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Radio-tracking of the Hawaiian Hoary Bat: A strategy to increase our understanding of roosting and foraging ecology in winter and summer

Project #7860

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November 2015

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Section 1. Background and Objectives

Little is known about the ecology of the Hawaiian hoary bat, which is hampering efforts to develop and evaluate effective mitigation and recovery plans. Capture and radiotelemetry offer a tool to learn about many aspects of Hawaiian hoary bat ecology, including seasonal movements, home-range size, and roosting ecology. Although work has recently been published regarding home-range sizes on the Main Island Hawaii, replicating this work on other islands will greatly add to our knowledge of the species, as well as provide clues as to what may be limiting recovery in different habitats. Effective mitigation strategies and information about what currently limits populations will contribute to the recovery, downlisting, and delisting of the species.

Although the Hawaiian hoary bat is widespread—that is, it occurs throughout the Hawaiian Islands—it occurs in very low densities throughout much of its range. Because of these widespread but very low densities, bat populations likely vary in their life history strategies for the various habitats they inhabit. Before 2013, the prevailing thinking was either that the species had gone extinct on Oahu or that the very low numbers of bats occurring there were transient males. In 2013, H. T. Harvey & Associates mist-netted and radio-tracked a lactating female at the U'koa wetland, where bat activity is very low (less than one detection per week per detector). This capture changed the understanding of the Hawaiian hoary bat population on Oahu, demonstrating that a breeding population is present on that island. The bat population on Oahu is likely smaller than on less developed islands, such as the Main Island Hawaii, Maui, and Kauai.

We propose to capture and radio-track bats in areas with known higher densities that therefore offer a better chance of capturing the bats during both winter and summer. Thus, we intend to maximize the likelihood of collecting larger amounts of data for foraging bats, roost sites and their characteristics, home-range sizes, mother-pup interactions and the survivorship of pups, and the availability and selection of prey where bats are foraging.

One region where we can study the winter ecology of the bat is on Kauai, where members of the Kauai Forest Birds Recovery Program staff have observed fairly high densities of bats in wet forests at higher altitudes in winter, about 30 kilometers east of the summer foraging bats found by the U.S. Geological Survey (USGS). We believe that bats are making seasonal movements between lowland areas in summer and higher-altitude areas in winter, much like the behavior that has been observed on the Main Island Hawaii—the difference being that the summer areas are typically xeric (on the dry leeward side of Kauai) and the wintering areas are normally mesic (Alakaʻi Swamp).

Studying the home ranges, roosting ecology, and seasonal movements of bats on western Kauai would provide valuable information on the ecology of the bat in different habitat types than have been studied thus far. The USGS team has studied home ranges, roosting ecology, and seasonal movements on the Main Island Hawaii, where winters are dry at high altitudes and females raise young in mesic habitats. Because of the El Niño effect, summer 2015 in Hawaii was one of the wettest summers in 30 years. Conversely, the winter of 2015–2016 is expected to be one of the driest in recent history. With a predicted dry winter at the Alakaʻi Swamp, this 2015–2016 winter season is likely an excellent year to begin studying the bat's winter ecology in a known wintering area (because it should be easier to work). Thus, we plan to radio-track Hawaiian hoary bats at the Alakaʻi

Swamp during a relatively dry winter and a presumed normal wet winter in 2016–2017 to learn about their winter ecology, roost selection, and activity patterns.

Another area where Hawaiian hoary bats have been regularly caught by USGS staff is on Maui during the maternity season in the vicinity of Highway 377. For the 2016 summer maternity season (June 1 through September 15), we plan to radio-track bats in midelevations to low elevations (1,000–3,500 feet) on Maui. Thus, on Maui, we will track lactating females to their maternity roosts and study mother-pup interactions with cameras and acoustic monitors. Additionally, we will record data that provides a better understanding of young survivorship.

By radio-tracking at the Kauai winter sites and the Maui summer sites, where relatively high densities have been observed, we will greatly improve the chances of collecting statistically robust sample sets for each of these seasons.

For both the winter and the summer sites, we will radio-track bats to determine home-range sizes and roost site characteristics. Toward the end of each season, we will collect data on their seasonal movements through the use of stationary receiver towers. Additionally, we will collect data on the prey availability near mist-netting and radio-tracking sites through the use of light traps and flight interceptor traps. The DNA barcoding (barcoding) of these insects (to be accomplished by University of Hawaii lab or other resource) will help establish barcodes for insect parts recovered from guano samples. This proposal does not include funding for barcoding insects or dietary analysis through barcoding techniques.

The budget for two years, including two winters on Kauai and two summers on Maui, is $597,897. The budget is broken down by Tasks as seasons, so Tasks could be funded and implemented independently assuming Task 1 is first and that start-up costs are covered per Task 1. We have also included costs of submitting a peer-reviewed journal article, to be co-authored by SunEdison, to help provide agencies with some assurance of the quality of the science performed. With the additional excise tax the total for the two-year study is $617,230.

Our objectives are summarized as follows:

1. Obtain data on foraging patterns and home-range sizes of bats on Kauai during two winters at the Alakaʻi Swamp and on Maui for two summers in midaltitudes to low altitudes.
2. Characterize roosting and foraging habitats.
3. Observe roost fidelity and characteristics of roosts.
4. Observe mother-pup behavior.
5. Measure fecundity rates until the young leave maternal roost sites.
6. Track large-scale seasonal movements at the end of the winter and summer periods.
7. Collect available prey during mist-netting and radio-tracking operations.

Section 2. Methods

Capturing Bats

We will capture bats using mist nets and a combination of acoustic lures (Reyes 2015) and conventional mist netting. For conventional mist netting, sites will be selected either based on prior experience and observations of foraging hoary bats or based on habitat features conducive to mist netting. Up to five mist nets will be placed across flyways or over water to capture flying bats. Typically, two staff members and two volunteers will perform this work. Use of an acoustic lure has been shown to increase capture rates in difficult capture locations for mainland hoary bats, as well as in Hawaii. Mist nets, to be used with acoustic lures, will be placed out of direct flyways, against vegetation or hidden under trees, with at least two Ultrasoundgate Player BL Pro broadcasters using Avisoft-SASLab software (Avisoft Bioacoustics, Glienicke, Germany), each with a laptop computer and powered by an external 12-volt battery. Hoary bat social calls will be broadcast until 2 a.m. on most nights. No more than five nets will be open at any one time, and large nets (6 meters and 9 meters x 30 meters) (Johnston 2000) may be used. Nets will be deployed along movement corridors to increase the chance of capture (Palmereirim and Etheridge 1985), and the nets will be physically checked no less frequently than every 20 minutes.

When bats are captured, we will collapse all nets to focus on collecting data from our captured bat. We will record sex, age (adult or subadult, based on closure of epiphyseal growth plates of the carpals), reproductive condition, forearm length (millimeters), and weight (grams). We also will mark bats with an identifying split wing band. We will collect two tissue samples from biopsy wing punches and attach a radio transmitter and micro light-emitting diode to the intrascapular area of the bat's back and release it on site. We will collect guano samples left in the bat bag for diet analysis. All capture and telemetry methods and restrictions stated in the U.S. Fish and Wildlife Service permit issued to H. T. Harvey & Associates (# TE80538A-0) and in the Division of Forestry and Wildlife permit issued to David S. Johnston will be adhered to.

Radio-Tracking Methods for Daily and Seasonal Movements

The study of seasonal movements in hoary bats has been severely limited by their elusive nature and by the cost and size limitations of available technologies used to follow their movements. Recent technological advancements now make it possible to track large numbers of bats over great distances with automated telemetry networks and to ask a variety of questions that were previously impractical or impossible to address. In addition to conventional radio-tracking methods of establishing locations of roosts and foraging using Yagi antennae and triangulation, we propose using radiotelemetry receiver towers to record larger movements of bats.

Recently developed open-source radiotelemetry receivers (www.sensorgnome.org) (Figure 1) have allowed the use of collaborative automated telemetry networks (McGuire 2015) in southern Ontario, Canada, and along seacoasts in the northeast United States. This network now comprises more than 250 towers in North America (www.motus-wts.org), each with a detection range of up to approximately 20 kilometers under perfect conditions. Bat biologists and ornithologists are using the same towers to track their prospective study animals

because these receivers can track multiple animals on a single frequency by using a unique pulse pattern for each radio transmitter. Automated telemetry networks provide an opportunity to address many aspects of movement ecology, including establishing movement corridors and sex-biased movements and timing.

Dr. Lisa Crampton (Kaua'i Forest Bird Recovery Project director) has indicated that she is interested in collaborating on an automated telemetry network on Kaua'i. Official agreements will be established after the proposal is approved. Dr. Crampton has offered to have her staff construct and set up receiving antennae in the Alaka'i Swamp and areas of the west slope of Kaua'i if the equipment is purchased by another entity and H. T. Harvey & Associates collaborated with data downloads. The Kaua'i Forest Bird Recovery Project currently radio-tracks native Hawaiian forest birds. The addition of these towers would greatly facilitate the project's data collection. Additionally, we will be using mobile telemetry receivers (Communications Specialists, Orange, California or Lotek, FUNcube Dongle Shop, London, UK) to read coded transmitters, and a Yagi antennae to triangulate more accurate positional data than the automated telemetry network can provide.

On the night of capture, after we release the bat, we will attempt to follow it until dawn to identify its roost location. We will track it by recording bearings of its direction of travel and attempting to follow it in a vehicle, stopping periodically at vantage points to maintain radio contact. Mobile radio-tracking teams will obtain better bearings as we become familiar with the individual bat's flight patterns. The day following capture and attachment of the radio transmitter, we will bring a third biologist onto the project to work with us. We will each have a datasheet, compass, Global Positioning System device, radio receiver with decoder, Yagi antenna, two-way radio, and a vehicle. During the day, we will search for roosting locations by driving established roads and going to high vantage points to attempt to locate signals from roosting bats. To obtain data on foraging behavior, we will coordinate over radio to take simultaneous bearings every 3 minutes from three stationary locations surrounding the bats primary presumed foraging area. As we become more familiar with the foraging and movement patterns, we will modify our positions to obtain more accurate location data.

Figure 1. Example of the Motus wildlife tracking system tower setup (www.sensorgnome.org).

Roost Observations

A bat detector will monitor vocalizations, which will help identify the timing of arousals, emergence and returns, and behavior in the roost. If a maternity roost is found, we will record roost behavior with low-cost security camera technology. Because we will be able to get relatively close to the roost, the much more expensive near-infrared and thermal-imaging cameras probably will not be needed. To assess the microclimate of hoary bat roosts, we will replicate a study conducted by Willis and Brigham (2005) on the roost selection of mainland hoary bats. After we can visually locate a hoary bat maternity roost in a tree, we will record the tree species, the tree diameter at breast height, the height of the bat in the tree, the aspect of the roost tree branch, the forest cover over and under roost location, and the locations of all trees in the surrounding 0.045-hectare plot. We will place an iButton temperature logger on the roost branch with the roosting bat. We will then randomly select a tree within 1 hectare from the roost tree and record all identical information as the roost tree.

Analyses

Triangulation of locations from telemetry data will be conducted in LOAS (Ecological Software Solutions LLC, Hegymagas, Hungary). We will remove locations with unreasonably large error polygons or locations far beyond the range of our telemetry stations.

Foraging range and core use area analysis will be conducted using Geospatial Modeling Environment (Spatial Ecology, LLC) in conjunction with ARCGIS (Environmental Systems Resource Institute, Redlands, California) and R (R Core Team 2013).

To analyze bat activity in relation to weather conditions, we will conduct a logistic regression of bat activity over 10-minute intervals in R (R Core Team 2013). Weather variables will be collected from the weather station closest to the bat's area of site use and foraging. We will analyze the presence of the bat over 10-minute intervals in relation to wind speed, temperature, humidity, precipitation, moon illumination, and wind direction.

Assessing Prey Availability

To help determine how prey availability plays a role in foraging behavior and home range, we will sample the availability of prey with methods modified from Todd (2012). We will be using Universal black light traps (Bioquip Products, Inc. Rancho Dominquez, California) composed of a 22-watt, U-shaped fluorescent black light tube; a 30.5-centimeter-diameter lid; and an aluminum funnel to direct falling insects into a collecting bucket filled with ethylene glycol. Light traps will be switched on and off with photoelectric switches. A light trap will be deployed within 100 meters of mist netting and radio-tracking activities for seven consecutive nights twice per season per study area to adequately sample all flying insects (Hirao et al. 2008). At the end of the first year of collecting insect data, a power analysis of the data will be performed to determine whether the sampling regime is appropriate for the questions asked.

Additionally, we will use Flight Interception Traps to collect nocturnal flying insects that may not be attracted to light, as suggested by Christopher Todd (pers. comm.). Because Hawaiian hoary bats are obligate aerial foragers, we will not use other traditional methods of insect sampling, such as sweep nets and sticky (Tanglefoot) traps that primarily collect insects from vegetation. Further, light trap sampling is relatively

unbiased and more efficient than other sampling methods (Raimondo et al. 2004). We plan to test the efficacy of insect collecting equipment during our reconnaissance-level survey and to begin collecting data in winter 2015–2016.

We will analyze spatial and temporal variation of insect abundance and diversity, overall prey abundance, and abundance of specific insect guilds.

Dietary Analysis

Bat guano will be stored in individual vials containing desiccant that are labeled with a unique identifier for each bat, date, and location of capture. Samples will be sent to USGS so that barcoding can eventually be used to help determine the bats' diets. Barcoding is a method of DNA sequencing used to identify to species or to a certain level of taxa from biological tissue samples. As an alternative, if a molecular geneticist is not available to proceed with a barcoding analysis of the bats' fecal pellets, under a separate budget, we can follow methods outlined in Whitaker and Tomich (1983) to identify insect parts to the highest level of taxonomy possible, comparing parts to reference samples from local insect collections and the contents of our insect traps. This approach will allow us to examine the local contents of the diet and compare the insect parts to available insect taxa.

Section 3. Budget