HAWAIIAN HOARY BAT CONSERVATION BIOLOGY: MOVEMENTS, ROOSTING BEHAVIOR, AND DIET

A Proposal Prepared for State of Hawaii Endangered Species Committee

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SUMMARY

This proposal is designed to advance understanding of key aspects of Hawaiian hoary bat (*Lasiurus cinereus semotus*) ecology and population biology listed as priority research goals both in the ESRC "Request for Proposals" and the USFWS 1998 Recovery Plan for the Hawaiian Hoary Bat. Central topics include: 1) seasonal and annual home range and movement patterns, 2) diet composition and food availability, 3) identifying habitats used for foraging roosting, and breeding, and 4) mother-pup demographics and predation at maternity roosts.

A key feature of our project will be deployment of a network of antennae masts wired to automated radio-telemetry systems supplemented by ground crew hand-held radio-telemetry that will provide coverage of a 1,500 km^2 area of eastern Hawaii Island to include native forests, agro-ecosystems, lava tubes, and urban/suburban landscapes from sea level to 3,500 m elevation, all in a region with previously demonstrated high presence levels for hoary bats. We plan to radio-tag 48 bats per year with a goal of 8 radio-tagged bats pulsed every two months over a three year period for a total of 144 tagged bats. The capture and release effort will provide opportunity to collect and bank skin, fecal, and hair samples for dietary analysis (this study), population genetics, and examination of pesticides and heavy metal accumulation in hoary bats (the latter two topics are proposed elsewhere by collaborative USGS teams). When possible, bats that are recaptured multiple times and identifiable from permanent wrist bands will become focal animals for tracking long term movements and monitoring site fidelity. We will also track bats to day roost trees and monitor bats with video, acoustic, and microclimate recording devices to study mother-pup behaviors and demographics through fledging. We will select among important bat foraging locations determined from radio-telemetry sites locations to sample insect diversity, abundance and biomass. Fecal pellets collected in this study from bat capture/release will be used in a meta-barcoding dietary study to identify and quantify insect prey items from matched barcodes in a reference library of insects we will compile to understand prey choice and seasonal movement patterns of the bat.

Major objectives in our study of Hawaiian hoary bats will document all the following points identified as Priority Objectives by the ESRC:

- foraging and home range size including winter and summer seasonal ranges over three annual cycles
- habitat use devoted to foraging, roosting, and breeding
- roost fidelity and roost tree geometry and characteristics
- mother-pup behavior and demographics through fledging at breeding roost trees
- quantitative diet analysis of insect prey selection and availability using molecular bar-coding techniques
- examination of the relationships between movement patterns and food availability
- insect prey-host plant associations providing guidance to wildlife managers for bat habitat restoration
- a tissue and fecal collection bank for genetic, dietary studies, and pesticide studies

Our research plan represents the largest sampling effort ever attempted to characterize Hawaiian hoary bat movement ecology and behavior through radio-telemetry. Only a single published radio-telemetry study of Hawaiian hoary bats spanning multiple years (Bonaccorso et al. 2015) exists and although informative about individual movements this study was limited to hand-held tracking in lowland areas and did not sample high elevation winter range of the bat. Our understanding of hoary bat spatial ecology will be vastly improved by successful completion of our

proposed objectives and will provide wildlife managers much more thorough home range estimates than those now existing.

The USGS and HCSU biologists available for this research project have unparalleled experience (over 125 years cumulative in Hawaii) in practicing field ecology throughout the ecosystems of Hawaii and specifically on the conservation biology of Hawaiian hoary bats. Furthermore, the USGS as an organization has an exceptional staff of field biologists at the Pacific Island Ecosystems Research Center (PIERC) at Kilauea Field Station and can call upon a national network of multi-disciplinary scientists for numerous specialized fields. USGS/PIERC ecologists and entomologists will lead the insect prey aspects of our study as well as providing expertise in the use of automated radio-telemetry arrays.

Information forthcoming from this study will provide wildlife managers key information, data, and maps for planning recovery of the Hawaiian hoary bat, as well as information that will better guide planning and implementation of current and future mitigation and management areas. Examples of new critical information expected as outcomes include first estimates of the size of the winter foraging range, survivorship of pups from birth to fledging, identification of predators of infant bats and other causes of mortality, and assessment of bat diet-insect prey base-host plant inter-relationships.

Budget Requested from the Bat Mitigation Research Fund by USGS: $1,831,565
Budget Match Provided courtesy of USGS: $ 175,618

GOALS

The strategic goal is to provide strong multi-disciplinary sets of data showing the inter-relationships between daily and annual movement patterns, breeding biology, roosting biology, predation, and relationships of insect prey abundance, biomass, diversity, and distribution as drivers of hoary bat ecology. The information we gather will directly help managers make informed decisions assisting the recovery of Hawaiian hoary bats and for improved selection and design of bat mitigation reserves that will offer a balance of winter and summer habitat, foraging and roosting habitat, guidance on key plant species for propagation to benefit bats in restoration-mitigation areas, and potential precautions such as predator control that may be warranted.

Furthermore, tissue samples from bats captured for radio-telemetry will be banked for future use in population demographic studies and for study of heavy metal/pesticides accumulation both in hoary bats and lower levels of their food web as funds and partners become available.

OBJECTIVES

Major objectives in our study of Hawaiian hoary bats will document the following topics identified as Priority Objectives by the ESRC:

- foraging/home range size including winter and summer seasonal ranges over three annual cycles (ESRC Goal 1a, 1c)
- habitat use devoted to foraging, roosting, and breeding (ESRC 2a)
- roost fidelity and roost tree geometry and characteristics (2a)
- mother-pup demographics including predation/mortality at maternity roosts (1b, 2d)
- diet composition and insect prey availability (ESRC 2b)
- relationships of home range to food availability (ESRC 2b)

- prey-host plant associations (ESRC 2a, 2b, 4)
- tissue and fecal collections for presently proposed and future diet, population demographic, and pesticide/heavy metal studies (banking materials for ESRC 1d, 2b, 2c)

Each of the objectives when fulfilled will contribute to a more informed guidance toward mitigation strategies for the future selection, restoration and protection of natural reserve lands for the management to recovery of Hawaii hoary bats.

TASKS AND ACTIVITIES

- Capture and release – Hawaiian hoary bats will be captured with mist nets by an experienced and fully permitted group of bat ecologists having extensive experience in Hawaiian ecosystems. The use of social and foraging call playback will be used to enhance mist-net capture rates. Eastern Hawaii as proposed for our study is the best proven region in the state to capture large numbers of bats in order to produce robust data sets. Bats will be taken through a data collection protocol in less than 45 minutes and released at the capture site with radio-tags and individual wrist bands. Fecal pellets for dietary study will be collected from bats as expelled in soft cloth holding bags within the 45 minute handling protocol. Biological sampling of bat skin biopsies and hair clippings will be banked and available for complementary studies of bat genetics and pesticides.
- Radio-tagging – application of BD-2XC Holohil radio transmitters will be applied by a proven collar method for attachment of radios to small bats described in detail by Winkelmann *et al* (2003). Collars are designed to drop off bats soon after the 6 week battery life is expended via a cotton thread weak point in the collar. The BD-2XC offers a greatly extended battery life (John Edwards, Holohil Inc., personal communication) for tracking bats than previously employed by any study of Hawaiian hoary bats (6 week potential versus 13 days achieved previously).
- Banding—USFWS and DLNR permit approved plastic split rings color coded for individual visual identity will be used to identify bats both in hand and at roosts. Banding will permit long term identification of individuals upon recapture or at roost observations on a permanent basis long after radio-tags have ceased to function. Banding will be particularly important in our study of roost fidelity as well as providing some information on lifespan (banded hoary bats have been captured previously by us up to 4 years after banding).
- Radio-tracking—automated tracking using an array of elevated (mast) antennae/receiver systems will be deployed around eastern Hawaii to track movements in a 1500 km^2 area and supplemented with hand-held ground based tracking teams. Hand held tracking by humans in real time will permit homing to exact roost tree locations and visual observation of roosting bats essential for videography and acoustic monitoring of roosting bats. The automated tracking will provide minute by minute tracking of individuals and offers long distance tracking tens of miles beyond range of a ground based, hand held antennae. The antennae masts will be placed in the extensive study area to provide maximum line of sight coverage for effective triangulation of bat positions. The automated system will

rotate between up to 8 individual bats with a position triangulation recorded every minute during entire nights and hourly by daylight hours. This will make it possible to track individuals for up to 6 weeks on daily movements with a high probability of tracking some transition movements between summer and winter foraging ranges and for the first time make it possible to calculate true annual home ranges for the Hawaiian hoary bats. Our goal is to radio-tag and track eight individuals in each of six bimonthly periods throughout the year over a three year time-span. The telemetry combination of automated systems tracking from elevated antennae and ground based tracking will provide a very thorough monitoring of bat presence at day roosts and permit complimentary monitoring using video and acoustic apparatus in close proximity to day roosts thus providing details of roost fidelity, frequency of roost switching (multiple roost use), weather attributes confining bats to roosts or acceptable for foraging, predator presence, and mother-pup behaviors and demographics.

- Video monitoring—both thermal imaging and near infra-red cameras will be used to record bats at roosting trees to provided visual documentation of timing of roost departures and returns, observations of predators such as rats, owls or ants, and responses by bats, recordings of mother-pup interactions including times mothers are with pups during day roosting and intermittently between foraging bouts by the mother through the night.
- Acoustic Monitoring—will primarily be used in this study to record social calls of mother-pup communication and adult social communication in the vicinity of maternity roosts. We will use the latest available range of automated bat detector and ultrasonic microphones available from Wildlife Acoustics and Pedersen Electronik.
- Roost Tree Characterization—measurements will be taken of tree species, height, DBH, percent foliage cover, canopy geometry, bat perch height and position, slope aspect, and elevation among other attributes that may be deemed valuable.
- Prey Base—insects will be evaluated for biomass, abundance, and taxon diversity through light trap, malaise trap, sweep netting, and branch clipping collection techniques. Collections will be pulsed at two month intervals over two-years to provide insect phenology data as these prey items will have seasonal and spatial variation as aerial bat prey. Associations of insect communities on native Hawaiian plants potentially suitable for habitat restoration at bat mitigation sites will be evaluated. Insects will be identified by our staff entomologists using the extensive museum collections of USGS, USDA, and the Bishop Museum. Samples from the insect collections will be retained to provide tissue for expanding a bar code library for identification of insects in our dietary study as well as implementing a tissue bank for companion studies of heavy metal (eg. lead and mercury) and pesticide levels in Hawaiian hoary bats and insect prey tissues as such studies are funded and partners identified.
- Diet Analysis—fecal pellet samples will be collected during mist netting events, under bat roosts, and taken from our existing banked collections. Insect prey DNA inside the feces will be amplified using meta-barcoding techniques. A library of insect DNA barcode sequences will be generated from the most common prey base

insects including know agricultural pests collected from our study sites. Diet composition will be explored using bioinformatics techniques, through comparison of prey items barcoded in fecal matter to our reference library of local insects as well as publically available sequence data. Bat diet will be analyzed with respect to age, sex, season, and habitat. Important prey species will be linked to host plant associations as possible with emphasis on native plant community restoration.

OUTPUTS

Data outputs will include measurement of summer and winter foraging ranges (95% kernel) and core area (50% kernel), total home range and core area, habitat preferences for foraging and roosting, site fidelity for roosting and foraging core areas, weather correlates of flight activity, pup survivorship, description of mother-pup behavior, skin and ambient foliage temperatures of roosting bats, roost tree geometry, insect prey-base abundance, diversity, and biomass, insect-plant host associations for restoration of bat habitat, dietary contents of bat fecal pellets using molecular genetics. Biological samples from captured bats (tissue, fecal, hair) will directly contribute to our proposed and future studies which will analyze population genetics and demographics, diet composition, and prey selection. Biological samples from both hoary bat and insect tissue samples will be banked for possible pesticide and heavy metal analysis of the hoary bat food. Insect CO1 barcode sequences generated from the bat diet study will be an important contribution to entomological science in Hawaii, adding to the genetic data available for studies in Hawaiian biodiversity and ecological food webs.

OUTCOMES

While the USGS is a research agency, its project staff will be available to advise state, federal and private organizations about the applicability of data outputs in relation to bat ecology and behavior. We will do this through providing technical assistance by phone, in person conferences, presentations at scientific meetings, management workshops, technical reports, and publication of peer reviewed scientific publications. USGS and HCSU biologists will frequently present data at appropriate conferences such as the Hawaii Conservation Conference and the North American Symposium for Bat Research or at such relevant conferences as periodically are hosted in the State of Hawaii.

MATERIALS AND METHODS

Radio Tracking and Roost Monitoring

We propose a three year radio-telemetry study on the island of Hawaii with a study area spanning the Wailoa-Wailuku-Waikaumalo watersheds from near sea-level to montane sites at 3,500 m and including the northern slope of Mauna Loa that harbors important winter foraging habitat for Hawaiian hoary bats (Bonaccorso et al. 2016). USGS currently is using an automated telemetry system for tracking forest birds across difficult terrain in the Hakalau

Forest National Wildlife Refuge. We propose to supplement the existing network with seven additional masts that will expand coverage for the purpose of tracking of hoary bats across 1,500 km^2 of the island's windward region (Figure 1). Final locations for placement of telemetry masts will be based on local topography designed to maximize line-of-sight coverage as well as security from vandalism.

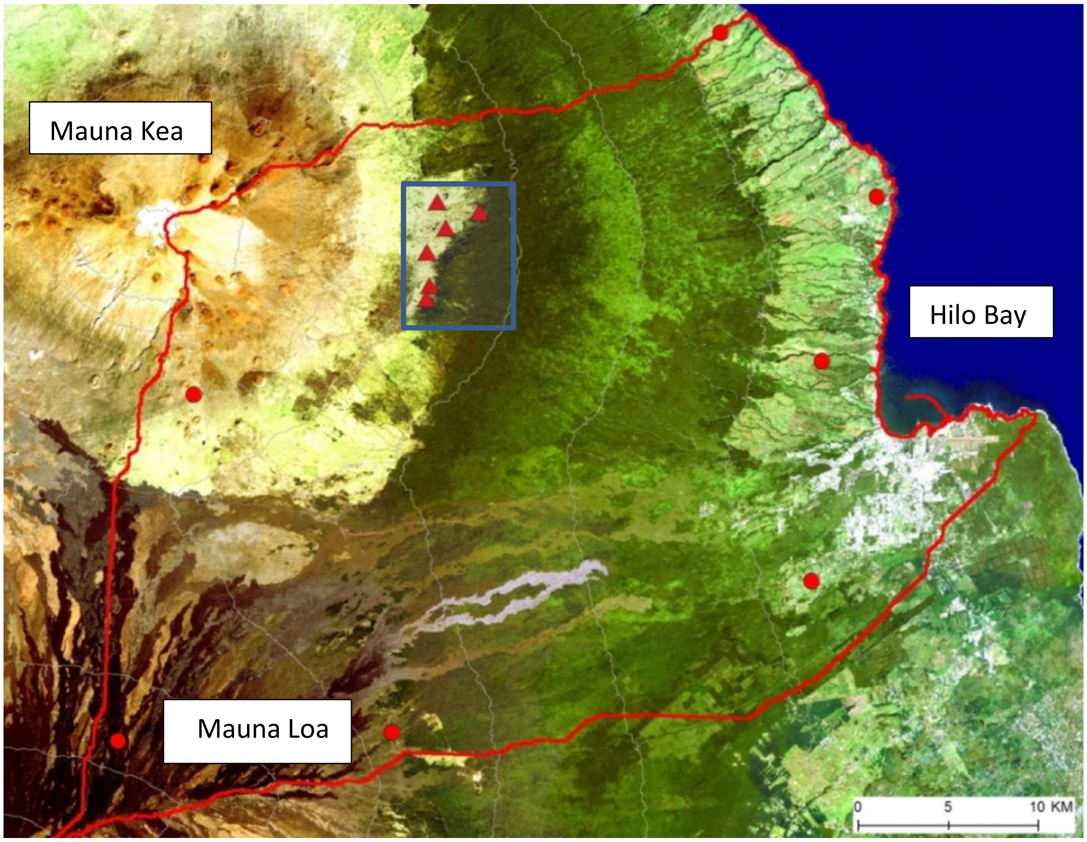


Figure 1. Map of proposed study on eastern Hawaii Island showing the existing Hakalau antennae array (rectangular blue outline enclosing red triangles) and approximate point locations for additional antennae (red dots).

Figure 2 Forty foot telemetry mast at Hakalau Forest NWR.

Bats will be captured by mist-netting following guidelines of the American Society of Mammalogists (Sikes et al. 2011). Our staff scientists hold current permits from USFWS, Hawaii DLNR, and University of Hawaii at Hilo IACUC that include all research protocols described in this proposal. Upon capture we will record sex, age class, morphology, and reproductive status. We will collect skin and hair tissue to bank for genetics and pesticide analysis. We will collect fecal pellets to bank for dietary analysis. Conducting this study in Eastern Hawaii offers the most dependable region known for hoary bat live capture. Nevertheless, the proposed study duration of three years will greatly enhance the opportunity to obtain statistically robust telemetry data on large numbers of bats.

Bats will be tagged with transmitters ≤5% body weight (Sikes et al. 2011) that operate continuously up to 40 days (BD-2XC model, Holohil Systems). Automatic Receiving Units (ARU; Orion model; Sigma Eight) will scan transmitter frequencies with 6 to 8 directional antennae while recording signal strength, date, and time used in combination with a network of 20 or 40 ft high antennae masts. Post-processing converts signal strengths into bearings and bat location is triangulated from multiple masts. Field testing has confirmed a reception potential of 30 km. Masts may be repositioned as needed to track long range bat movements.

Ground-crews will supplement the ARU system using hand-held receivers and directional yagi antennae to track bats to day roost locations and record fine-scale foraging movements from close range. Warbling (rapidly variable) versus steady signal strengths from radio transmitters will allow us to reconstruct flight and roost time budgets within each night.

Near-infrared and thermal videography will image roosting individuals, particularly recording mother-pup behavior and documenting pup survivorship. A Fluke Thermal Imaging Camera (FLUKE FLK-TIS75 30HZ Thermal Imager with IR-Fusion Technology, -20 °C to

550 °C, 320 x 240 Resolution, 30 Hz) will remotely measure bat skin temperature while roosting and temperature of surrounding foliage at the roost to track thermoregulatory patterns and the possible use of shallow torpor. Data loggers (iButton DS1921) also will record ambient temperature in roost trees.

Seasonal patterns in habitat use and movement patterns will be derived from the movement of successive individuals across a year to quantify composites of annual home range and population movements. Data will be analyzed with customized R software to determine spatial coordinates that will be mapped with ArcGIS to determine range size, elevation, and land-cover associations. Vegetation attributes of trees and stands used by bats as day roosts will be compared to randomly selected stands. Tree attributes will include species, diameter, height, roost aspect, elevation, and proximity to nearest road. Stand attributes will include land-cover class, composition of neighboring dominant tree species, canopy closure, and understory density. Roosts will be monitored with surveillance cameras to obtain information on predators, mother-pup behavior, frequency and duration of foraging bouts, time budgets and pup survivorship (Winchell and Kunz 1993). Acoustic sampling at roost sites will collect information on vocalization including mother-pup communication.

Home range – Bat locations from telemetry will be analyzed with kernel density estimators in the R package *adehabitat*. Brownian bridge movement modeling will predict trajectories of movement between successive locations (Horne et al. 2007).

Foraging habitat - Euclidean distance analysis will quantify habitat use (Conner and Plowman 2001) by comparing the mean distance of an individual's locations to each habitat type and the mean distance of a set of random locations to each habitat type. This analysis: 1) does not require explicit error modeling or equal sampling of individuals; 2) avoids habitat misclassification resulting from telemetry error; and 3) allows evaluation of surrounding habitat regardless if included within home range (Conner et al. 2003).

Roost selection and behavior – Logistic regression models will compare tree and stand characteristics at day roosts to randomly selected locations. An information theoretic model will rank variable importance. Descriptive statistics on behavior and body temperatures will be produced from video, thermal imaging, and acoustic recordings of mother-pup interactions at roosts. Generalized linear models will examine the proportion of the night which bats spend roosting and foraging, and its relationship to reproductive condition, regional weather conditions (temperature, precipitation, wind speed and barometric pressure), moon illumination and time of year (Anthony et al. 1981).

Insect Prey Base and Host Plant-Insect Associations

The abundance of nocturnal, flying insects that may act as prey for bats will be quantitatively assessed in the second and third years of radio-tracking after important foraging locations have been identified. Site selection for insect sampling will include low elevation rain forest, mid elevation rain forest, high elevation shrubland with lava tubes present, macadamia nut orchard, and a mixed agro-ecosystem with cattle because Todd (2012) identified insects associated with cattle in the bat's diet. We will use several standard entomological methods to assess insect diversity and abundance, including light traps, malaise traps, sweep nets, and lightly beating vegetation. Light traps utilize ultraviolet light to attract night-flying insects and are particularly effective at attracting moths and some beetles. Light traps utilize ultraviolet light to attract night-flying insects and are particularly effective at drawing moths and some beetles. Malaise traps are mesh, tent-like structures that intercept insects that fly close to the ground and trap a wide variety of insects but most effectively collect moths and flies. An insect net will be used to sweep grass and a beating stick and sheet will be used to dislodge and collect insects from shrubs and trees. The latter two methods will focus on collecting beetles and moth larvae (caterpillars) that can be projected as future prey in the adult moth. Collectively, these methods will sample the vast majority of the potential prey base. However, if diet analyses suggest that we are missing particular prey then we will adapt our sampling strategy to target those taxa (e.g. bark emergence traps aimed to collect bark beetles).

The bat prey base assessment will be conducted over five day periods at two month intervals at 5-6 sites within the study area (Figure 1). At each site, two light traps and two malaise traps will be operated; light traps will be operated 3-4 nights per month and malaise traps, which run continuously, will be serviced twice per month. For each of the most common species of grass, shrub and tree, 20 sweep-net or vegetation beating samples will be obtained during the sampling period. Regardless of abundance, we will sample mature specimens of the plant species that are currently being out-planted as part of the effort to restore native plants throughout the state (Table 1). All arthropods collected will be counted, weighed, and identified to species or to the greatest taxonomic precision practical.

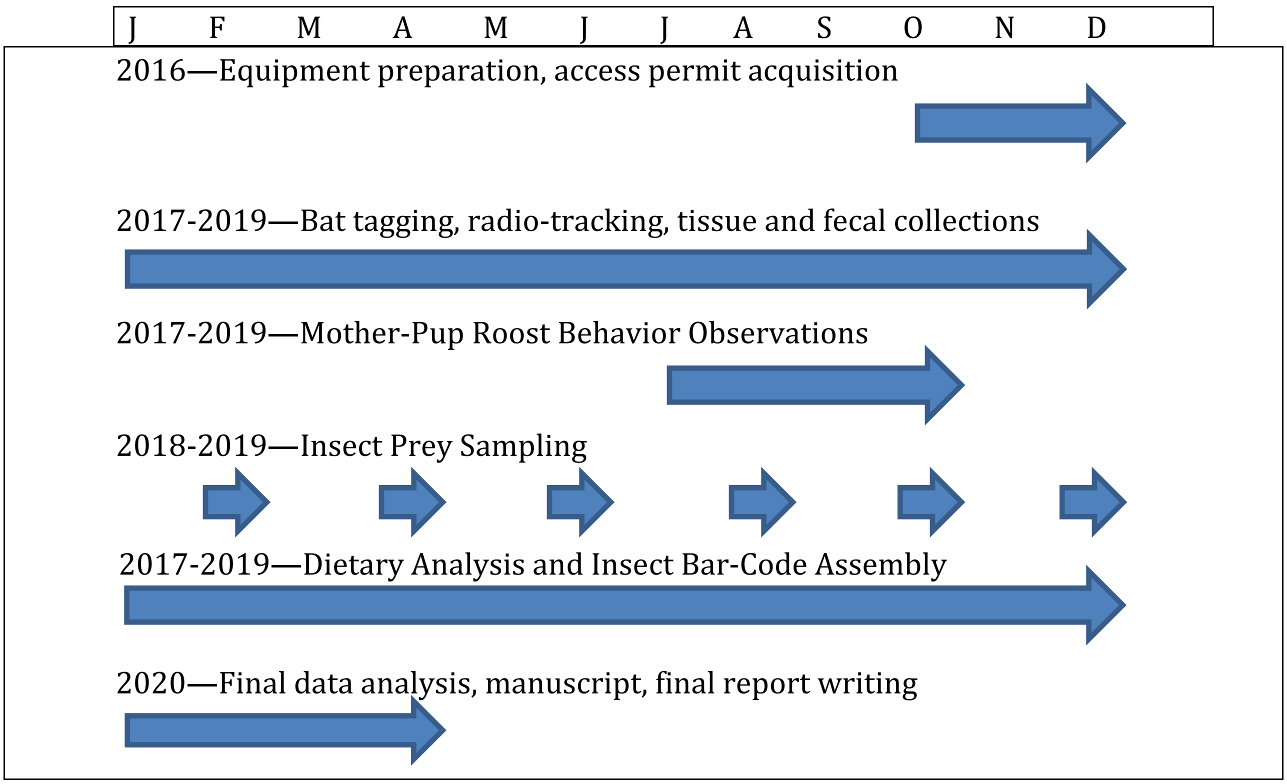
Insect Reference Library Barcoding and Hoary Bat Dietary Analysis

Detailed information on the insect prey taxa and relative compositions of prey within Hawaiian hoary bat diets are generally understated in previous studies concerning food habits and dietary needs for this endangered species. Past studies exploring the composition of hoary bat diet have relied on microscopy and dried collection comparison methods to determine the taxonomic identity and general abundance of insect prey items (Belwood & Fuller 1984, Jacobs 1999, Todd 2012, Valdez & Cryan 2013). These methods can limit or even bias the information gained since hard-bodied insects, such as beetles, are easier to recognize from fragments in the fecal matter than those with soft bodies, such as moths. New molecular genetics techniques are available that overcome many of the observational limitations in insect identification by using DNA barcoding (Clare 2014, Pompanon et al. 2012, Zeale et al. 2011) and have been successfully used on many bat species around the world including tree-roosting lasurine bats (Clare et al. 2009) and endangered bat species including the Ozark big-eared bat (Van Den Bussche et al. 2016). Specifically, the use of high throughput sequencing and meta-barcoding analyses of the mitochondrial cytochrome I gene (COI) of insects have aided in detecting the diversity and quantifying the relative contributions of insect taxa in bat diets across differing habitats, seasons, between the sexes, and prey selection (Bohmann et al. 2011, Burger et al 2013, Clare et al. 2014, Mata et al. 2016, and Vesterinen et al. 2013, 2016)

We will utilize meta-barcoding services and bioinformatics analysis at the University of Hawaii, to prepare and sequence thousands of insect CO1 barcodes from each individual fecal sample using high-throughput sequencing techniques. Barcodes generated from bat fecal pellets will be compared to a library of insect DNA barcodes sequences established from our insect sampling from the sites within our 1,500 km^2 field study area and publically available barcode databases (such as BOLD, www.barcodinglife.org). This reference library database will be based on the CO1 gene barcodes which has been cross-checked with local insect distribution and publically available data. Thus, we will identify insects consumed by bats to the most specific level of taxonomy possible, in many cases to species level. Our analysis will look for differences in diet for bats of differing sex, age class, season, foraging habitat and available prey.

TIMETABLE AND MILESTONES

Hoary Bat Research Timeline



PERMITS AND AUTHORIZATIONS

U. S. Geological Survey holds current research/take permits from U. S. Fish and Wildlife Service (Permit TE 003483-29) and Hawaii Department of Lands and Natural Resources (Permit WL-16-04), and additionally has an approved IACUC protocol approved by the University of Hawaii for vertebrate animal research. USGS has an excellent network of contacts with both private and public land stewards throughout the island of Hawaii that have frequently provided access to lands for bat research.

MONITORING AND EVALUATION

The project manager will closely supervise all aspects of research. Staff will have periodic meetings (usually quarterly) with the project manager and with supervisory directors of USGS and HCSU. Data downloads (e.g. telemetry data will be downloaded and reviewed frequently to better position tracking stations for focal animals) will be reviewed on weekly, monthly, bimonthly schedules as appropriate for specific analyses and cumulative data sets updated frequently. Project managers will employ adaptive management to improve and refine data collection with major reviews of success or weakness each year as the project proceeds. Annual reports will be provided to key wildlife management contacts (ESRC, DOFAW, USFWS) as well as oral reports or posters at the annual Hawaii Conservation Conference. Research staff will be available for phone consultations with wildlife managers when management issues arise in which new data inputs from the project may be helpful as updates.

ORGANIZATIONS AND KEY PERSONNEL

U. S. Geological Survey (USGS) is based at Kilauea Field Station inside Hawaii Volcanoes National Park and offers computer and research labs and a large multi-disciplinary staff of senior biologist researchers and technicians.

Hawaii Cooperative Studies Unit (HCSU) is based at the University of Hawaii at Hilo and offers research lab facilities and opportunities to collaborate with senior staff, technicians and students in the biological sciences.

Project Manager: Dr. Frank Bonaccorso, USGS, has 45 years of global experience in field biology and research on bats including 12 years of field work on hoary bats in Hawaii. He has 8 peer reviewed publications in major journals involving wildlife telemetry and over 50 publications overall in animal ecology. Ph. D. University of Florida. (Detailed CV provided below)

Co-Project Manager Radiotelemetry: Dr. Eben Paxton, USGS, has over 15 years of global experience in field biology including avian ecology, population demography, and wildlife telemetry conducted in Hawaii. He has published over 50 peer reviewed publications. Ph.D. Northern Arizona University.

Co-Project Manager Entomology: Dr. Paul Banko, USGS, Research Wildlife Biologist, has over 25 years of post-graduate experience in Hawaiian forest bird feeding behavior, food web ecology, and habitat requirements. This line of research has resulted in 20 book chapters, journal articles, and technical reports. Ph.D. University of Washington.

Robert Peck, Entomologist, Hawaii Cooperative Studies Unit, Robert Peck, *HCSU Research Specialist (Entomologist)*, has over 15 years of experience studying bird diet, food webs and the ecology of arthropod communities in Hawaii. Master's Degree, University of Hawaii at Manoa.

Marcos Gorresen, Quantitative Biologist, Hawaii Cooperative Studies Unit, has 22 years of global experience in vertebrate field biology and quantitative ecology including 14 years of field and modeling work on hoary bats in Hawaii. He has authored over 30 peer reviewed publications. Master's of Science, Texas Tech University.

Corinna Pinzari, Hoary Bat Conservation Biologist, Hawaii Cooperative Studies Unit, has 8 years of experience in working with field ecology of hoary bats in Hawaii including peer reviewed publications and technical reports. Master's Degree Candidate, University of Hawaii at Hilo.

Kristina Montoya-Aiona, Vertebrate Zoologist, has 5 years of experience working in the field ecology of bats including work in Hawaii on hoary bats and in the Commonwealth of the Northern Marianas working with bats. B.A. Degree, University of New Mexico.

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