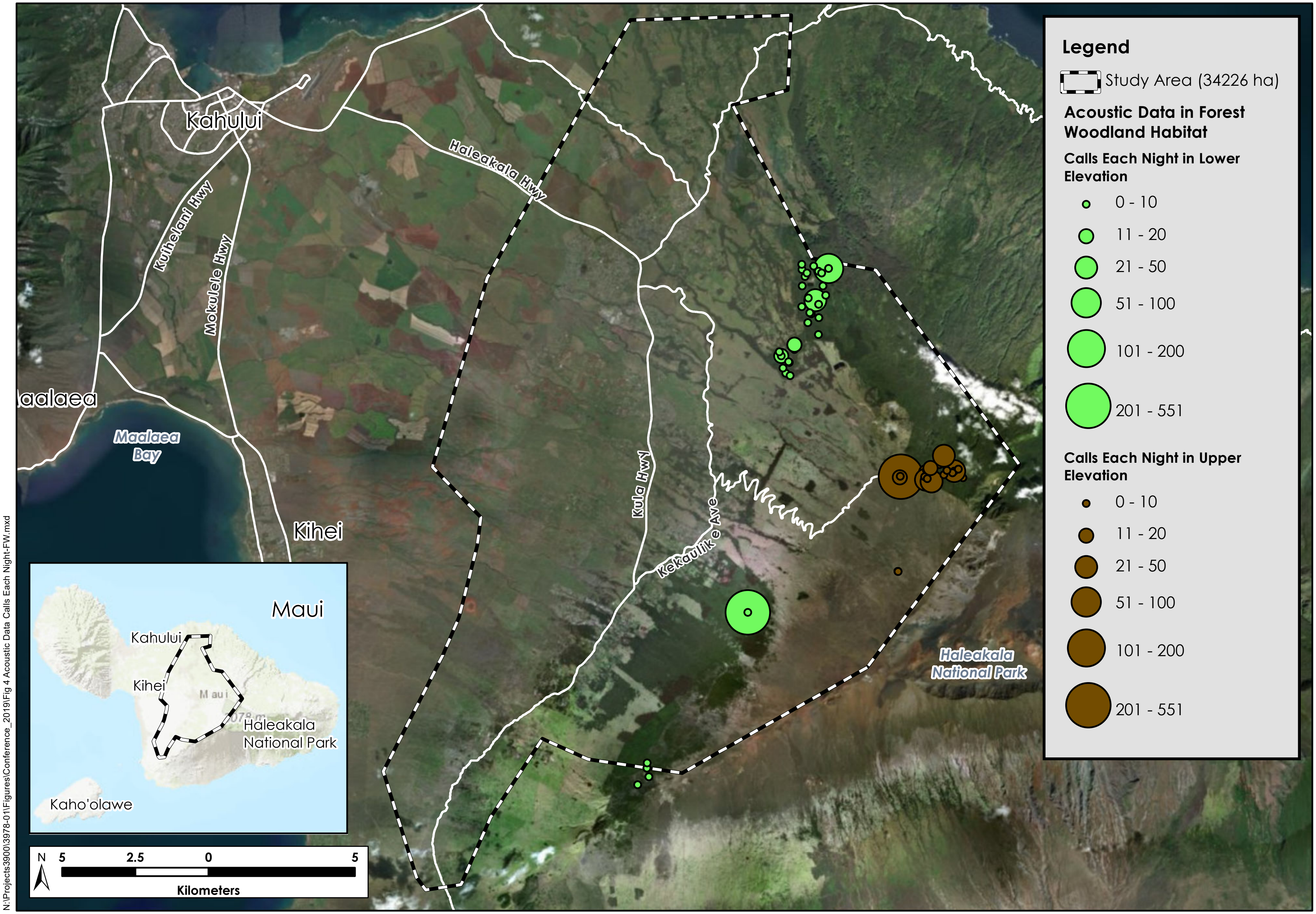
Appendix D. Acoustic Data in Developed Habitat

Ecology of the Hawaiian Hoary Bat (3978-01)

December 2019



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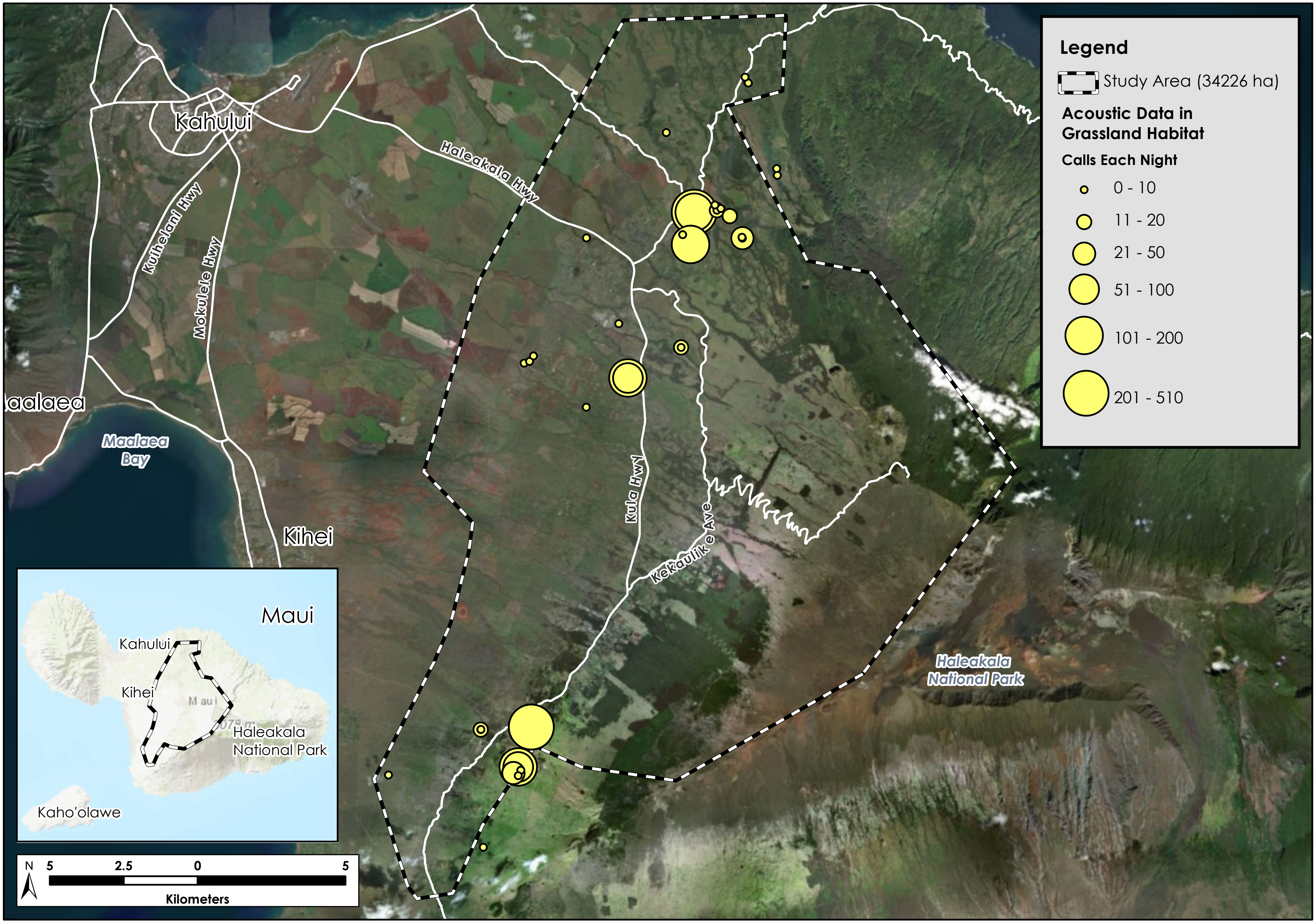
Appendix D. Acoustic Data in Forest Woodland Habitat

Ecology of the Hawaiian Hoary Bat (3978-01)
December 2019



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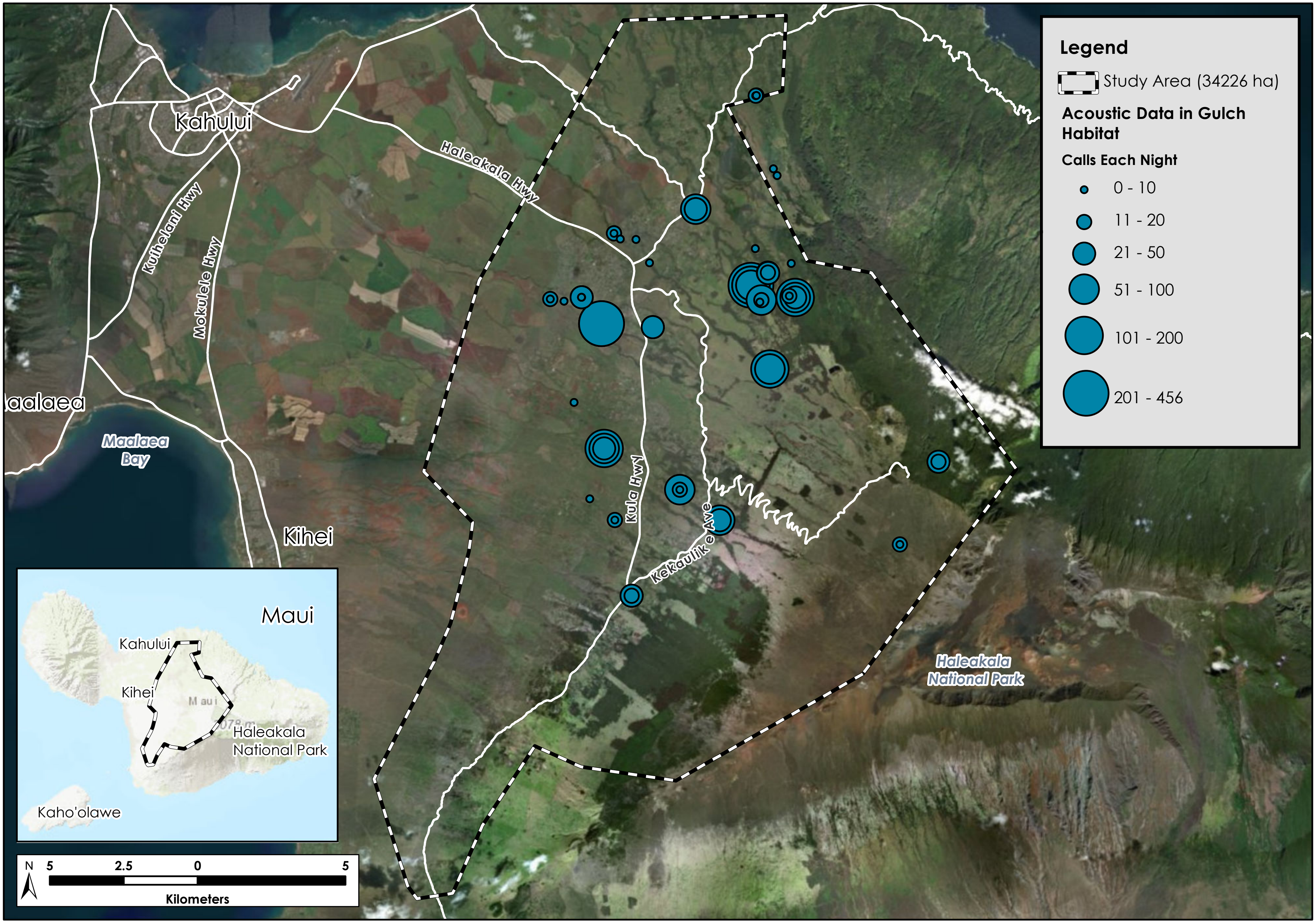
Appendix D Acoustic Data in Grassland Habitat

Ecology of the Hawaiian Hoary Bat (3978-01)

December 2019



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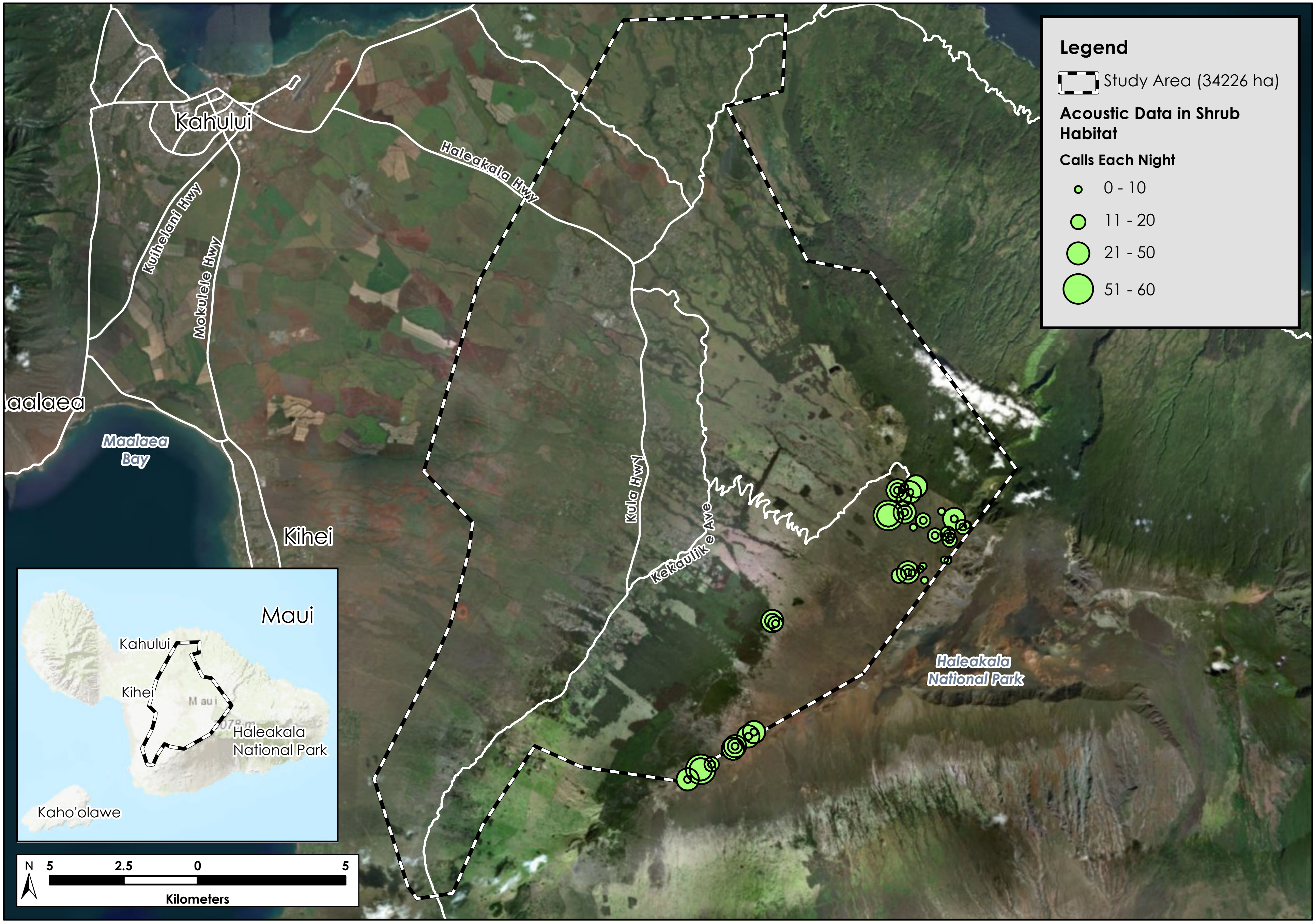
Appendix D. Acoustic Data in Gulch Habitat
Ecology of the Hawaiian Hoary Bat (3978-01)
December 2019



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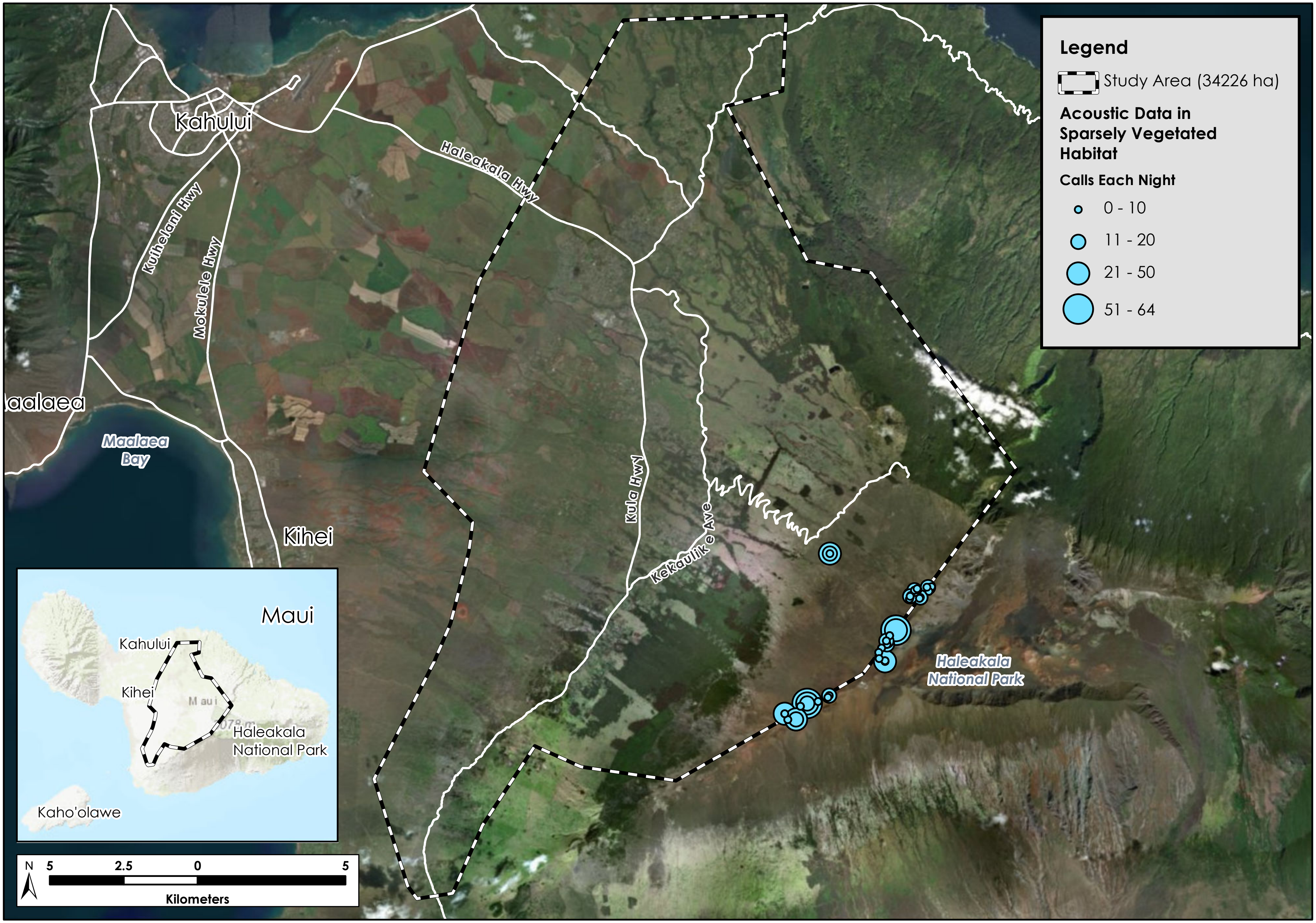
Appendix D. Acoustic Data in Shrub Habitat

Ecology of the Hawaiian Hoary Bat (3978-01)

December 2019



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Appendix D. Acoustic Data in Sparsely Vegetated Habitat

Ecology of the Hawaiian Hoary Bat (3978-01)

December 2019

Appendix E. Individual 50% Kernel (Core Use Areas) and 95% Kernel (Foraging Areas) for Individual Bats

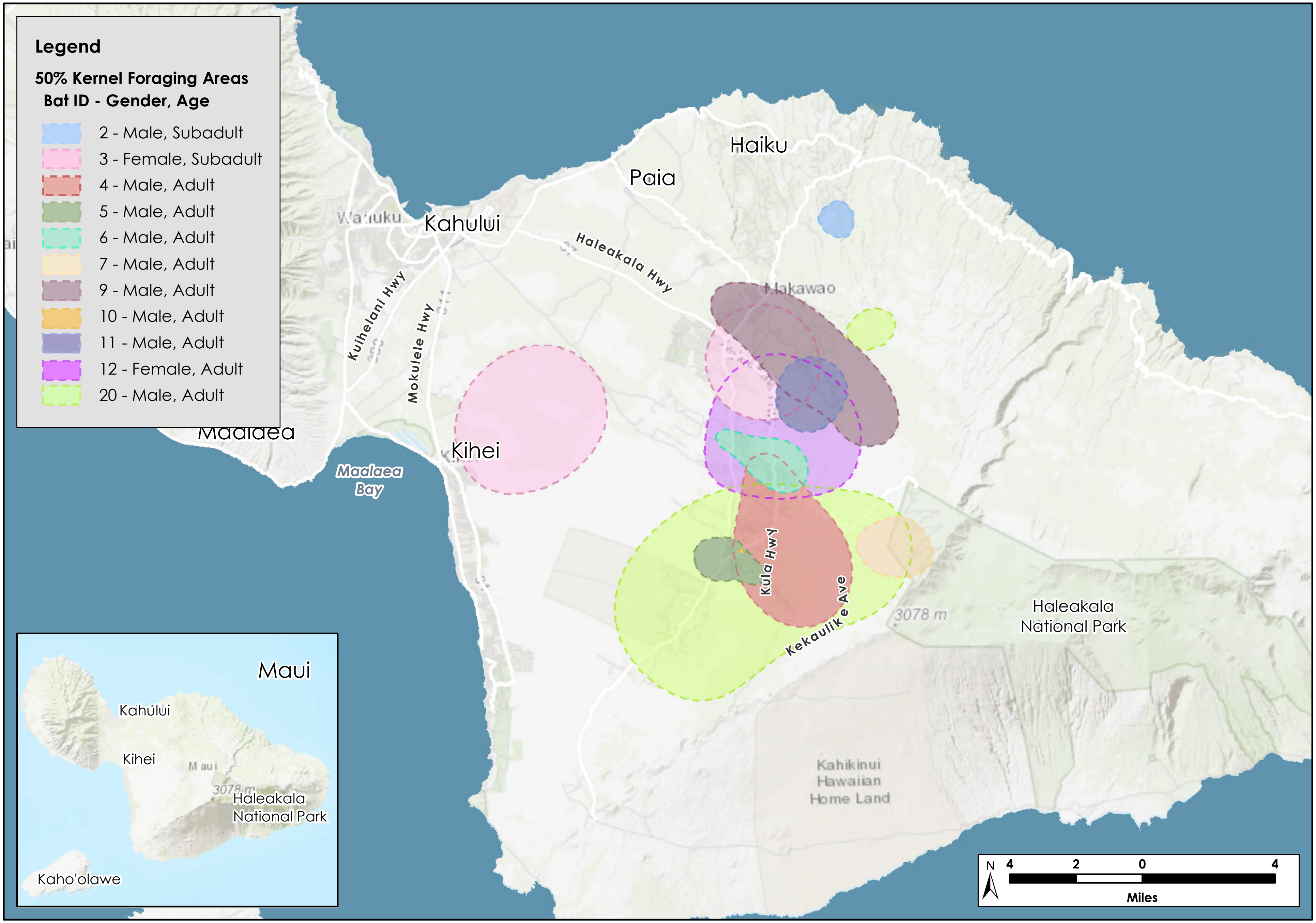

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Figure 14. Core Use Areas (50% Kernel)
Ecology of the Hawaiian Hoary Bat(3978-01)
December 2019

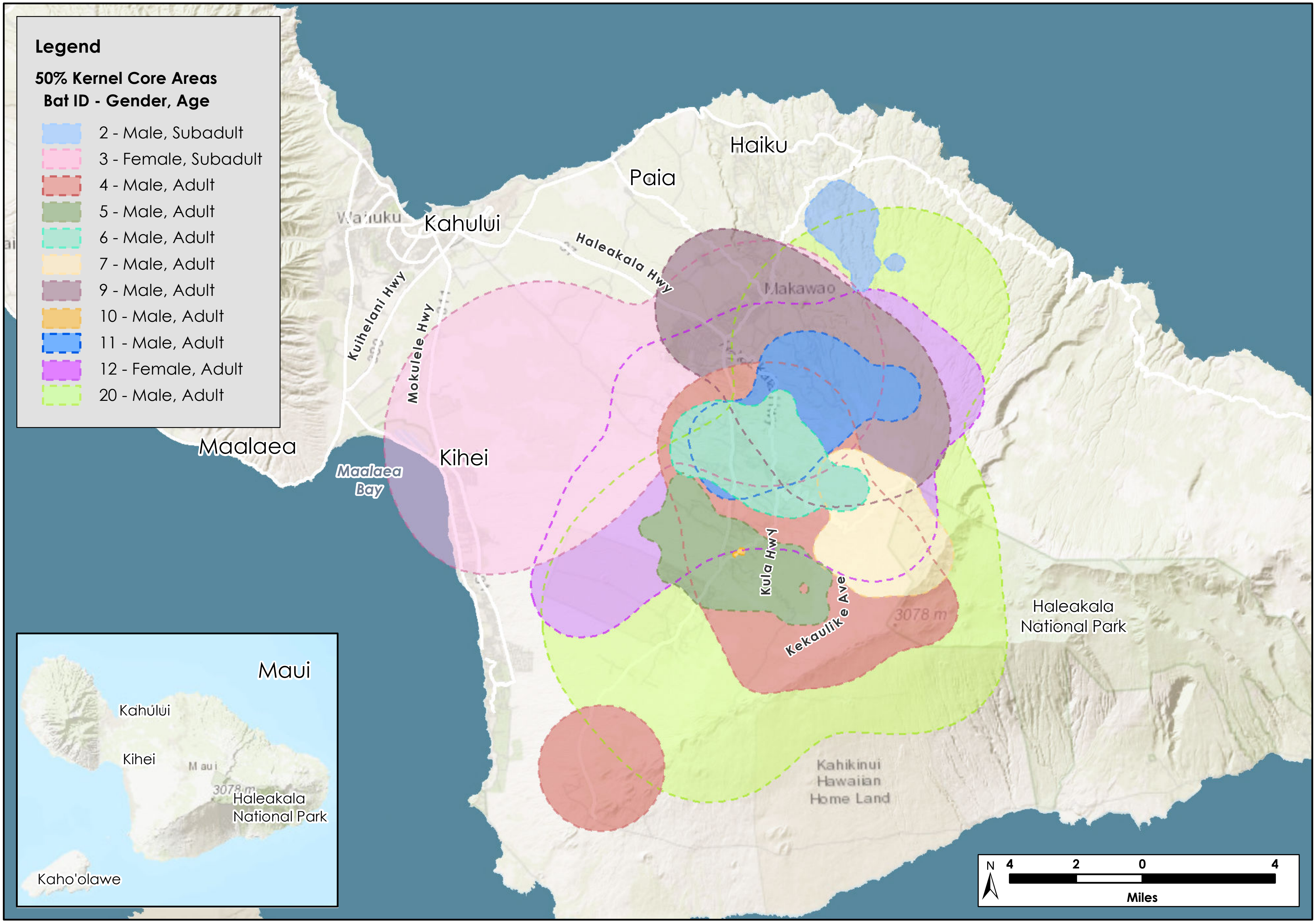

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Figure 15. Foraging Areas (95% Kernel)
Ecology of the Hawaiian Hoary Bat (3978-01)
December 2019

Appendix F. Movement Accounts of each Radio-Tagged Bat

Bat 01, adult female, was captured in west Kula on July 16, 2017 and telemetry fixes were only obtained on one night, during which she flew south from Kula toward Keokea. Her roost was never located and because of the limited number of data points, no core use area was determined.

Bat 02, subadult male, was captured in west Kula on July 27, 2017 and tracked as he foraged from approximately 7:00 pm until 9:30 pm on six nights between August 1 and 7, 2017. He roosted and foraged within the forested gulches of Haiku. His foraging range was approximately 10 miles from his capture location in Kula. His homerange likely extended considerably further eastward, as telemetry signal was often lost in that direction during tracking, and was eventually lost in that direction completely. The 95% kernel area (foraging range) was calculated at 3,122 acres and the 50% kernel (CUA) was 583 acres.

Bat 03, subadult female, was captured near the entrance to Waihou Spring Trail on August 14, 2017 and tracked as she foraged from approximately 7:30 pm until 10:30 pm on two nights and from approximately 7:30 pm until 12:00 am on one night between August 15 and 17, 2017. She roosted in a forested gulch less than a mile from Makawao and foraged both in the gulch where her day roost was located and over cane fields up to 9 miles away. The 95% kernel area was 64,406 acres and the 50% kernel area was 16,081 acres.

Bat 04, adult male, was captured near the entrance to Waihou Spring Trail on September 7, 2017 and tracked as he foraged from approximately 6:00 pm until 9:30 pm on seven nights between September 8 and 18, 2017. He roosted in multiple gulches in Kula and foraged over a large area in the mixed forest and pasture of leeward Haleakala, approximately four miles away from his day roosts. On one night, he flew an additional nine miles to spend two hours in Ulupalakua before heading back. No part of this additional area in his foraging range made it into his 50% kernel CUA. The 95% kernel area was 45,721 acres and the 50% kernel area was 8,476 acres.

Bat 05, adult male, was captured in west Kula on September 22, 2017 and tracked as he foraged from approximately 6:30 pm to 8:00 pm on six nights between September 23 and 28, 2017. He roosted in multiple nonnative trees, all adjacent to roads in Kula. His day- and night-roost trees were within his foraging range and he appeared to forage primarily over a complex low-density developed landscape. The 95% kernel area was 8,926 acres and the 50% kernel area was 1,420 acres.

Bat 06, adult male, was captured near the entrance to Waihou Spring Trail on October 2, 2017 and tracked as he foraged from approximately 6:00 pm until 8:30 pm on four nights between October 3 and 7, 2017. He used a stand of silk oaks (*Grevillea robusta*) in northwest Kula for both day and night roosts and foraged over a large area approximately 3 miles away from his roost. His foraging range included both a low-density developed landscape and forested pasture. The 95% kernel area was 9,160 acres and the 50% kernel area was 1,961 acres.

Bat 07, adult male, was captured over a pond just upslope of Haleakala National Park Headquarters on January 10, 2018 and tracked as he foraged from approximately 7:00 pm to 9:00 pm on six nights between January 11 and January 16, 2018. He roosted in the forest downslope of Haleakala National Park and slowly weaved his way upslope and into the National Park each evening. His foraging range included shrub, pasture, and gulches with sparse forest edge, and his core-use area was mainly high-elevation shrubland and gulches. On Jan 11, his signal was lost after the bat flew through Haleakala Crater and no triangulations could be obtained. The last signal on bat 07 showed the bat leaving the National Park and flying westerly where continued tracking was not possible. The 95% kernel area was 8,696 acres and the 50% kernel area was 2,081 acres.

Bat 08, adult male, was captured outside of the forest adjacent to the Haleakala National Park Entrance Station on February 2, 2018. He was searched for, but his signal was never located.

Bat 09, adult male, was captured near the entrance to Waihou Spring Trail on February 20, 2018 and tracked as he foraged from approximately 6:30 pm until 8:30 pm on seven nights between February 23 and March 2, 2018. He roosted in Haiku, but flew directly to the area around Makawao to forage. His foraging range appeared to consist primarily of forest, forested gulches, and forest clearings. Although his foraging range includes the highly developed portions of Makawao, all positions of the bat in the town were on the outskirts, which suggests that he was avoiding the urban center and foraging in the low density population fringes of the town. The 95% kernel area was 30,636 acres and the 50% kernel area was 8,726 acres.

Bat 10, adult male, was captured outside of the forest adjacent to the Haleakala National Park Entrance Station on March 7, 2018 at 7:45 pm. Although he was caught early in the night, he had already fed and produced guano that included recognizable bits of beetle chitin. He was tracked as he foraged from approximately 7:30 pm to 9:00 pm on three nights (March 9, 10, and 11, 2018). He day roosted in a loquat tree (*Eriobotrya japonica)* next to a house in a low-density developed part of south Kula. Each night that he was tracked, he foraged in a very small area near his roost which appeared abundant with scarab beetles. Although he stayed in a very small part of his range during the window of time when he was tracked, the entirety of his calculated foraging range was approximately 5 miles from his capture site. The 95% kernel area was 36 acres and the 50% kernel area was 7 acres.

Bat 11, adult male, was captured near the entrance to Waihou Spring Trail on March 21, 2018 and tracked as he foraged from approximately 7:00 pm until 8:30 pm on three nights between March 22 and March 29, 2018. He roosted in, or near to, Waihou Spring Forest Reserve, but foraged south of it, over a large section of the pastures east of Haleakala Highway. Based on the rapid attenuations in telemetry signals observed while tracking bat 11, we believe that much of his foraging time was spent at gulches and possibly very dense treelines. The area of the 95% kernel foraging range calculated for bat 11 was acres and the area of the 50% kernel CUA was acres. The 95% kernel area was 12,871 acres and the 50% kernel area was 2,399 acres.

Bat 12, adult female, was captured near the entrance to Waihou Spring Trail on June 19, 2018 and tracked as she foraged from approximately 7:30 pm until 8:30 pm on the nights of June 20 – 23, and from approximately 7:30 pm until 9:30 pm on the night of June 24, 2018. Roosting signal could not be detected during the daytime, despite first flying signal emerging in north Kula, just south of Makawao, suggesting that she roosted in a nearby gulch. She foraged in and around multiple gulches in Kula, both upslope and downslope of Haleakala Highway. On the night of June 24, 2018, she flew a slow 40-minute circuit around her CUA, presumably foraging, or looking for a place to forage, briefly foraged in a gulch within her CUA, then left her previous foraging range completely, heading downslope from south Kula in the direction of Wailea. The 95% kernel area was 57,721 acres and the 50% kernel area was 10,538 acres.

Bat 13, adult male, was captured near the entrance to Waihou Spring Trail on July 17, 2018. He was searched for, but his signal was never detected.

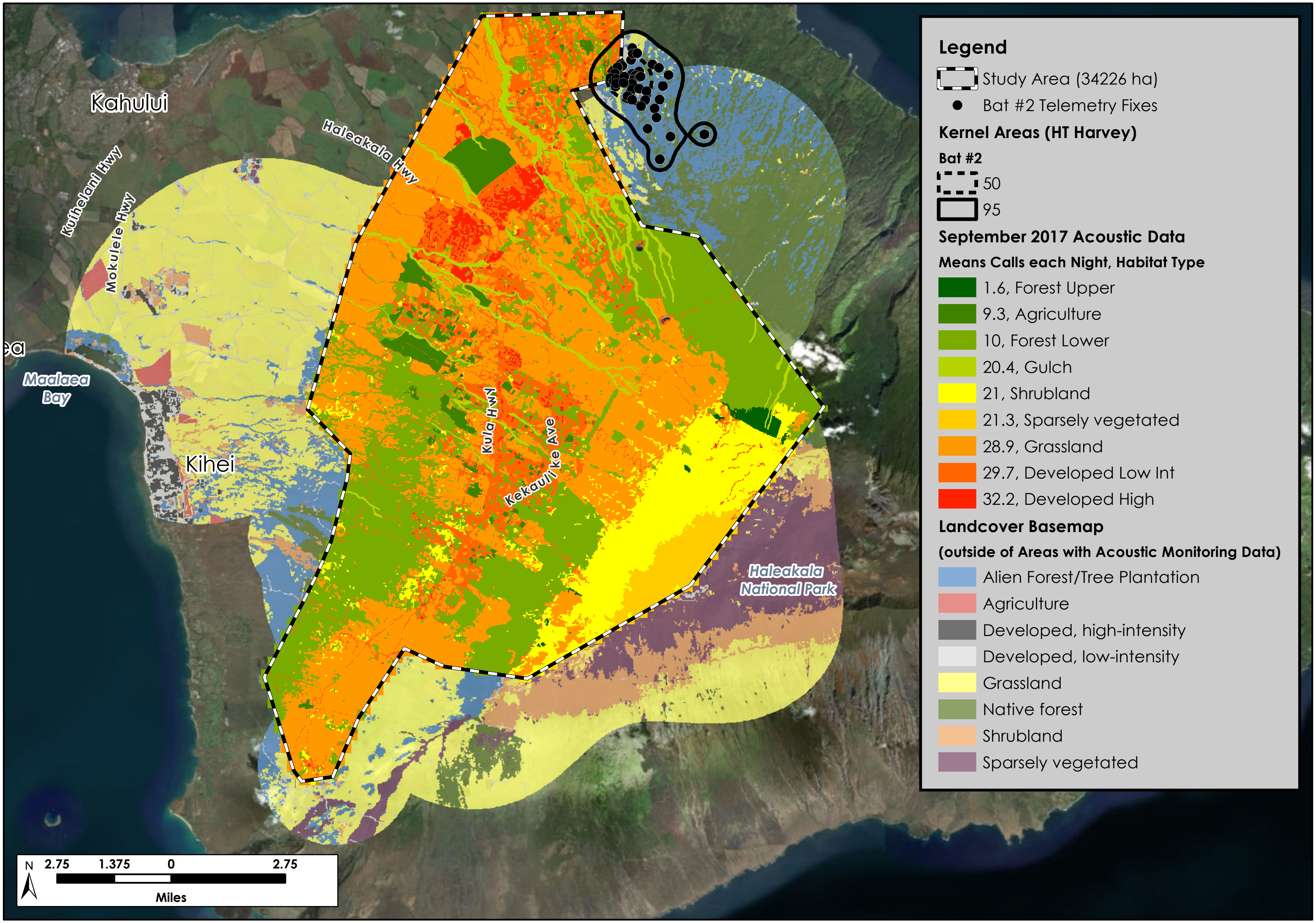
Bat 14, subadult male, was captured near the entrance to Waihou Spring Trail on August 5, 2018. Two single bearings were obtained on August 6, 2018 at 7:14 and 7:19 PM of the bat heading southward east of Haleakala Highway. Signal was never located again after this.

Bats 15 through 18 were not radio-tagged because we were waiting for the manufacturer to send us additional radio tags. Nonetheless, guano was recovered from these bats that was used in the diet studies.

Bat 19, subadult male, was captured near the entrance to Waihou Spring Trail on September 2, 2018. Bat 15 could only be faintly heard for a few minutes each night while leaving its roost north of Haleakala National Park with no better vantage points to track from.

Bat 20, adult male, was captured outside of the forest adjacent to the Haleakala National Park Entrance on September 18, 2018 and tracked as he foraged from approximately 7:30 pm to 9:00 pm on five nights between September 23 and October 3, 2018. Although his day-roost was never located, it is likely that he roosted near to, or within, Polipoli Spring State Recreation Area based on triangulations obtained just after he left his roost each evening. Each night after leaving his roost, bat 20 followed a similar routine, foraging initially in Keokea and South Kula before rapidly moving to another area: the forested area near Waihou Spring Trail on two nights and near the capture site in Haleakala National Park on two nights. The area of the 95% kernel foraging range calculated for bat 20 was acres and the area of the 50% kernel CUA was acres. The 95% kernel area was 200,597 acres and the 50% kernel area was 48,762 acres.

Appendix G. Foraging Range and Core Use Areas with the Distribution of Telemetry Fixes Superimposed on the Study Area Habitat Map



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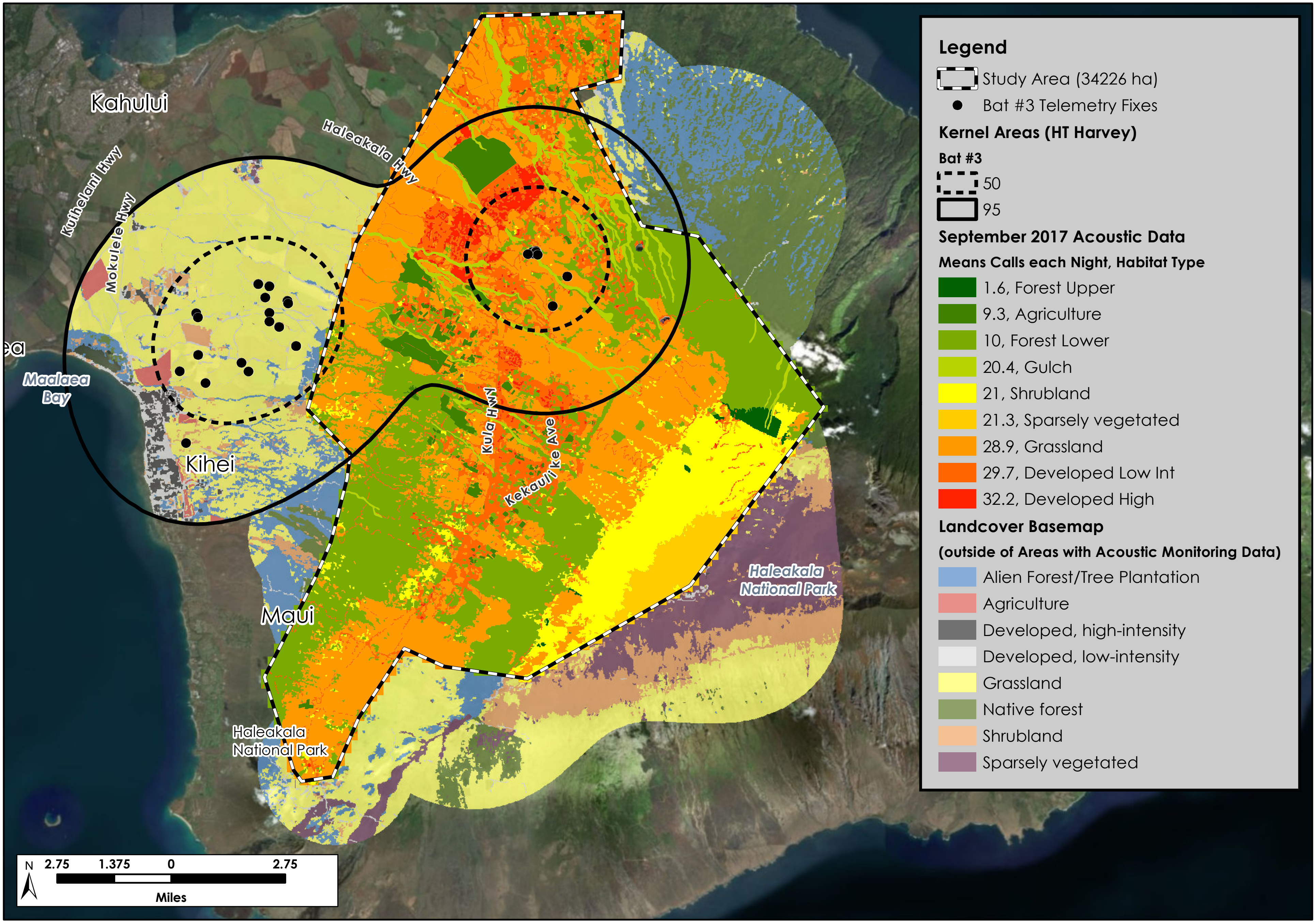
Bat #2 Telemetry Over September 2017 Acoustic Monitoring Data

Ecology of the Hawaiian Hoary Bat (3978-01)

February 2020



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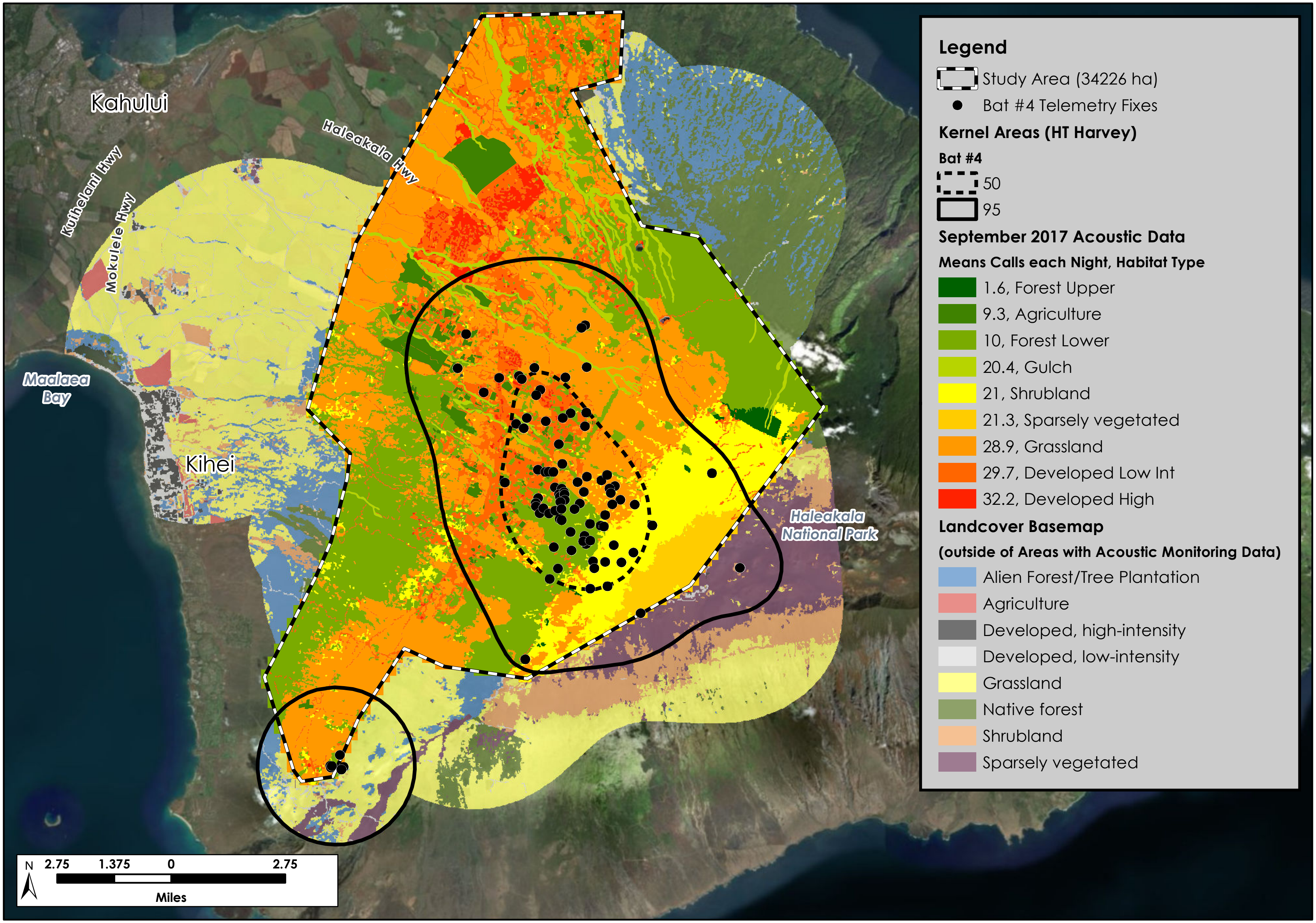
Bat #3 Telemetry Over Acoustic Data per Habitat for September 2017

Ecology of the Hawaiian Hoary Bat (3978-01)

February 2020



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Bat #4 Telemetry Over September 2017 Acoustic Monitoring Data

Ecology of the Hawaiian Hoary Bat (3978-01)

February 2020

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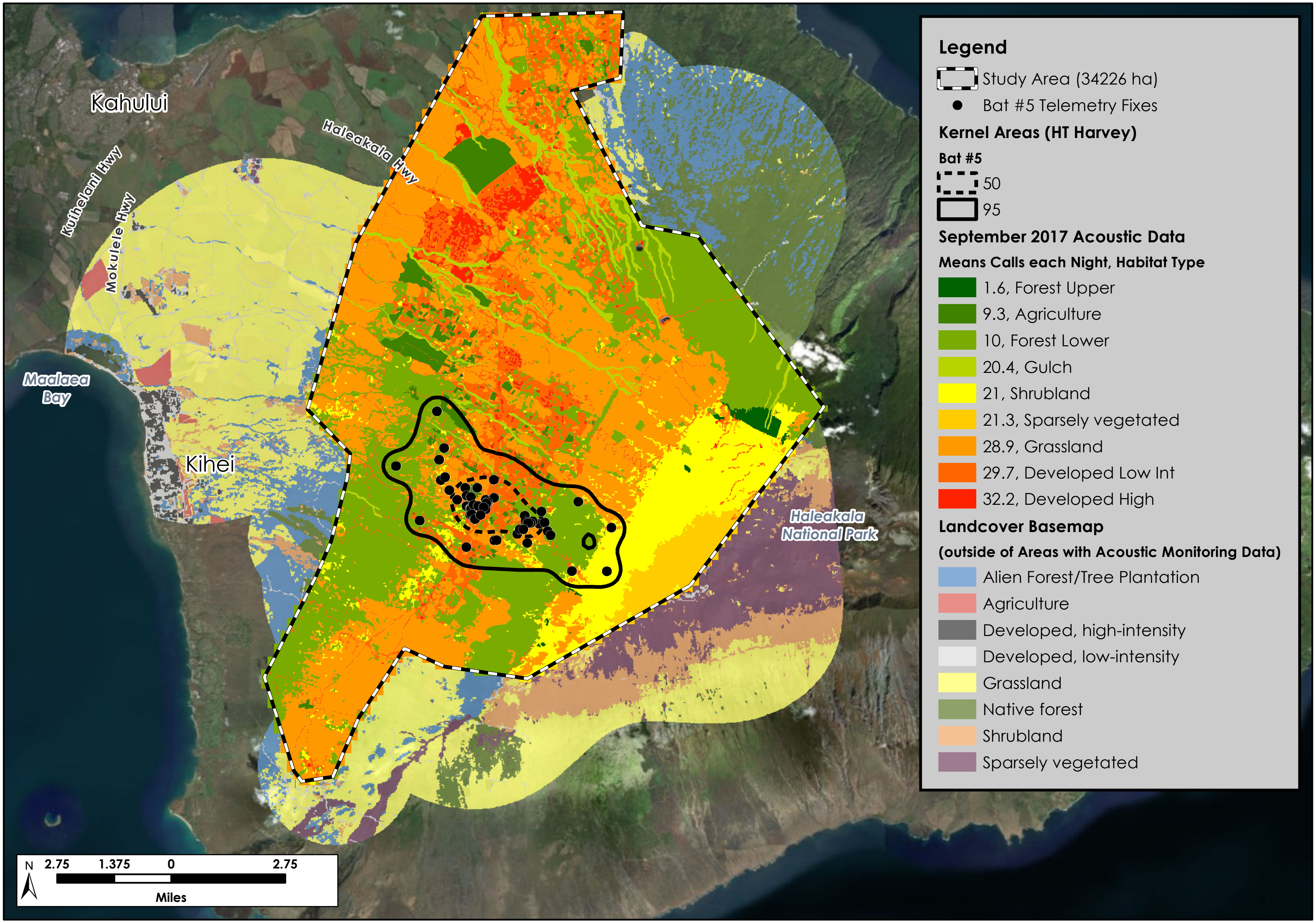

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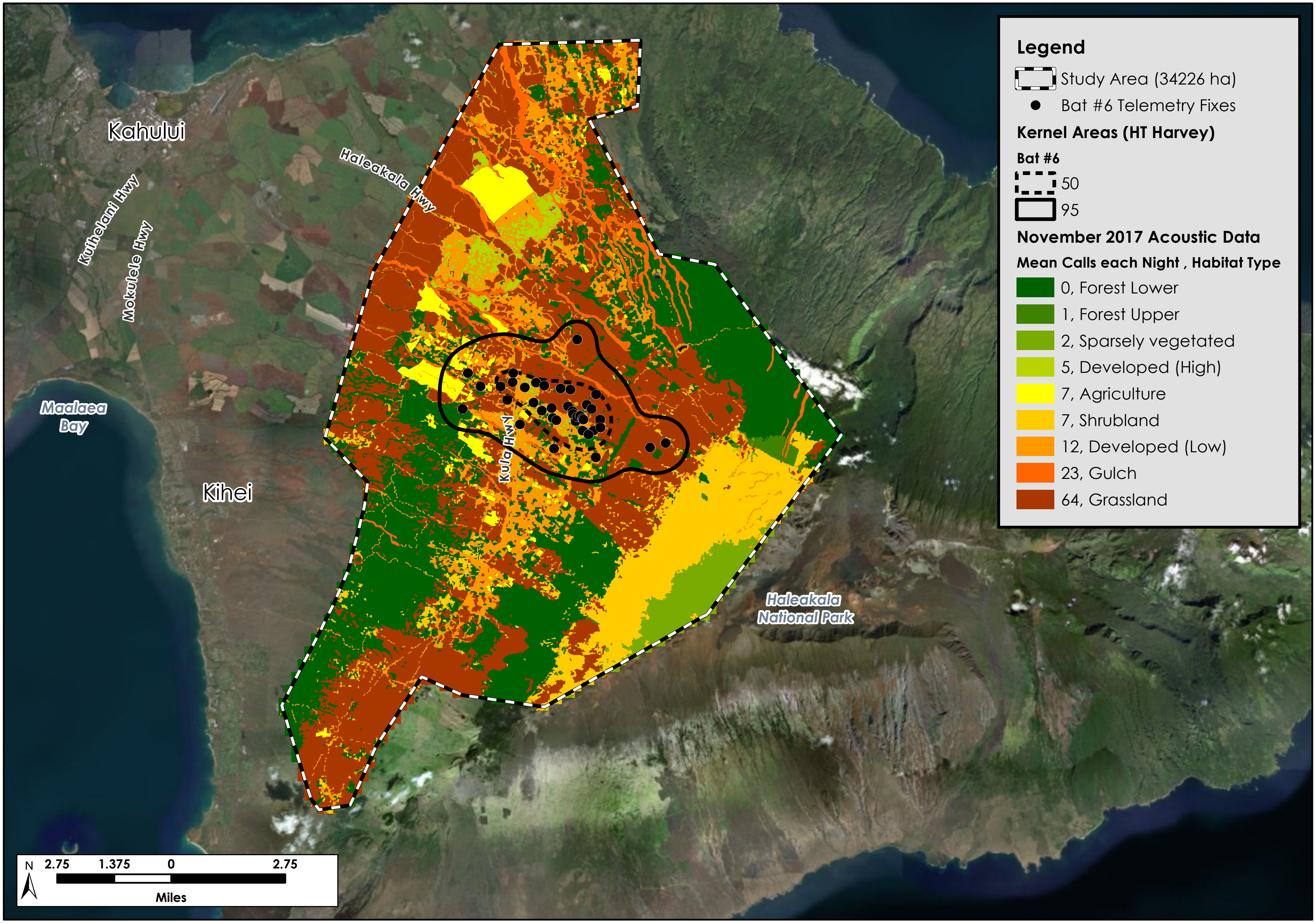
Bat #5 Telemetry Over September 2017 Acoustic Monitoring Data

Ecology of the Hawaiian Hoary Bat (3978-01)

February 2020



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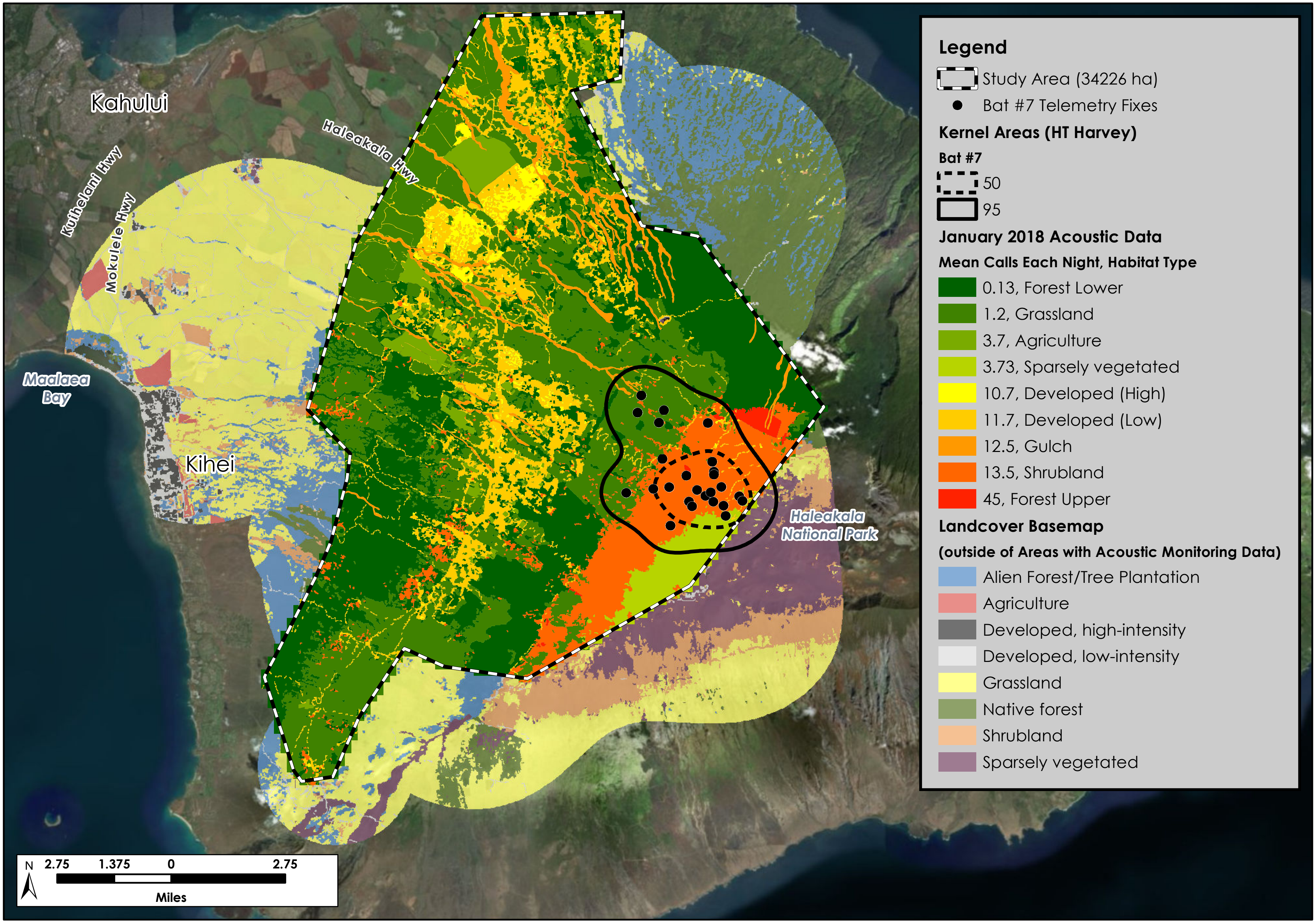
Bat #6 Telemetry Over November 2017 Acoustic Monitoring Data

Ecology of the Hawaiian Hoary Bat (3978-01)

February 2020



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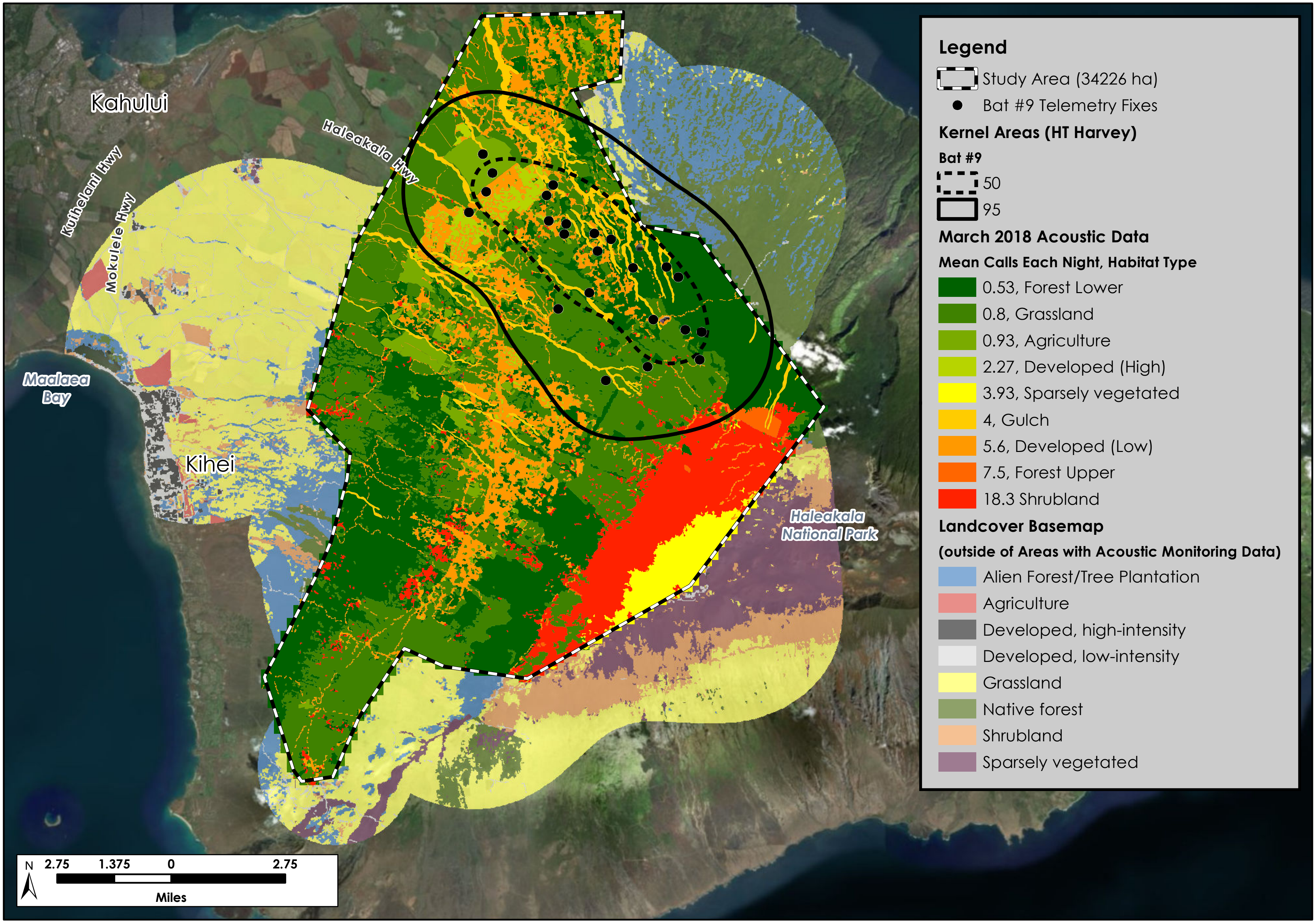
Bat #7 Telemetry Over January 2018 Acoustic Monitoring Data

Ecology of the Hawaiian Hoary Bat (3978-01)

February 2020



N:\Projects3900\3978-01\Figures\Home Range Report\Bat9 over Acoustic Habs2.mxd

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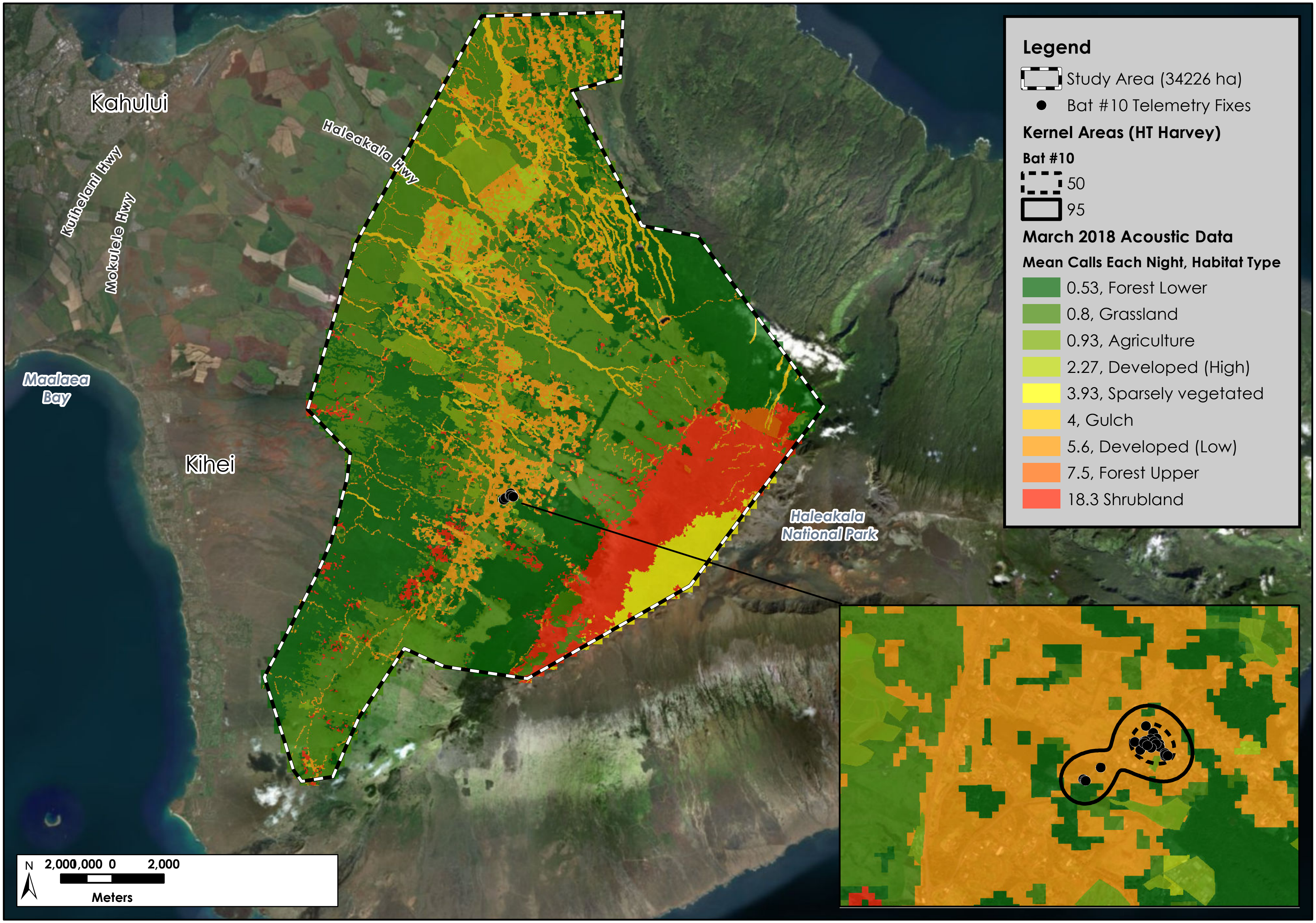
Bat #9 Telemetry Over March 2018 Acoustic Monitoring Data
Ecology of the Hawaiian Hoary Bat (3978-01)
February 2020



N:\Projects3900\3978-01\Figures\Home Range Report\Bat10 over Acoustic Habs2.mxd

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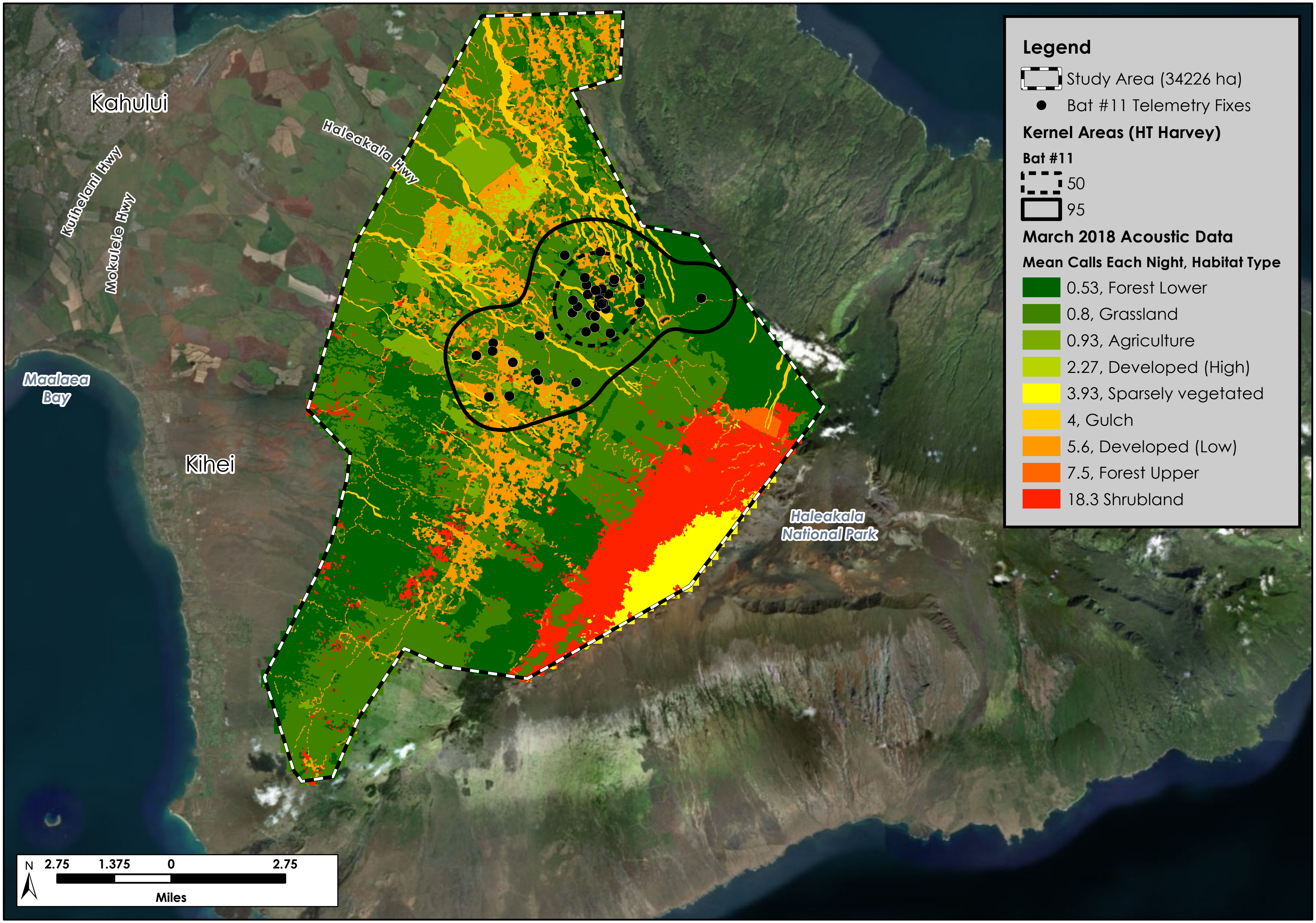
Bat #10 Telemetry Over March 2018 Acoustic Monitoring Data

Ecology of the Hawaiian Hoary Bat (3978-01)

February 2020



N:\Projects3900\3978-01\Figures\Home Range Report\Bat11 over Acoustic Habs2.mxd

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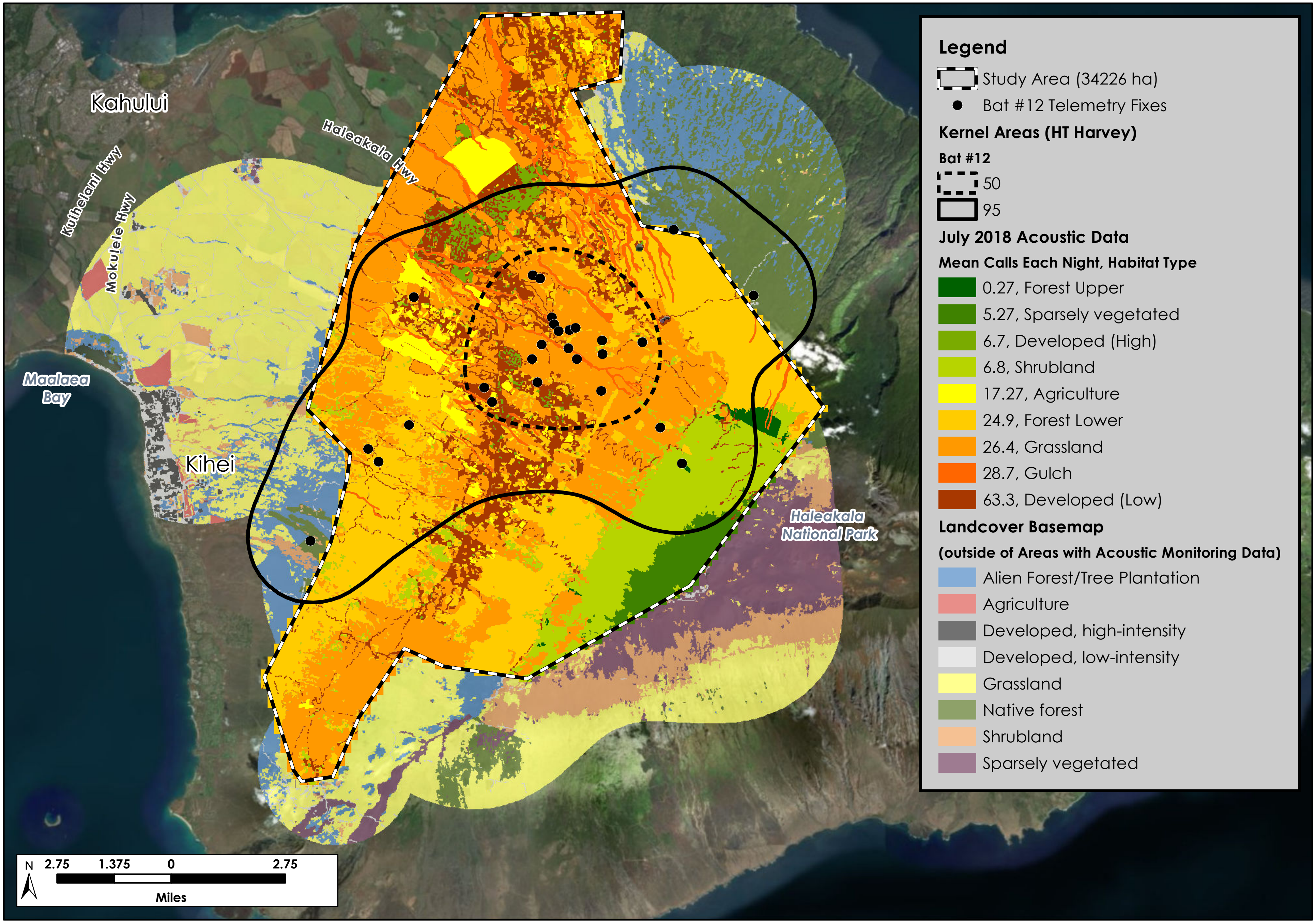
Bat #11 Telemetry Over March 2018 Acoustic Monitoring Data

Ecology of the Hawaiian Hoary Bat (3978-01)

February 2020



N:\Projects3900\3978-01\Figures\Home Range Report\Bat12 over Acoustic Habs2.mxd

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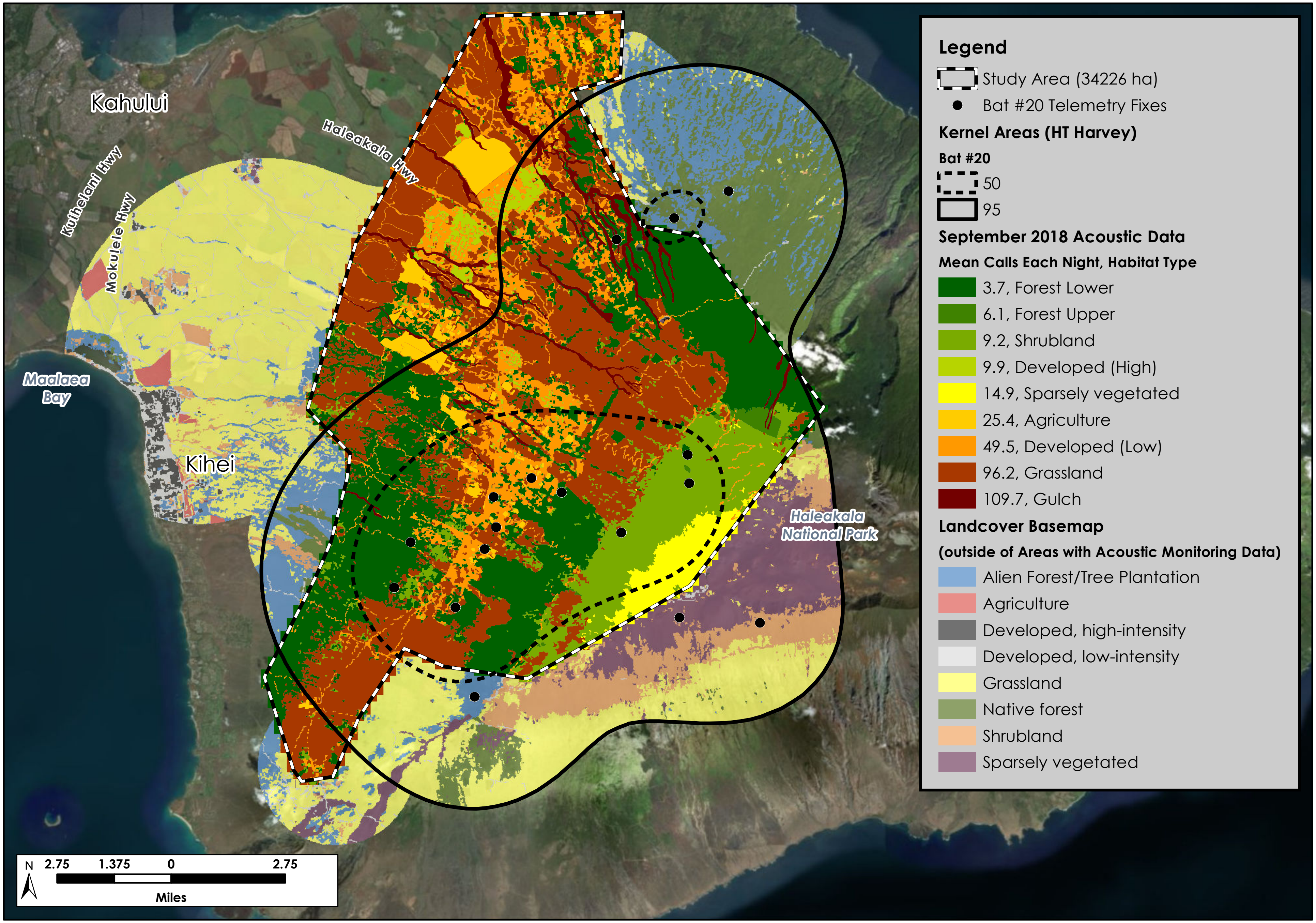
Bat #12 Telemetry Over July 2018 Acoustic Monitoring Data
Ecology of the Hawaiian Hoary Bat (3978-01)
February 2020



N:\Projects3900\3978-01\Figures\Home Range Report\Bat20 over Acoustic Habs2.mxd

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Bat #20 Telemetry Over September 2018 Acoustic Monitoring Data

Ecology of the Hawaiian Hoary Bat (3978-01)

February 2020

Appendix H. Model Output, Model Estimates, and the Significant Differences in Dry Insect Weights between Habitats and Months

By Month, across all habitats

	Month.yr	N	Dry.weight.per.sample	sd	se	ci
1	Aug-17	4	20.84500	16.07773	8.038865	25.583258
2	Oct-17	8	19.97500	11.36709	4.018873	9.503124
3	Jan-18	8	21.91875	22.95523	8.115901	19.191057
4	Feb-18	9	40.45111	35.88806	11.962687	27.586007
5	May-18	9	57.42222	64.91973	21.639912	49.901726
6	Jun-18	9	47.74000	71.57901	23.859670	55.020498
7	Aug-18	5	41.39400	35.04634	15.673198	43.515774

By Habitat, across all Months

	Habitat	N	Dry.weight.per.sample	sd	se	ci
1	AV	7	85.357143	59.906785	22.642636	55.404535
2	DevH	6	6.696667	6.079216	2.481830	6.379746
3	DevL	6	58.433333	46.485596	18.977665	48.783642
4	FWL	6	6.235000	5.847953	2.387417	6.137050
5	FWU	6	6.255000	3.862366	1.576804	4.053304
6	Grass	6	75.216667	56.788077	23.183635	59.595432
7	Gulch	5	27.920000	7.526420	3.365917	9.345285
8	Scrub	5	40.660000	38.425161	17.184254	47.711139
9	SV	5	15.720000	27.162419	12.147403	33.726598

Modeled Results

Model Output

```
glm.nb(formula = Dry.weight.per.sample ~ Month.yr + Habitat,
    data = Insect, link = "log", init.theta = 2.480127055)

Deviance Residuals:
    Min       1Q   Median       3Q      Max
-2.4781  -0.9515  -0.3527   0.3910   2.3101

Coefficients:
               Estimate Std. Error z value Pr(>|z|)
(Intercept)     4.51501    0.40753  11.079  < 2e-16 ***
Month.yrOct-17 -0.23320    0.44203  -0.528  0.59780
Month.yrJan-18 -0.64849    0.45197  -1.435  0.15134
Month.yrFeb-18  0.32149    0.42772   0.752  0.45227
Month.yrMay-18  0.20907    0.42842   0.488  0.62554
Month.yrJun-18 -0.03461    0.43020  -0.080  0.93587
Month.yrAug-18 -0.21093    0.48809  -0.432  0.66563
HabitatDevH    -2.51973    0.39201  -6.428 1.30e-10 ***
HabitatDevL    -0.35045    0.36409  -0.963  0.33578
HabitatFWL     -2.62682    0.39425  -6.663 2.69e-11 ***
```

```
HabitatFWU     -2.59594    0.39643  -6.548 5.82e-11 ***
HabitatGrass   -0.17238    0.36343  -0.474  0.63528    
HabitatGulch   -1.20487    0.38943  -3.094  0.00198 ** 
HabitatScrub   -0.89419    0.38966  -2.295  0.02174 *  
HabitatSV      -1.89866    0.40269  -4.715 2.42e-06 ***
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

(Dispersion parameter for Negative Binomial(2.4801) family taken to be 1)

    Null deviance: 172.285  on 51  degrees of freedom
Residual deviance:  54.537  on 37  degrees of freedom
AIC: 447.58

Number of Fisher Scoring iterations: 1


              Theta:  2.480 
          Std. Err.:  0.542 

 2 x log-likelihood:  -415.575 
```

Model Estimates: Mean, SE, and CI Estimates

Habitat

Response = in this table is the back-transformed “mean estimate”.
SE = one standard error of the mean
LCL = lower confidence interval, UCL = upper CI (95%)

Habitat	response	SE	df	asymp.LCL	asymp.UCL
AV	83.91	20.45	Inf	52.05	135.3
DevH	6.75	2.07	Inf	3.70	12.3
DevL	59.11	15.99	Inf	34.78	100.4
FWL	6.07	1.88	Inf	3.30	11.1
FWU	6.26	1.96	Inf	3.39	11.5
Grass	70.63	19.04	Inf	41.64	119.8
Gulch	25.15	7.64	Inf	13.86	45.6
Scrub	34.31	10.43	Inf	18.91	62.3
SV	12.57	4.03	Inf	6.70	23.6

Results are averaged over the levels of: Month.yr
Confidence level used: 0.95
Intervals are back-transformed from the log scale

Month.yr	response	SE	df	asymp.LCL	asymp.UCL
Aug-17	23.4	8.52	Inf	11.46	47.8
Oct-17	18.5	4.53	Inf	11.47	29.9
Jan-18	12.2	3.15	Inf	7.38	20.3
Feb-18	32.3	7.21	Inf	20.82	50.0
May-18	28.8	6.48	Inf	18.56	44.8
Jun-18	22.6	5.15	Inf	14.46	35.3
Aug-18	18.9	6.08	Inf	10.10	35.5

Results are averaged over the levels of: Habitat
Confidence level used: 0.95
Intervals are back-transformed from the log scale

Significant Differences

Habitat

Pairwise Comparisons – in all of the below combinations, if the z-ratios are > 0, the habitat on the left had higher insect weights than the habitat on the right; if z-ratio < 0, then the habitat on the left had lower insect weights than the habitat on the right. Significant differences are in red, and shown in the summary below that by differences in letters. Underlined are "borderline" significant (just over p = 0.05).

$contrasts

contrast	ratio	SE	df	z.ratio	p.value
AV / DevH	12.4253	4.8708	Inf	6.428	<.0001
AV / DevL	1.4197	0.5169	Inf	0.963	0.9891
AV / FWL	13.8297	5.4524	Inf	6.663	<.0001
AV / FWU	13.4091	5.3158	Inf	6.548	<.0001
AV / Grass	1.1881	0.4318	Inf	0.474	0.9999
AV / Gulch	3.3363	1.2993	Inf	3.094	0.0512
AV / Scrub	2.4454	0.9529	Inf	2.295	0.3451
AV / SV	6.6769	2.6887	Inf	4.715	0.0001
DevH / DevL	0.1143	0.0470	Inf	-5.277	<.0001
DevH / FWL	1.1130	0.4860	Inf	0.245	1.0000
DevH / FWU	1.0792	0.4745	Inf	0.173	1.0000
DevH / Grass	0.0956	0.0392	Inf	-5.719	<.0001
DevH / Gulch	0.2685	0.1143	Inf	-3.089	0.0519
DevH / Scrub	0.1968	0.0842	Inf	-3.800	0.0046
DevH / SV	0.5374	0.2362	Inf	-1.413	0.8933
DevL / FWL	9.7412	4.0212	Inf	5.514	<.0001
DevL / FWU	9.4450	3.8370	Inf	5.527	<.0001
DevL / Grass	0.8369	0.3130	Inf	-0.476	0.9999
DevL / Gulch	2.3500	0.9640	Inf	2.083	0.4851
DevL / Scrub	1.7224	0.6891	Inf	1.359	0.9130
DevL / SV	4.7030	1.9414	Inf	3.750	0.0055
FWL / FWU	0.9696	0.4279	Inf	-0.070	1.0000
FWL / Grass	0.0859	0.0354	Inf	-5.954	<.0001
FWL / Gulch	0.2412	0.1048	Inf	-3.274	0.0294
FWL / Scrub	0.1768	0.0772	Inf	-3.970	0.0023
FWL / SV	0.4828	0.2163	Inf	-1.625	0.7911
FWU / Grass	0.0886	0.0359	Inf	-5.974	<.0001
FWU / Gulch	0.2488	0.1091	Inf	-3.173	0.0403
FWU / Scrub	0.1824	0.0783	Inf	-3.961	0.0024
FWU / SV	0.4979	0.2198	Inf	-1.580	0.8162
Grass / Gulch	2.8081	1.1503	Inf	2.520	0.2219
Grass / Scrub	2.0582	0.8222	Inf	1.807	0.6777
Grass / SV	5.6197	2.3166	Inf	4.188	0.0009
Gulch / Scrub	0.7330	0.3130	Inf	-0.728	0.9984
Gulch / SV	2.0013	0.8777	Inf	1.582	0.8150
Scrub / SV	2.7304	1.1706	Inf	2.343	0.3162

Results are averaged over the levels of: Month.yr
P value adjustment: tukey method for comparing a family of 9 estimates
Tests are performed on the log scale

	Habitat	response	SE	df	asymp.LCL	asymp.UCL	.group
4	FWL	6.067549	1.880776	Inf	2.574654	14.29906	a
5	FWU	6.257839	1.956725	Inf	2.635568	14.85849	a
2	DevH	6.753348	2.074078	Inf	2.888373	15.79011	ab
9	SV	12.567486	4.028984	Inf	5.178511	30.49944	abc
7	Gulch	25.151061	7.643971	Inf	10.852480	58.28860	bcd

```
8   Scrub 34.314789 10.433189 Inf 14.801598  79.55254     cd
3    DevL 59.105081 15.986960 Inf 27.974302 124.87928      d
6   Grass 70.625781 19.039499 Inf 33.510404 148.84933      d
1      AV 83.912140 20.447505 Inf 42.771536 164.62461      d
```

Month

```
$contrasts
 contrast        ratio    SE  df z.ratio p.value
 Aug-17 / Oct-17 1.263 0.558 Inf  0.528  0.9985
 Aug-17 / Jan-18 1.913 0.864 Inf  1.435  0.7830
 Aug-17 / Feb-18 0.725 0.310 Inf -0.752  0.9892
 Aug-17 / May-18 0.811 0.348 Inf -0.488  0.9990
 Aug-17 / Jun-18 1.035 0.445 Inf  0.080  1.0000
 Aug-17 / Aug-18 1.235 0.603 Inf  0.432  0.9995
 Oct-17 / Jan-18 1.515 0.537 Inf  1.172  0.9048
 Oct-17 / Feb-18 0.574 0.190 Inf -1.678  0.6311
 Oct-17 / May-18 0.643 0.213 Inf -1.334  0.8358
 Oct-17 / Jun-18 0.820 0.273 Inf -0.596  0.9970
 Oct-17 / Aug-18 0.978 0.395 Inf -0.055  1.0000
 Jan-18 / Feb-18 0.379 0.129 Inf -2.847  0.0665
 Jan-18 / May-18 0.424 0.145 Inf -2.511  0.1551
 Jan-18 / Jun-18 0.541 0.186 Inf -1.787  0.5568
 Jan-18 / Aug-18 0.646 0.263 Inf -1.075  0.9356
 Feb-18 / May-18 1.119 0.354 Inf  0.355  0.9998
 Feb-18 / Jun-18 1.428 0.455 Inf  1.117  0.9232
 Feb-18 / Aug-18 1.703 0.665 Inf  1.363  0.8216
 May-18 / Jun-18 1.276 0.408 Inf  0.762  0.9884
 May-18 / Aug-18 1.522 0.596 Inf  1.073  0.9360
 Jun-18 / Aug-18 1.193 0.469 Inf  0.449  0.9994

Results are averaged over the levels of: Habitat
P value adjustment: tukey method for comparing a family of 7 estimates
Tests are performed on the log scale

  Month.yr response       SE  df asymp.LCL asymp.UCL .group
3   Jan-18 12.23084 3.150644 Inf  6.128040  24.41129      a
2   Oct-17 18.52742 4.534281 Inf  9.608809  35.72402      a
7   Aug-18 18.94460 6.077498 Inf  8.011407  44.79836      a
6   Jun-18 22.59740 5.150401 Inf 12.260355  41.64991      a
1   Aug-17 23.39331 8.521339 Inf  8.803963  62.15914      a
5   May-18 28.83312 6.479326 Inf 15.778538  52.68859      a
4   Feb-18 32.26351 7.209087 Inf 17.716229  58.75597      a
```

Appendix I. List of species identified from samples from specific habitats

Jar Code	Specimen ID	Abundance	Order	Family	Genus	Species	Sort Date	Greater than 10mm?
Maui_06/2018_FWL	HHB-00001	5	Coleoptera			*Morphospecies* [1]	9/11/2018	
Maui_06/2018_FWL	HHB-00002	1	Lepidoptera	Noctuidae	*Mythimna*	*unipuncta*	9/11/2018	
Maui_06/2018_FWL	HHB-00003	1	Lepidoptera	Crambidae	*Eudonia*	*Eudonia?* [1]	9/11/2018	
Maui_06/2018_FWL	HHB-00004	4	Isoptera				9/12/2018	
Maui_06/2018_FWL	HHB-00005	1	Lepidoptera				9/12/2018	
Maui_06/2018_FWL	HHB-00006	1	Lepidoptera				9/12/2018	
Maui_06/2018_FWL	HHB-00007	1	Lepidoptera				9/12/2018	
Maui_06/2018_FWL	HHB-00008	1	Lepidoptera	Erebidae	*Schrankia*	*altivolans*	9/13/2018	
Maui_06/2018_FWL	HHB-00009	1	Lepidoptera				9/14/2018	
Maui_06/2018_FWL	HHB-00010	1	Lepidoptera	Geometridae	*Scotorythra*	*euryphaea*	9/14/2018	
Maui_06/2018_FWL	HHB-00011	1	Homoptera	Psocoptera	*Caeciliidae*		9/14/2018	
Maui_06/2018_FWL	HHB-00012	1	Lepidoptera	Torticidae			9/14/2018	
Maui_06/2018_FWL	HHB-00013	1	Lepidoptera	Noctuidae	*Mythimna*	*unipuncta*	9/14/2018	
Maui_06/2018_FWL	HHB-00014	1	Lepidoptera	Cosmopterigidae	*Hyposmocoma*		9/14/2018	
Maui_06/2018_FWL	HHB-00015	7	Coleoptera	Elateridae			9/19/2018	
Maui_06/2018_FWL	HHB-00016	15	Coleoptera	Curculionidae			9/19/2018	
Maui_06/2018_FWL	HHB-00017	6	Coleoptera	Carabidae			9/19/2018	
Maui_06/2018_FWL	HHB-00018	6	Coleoptera	Staphylinidae			9/19/2018	
Maui_06/2018_FWL	HHB-00019	22	Lepidoptera	Noctuidae	*Mythimna*	*unipuncta*	9/19/2018	
Maui_06/2018_FWL	HHB-00020	1	Lepidoptera	Tortricidae	*Epiphyas*	*postvittana*	9/19/2018	
Maui_06/2018_FWL	HHB-00021	2	Lepidoptera				9/19/2018	
Maui_06/2018_FWL	HHB-00022	1	Lepidoptera				9/19/2018	
Maui_06/2018_FWL	HHB-00023	1	Lepidoptera	Crambidae	*Orthomecyna*	*exigua exigua*	9/19/2018	
Maui_06/2018_FWL	HHB-00024	1	Lepidoptera	Tortricidae	*Amorbia*	*emigratella*	9/19/2018	
Maui_06/2018_FWL	HHB-00025	1	Lepidoptera	Crambidae	*Eudonia*		9/20/2018	

Jar Code	Specimen ID	Abundance	Order	Family	Genus	Species	Sort Date	Greater than 10mm?
Maui_06/2018_FWL	HHB-00026	1	Lepidoptera	Cosmopterigidae	*Hyposmocoma (Euperissus)*		9/20/2018	
Maui_06/2018_FWL	HHB-00027	7	Homoptera	Cicadellidae			9/20/2018	
Maui_06/2018_FWL	-	67	Lepidoptera	less than 16mm			9/11/2018	
Maui_06/2018_FWL	HHB-00028	7	Diptera				9/24/2018	
Maui_06/2018_FWL	HHB-00029	1	Hemiptera				9/24/2018	
Maui_06/2018_FWL	HHB-00030	1	Lepidoptera	Cosmopterigidae	*Hyposmocoma*		9/24/2018	
Maui_06/2018_FWL	HHB-00031	1	Lepidoptera	Crambidae	*Orthomecyna*	*exigua exigua*	9/24/2018	
Maui_06/2018_FWL	HHB-00032	1	Lepidoptera	Erebidae	*Schrankia*	*altivolans*	9/24/2018	
Maui_06/2018_FWL	HHB-00033	1	Lepidoptera	Crambidae	*Orthomecyna*	*exigua exigua*	10/9/2018	
Maui_06/2018_FWL	-	44	Lepidoptera	female greater than 16mm			9/11/2018	
Maui_06/2018_FWL	HHB-00034	1	Lepidoptera	Crambidae	*Omiodes*		10/9/2018	
Maui_06/2018_FWL	HHB-00035	1	Lepidoptera	Erebidae	*Schrankia*	*altivolans*	10/9/2018	
Maui_06/2018_FWL	HHB-00036	1	Lepidoptera	Crambidae	*Orthomecyna*	*exigua exigua*	10/9/2018	
Maui_06/2018_FWL	HHB-00037	1	Hemiptera	Pentatomidae			10/9/2018	
Maui_06/2018_FWL	HHB-00038	1	Araneae				10/11/2018	
Maui_06/2018_FWL	HHB-00039	1	unknown				10/11/2018	
Maui_06/2018_FWL	HHB-00040	1	Lepidoptera	Erebidae	*Schrankia*	*altivolans*	10/15/2018	
Maui_06/2018_FWL	HHB-00041	1	Lepidoptera	Crambidae	*Herpetogramma*	*licarsisalis*	10/15/2018	
Maui_06/2018_FWL	HHB-00042	1	Lepidoptera	Crambidae	*Orthomecyna*	*exigua exigua*	10/15/2018	
Maui_06/2018_FWL	HHB-00043	1	Lepidoptera	Crambidae	*Orthomecyna*	*exigua exigua*	10/15/2018	
Maui_06/2018_FWL	HHB-00044	1	Lepidoptera	Tortricidae	*Amorbia*	*emigratella*	10/24/2018	
Maui_06/2018_FWL	HHB-00045	1	Hymenoptera	Ichneumonidae			10/24/2018	
Maui_01/2018_AV3/5	HHB-00046	23	Lepidoptera	Noctuidae	*Mythimna*	*unipuncta*	6/17/2019	
Maui_01/2018_AV3/5	HHB-00047	12	Lepidoptera	less than 10mm			6/17/2019	
Maui_01/2018_AV3/5	HHB-00048	4	Coleoptera			*Morphospecies* [2]	6/18/2019	

Jar Code	Specimen ID	Abundance	Order	Family	Genus	Species	Sort Date	Greater than 10mm?
Maui_01/2018_AV3/5	HHB-00049	5	Lepidoptera	female greater than 10mm			6/18/2019	
Maui_01/2018_AV3/5	HHB-00050	1	Coleoptera			*Morphospecies* [1]	6/18/2019	
Maui_01/2018_AV3/5	HHB-00051	2	Diptera				6/18/2019	
Maui_01/2018_AV3/5	HHB-00052	1	Lepidoptera	Tineidae	*Decadarchis*	*flavistriata?*	6/18/2019	
Maui_01/2018_AV3/5	HHB-00053	1	Lepidoptera	Geometridae	*Macaria*	*abydata*	6/18/2019	
Maui_01/2018_AV3/5	HHB-00054	1	Lepidoptera	Geometridae	*Macaria*	*abydata*	6/18/2019	
Maui_02/2018_SV1/2	HHB-00055	50	Lepidoptera	Noctuidae	*Mythimna*	*unipuncta*	6/20/2019	
Maui_01/2018_DevL1/4	HHB-00056	1	Coleoptera	Carabidae			6/21/2019	
Maui_01/2018_DevL1/4	HHB-00057	19	Lepidoptera	Noctuidae	*Mythimna*	*unipuncta*	6/21/2019	
Maui_01/2018_DevL1/4	HHB-00058	1	Hymenoptera	Ichneumonidae			6/21/2019	
Maui_01/2018_DevL1/4	HHB-00059	11	Lepidoptera	less than 10mm			6/21/2019	
Maui_01/2018_DevL1/4	HHB-00060	8	Diptera	less than 5mm			6/21/2019	
Maui_01/2018_DevL1/4	HHB-00061	1	Lepidoptera	Crambidae	*Eudonia*		6/21/2019	
Maui_01/2018_DevL1/4	HHB-00062	5	Lepidoptera	female greater than 10mm			6/21/2019	
Maui_01/2018_DevL1/4	HHB-00063	1	Lepidoptera	Crambidae	*Eudonia*		6/21/2019	
Maui_01/2018_DevL1/4	HHB-00064	1	Coleoptera			*Morphospecies* [1]	6/21/2019	
Maui_01/2018_DevL1/4	HHB-00065	2	Coleoptera			*Morphospecies* [2]		
Maui_02/2018_Gulch2/2	HHB-00066	19	Lepidoptera	Noctuidae	*Mythimna*	*unipuncta*	6/23/2019	
Maui_02/2018_Gulch2/2	HHB-00067	1	Lepidoptera	Geometridae	*Macaria*	*abydata*	6/23/2019	
Maui_02/2018_Gulch2/2	HHB-00068	7	Lepidoptera	less than 10mm			6/23/2019	
Maui_02/2018_Gulch2/2	HHB-00069	3	Lepidoptera	female greater than 10mm			6/23/2019	
Maui_02/2018_Gulch2/2	HHB-00070	1	Lepidoptera				6/23/2019	
Maui_02/2018_Gulch2/2	HHB-00071	10	Diptera	less than 5mm			6/23/2019	
Maui_02/2018_Gulch2/2	HHB-00072	1	Heteroptera	Miridae			6/23/2019	
Maui_02/2018_Gulch2/2	HHB-00073	4	Homoptera	*Ciccadellidae?, Psyllidae*			6/23/2019	

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Maui_02/2018_Gulch2/2	HHB-00074	1	Lepidoptera	Geometridae	*Macaria*	*abydata*	6/23/2019	
Maui_02/2018_Gulch2/2	HHB-00075	1	Coleoptera	Lyctidae			6/23/2019	
Maui_02/2018_Gulch2/2	HHB-00076	1	Lepidoptera	Noctuidae	*Mythimna*	*unipuncta*	6/23/2019	
Maui_02/2018_Gulch2/2	HHB-00077	1	Lepidoptera	Crambidae	*Herpetogramma*	*licarsisalis*	6/23/2019	
Maui_07/2017_NativeNursery1/1	HHB-00078	6	Coleoptera	Scarabeidae			6/26/2019	
Maui_07/2017_NativeNursery1/1	HHB-00079	2	Coleoptera	Scolytinae			6/26/2019	
Maui_07/2017_NativeNursery1/1	HHB-00080	2	Coleoptera	Carabidae			6/26/2019	
Maui_07/2017_NativeNursery1/1	HHB-00081	16	Lepidoptera	less than 10mm			6/26/2019	
Maui_07/2017_NativeNursery1/1	HHB-00082	1	Neuroptera	Chrysopidae			6/26/2019	
Maui_07/2017_NativeNursery1/1	HHB-00083	1	Lepidoptera	Geometridae	*Macaria*	*abydata*	6/26/2019	
Maui_07/2017_NativeNursery1/1	HHB-00084	5	Lepidoptera	female greater than 10mm			6/26/2019	
Maui_07/2017_NativeNursery1/1	HHB-00085	4	Coleoptera	Staphylinidae			6/26/2019	
Maui_07/2017_NativeNursery1/1	HHB-00086	11	Heteroptera	Lygaeidae			6/26/2019	
Maui_07/2017_NativeNursery1/1	HHB-00087	1	Coleoptera	Elateridae			6/26/2019	
Maui_07/2017_NativeNursery1/1	HHB-00088	1	Lepidoptera	Noctuidae	*Amyna*	*natalis*	6/26/2019	
Maui_11/2018_FWU1/1	HHB-00089	9	Lepidoptera	less than 10mm			6/27/2019	n
Maui_11/2018_FWU1/1	HHB-00090	8	Lepidoptera	female greater than 10mm			6/27/2019	y
Maui_11/2018_FWU1/1	HHB-00091	18	Diptera				6/27/2019	n
Maui_11/2018_FWU1/1	HHB-00092	10	Lepidoptera	Noctuidae	*Mythimna*	*unipuncta*	6/27/2019	y
Maui_11/2018_FWU1/1	HHB-00093	1	Lepidoptera	Tortricidae	*Bactra*		6/27/2019	
Maui_11/2018_FWU1/1	HHB-00094	1	Lepidoptera	Crambidae	*Eudonia*		6/27/2019	
Maui_11/2018_FWU1/1	HHB-00095	1	Lepidoptera	Pterophoridae	*Stenoptilodes*		6/27/2019	
Maui_11/2018_FWU1/1	HHB-00096	1	Lepidoptera	Crambidae	*Eudonia*		6/27/2019	
Maui_11/2018_FWU1/1	HHB-00097	1	Lepidoptera	Crambidae	*Eudonia*		6/27/2019	
Maui_10/2017_Grass2/2	HHB-00098	2	Lepidoptera	Noctuidae	*Mythimna*	*unipuncta*	6/28/2019	y

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Maui_10/2017_Grass2/2	HHB-00099	4	Coleoptera	Scarabeidae			6/28/2019	y
Maui_10/2017_Grass2/2	HHB-00100	5	Coleoptera	Scolytinae			6/28/2019	both
Maui_10/2017_Grass2/2	HHB-00101	16	Coleoptera			*Morphospecies* [2]	6/28/2019	n
Maui_10/2017_Grass2/2	HHB-00102	2	Coleoptera	Staphylinidae			6/28/2019	n
Maui_10/2017_Grass2/2	HHB-00103	3	Coleoptera	Carabidae			6/28/2019	both
Maui_10/2017_Grass2/2	HHB-00104	6	Diptera				6/28/2019	n
Maui_10/2017_Grass2/2	HHB-00105	3	Lepidoptera	less than 10mm			6/28/2019	n
Maui_10/2017_Grass2/2	HHB-00106	1	Coleoptera	Silphidae?			6/28/2019	n
Maui_10/2017_Grass2/2	HHB-00107	2	Heteroptera	Lygeidae			6/28/2019	n
Maui_10/2017_Grass2/2	HHB-00108	3	Hymenoptera	Braconidae			6/28/2019	n
Maui_10/2017_Grass2/2	HHB-00109	1	Homoptera	Cicadellidae			6/28/2019	n
Maui_10/2017_Grass2/2	HHB-00110	1	Lepidoptera	Limacodidae	*Darna*	*pallivitta*	6/28/2019	y
Maui_10/2017_Grass2/2	HHB-00111	1	Acari				6/28/2019	n
Maui_08/2017_DevH1/1	HHB-00112	4	Heteroptera	Pentatomidae			7/5/2019	y
Maui_08/2017_DevH1/1	HHB-00113	7	Coleoptera	Elateridae			7/5/2019	y
Maui_08/2017_DevH1/1	HHB-00114	14	Coleoptera	Carabidae			7/5/2019	n
Maui_08/2017_DevH1/1	HHB-00115	11	Coleoptera	Scarabeidae			7/5/2019	y
Maui_08/2017_DevH1/1	HHB-00116	6	Lepidoptera	Noctuidae	*Mythimna*	*unipuncta*	7/5/2019	y
Maui_08/2017_DevH1/1	HHB-00117	1	Heteroptera				7/5/2019	n
Maui_08/2017_DevH1/1	HHB-00118	2	Coleoptera	Staphylinidae			7/5/2019	n
Maui_08/2017_DevH1/1	HHB-00119	1	Lepidoptera	female greater than 10mm			7/5/2019	y
Maui_08/2017_DevH1/1	HHB-00120	2	Diptera				7/5/2019	n
Maui_08/2017_DevH1/1	HHB-00121	1	Coleoptera				7/5/2019	y
Maui_08/2017_DevH1/1	HHB-00122	1	Lepidoptera	Crambidae	*Herpetogramma*	*licarsisalis*	7/5/2019	y
Maui_08_2018_DevL3/4	HHB-00123	7	Heteroptera				7/24/2019	n

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Maui_08_2018_DevL3/4	HHB-00124	1	Lepidoptera	Crambidae	*Omiodes*		7/24/2019	y
Maui_08_2018_DevL3/4	HHB-00125	1	Lepidoptera	Crambidae	*Eudonia*		7/24/2019	n
Maui_08_2018_DevL3/4	HHB-00126	1	Lepidoptera				7/24/2019	n
Maui_08_2018_DevL3/4	HHB-00127	1	Homoptera	Delphacidae			7/24/2019	n
Maui_08_2018_DevL3/4	HHB-00128	14	Lepidoptera	female			7/24/2019	both
Maui_08_2018_DevL3/4	HHB-00129	1	Coleoptera			*morphospecies* [1]	7/24/2019	n
Maui_08_2018_DevL3/4	HHB-00130	8	Coleoptera			*morphospecies* [2]	7/24/2019	n
Maui_08_2018_DevL3/4	HHB-00131	1	Coleoptera	Carabidae			7/24/2019	y
Maui_08_2018_DevL3/4	HHB-00132	1	Lepidoptera	Geometridae	*Macaria*	*abydata*	7/24/2019	y
Maui_08_2018_DevL3/4	HHB-00133	1	Lepidoptera	Crambidae	*Eudonia*		7/24/2019	n
Maui_08_2018_DevL3/4	HHB-00134	1	Lepidoptera	Torticidae	*Cryptophlebia*	*illepida*	7/24/2019	n
Maui_08_2018_DevL3/4	HHB-00135	1	Lepidoptera	Crambidae	*Eudonia*		7/24/2019	n
Maui_08_2018_DevL3/4	HHB-00136	1	Lepidoptera	Cosmopterigidae	*Hyposmocoma*	*nr. malornata*	7/24/2019	n
Maui_08_2018_DevL3/4	HHB-00137	1	Lepidoptera	Pyralidae	*Ephestiodes*		7/24/2019	n
Maui_08_2018_DevL3/4	HHB-00138	1	Lepidoptera	Crambidae	*Eudonia*		7/24/2019	n
Maui_08_2018_DevL3/4	HHB-00139	2	Coleoptera	Staphylinidae			7/24/2019	n
Maui_08_2018_DevL3/4	HHB-00140	1	Lepidoptera	Noctuidae	*Mythimna*	*unipuncta*	7/24/2019	y
Maui_08_2018_DevL3/4	HHB-00141	2	Coleoptera	Elateridae			7/24/2019	y
Maui_08_2018_DevL3/4	HHB-00142	1	Lepidoptera	Torticidae	*Cryptophlebia*	*illepida*	7/24/2019	n
Maui_08_2018_DevL3/4	HHB-00143	1	Lepidoptera	Torticidae	*Cryptophlebia*	*illepida*	7/24/2019	n
Maui_08_2018_DevL3/4	HHB-00144	1	Lepidoptera	Crambidae	*Eudonia*		7/24/2019	n
Maui_08_2018_DevL4/4	HHB-00145	1	Mantodea	Mantidae			7/25/2019	y
Maui_08_2018_DevL4/4	HHB-00146	1	Coleoptera	Cerambycidae			7/25/2019	y
Maui_08_2018_DevL4/4	HHB-00147	15	Heteroptera				7/25/2019	various sizes
Maui_08_2018_DevL4/4	HHB-00148	1	Coleoptera	Scarabeidae			7/25/2019	y

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Maui_08_2018_DevL4/4	HHB-00149	2	Coleoptera	Carabidae			7/25/2019	y
Maui_08_2018_DevL4/4	HHB-00150	6	Coleoptera			*morphospecies* [2]	7/25/2019	n
Maui_08_2018_DevL4/4	HHB-00151	1	Diptera				7/25/2019	n
Maui_08_2018_DevL4/4	HHB-00152	1	Homoptera	Delphacidae			7/25/2019	n
Maui_08_2018_DevL4/4	HHB-00153	1	Isoptera				7/25/2019	y
Maui_08_2018_DevL4/4	HHB-00154	10	Lepidoptera	female			7/25/2019	various sizes
Maui_08_2018_DevL4/4	HHB-00155	1	Heteroptera	Pentatomidae			7/25/2019	y
Maui_08_2018_DevL4/4	HHB-00156	4	Coleoptera	Elateridae			7/25/2019	y
Maui_08_2018_DevL4/4	HHB-00157	1	Lepidoptera	Crambidae	*Orthomecyna*		7/25/2019	n
Maui_08_2018_DevL4/4	HHB-00158	1	Lepidoptera	Torticidae	*Cryptophlebia*	*illepida*	7/25/2019	n
Maui_08_2018_DevL4/4	HHB-00159	2	Lepidoptera	Torticidae	*Cryptophlebia*	*illepida*	7/25/2019	n
Maui_08_2018_DevL4/4	HHB-00160	1	Lepidoptera	Pyralidae	*Ephestiodes*		7/25/2019	n
Maui_08_2018_DevL4/4	HHB-00161	1	Lepidoptera				7/25/2019	n
Maui_08_2018_DevL1/4	HHB-00162	14	Lepidoptera	female			7/25/2019	various sizes
Maui_08_2018_DevL1/4	HHB-00163	5	Coleoptera			*morphospecies* [2]	7/25/2019	n
Maui_08_2018_DevL1/4	HHB-00164	5	Coleoptera	Elateridae			7/25/2019	y
Maui_08_2018_DevL1/4	HHB-00165	1	Coleoptera	Staphylinidae			7/25/2019	n
Maui_08_2018_DevL1/4	HHB-00166	1	Blattodea				7/25/2019	y
Maui_08_2018_DevL1/4	HHB-00167	1	Lepidoptera	Pyralidae	*Unadilla*	*bidensana?*	7/25/2019	y
Maui_08_2018_DevL1/4	HHB-00168	1	Lepidoptera	Torticidae	*Cryptophlebia*	*illepida*	7/25/2019	n
Maui_08_2018_DevL1/4	HHB-00169	1	Lepidoptera	Torticidae	*Cryptophlebia*	*illepida*	7/25/2019	n
Maui_08_2018_DevL1/4	HHB-00170	1	Lepidoptera	Pyralidae	*Ephestiodes*		7/25/2019	n
Maui_08_2018_DevL1/4	HHB-00171	1	Lepidoptera	Noctuidae	*Mythimna*	*unipuncta*	7/25/2019	y
Maui_08_2018_DevL1/4	HHB-00172	5	Coleoptera	Carabidae			7/25/2019	various sizes

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Maui_08_2018_DevL1/4	HHB-00173	9	Heteroptera				7/25/2019	n
Maui_08_2018_DevL1/4	HHB-00174	1	Isoptera				7/25/2019	y
Maui_08_2018_DevL1/4	HHB-00175	1	Coleoptera			*morphospecies* [3]	7/25/2019	n
Maui_08_2018_DevL1/4	HHB-00176	1	Lepidoptera	Crambidae	*Eudonia*		7/25/2019	n
Maui_08_2018_DevL1/4	HHB-00177	1	Coleoptera	Scarabeidae			7/25/2019	y
Maui_08_2018_DevL1/4	HHB-00178	1	Coleoptera				7/25/2019	n
Maui_01_2018_FWU1/1	HHB-00179	15	Lepidoptera	Noctuidae	*Mythimna*	*unipuncta*	8/20/2019	y
Maui_01_2018_FWU1/1	HHB-00180	1	Neuroptera	Hemerobiidae			8/20/2019	n
Maui_01_2018_FWU1/1	HHB-00181	5	Diptera	Tipulidae?			8/20/2019	n
Maui_01_2018_FWU1/1	HHB-00182	6	Diptera	Culicidae?			8/20/2019	n
Maui_01_2018_FWU1/1	HHB-00183	16	Lepidoptera	female			8/20/2019	n
Maui_01_2018_FWU1/1	HHB-00184	1	Diptera	Ephydridae?			8/20/2019	n
Maui_01_2018_FWU1/1	HHB-00185	1	Lepidoptera	Carposinidae	*Carposina*	*inscripta*	8/20/2019	n
Maui_01_2018_FWU1/1	HHB-00186	1	Lepidoptera	Crambidae	*Eudonia*		8/20/2019	n
Maui_01_2018_FWU1/1	HHB-00187	1	Lepidoptera	Carposinidae	*Carposina*	*gracillima*	8/20/2019	n
Maui_01_2018_FWU1/1	HHB-00188	1	Lepidoptera	Carposinidae	*Carposina*	*inscripta*	8/20/2019	n
Maui_01_2018_FWU1/1	HHB-00189	1	Lepidoptera	female			8/20/2019	n
Maui_01_2018_FWU1/1	HHB-00190	1	Lepidoptera	Crambidae	*Eudonia*		8/20/2019	n
Maui_08/2017_DevL1/1	HHB-00191	1	Lepidoptera	Geometridae	*Scotorythra*		8/22/2019	y
Maui_08/2017_DevL1/1	HHB-00192	17	Coleoptera	Elateridae			8/22/2019	y
Maui_08/2017_DevL1/1	HHB-00193	9	Lepidoptera	female			8/22/2019	various sizes
Maui_08/2017_DevL1/1	HHB-00194	1	Homoptera	Delphacidae			8/22/2019	n
Maui_08/2017_DevL1/1	HHB-00195	3	Psocoptera				8/22/2019	n
Maui_08/2017_DevL1/1	HHB-00196	1	Coleoptera	Scarabeidae			8/22/2019	y
Maui_08/2017_DevL1/1	HHB-00197	6	Coleoptera				8/22/2019	n

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Maui_08/2017_DevL1/1	HHB-00198	1	Isoptera				8/22/2019	y
Maui_08/2017_DevL1/1	HHB-00199	3	Homoptera	Psyllidae			8/22/2019	n
Maui_08/2017_DevL1/1	HHB-00200	1	Hymenoptera	Braconidae			8/22/2019	n
Maui_08/2017_DevL1/1	HHB-00201	1	Coleoptera	Carabidae			8/22/2019	y
Maui_08/2017_DevL1/1	HHB-00202	1	Lepidoptera				8/22/2019	n
Maui_08/2017_DevL1/1	HHB-00203	1	Lepidoptera	Cosmopterigidae	*Hyposmocoma*		8/22/2019	n
Maui_08/2017_DevL1/1	HHB-00204	1	Lepidoptera	Torticidae	*Cryptophlebia*	*illepida*	8/22/2019	n
Maui_08/2017_DevL1/1	HHB-00205	1	Lepidoptera	Cosmopterigidae	*Hyposmocoma*		8/22/2019	n
Maui_08/2017_DevL1/1	HHB-00206	1	Lepidoptera	Torticidae	*Cydia*		8/22/2019	n
Maui_08/2017_DevL1/1	HHB-00207	1	Lepidoptera				8/22/2019	n
Maui_03/2018_FWU1/1	HHB-00208	8	Lepidoptera	Noctuidae	*Mythimna*	*unipuncta*	9/3/2019	y
Maui_03/2018_FWU1/1	HHB-00209	1	Hymenoptera	Ichneumonidae			9/3/2019	y
Maui_03/2018_FWU1/1	HHB-00210	24	Lepidoptera	female			9/3/2019	various sizes
Maui_03/2018_FWU1/1	HHB-00211	1	Diptera	Tipulidae			9/3/2019	y
Maui_03/2018_FWU1/1	HHB-00212	3	Diptera				9/3/2019	n
Maui_03/2018_FWU1/1	HHB-00213	1	Lepidoptera	Pterophoridae			9/3/2019	y
Maui_03/2018_FWU1/1	HHB-00214	1	Coleoptera	Staphylinidae			9/3/2019	n
Maui_03/2018_FWU1/1	HHB-00215	1	Psocoptera				9/3/2019	n
Maui_03/2018_FWU1/1	HHB-00216	1	Lepidoptera	Crambidae	*Udea*		9/3/2019	y
Maui_03/2018_FWU1/1	HHB-00217	1	Lepidoptera	Crambidae	*Eudonia*		9/3/2019	n
Maui_03/2018_FWU1/1	HHB-00218	1	Lepidoptera	Tortricidae	*Epiphyas*	*postvittana*	9/3/2019	n
Maui_03/2018_FWU1/1	HHB-00219	1	Lepidoptera	Crambidae	*Eudonia*		9/3/2019	n
Maui_03/2018_FWU1/1	HHB-00220	1	Lepidoptera	Crambidae	*Eudonia*		9/3/2019	n
Maui_03/2018_FWU1/1	HHB-00221	1	Lepidoptera	Crambidae	*Udea*		9/3/2019	y

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Maui_03/2018_FWU1/1	HHB-00222	1	Lepidoptera	Crambidae	*Eudonia*		9/3/2019	n
Maui_03/2018_FWU1/1	HHB-00223	1	Lepidoptera	Geometridae	*Scotorythra*		9/3/2019	y
Maui_03/2018_FWU1/1	HHB-00224	1	Lepidoptera	Carposinidae	*Carposina*		9/3/2019	n
Maui_03/2018_FWU1/1	HHB-00225	1	Lepidoptera	Crambidae	*Udea*		9/3/2019	n
Maui_10/2017_Gulch3/3	HHB-00226	17	Lepidoptera	Noctuidae	*Mythimna*	*unipuncta*	9/9/2019	y
Maui_10/2017_Gulch3/3	HHB-00227	1	Coleoptera			*morphospecies* [1]	9/9/2019	n
Maui_10/2017_Gulch3/3	HHB-00228	1	Lepidoptera	Crambidae	*Eudonia*		9/9/2019	y
Maui_10/2017_Gulch3/3	HHB-00229	2	Lepidoptera	Torticidae	*Cryptophlebia*	*illepida*	9/9/2019	n
Maui_10/2017_Gulch3/3	HHB-00230	16	Lepidoptera	female			9/9/2019	various sizes
Maui_10/2017_Gulch3/3	HHB-00231	1	Diptera				9/9/2019	n
Maui_10/2017_Gulch3/3	HHB-00232	2	Coleoptera	Staphylinidae			9/9/2019	n
Maui_10/2017_Gulch3/3	HHB-00233	1	Psocoptera				9/9/2019	n
Maui_10/2017_Gulch3/3	HHB-00234	1	Coleoptera	Carabidae			9/9/2019	n
Maui_10/2017_Gulch3/3	HHB-00235	1	Coleoptera			*morphospecies* [3]	9/9/2019	n
Maui_10/2017_Gulch3/3	HHB-00236	1	Lepidoptera	Geometridae	*Scotorythra*		9/9/2019	y
Maui_10/2017_Gulch3/3	HHB-00237	1	Lepidoptera	Torticidae	*Cydia*		9/9/2019	n
Maui_10/2017_Gulch3/3	HHB-00238	1	Lepidoptera	Noctuidae	*Mythimna*	*unipuncta*	9/9/2019	y
Maui_10/2017_Gulch3/3	HHB-00239	1	Lepidoptera	Crambidae	*Orthomecyna*		9/9/2019	n
Maui_10/2017_Gulch3/3	HHB-00240	1	Lepidoptera	male			9/9/2019	n
Maui_10/2017_Gulch3/3	HHB-00241	1	Lepidoptera	Cosmopterigidae	*Hyposmocoma*		9/9/2019	n
Maui_10/2017_Gulch3/3	HHB-00242	1	Lepidoptera	Torticidae	*Amorbia*	*emigratella*	9/9/2019	n
Maui_10/2017_Gulch1/3	HHB-00243	10	Lepidoptera	Noctuidae	*Mythimna*	*unipuncta*	10/8/2019	y
Maui_10/2017_Gulch1/3	HHB-00244	1	Lepidoptera	Torticidae	*Cryptophlebia*	*illepida*	10/8/2019	n
Maui_10/2017_Gulch1/3	HHB-00245	12	Lepidoptera	female			10/8/2019	both
Maui_10/2017_Gulch1/3	HHB-00246	1	Lepidoptera	Erebidae	*Schrankia*	*altivolans*	10/8/2019	n

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Maui_10/2017_Gulch1/3	HHB-00247	1	Coleoptera	Carabidae			10/8/2019	y
Maui_10/2017_Gulch1/3	HHB-00248	4	Coleoptera	Scarabeidae			10/8/2019	y
Maui_10/2017_Gulch1/3	HHB-00249	3	Coleoptera	Elateridae			10/8/2019	y
Maui_10/2017_Gulch1/3	HHB-00250	1	Homoptera	Delphacidae			10/8/2019	n
Maui_10/2017_Gulch1/3	HHB-00251	2	Diptera	multiple families			10/8/2019	less than 2mm
Maui_10/2017_Gulch1/3	HHB-00252	1	Coleoptera	Scolytinae			10/8/2019	less than 2mm
Maui_10/2017_Gulch1/3	HHB-00253	3	Coleoptera	multiple families			10/8/2019	n
Maui_10/2017_Gulch1/3	HHB-00254	1	Lepidoptera	Erebidae	*Schrankia*	*altivolans*	10/8/2019	y
Maui_10/2017_Gulch1/3	HHB-00255	1	Lepidoptera	Crambidae	*Udea*		10/8/2019	n
Maui_10/2017_Gulch1/3	HHB-00256	1	Lepidoptera	Crambidae	*Orthomecyna*	*exigua exigua*	10/8/2019	y
Maui_10/2017_Gulch1/3	HHB-00257	1	Lepidoptera	Crambidae	*Omiodes*		10/8/2019	y
Maui_10/2017_Gulch1/3	HHB-00258	1	Lepidoptera	Crambidae	*Herpetogramma*	*licarsisalis*	10/8/2019	y
Maui_10/2017_Gulch1/3	HHB-00259	1	Lepidoptera	male			10/8/2019	n
Maui_10/2017_Gulch1/3	HHB-00260	1	Lepidoptera	Tineidae	*Tinea*	*despecta?*	10/8/2019	n
Maui_10/2017_Gulch1/3	HHB-00261	1	Lepidoptera	Crambidae	*Orthomecyna*	*exigua exigua*	10/8/2019	n
Maui_10/2017_Gulch1/3	HHB-00262	1	Lepidoptera	Crambidae	*Udea*		10/8/2019	n
Maui_10/2017_Gulch1/3	HHB-00263	1	Lepidoptera	Erebidae	*Schrankia*	*altivolans*	10/8/2019	n
Maui_10/2017_Gulch1/3	HHB-00264	1	Lepidoptera				10/8/2019	n
Maui_10/2017_Grass1/2	HHB-00265	18	Coleoptera	Scarabeidae			10/10/2019	y
Maui_10/2017_Grass1/2	HHB-00266	16	Coleoptera			*morphospecies* [4]	10/10/2019	n
Maui_10/2017_Grass1/2	HHB-00267	1	Coleoptera	Carabidae			10/10/2019	y
Maui_10/2017_Grass1/2	HHB-00268	1	Hymenoptera				10/10/2019	y
Maui_10/2017_Grass1/2	HHB-00269	5	Lepidoptera	female			10/10/2019	both

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Maui_10/2017_Grass1/2	HHB-00270	1	Lepidoptera	Noctuidae	*Agrotis*		10/10/2019	y
Maui_10/2017_Grass1/2	HHB-00271	2	Coleoptera				10/10/2019	n
Maui_10/2017_Grass1/2	HHB-00272	1	Diptera	Ephydridae			10/10/2019	n
Maui_10/2017_Grass1/2	HHB-00273	4	Coleoptera	Staphylinidae			10/10/2019	n
Maui_10/2017_Grass1/2	HHB-00274	1	Coleoptera			*morphospecies* [3]	10/10/2019	n
Maui_08/2018_DevL2/4	HHB-00275	4	Lepidoptera	Noctuidae	*Mythimna*	*unipuncta*	10/14/2019	y
Maui_08/2018_DevL2/4	HHB-00276	1	Lepidoptera	Crambidae	*Omiodes*		10/14/2019	y
Maui_08/2018_DevL2/4	HHB-00277	9	Lepidoptera	female			10/14/2019	y
Maui_08/2018_DevL2/4	HHB-00278	1	Lepidoptera	Noctuidae	*Megalographa*	*biloba*	10/14/2019	y
Maui_08/2018_DevL2/4	HHB-00279	4	Coleoptera	Elateridae			10/14/2019	y
Maui_08/2018_DevL2/4	HHB-00280	3	Coleoptera	Staphylinidae			10/14/2019	n
Maui_08/2018_DevL2/4	HHB-00281	12	Coleoptera			*morphospecies* [4]	10/14/2019	n
Maui_08/2018_DevL2/4	HHB-00282	3	Heteroptera	Lygaeidae			10/14/2019	n
Maui_08/2018_DevL2/4	HHB-00283	2	Heteroptera	Cydnidae			10/14/2019	n
Maui_08/2018_DevL2/4	HHB-00284	1	Coleoptera				10/14/2019	n
Maui_08/2018_DevL2/4	HHB-00285	1	Lepidoptera	Tortricidae	*Cryptophlebia*	*illepida*	10/14/2019	n
Maui_08/2018_DevL2/4	HHB-00286	3	Lepidoptera	Crambidae	*Eudonia*		10/14/2019	n
Maui_08/2018_DevL2/4	HHB-00287	1	Lepidoptera	Hyposmocoma			10/14/2019	n
Maui_08/2018_DevL2/4	HHB-00288	1	Coleoptera	Scolytinae			10/14/2019	n
Maui_08/2018_DevL2/4	HHB-00289	1	Coleoptera	Scarabeidae			10/14/2019	y
Maui_08/2018_DevL2/4	HHB-00290	1	Coleoptera	Curculionidae			10/14/2019	n
Maui_08/2018_DevL2/4	HHB-00291	1	Acari				10/14/2019	n
Maui_08/2018_DevL2/4	HHB-00292	1	Lepidoptera	Noctuidae	*Agrotis*		10/14/2019	y
Maui_06/2018_FWU1/1	HHB-00293	5	Lepidoptera	Noctuidae	*Mythimna*	*unipuncta*	10/23/2019	y
Maui_06/2018_FWU1/1	HHB-00294	39	Diptera	Tipulidae			10/23/2019	y

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Maui_06/2018_FWU1/1	HHB-00295	4	Lepidoptera	female			10/23/2019	both
Maui_06/2018_FWU1/1	HHB-00296	1	Lepidoptera	male			10/23/2019	y
Maui_06/2018_FWU1/1	HHB-00297	1	Lepidoptera	Crambidae	*Eudonia*		10/23/2019	y
Maui_01/2018_Grass1/3	HHB-00298	6	Lepidoptera	Noctuidae	*Mythimna*	*unipuncta*	10/23/2019	y
Maui_01/2018_Grass1/3	HHB-00299	1	Coleoptera	Elateridae			10/23/2019	y
Maui_01/2018_Grass1/3	HHB-00300	7	Coleoptera	Scarabeidae			10/23/2019	y
Maui_01/2018_Grass1/3	HHB-00301	25	Lepidoptera	female			10/23/2019	both
Maui_01/2018_Grass1/3	HHB-00302	1	Heteroptera	Lygaeidae			10/23/2019	n
Maui_01/2018_Grass1/3	HHB-00303	4	Coleoptera			*morphospecies* [4]	10/23/2019	n
Maui_01/2018_Grass1/3	HHB-00304	2	Coleoptera	Carabidae			10/23/2019	y
Maui_01/2018_Grass1/3	HHB-00305	1	Diptera	Ephydridae?			10/23/2019	n
Maui_01/2018_Grass1/3	HHB-00306	1	Lepidoptera	Crambidae	*Orthomecyna*		10/23/2019	n
Maui_01/2018_Grass1/3	HHB-00307	1	Lepidoptera	Autostichidae	*Stoeberhinus*	*testaceus*	10/23/2019	n
Maui_01/2018_Grass1/3	HHB-00308	1	Lepidoptera	Crambidae	*Herpetogramma*	*licarsisalis*	10/23/2019	y
Maui_01/2018_DevL3/4	HHB-00309	23	Lepidoptera	Noctuidae	*Mythimna*	*unipuncta*	10/24/2019	y
Maui_01/2018_DevL3/4	HHB-00310	2	Coleoptera			*morphospecies* [4]	10/24/2019	n
Maui_01/2018_DevL3/4	HHB-00311	14	Lepidoptera	female			10/24/2019	both
Maui_01/2018_DevL3/4	HHB-00312	1	Lepidoptera	Geometridae	*Scotorythra*		10/24/2019	y
Maui_01/2018_DevL3/4	HHB-00313	2	Diptera				10/24/2019	n
Maui_01/2018_DevL3/4	HHB-00314	2	Lepidoptera	Crambidae	*Eudonia*		10/24/2019	n
Maui_01/2018_DevL3/4	HHB-00315	1	Lepidoptera	male			10/24/2019	n
Maui_01/2018_DevL3/4	HHB-00316	1	Lepidoptera	Crambidae	*Udea*		10/24/2019	n
Maui_01/2018_DevL3/4	HHB-00317	1	Lepidoptera	Crambidae	*Orthomecyna*		10/24/2019	n
Maui_01/2018_DevL3/4	HHB-00318	1	Lepidoptera	Noctuidae	*Agrotis*		10/24/2019	y
Maui_01/2018_DevL3/4	HHB-00319	1	Lepidoptera	Geometridae	*Macaria*	*abydata*	10/24/2019	y

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Maui_01/2018_DevL3/4	HHB-00320	1	Lepidoptera	male			10/24/2019	y
Maui_08/2018_FWU1/1	HHB-00321	3	Lepidoptera	Noctuidae	*Mythimna*	*unipuncta*	10/28/2019	y
Maui_08/2018_FWU1/1	HHB-00322	2	Lepidoptera	Geometridae	*Scotorythra*		10/28/2019	y
Maui_08/2018_FWU1/1	HHB-00323	19	Lepidoptera	female			10/28/2019	y
Maui_08/2018_FWU1/1	HHB-00324	1	Coleoptera	Scarabeidae			10/28/2019	y
Maui_08/2018_FWU1/1	HHB-00325	9	Diptera	Tipulidae			10/28/2019	n
Maui_08/2018_FWU1/1	HHB-00326	3	Diptera				10/28/2019	n
Maui_08/2018_FWU1/1	HHB-00327	1	Lepidoptera	Tortricidae	*Bactra*	*straminea*	10/28/2019	n
Maui_08/2018_FWU1/1	HHB-00328	1	Lepidoptera	Tortricidae	*Epiphyas*	*postvittana*	10/28/2019	n
Maui_08/2018_FWU1/1	HHB-00329	1	Lepidoptera				10/28/2019	n
Maui_08/2018_FWU1/1	HHB-00330	1	Lepidoptera	male			10/28/2019	n
Maui_08/2018_FWU1/1	HHB-00331	1	Lepidoptera	Crambidae	*Udea*		10/28/2019	n
Maui_08/2018_FWU1/1	HHB-00332	2	Hymenoptera	Ichneumonidae			10/30/2019	y
Maui_08/2018_FWU1/1	HHB-00333	1	Neuroptera	Hemerobiidae			10/30/2019	y
Maui_08/2018_FWU1/1	HHB-00334	1	Lepidoptera	Crambidae	*Eudonia*		10/30/2019	n
Maui_08/2018_FWU1/1	HHB-00335	1	Lepidoptera	Crambidae	*Udea*		10/30/2019	y
Maui_08/2018_FWU1/1	HHB-00336	1	Lepidoptera	Crambidae	*Udea*		10/30/2019	y
Maui_08/2018_FWU1/1	HHB-00337	1	Lepidoptera	Crambidae	*Udea*		10/30/2019	y
Maui_08/2018_FWU1/1	HHB-00338	1	Lepidoptera	Pterophoridae	*Stenoptilodes*		10/30/2019	y
Maui_02/2018_Gulch1/2	HHB-00339	24	Lepidoptera	Noctuidae	*Mythimna*	*unipuncta*	11/16/2019	y
Maui_02/2018_Gulch1/2	HHB-00340	3	Diptera	Drosophilidae?	*Drosophila?*		11/16/2019	n
Maui_02/2018_Gulch1/2	HHB-00341	6	Diptera				11/16/2019	n
Maui_02/2018_Gulch1/2	HHB-00342	1	Heteroptera				11/16/2019	n
Maui_02/2018_Gulch1/2	HHB-00343	6	Lepidoptera	female			11/16/2019	both
Maui_02/2018_Gulch1/2	HHB-00344	2	Coleoptera			*morphospecies* [4]	11/16/2019	n

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Maui_02/2018_Gulch1/2	HHB-00345	1	Heteroptera	Pentatomidae			11/16/2019	y
Maui_02/2018_Gulch1/2	HHB-00346	1	Homoptera				11/16/2019	n
Maui_02/2018_Gulch1/2	HHB-00347	1	Diptera	Syrphidae			11/16/2019	n
Maui_02/2018_Gulch1/2	HHB-00348	1	Lepidoptera	male			11/16/2019	n
Maui_02/2018_Gulch1/2	HHB-00349	1	Lepidoptera	Noctuidae	*Spodoptera*	*exigua*	11/16/2019	y
Maui_02/2018_Gulch1/2	HHB-00350	1	Lepidoptera	Geometridae	*Macaria*	*abydata*	11/16/2019	y
Maui_02/2018_Gulch1/2	HHB-00351	1	Lepidoptera	Geometridae	*Macaria*	*abydata*	11/16/2019	y
Maui_02/2018_Gulch1/2	HHB-00352	1	Lepidoptera	Geometridae	*Macaria*	*abydata*	11/16/2019	y
Maui_10/2017_Gulch2/3	HHB-00353	14	Lepidoptera	Noctuidae	*Mythimna*	*unipuncta*	11/22/2019	y
Maui_10/2017_Gulch2/3	HHB-00354	4	Coleoptera	Scarabeidae			11/22/2019	y
Maui_10/2017_Gulch2/3	HHB-00355	3	Coleoptera	Staphylinidae			11/22/2019	both
Maui_10/2017_Gulch2/3	HHB-00356	1	Coleoptera	Scolytinae			11/22/2019	n
Maui_10/2017_Gulch2/3	HHB-00357	4	Coleoptera	Elateridae			11/22/2019	y
Maui_10/2017_Gulch2/3	HHB-00358	1	Coleoptera			*morphospecies* [4]	11/22/2019	n
Maui_10/2017_Gulch2/3	HHB-00359	1	Lepidoptera	Torticidae	*Cryptophlebia*	*illepida*	11/22/2019	n
Maui_10/2017_Gulch2/3	HHB-00360	1	Heteroptera	Cydnidae			11/22/2019	n
Maui_10/2017_Gulch2/3	HHB-00361	1	Coleoptera			*morphospecies* [3]	11/22/2019	n
Maui_10/2017_Gulch2/3	HHB-00362	3	Lepidoptera	Crambidae	*Eudonia*		11/22/2019	both
Maui_10/2017_Gulch2/3	HHB-00363	10	Lepidoptera	female			11/22/2019	both
Maui_10/2017_Gulch2/3	HHB-00364	2	Isoptera				11/22/2019	y
Maui_10/2017_Gulch2/3	HHB-00365	1	Lepidoptera	Crambidae	*Orthomecyna*		11/22/2019	n
Maui_10/2017_Gulch2/3	HHB-00366	1	Lepidoptera	Torticidae	*Amorbia*	*emigratella*	11/22/2019	n
Maui_10/2017_Gulch2/3	HHB-00367	1	Lepidoptera	Crambidae	*Herpetogramma*	*licarsisalis*	11/22/2019	y
Maui_10/2017_Gulch2/3	HHB-00368	1	Lepidoptera	Crambidae	*Herpetogramma*	*licarsisalis*	11/22/2019	y
Maui_10/2017_Gulch2/3	HHB-00369	1	Lepidoptera	Crambidae	*Herpetogramma*	*licarsisalis*	11/22/2019	y