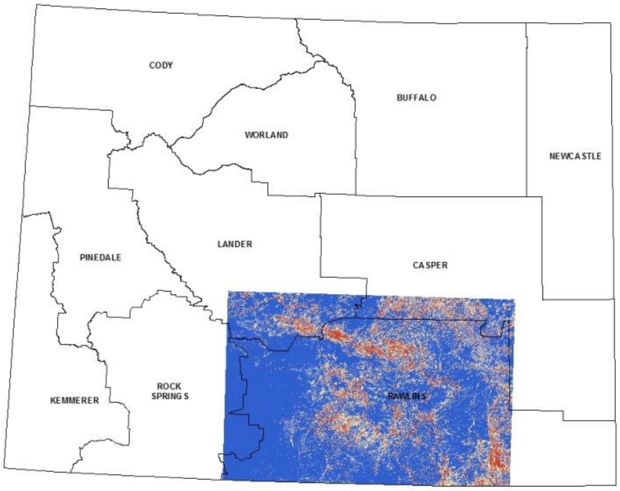
BATS OF SOUTHERN WYOMING:

DISTRIBUTION & MIGRATION

YEAR 1 REPORT
2012

Prepared by:
Hannah Griscom, Zoologist
Mark Andersen, GIS Specialist
Douglas Keinath, Lead Zoologist

Wyoming Natural Diversity Database
University of Wyoming
1000 E. University Ave., Department 3381
Laramie, Wyoming 82071



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5353 Yellowstone
Cheyenne, WY 82009

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EXECUTIVE SUMMARY

We conducted bat surveys throughout southern Wyoming to gain a better understanding of species composition, distribution, habitat, and migration. The impetus for this work is the ongoing expansion of wind energy development and its potential impact on resident and migratory bats. Previous studies have suggested that the location of wind turbines in relation to bat habitat and movement could significantly mitigate the number of bats killed annually. Our aim is to better understand bat distribution and migration in order to map it in relation to areas of high wind energy potential. The result is a tool for managers and planners to use in mitigating the potential impacts of proposed wind energy facilities on bats. Our work is also intended to provide a baseline of bat health in the face of White-nose Syndrome, a disease that has devastated bat populations elsewhere, and is predicted to spread to Wyoming in the near future.

We completed 17 mist net and 76 acoustic surveys in 2011 which resulted in 333 occurrences of 11 bat species. Several species typically associated with forests were commonly found in sagebrush steppe and one species was found far south of its purported range. All three of Wyoming's migratory bat species (hoary, silver-haired, and eastern red bat) were found in the study area, and the hoary and silver-haired bat were widespread. Most species exhibited a male-biased sex ratio suggesting that females may be raising young elsewhere. No evidence of White-nose Syndrome was detected in 2011.

Summer and migration models were created to represent bat use in Southern Wyoming. Summer distribution models were derived primarily from 2011 survey data using Maxent for 9 of the 11 species detected. Because of a lack of empirical data from migrating bats, migration models were deduced for hoary, silver-haired, and eastern red bat based on stopover habitat and behavior documented in the literature. All models were then superimposed in order to highlight important bat areas and habitat features. As a result of the modeling effort, summer species richness is predicted to be highest along major rivers, lakes, and foothill drainages in

the study area, especially in proximity to cliffs, rocks, or cave formations. Important stopover habitat for migratory bats is predicted primarily along riparian corridors and foothills that have both forest cover and perennial water nearby. Wind farms built along drainages and in forested areas could have a higher likelihood of bat conflicts, suggesting mitigation measures may be warranted.

Combined summer species richness and migration stopover maps were then overlaid with The Nature Conservancy's recently completed wind energy potential map to identify areas that have both a high likelihood of bat use *and* wind energy development. These areas generally fall into the following regions: (1) south of Rawlins on both sides of Hwy 71, (2) along the Medicine Bow and Rock Rivers as they flow into Shirley Basin, (3) the Laramie Mountain Foothills and Boulder Ridge, and (4) the Seminoe and Shirley Mountains. All presented models have serious shortfalls in the amount of input data and the accuracy of predictive layers, so caution should be used in their interpretation. The models are best used as conceptual tools to show us where bats may spend most of their time, but they do not account for bat movement between areas of use, and they should not be applied at the fine-scale planning level.

Other products presented in this report are a literature review of bat migration in relation to wind energy, detailed information and maps of each species detected, raw occurrence and capture data, species keys, and blank datasheets. This report represents the first year of an ongoing study. Survey efforts in 2012 will focus on stratified sampling of different habitat types and documenting occurrences during the fall migration season. This information will be used to improve the habitat, distribution and migration models presented herein, with specific attention to modeling migration flight paths through the study area.

INTRODUCTION

Little is known about bat distribution and habitat use in southern Wyoming. This is due to a lack of systematic survey effort and a general perception that sagebrush shrublands support few species and at low densities. Recent distribution maps produced by the Wyoming Natural Diversity Database (WYNDD) have provided a much-needed tool for bat management (Keinath et al. 2010), but they also highlight the dearth of bat occurrences available for generating these maps and the resulting uncertainty associated with them. This gap in our understanding of where bats occur and how they use the landscape has become particularly problematic in southern Wyoming due to increasing pressure from wind energy. Several wind facilities on public land are already operational, approximately four more are under construction, and numerous others are being considered by the Bureau of Land Management (BLM); the principle manager of public land in southern Wyoming.

The potential conflict between bats and wind power facilities stems from bat fatalities caused by moving turbine blades, a phenomenon that has been well documented in Wyoming and around the world (Young et al. 2003, Kunz et al. 2007, Arnett et al. 2008). When bats fly too close to moving rotor blades, they are either hit by the blades themselves or by the vortex of pressure surrounding the blades 'barotrauma' (Cryan and Barclay 2009). Although these bat fatalities occur at a fairly low rate (2 bats/turbine/year in Wyoming; Young et al. 2003), bat reproductive rates are naturally low, and as wind turbines become more numerous, the ability of bat populations to recover from the impact is unknown.

Concern about the trend has generated an impressive amount of funding and research to find ways to mitigate the impact of wind energy to bats. The most promising line of research indicates that minor modifications to turbine operations, such as shutting down rotors on low wind speed nights during bat migration, could drastically reduce the number of bats killed at wind energy facilities (Arnett et al. 2008; Appendix B). Another line of research has focused on the location of wind turbines in relation to bat habitat. Although results are not consistent across studies, some have shown that fatalities can be reduced by placing turbines in locations where fewer bats are likely to come into contact with them in the first place (Baerwald and Barclay 2009). This is the focus of our work here. Our aim is to better understand bat distribution and migration so that we can map it in relation to areas with high wind energy potential. This tool will be available to managers and planners seeking ways to mitigate the impact of wind energy on bats. Eventually we would like to expand the work to provide a bat/wind energy exposure map for all of Wyoming.

Another challenge currently facing bats in North America is White-nose Syndrome, a disease that has devastated entire populations of cave-roosting bats in the eastern United States since 2006. Although not present in Wyoming yet, White-nose Syndrome (WNS) has spread westward and was documented in Oklahoma in 2010 (BCI 2010). Some species, such as the little brown myotis, are more susceptible to the disease than others, perhaps because they consistently hibernate in large colonies. The surveys described in this report represent an important baseline inventory of bat health and abundance in southern Wyoming and lay the groundwork for future bat monitoring. Ongoing monitoring in Wyoming will be important to measure the potential impacts of WNS, wind turbines, and other potential stressors in coming years.

Two basic life-history strategies are used by the roughly 14 bat species that inhabit southern Wyoming; ‘hibernate’ or ‘migrate’. The majority escape winter by hibernating deep within caves from October to April. They breed in the fall before entering hibernation and females delay egg implantation until April or May when they emerge to raise their young (Adams 2003). The other life-history strategy is to escape winter by migrating to a warmer climate. In Wyoming, this tactic is only employed by three foliage-roosting species; the hoary, silver-haired, and eastern red bat (Popa-Lisseanu and Voigt 2009). These three species have been the main focus of the wind energy fatality debate because they comprise roughly 80% of turbine fatalities and are typically killed during their fall migration southwards (See Appendix B for details). However, year-round residents are also at risk for being killed by wind turbines and account for approximately 20% of turbine fatalities (Johnson 2005, Jain et al. 2011). Wind turbines also have the potential to fragment habitat for all bats by creating ground and air barriers that prevent or restrict movement across the landscape. Because of these potential direct and indirect impacts to migratory and resident bats, we focus on both year-round resident and migratory bats by modeling the distribution of all species during summer months as well as modeling the stopover habitat likely used by the three migrating species as they move through the study area.

Study Objectives

Most of the funding for this project is provided by the Wyoming Office of the BLM. Although all reports, maps, and data will be freely available to the public, the BLM expects to see the most benefit by using the information to help fulfill their multiple-use mandate on public lands in southern Wyoming. This report details the results of the first year of a multi-year research effort which has two overarching objectives:

> **(1) To conduct an inventory of bat species and their habitats in southern Wyoming.** This involves targeted bat surveys using mist nets and passive recording devices. Our aim is to better understand which species live where, how common they are, and what habitat features are most important for their conservation.
>
> **(2) To model zones of bat vulnerability to impacts from wind energy development during the summer and migrating seasons**. By overlaying these models with a wind energy potential map, we can begin to see where bats might be most vulnerable to impacts from wind turbines both in the summer and migration seasons.

METHODS

Field Surveys

Our study area in 2011 encompassed most of the Rawlins Field Office of the BLM in south-central Wyoming (Fig.1). Because the study area is quite large (48,000 km^2), we elected to focus surveys within several sub-regions according to the following criteria developed in consultation with BLM biologists; current wind energy development pressure, abundance of suitable mist netting sites, and public access to those sites. This resulted in six focal areas; (1) Laramie plains and foothills, (2) greater Chokecherry-Sierra Madre project areas, (3) North Platte River riparian corridor, (4) Seminoe Mountain foothills, (5) Shirley Basin, and (6) lower Sweetwater River (Fig.1).

We trained and deployed one crew of two people from June 15 to August 31 to conduct 2 types of surveys; mist net (active) and acoustic (passive). Capturing live bats with mist nets allowed us to verify species presence, inspect individuals for disease, assess physical condition, and collect demographic information. Passive surveys with multiple remote recording devices allowed us to efficiently collect species presence information from multiple sites every night. Basic weather information, time of sunset, and moon phase were recorded at all sites. General habitat categories were also assigned using the WYGFD Wildlife Observation System categories (Table 1).

When choosing survey locations, we avoided high elevation sites on US Forest Service lands in the study area in order to focus on sagebrush and foothills habitats, but also to avoid duplicating a concurrent survey effort by the Wyoming Game and Fish Department (WYGFD: Grenier pers. comm.). Passive bat monitoring results from a wildlife inventory of the Ferris Mountains (Estes-Zumpf and Keinath 2012) and mist netting results from the Pathfinder Wind Energy Project (Lockman pers. comm.) were also incorporated into our modeling analyses.

Mist Net Surveys

Two to four mist nets[1] were suspended between aluminum poles in single or double-high arrangements to catch bats while feeding or drinking. Most nets were placed over water but some were suspended under a forest canopy. We opened nets at dusk and closed them at 1:00am, although nets were closed earlier in the event of inclement weather limiting bat

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[1] Avinet.com: bat -specific mist nets: 38mm mesh, black polyester, USA made.

activity such as high wind or persistent rain. We checked nets every 15 minutes and carefully removed, processed, and released bats within 45 minutes of capture. All sites were mist netted for one night only. We also kept a stationary recorder (Anabat) running at mist net sites to detect any additional bat species not captured in nets.

In addition to recording species, sex, age, and reproductive status, wing damage index was scored and a wing photo was taken of each bat. Wing damage is the primary way that White-nose Syndrome is detected in non-hibernating bats and we followed the 2011 bat handling protocol laid out by the WYGFD both in handling and preventing potential contamination between bats. Specifically, with regards to cross-contamination, all bat processing equipment was cleaned/washed with Lysol between each processed bat.

Acoustic Surveys

We deployed two kinds of acoustic recorders to capture bat echolocations for species identification; Anabats[2] and Song Meters[3]. Although both devices are effective echolocation recorders, the Song Meter appears to have at least two advantages over the Anabat. First, it has a multi-directional microphone which allows it to pick up more bat activity around the recorder (see Table 1 for greater efficiency values). Second, although questionable files were reviewed by hand, most of the post-processing was automated through the use of Sonobat[4] software. In contrast, Anabat files need to be reviewed and identified individually by hand. We consulted with Anabat expert Dr. Michael O'Farrell[5] for the identification of 30% of our 2011 Anabat data, and combined that information with the key in Appendix F to identify the rest of the Anabat files ourselves using AnalookW[6].

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[2] Anabat SD1 Bat Detector. Columbia, MO www.titley-scientific.com

[3] Song Meter SM2Bat. Ultrasonic monitoring. Concord, MA www.wildlifeacoustics.com

[4] SonoBat 3, Wyoming species package, Arcata, CA. www.sonobat.com (Szewczak 2011)

[5] O'Farrell Biological Consulting, http://mammalogist.org/consulting/consulting.htm

[6] Analook W, viewing software for Anabat files, http://users.lmi.net/corben/Beta/ (Corben 2011)

Because bats need to drink and roost in trees or rock formations every day, we targeted sampling of sites with permanent water, trees, and/or rock formations. To test our assumption that bats are more common in these habitats, however, we also conducted acoustic surveys in dry grassland and sagebrush sites. Most acoustic surveys were stationary where recording took place at one location for one night. Typically, these stationary monitoring sites were strategically selected to maximize exposure to foraging bats. In addition, six mobile acoustic surveys were conducted from a vehicle. Prior to surveying, two sections of the same road were identified; one 2-mile section surrounded by open sagebrush, and one 2-mile section surrounded by forested or riparian habitat. Eight stops were made along each section by stopping every 0.25miles and recording for 15min before proceeding to the next stop.

Definitions of Common Terms

Mist net capture: Positive identification of a bat species captured in a mist net at one site.

Acoustic recording: Positive identification of a bat species from an Anabat or Sonobat file.

Occurrence: The positive detection of a species at a site (mist net or acoustic). Often one occurrence is comprised of several mist net captures and/or acoustic recordings from one site.

Habitat Analyses

Habitat as a predictor of bat richness and activity

Because bats are dependent on landscapes that contain both roosting habitat (e.g. caves, rock crevices, and/or trees) and foraging habitat (e.g. water bodies), our assumption was that they are more likely to be found in such habitats than in dry sagebrush. Testing this assumption is a coarse-scale approach to understanding how bats are generally distributed and use the landscape of southern Wyoming. We tested this assumption two ways; using mobile acoustic surveys and conducting a qualitative assessment with aerial imagery.

Mobile Surveys: Pooled mobile survey data collected at 'sagebrush' stops was compared to pooled data collected at 'forest/riparian' stops. The paired design of surveying both habitats on the same night and in the same area helped control for differences in activity due weather and local environmental factors. Two metrics were compared using a paired t-test and Chi-square test; number of species and number of bats passing over (no. of Anabat call files).

Aerial Imagery: A qualitative assessment using aerial imagery involved comparing site attributes between the 7 most active and the 7 least active sites (based on number of Anabat call files). Local and landscape context attributes were characterized and recorded for each site. Local attributes (within 1km) included presence of water, water feature type, water feature size, presence of rocks/cliffs, presence of deciduous trees, and presence of coniferous trees. Landscape context attributes (within 5km) included landform type (mountains, foothills, plains), presence of possible cave-formations, and water sources. Attributes that were repeatedly seen at the most active sites and not seen at the least active sites were tagged as potential variables explaining heavy bat use.

Habitat as a predictor of species presence

Chi-square analysis is an appropriate tool for handling categorical data such as habitat type and was used to search for possible habitat relationships from 2011 field surveys. Compared with the approach above, this was a more fine-scale analysis to look for positive or negative relationships between species and habitat types. The test was conducted by comparing the prevalence of a habitat type at all sites sampled to the prevalence of that type where only 'species A' was found. All habitat types were compared for all species. The Chi-square value for each comparison was used to determine if there was a positive or negative relationship between the species and the habitat type at the 95% confidence level.

Distribution and Migration Models

Two types of models were produced to reflect two distinct patterns of seasonal distribution and habitat usage by bats within the study area. The first type of model was created to represent predicted summer distribution of eleven bat species using inductive methods that relate known bat occurrences to environmental parameters. The second type of model represents migration stopover habitat used by the three migratory bat species in the study area. Because we currently have very few migrating bat occurrences, we were forced to use a deductive, or knowledge-based approach in creating this model.

Summer Distribution Models

We used Maxent, a commonly applied algorithm for predicting species distributions (Phillips et al. 2006), to model the spatial distribution of eleven bat species detected in 2011 during the summer season. Maxent can generate useful models with relatively limited training data (Hernandez et al. 2006), and does not require absence data for model building. Multiple iterations of modeling via Maxent were used to arrive at a set of final models for all species. Final summer models for each species were combined to generate a single map representing bat richness in summer across the study area.

Summer Input Data

Occurrence (i.e., species presence) data used for model building came primarily from 2011 surveys and secondarily from existing datasets within WYNDD’s database. Any existing dataset occurrences that were outside the study area, were old (pre-1980), or imprecise (>1km) were removed from the analysis (Table 6).

Additionally, opportunistically collected observation data often exhibit strong spatial biases that reflect sampling effort or intensity, rather than habitat preferences by the species (Jimenez-Valverde and Lobo 2006, Johnson and Gillingham 2008). Thus, we followed methods described by Keinath et al. (2010) to subsample occurrence data to reduce spatial biases in the data. All occurrence data were first attributed with a Point Quality Index (PQI), based on the mapping precision, age, and certainty of taxonomic identification for each point (Table 7). Then, any points for a given species within 1600 m of a higher quality (i.e., higher PQI) point for the species were eliminated. This reduces spatial biases in occurrence data at a fine scale. Next, a multi-pass filtering algorithm was run that iteratively selected the highest PQI point within each occupied 12-digit Hydrologic Unit Code boundary (HUC; Simley and Carswell 2009), until points were being drawn from a subset of HUCs representing less than 20% of the original set of occupied HUCs, or until there were no additional points left for the species. Points selected using this routine comprised the final model training dataset as shown in the last column of Table 6. Ten-thousand randomly placed "background" points were then generated to compare to this training dataset.

Summer Predictor Data Layers

Predictor data layers used to generate summer season models were resampled to match the extent of the study area from datasets created by previous researchers (Keinath et al. 2010). These predictors spanned basic categories of environmental variation, including climate, topography, hydrology, soil and substrate, land cover and landscape metrics, as well as variables intended to identify unique habitat features important to bats (e.g., caves, cliffs, and rock outcrops). Occurrence training data and background points were attributed with each of the potential predictors.

Summer Model Building & Selection

We constructed initial models of all eleven summer target species in Maxent using 79 predictor layers from Keinath et al. (2010), using 10-fold cross-validation. Cross-validation was used to reduce the possibility of overfitting models to noise in the training data, by ensuring that variables included in the final models were those that were most important in predicting occurrence across each of the 10-folds of training data (Baumann 2003). Selected variables from Keinath et al. were excluded from these initial runs, as they were not deemed to be biologically meaningful for bats, and may have produced misleading results. For example, the

"Distance to Roads" variable likely would have shown an inverse relationship with bat distribution because many of the bat occurrence data were collected from or near roads for ease of sampling. Once the cross-validation models were run, those variables that explained none of the variation were excluded from the final models. Maxent is robust to over-fitting even with large numbers of predictors and relatively small numbers of samples (e.g., Bedia et al. 2011), so no further variable reduction was done. Models with ten or fewer training data points (eastern red bat and Townsend's big-eared bat) were not used in subsequent model overlays because we had low confidence in their accuracy.

Logistic output rasters were generated from the final models constructed for each of the remaining nine species. Though not strictly interpretable as logistic probability, these rasters provide an indication of relative habitat suitability for all the cells in a study area (Phillips et al. 2006). Binary versions (predicted absent/predicted present) were then created for each species by applying a threshold (specifically, the "Minimum Training Presence" threshold identified by Maxent) to each logistic raster.

A predicted summer bat species richness map was generated by combining the above binary versions of each species' model. This was done by first performing a simple additive overlay, and then standardizing the resulting raster so that it ranged from 0 to 1. We standardized model output so that it could be overlaid with the subsequent models described below. In this final summer richness model, a value of 0 indicates that none of the target species were predicted present, and 1 indicates that all of the 9 target species were predicted present.

Migration Stopover Models

Appendix B is a literature review of bat migration behavior and physiology in relation to wind turbine fatality trends. It is intended to provide background information, support for model parameters, and provide a starting point for improved model iterations in coming years. Here we discuss the main points pertinent to model creation.

Bat migration spans several weeks and is composed of two repeating phases; ‘migration flight’ and ‘stopover’ (McGuire et al. 2012, Fleming and Eby 2003, Taylor et al. 2011). Migration flight occurs at night when bats fly approximately 30-50km in a southward direction, occasionally stopping to eat and drink along the way (see Appendix B for details). At the end of a migration flight, foliage-roosting bats such as our three species of interest, find a suitable roost tree and enter torpor during the following day. They then stay near this roost for one or more days, resting and stocking up on food and water until conditions are favorable for another migration flight (McGuire et al. 2012, Taylor et al. 2011, Fleming and Eby 2003).

In order to accurately represent bat migration, we need to model both the ‘migration flight’ and ‘stopover’ phases of migration. In fact, migration flight might be more important to model as bats tend to fly higher (in the turbine rotor-swept zone) during these periods (Appendix B). The problem is there is very little information available about the routes that bats take during migration flights, and the information that does exist, is inconsistent with regards to bats’ use of flight ‘corridors’ (Appendix B). Surveys in 2012 will focus on collecting empirical data on migration flight in an effort to represent this important phase directly. But for now we assume that our species of interest fly between stopover locations using irregular paths that we cannot model. In contrast, much more is known about the summer roosting and foraging habits of migrating bats which is assumed to be consistent with stopover habitat. Because stopover habitat represents the starting and ending points for migration flights, and because bats are somewhat vulnerable to wind turbines while ‘stopping over’, we are providing a reasonable representation of bat habitat use during migration.

Stopover habitat was modeled separately for each of the three migratory species (hoary bat, silver-haired bat, and eastern red bat) using Multi-Criteria Decision Analysis methods (Belton and Stewart 2002). In this deductive approach, information about the roosting and feeding behavior of all three species from Adams (2003) and NatureServe (2012) was used to pull out landscape features thought to influence the selection of stopover habitat. These were incorporated into a multiplicative, weighted model that ranked the value of cells based on the listed criteria shown in Table 8. Because all species are foliage-roosters, the presence of trees was the first condition necessary to define stopover habitat. Eastern red bats have predominantly been documented roosting in deciduous trees, so any deciduous tree cover above 0% was included in its model (Table 8a). Silver-haired and hoary bats use both deciduous and coniferous species (Adams 2003), so any type of tree cover above 0% was included for them (Table 8b & 8c).

Bats can lose up to 30% of their body weight in an eight-hour period, primarily due to metabolic evaporation (Adams 2003). Although some water can be derived from food, in most cases, bats need to replenish this water by drinking at least once a day (this is especially true during migration when metabolic demands are higher (Fleming and Eby 2003)). Therefore, we determined that proximity of perennial water to tree roosts was another condition of stopover habitat. A logarithmically declining relationship between the roost site and distance to perennial water was assumed because, all other variables being equal, a bat would be much more likely to use a water source 100m from its roost than a water source 1000m from its roost. For all species, a threshold of 5km was established between a potential roost site and perennial water. This is based on home range estimates of similar-sized bats from the literature (see Appendix B for details). Bats also need to eat while stopping over during migration, but because all three species have been documented feeding on insects near water or trees, the first two conditions of the models were deemed to fulfill foraging needs.

Based on differences in flight behavior and habitat (Adams 2003), some information is available about the types of water the three species prefer to eat and drink from. Eastern red bats are typically associated with riparian forests and, as a result, usually forage along large rivers (Table 8a.; stream order of 2 or more) and secondarily at large and medium-sized ponds. Hoary bats are fast flyers that pursue prey by aerial hawking. As a result, they are most comfortable foraging and drinking at large, open water bodies, rather than narrow rivers and streams. Silver-haired bats are typically found at ponds or open water in forested environments. They are agile flyers and as such, can also forage within the confines of streams and rivers.

Although hoary bats and silver-haired bats undoubtedly occur at high elevations and may even use them when migrating, we decided to use an elevation cutoff of 2600m (8530ft) in order to focus on lower-elevation BLM lands where wind energy development is most prevalent. In the case of eastern red bat, a cutoff of 2500m (8200ft) was used for biological reasons. Eastern red bats are primarily recorded along lower-elevation cottonwood forests in Wyoming, and have not been documented above 2500m to our knowledge.

As described above, predictive layers used in the migration stopover models include tree cover, elevation, water body and stream data. Conifer and deciduous canopy cover was derived from GAP Ecological Systems and LANDFIRE using methods described in Keinath et al. (2010). National Elevation Dataset (NED-1-arc second) data was used as the elevation input (Keinath et al. 2010). Water bodies, such as ponds and reservoirs, were selected from those present in the National Hydrography Dataset (Simley and Carswell 2009). Stream data used in the deductive model was derived from Enhanced 100k Digital Line Graph (DLG) stream data generated for the Wyoming GAP project layer (Merrill et al. 1996). This dataset contains Strahler stream order information (Strahler 1952), which allowed streams to be scored for relative importance based on their stream order (a proxy for size).

After migration stopover models were generated for each migratory species, they were combined and standardized into one map in order to overlay with summer distribution and wind potential maps. To do this, the models for each of the three species were converted to a binary format (i.e., a value of 1 was assigned when stopover suitability scores were greater than 0; a value of 0 was assigned when the stopover suitability score was 0). These three binary models were then combined via simple additive overlay, and standardized so as to range from 0 to 1, where 0 indicates absence of stopover habitat for all species, and 1 indicates presence of stopover habitat for all species.

Bat Exposure to Wind Energy Development

The standardized migration and summer overlay models (representing three and nine species, respectively), were then combined by taking their mean value (i.e., summing the layers and dividing by two), to generate a raster representing bat habitat importance for summer and migration seasons. This layer was then combined with a layer representing projected wind energy development (Copeland et al. in prep.; see below), using a multiplicative overlay, and the resulting layer was linearly rescaled so as to range from 0 (lowest predicted exposure) to 1 (highest predicted exposure). An exposure value of 1 would indicate that an area of high predicted bat richness for summer and migration seasons overlapped with an area with a high level of suitability for wind energy development.

The potential for wind energy development (Copeland et al. in prep.; The Nature Conservancy, Lander, WY) was mapped through a two-step process that used a predictive model to represent wind resource potential, followed by adjustments reflecting short-term development indicators and legal or operational constraints. Operational wind turbine locations were used as a response variable in a maximum entropy model with average wind resource potential at 50-m height, percent slope, and topographic position as predictor variables. Areas with model values below the logistic threshold of 0.314 (maximum training sensitivity plus specificity) were eliminated and the remaining values were rescaled to range from 0 (very low potential for wind farms) to 1 (very high potential for wind farms). The rescaled values were adjusted based on density of existing meteorological towers (met towers indicated increased likelihood of development), distance to proposed high-capacity electrical transmission lines (areas with access to existing lines have increased likelihood of development), proposed wind farm boundaries (areas in planned farms have increased likelihood of development), and current land tenure (private lands have fewer stipulations and have increased likelihood of development). Further adjustments were made for legally protected lands (less likely development), airport runway air space (no development allowed within 1524 meters), urban areas (no development allowed), mountainous areas above 2743 meters in elevation (less likelihood of development), and lakes (no development).

RESULTS

Mist Net and Acoustic Surveys

In 2011, we conducted 17 nights of mist netting and captured 68 bats representing 7 species (Table 4). Roughly 75% of captures were little brown myotis and big brown bats, while there where only a few captures of hoary bat, long-legged myotis, silver-haired bat, western long-eared myotis, and eastern red bat. Sex ratios were heavily biased towards males in all species except little brown myotis, which had an equal balance of males and females. Consistent with this pattern, the only species for which juveniles were captured (often in tandem with females) was little brown myotis. No evidence of White-nose Syndrome was found on any of the captured bats. Orange mites were found embedded in the skin of 9 bats captured in the Laramie Mountains, however this condition is somewhat common in Wyoming and not currently considered a threat to bat populations (WYGFD; Grenier pers. comm.).

A total of 70 stationary acoustic surveys (61 Anabat, 9 Song Meter) and 6 mobile surveys were completed in 2011. This resulted in about 800 hours of recording, 5500 Anabat files, and 300 species occurrences. Acoustic surveys were more efficient than mist netting in generating species occurrences (Table 2), though species identification from acoustic files can be difficult for some taxa. Of the acoustic devices, the Song Meter picked up almost twice as many species on average as the Anabat per night of sampling. This is probably due to its more sensitive and multi-directional microphone. Mobile acoustic surveys did not produce comprehensive species lists for sampled sites, but because 16 locations were sampled in one night instead of one, they were the most efficient at generating occurrences.

In addition to the 7 species identified during mist netting, 4 additional bat species were identified from acoustic recordings alone; western small-footed myotis, fringed myotis, pallid bat, and Townsend’s big-eared bat (Table 3). This underscores the value of acoustic surveys as an efficient tool for detecting and identifying bats, especially in open habitats where bats are better able to evade mist nets (Lockman, pers. comm.). This is best exemplified by the western small-footed myotis which was the second most abundant bat detected in the study area, but was never captured in a mist net (Table 3). Physical confirmation of small-footed myotis would be valuable in future surveys as its echolocations can be confused with other species, but we have high confidence in our identifications as they closely match those made by Michael O'Farrell. More detailed information about the ecology, habitat, and distribution of all 11 species is presented in Appendix A.

The species we detected during 2011 field surveys generally match existing range maps for bats in our study area (Adams 2003; Clark and Stromberg 1987; Keinath et al. 2010), however there were two exceptions. The pallid bat was routinely found south of its documented range (as far as 100km) and Yuma bat (*Myotis yumanensis*) recordings were detected 150km north of its documented range. An official extension of the pallid bat's range should be considered in light of our results, however the Yuma bat observation should be treated more cautiously. Several Yuma bat calls were identified by Sonobat at one site near Green Mountain. These calls were then reviewed by hand and visually verified, however, the observation was isolated and would represent a considerable range expansion for the species. Acoustic and mist net surveys should target the area in future years to confirm or refute the observation.

Habitat Analyses

Bat Richness and Activity

No differences in either richness or bat activity were found between 'sagebrush' and 'forested/riparian' stops during mobile surveys. Chi-square and t-test results indicated that neither bat activity (number of files) nor the number of species differed significantly between habitat types. Results from the aerial photo comparison of the 7 most active and the 7 least active acoustic survey sites yielded more results. The presence of water was generally associated with more bat activity, and isolated perennial water sources (streams or ponds with no other sources of water within 5km) were especially likely to have high bat activity. Low activity sites were generally more than 5km from any water source. Foothill riparian areas surrounded by sagebrush hillsides had an inordinately high amount of bat activity as did perennial water sources with cliff features nearby. These qualitative observations were also born out in the summer species richness model shown in Figure 3 and discussed below.

Species Presence

Chi-square analyses of species presence relative to habitat types did not yield any statistically significant positive or negative relationships. This is not to say that all species are generalists in the study area, but rather that our methods and sample size were not sufficient to pick up species-habitat affinities. Because many sites did not fit exclusively into one category (e.g., both willows and sagebrush were present), we allowed classification using multiple categories. In retrospect, this was not the right approach to take as it had the effect of obscuring real differences between sites and resulting in weak statistical relationships. There were however, indications of positive and negative relationships as interpreted by above-average chi-square scores (Table 5). These weak relationships were detected in 6 out of 11 species. Silver-haired bat had a positive association with water compared to the suite of sites sampled. Western long-eared myotis and big brown bat were positively associated with conifer and deciduous trees. Fringed myotis was more often found near conifers and the pallid bat near rocks or cliffs. All these relationships have support in the literature (Adams 2003) although species were also documented outside what is typically considered their habitat and range, as discussed in the next section.

Distribution, Migration & Exposure Models

Individual species models for the summer and migration seasons are displayed under their respective species account in Appendix A. Between 30 and 52 predictive variables were used to create each species' summer distribution model. There is considerable overlap in predicted species distribution because, in many cases, several species were detected at the same site. Despite this, subtle differences are evident between most species. For example, little brown bat is predicted to occur at water bodies throughout the plains and sagebrush, whereas western long-eared myotis is predicted to be confined to the foothill zone. Figure 3 displays the combined species richness model for 9 species during the summer season. High richness areas predominately occur along main rivers and foothill drainages. Individual migration stopover models are displayed in the hoary bat, silver-haired bat, and eastern red bat species accounts in Appendix A. Figure 4 displays the combined migration stopover model which clearly identifies riparian corridors and forested foothills below 2600 meters in elevation as important migration stopover areas.

DISCUSSION

Distribution and Habitat

One of the biggest discoveries of the 2011 season was the routine detection of forest-associated species in open sagebrush. This is especially true of long-legged myotis and silver-haired bat which typically occur in forests, but were the fourth and fifth most abundant species caught in our surveys. Overall, the bat species assemblage resembled what one would expect to see in Rocky Mountain foothills even though many of the sites were in open sagebrush steppe. The lack of tree and rock cover at many of our sites raises questions about where these forest bats are roosting and how far they might be traveling between roosting and foraging sites. Future analyses comparing ‘distance to nearest tree’ between ‘tree bats’ and ‘non-tree bats’ may help address these questions by seeing if there is a maximum threshold distance for ‘tree bats’.

One area that was surprisingly rich (9 of 11 species) was the Atlantic Rim region between Rawlins and the Sierra Madre Mountains. This seems to be an ecotone where low-elevation and forest-associated species routinely overlap. It is possible that the isolated aspen stands on leeward sides of bluffs in the area are providing valuable roosting habitat for several species.

Hoary bats were the third most abundant species (47 occurrences). They were widespread and detected as far as 14km from trees and 7km from water. This is significant because hoary bats are the most frequently killed species at wind turbines and appear to move easily through the sagebrush landscape of southern Wyoming. Another migratory species; silver-haired bat was found throughout the study area but in closer association to trees and water (within 7km and 3km, respectively). We only detected three eastern red bats. Two were in cottonwood habitat along the Laramie River and the other was in the Shirley Mountains in a forest opening. The study area encompasses the far western edge of the species’ range which might explain why they are somewhat uncommon.

Another interesting result from our 2011 surveys was the conspicuous absence of females and juveniles in all but two species; little brown myotis and big brown bat (Table 4). Bats often segregate by sex during the summer so that females can raise young in the best habitat (Adams 2003; Cryan 2003). Further mist netting efforts will help clarify whether sagebrush and foothills habitat in southern Wyoming provides suitable juvenile-rearing habitat, but initial results indicate that females of most species are probably rearing young elsewhere. The exception; little brown myotis, displayed a balanced sex ratio, reproductive females, and juveniles. This suggests that maternity colonies exist at various locations across the study area. The highest number of reproductive little brown myotis females and young were captured along the Sweetwater River near Jeffrey City indicating that there is probably at least one maternity colony in the Granite Mountains.

One potential pitfall of using ‘number of acoustic recordings’ to measure bat activity is that the particular placement of the recorder within a site can have a large influence on the number of calls it picks up. Certain features such as canyon pinch points, irrigation canals, and breaks in a forest canopy seem to draw and concentrate bats as they forage. This is helpful information for maximizing the number of species and recordings surveyors pick up, but it calls into question our ability to compare activity across sites. Another factor that complicates habitat analysis is the fact that bat activity seems to vary greatly with insect abundance, weather variables, and the probable interaction between the two (Rydell et al. 2010).

Management Implications and Important Bat Habitat

Bat species richness during the summer season is predicted highest along major rivers, lakes, and foothill drainages of the study area (Figure 3). Drainages close to rock formations in the Ferris, Seminoe, and Laramie Mountains pull out as especially important in supporting species richness. Bats are known to rely heavily on water, especially in desert environments (Adams 2003). Although our sites were somewhat skewed towards having water and trees nearby, most available habitat types were amply sampled (Table 1) and not found to be positive predictors of species presence in the modeling process. Although ongoing surveys in dry environments will help confirm this trend, our results indicate that bats are most likely to be found near water, trees, and rock formations in the study area. Species richness is only one measure of ‘bat value’ on the landscape, whereas density of bats (regardless of species) could be another. We did not have an effective way to measure bat density and can only make general statements about the kinds of features that appeared to drive the number of acoustic calls recorded. These features are similar to those predicting high species richness and include large, isolated water bodies, and riparian foothills (especially when near cliff or rock formations).

The combined migration stopover model (Figure 4) was derived from an imposed rule-set based on what is known about the roosting and foraging habits of hoary, silver-haired, and eastern red bats. We deemed tree cover within 5km of perennial water and below 8,500ft to be suitable stopover habitat. Not surprisingly, forested foothills pulled out as important for all species with low-elevation riparian corridors a close second. However, we believe that low-elevation riparian corridors are underrepresented in this map because the forest layer used seems to erroneously omit some patches of lower-elevation forest cover.

The bat exposure map is an overlay of all summer, migration, and wind energy potential models. Several regions pull out as having high predicted bat use *and* high potential for wind energy development:

1.) One region is south of Rawlins on both sides of Highway 71. There are at least two wind energy projects (Chokecherry and Sierra Madre) projected to begin construction in this area within the next few years. Distribution and migration models highlight the aspen stands and east-running drainages in this area as important bat habitat.

2.) Another area of overlap is along the Medicine Bow and Rock Rivers as they flow north into Shirley Basin and the nearby Freezeout Mountains. Existing wind energy facilities are already expanding in this region, but avoiding placing wind turbines near water bodies and river corridors may help mitigate some impact there.

3.) Another region is the lower Laramie Mountains/foothills, and extending around to Boulder Ridge along the Colorado border. The Boulder Ridge area is slated for a large wind energy project in the near future. Avoiding placing turbines within approximately 5km of forests may help ameliorate bat fatalities there (based on model results and home range estimates from Appendix B).

4.) Other regions of bat exposure are the Seminoe Mountains, Shirley Mountains and upper Laramie Mountains. Once again, foothills drainages are pulling out as important bat habitat, although to our knowledge, no current wind energy developments are proposed in these areas thus far.

There are some major weaknesses inherent to the models presented in this report, and caution should be used in their interpretation. First, when applying these models in a planning context, they should be used as conceptual tools rather than for fine-scale planning and decision-making. The maps are predicting general areas of habitat use, but limitations in input layers, predictive layers, and differences in map scales lead to multiplicative errors that will make interpretation at scales less than 2km very inaccurate. Second, a relatively small number of bat occurrences were used to create the summer distribution maps (Table 6). This, in combination with oversampling mesic sites undoubtedly skewed the results to favor water features and probably does not represent the full spectrum of bat habitat use on the landscape. Third, bats are opportunistic and move easily between roosting and foraging sites. Although our maps may predict where bats spend most of their time, they do not account for movement between areas of heavy use. For example, although ridgetops did not pull out as important habitat features for bats in our models, bats undoubtedly fly over ridgetops in order to access roosting and foraging habitat and may even forage above ridgetops when insect swarms are present (Rydell et al. 2010, McCracken et al. 2008). Third, the lack of predicted species richness in the southwest corner of the study area is most likely an artifact of little sampling in that region rather than a true reflection of available bat habitat. Future surveys will focus on sampling within the Great Divide Basin. Similarly, little data from elevations above 8,500ft were used in these models and they do not accurately depict species richness or migratory use of high-elevation conifer habitat.

As a result of one season of surveys and modeling, we now have a clearer picture of which species inhabit the area and what habitats are most important to conserve. Collectively, perennial water sources, especially near rock formations and in foothill regions, appear to be important as well as forested areas for migrating bats. Survey efforts will continue in 2012 and we plan to survey twice as many sites in a variety of habitats and extending into the fall migration season. This information will be used to improve the habitat, distribution and migration models presented here.

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TABLES

Table 1. Habitat types attributed at survey sites.

Habitat Type - percent of sampled sites where type was present
Shrubland/ shrub steppe - 51%
Grassland - 30%
Wetland/ open water - 62%
Rock outcrop/cliff /canyon - 32%
Conifer forest - 33%
Deciduous forest (cottonwoods) - 16%
Riparian shrub (willows) - 37%
Foothills chaparral - 0%
Badlands - 0%
Disturbed/ reclaimed/ mined/ oil & gas - 0%

Table 2. The number of occurrences and efficiency by survey method.

Survey method	**No. of species occurrences***	**No. of sites surveyed**	**Efficiency++**
Mist Net	28	17	1.6/night
Anabat	191	61	3.1/night
Song Meter	45	9	5.0/night
Mobile Survey (Anabat)	68	6	11.3/night

* An 'occurrence' is the detection of a species at a site (regardless of number of captures or recordings).
++ Efficiency is the average number of species occurrences per survey night.

Table 3. Bat species detected during 2011 surveys in southern Wyoming, their relative abundance and seasonal residency.

Common Name	Scientific Name	Relative Abundance	No. of mist net occurrences	No. of acoustic occurrences	Season of residency in Southern Wyoming
Little Brown Myotis	Myotis lucifugus	common	10	65	year-round
Western Small-footed Myotis	Myotis ciliolabrum	common	0	51	year-round
Hoary Bat	Lasiurus cinereus	common	6	41	spring-fall only
Long-legged Myotis	Myotis volans	common	3	44	year-round
Silver-haired Bat	Lasionycteris noctivagans	less common	4	26	spring-fall only
Western Long-eared Myotis	Myotis evotis	less common	1	25	year-round
Big Brown Bat	Eptesicus fuscus	less common	3	21	year-round
Fringed Myotis	Myotis thysanodes	less common	0	14	year-round
Pallid Bat	Antrozous pallidus	less common	0	13	year-round
Townsend's Big-eared Bat	Corynorhinus townsendii	uncommon	0	2	year-round
Eastern Red Bat	Lasiurus borealis	uncommon	1	2	spring-fall only

Table 4. **Sex and age information of captured bats in southern Wyoming.**

Common Name	Males (repro[2])	Female (repro[1])	Adults	Juveniles
Little Brown Myotis	17(2)	18(6)	32	3
Hoary Bat	6	0	6	0
Long-legged Myotis	5	0	5	0
Silver-haired Bat	6	1	7	0
Western Long-eared Myotis	1	0	1	0
Big Brown Bat	12(3)	1(1)	13	0
Eastern Red Bat	0	1	1	0
Total mist net captures = 68				

1 = number of females pregnant, lactating, or post-lactating females are in parentheses.
2 = number of males with descended testicles in parentheses.

Table 5. Chi-square analysis of habitat preferences in relation to all sites sampled (none were statistically significant).

Species	Conifer Tree	Decid. Tree	Willows	Water	Rock/ Cliff	Shrub	Grass
Little Brown Myotis							
Western Small-footed Myotis			-				
Hoary Bat							
Long-legged Myotis							
Silver-haired Bat				+			
Western Long-eared Myotis	+	+					
Big Brown Bat	+	+					
Fringed Myotis	+						
Pallid Bat					+		
Townsend's Big-eared Bat							
Eastern Red Bat							

Table 6. Occurrence record numbers and elimination by species.

Species	Total WYNDD Database Records	Old and/or Imprecise Records (Removed)	Records Outside Study Area (Removed)	Records w/in 1600m of Better Point (Removed)	Removed via Iterative Stratified Selection	Records in Final Modeling Set
Little brown myotis	**530**	202	239	37	2	**50**
Western small-footed myotis	**215**	4	148	21	1	**41**
Hoary bat	**197**	4	132	22	2	**37**
Long-legged myotis	**236**	6	153	33	0	**44**
Silver-haired bat	**261**	2	207	19	0	**33**
Western long-eared myotis	**172**	12	121	14	0	**25**
Big brown bat	**406**	238	136	9	0	**23**
Fringed myotis	**75**	1	58	2	1	**13**
Pallid bat	**41**	3	22	2	0	**14**
Townsend’s big-eared bat	**125**	16	93	6	0	**10**
Eastern red bat	**14**	0	9	0	0	**5**
Totals	**2,272**	**488**	**1,318**	**165**	**6**	**295**

Table 7. Scoring system used to evaluate the quality of occurrence records based on spatial precision (A), age of record (B), and taxonomic certainty of identification (C).

A. Spatial Precision of Occurrence Record

Score	***Definition***	***Example***
4	Location uncertainty ≤ 30 meters	Location via GPS
3	Location uncertainty > 30 meters and ≤ 100 m	Location via 7.5’ quad map
2	Location uncertainty > 100 meters and ≤ 300 ms	Location via 100k quad map
1	Location uncertainty > 300 meters and ≤ 600 m	Location via large-scale map or detailed written directions

B. Age of Occurrence Record

Score	***Calendar Year of Observation***	***Definition***
4	≥ 2000	Observation made within roughly 10 years of model creation
3	1990 - 1999	Observation made within roughly 20 years of model creation
2	1980 - 1989	Observation made within roughly 30 years of model creation

C. Taxonomic Certainty of Occurrence Record

Score	***Category***	***Definition***
4	Confirmed Identification	Adequate supporting information exists within the occurrence record to consider it a valid observation of the species in question
2	Questionable Identification	Supporting information within the occurrence record is insufficient to *confirm* correct identification of the species (e.g., no supporting documentation or observer credentials), but neither is there any reason to assume that the record is in error
U	Likely Misidentification	Unused: There is reason to believe that the observation could be erroneous. (e.g., extra-limital observation by amateur biologists of species that are easily misidentified)

Table 8. Landscape criteria and equations used to generate migratory stopover habitat models for eastern red bat (a), hoary bat (b), and silver-haired bat (c). Generated from roosting, foraging, and home range information from Adams (2003), NatureServe (2012) and sources detailed in Appendix B.

Table 8a. Stopover habitat model for eastern red bat (*Lasiurus borealis*)

Criteria	Values	Scores
Deciduous Tree Cover (*decid*)	0%	0
	>0%	1
Distance to Water (*waterdist*)	>5000m	0
	<5000m	1 to 0, where values decline logarithmically as a function of distance, between from a value of 1 at a distance of 0 m to a value of 0 at a distance of 5000m
Elevation (*elev*)	>2500m	0
	<2500m	1
Type of Water Feature (*watertype*)	Streams (Strahler Order > 2)	1
	Streams (Strahler Order = 2)	$0.\overline{8}$
	Medium/Large Ponds (>0.25 ha)	$0.7\overline{2}$
	Small Ponds (<0.25 ha)	$0.6\overline{1}$
	Small Streams (Strahler Order = 1)	$0.\overline{5}$

***Equation*:**

***Lasiurus borealis* Stopover Habitat Suitability = decid * waterdist * elev * watertype**

Table 8b. Stopover habitat model for hoary bat (*Lasiurus cinereus*)

Criteria	Values	Scores
Tree Cover (*tree*)	0%	0
	>0%	1
Distance to Water (*waterdist*)	>5000m	0
	<5000m	1 to 0, where values decline logarithmically as a function of distance, between from a value of 1 at a distance of 0 m to a value of 0 at a distance of 5000m
Elevation (*elev*)	>2600m	0
	<2600m	1
Type of Water Feature (*watertype*)	Medium/Large Ponds (>0.25 ha)	1
	Small Ponds (<0.25 ha)	0.9
	Streams (Strahler Order > 2)	0.9
	Streams (Strahler Order = 2)	0.6
	Small Streams (Strahler Order = 1)	0.2

***Equation*:**

***Lasiurus cinereus* Stopover Habitat Suitability = tree * waterdist * elev * watertype**

Table 8c. Stopover habitat model for silver-haired bat (*Lasionycteris noctivagans*)

Criteria	Values	Scores
Tree Cover (*tree*)	0%	0
	>0%	1
Distance to Water (*waterdist*)	>5000m	0
	<5000m	1 to 0, where values decline logarithmically as a function of distance, between from a value of 1 at a distance of 0 m to a value of 0 at a distance of 5000m
Elevation (*elev*)	>2600m	0
	<2600m	1
Type of Water Feature (*watertype*)	Any pond/water body	1
	Small Streams (Strahler Order = 1)	0.8
	Streams (Strahler Order > 2)	0.7
	Streams (Strahler Order = 2)	0.5

***Equation*:**

Lasionycteris noctivagans Stopover Habitat Suitability = tree * waterdist * elev * watertype

FIGURES

Figure 1. Overall study area (blue) and focal survey regions (red). Focal survey regions are (1) Laramie plains and foothills, (2) greater Chokecherry-Sierra Madre project areas, (3) North Platte River riparian corridor, (4) Seminoe Mountain foothills, (5) Shirley Basin, and (6) lower Sweetwater River

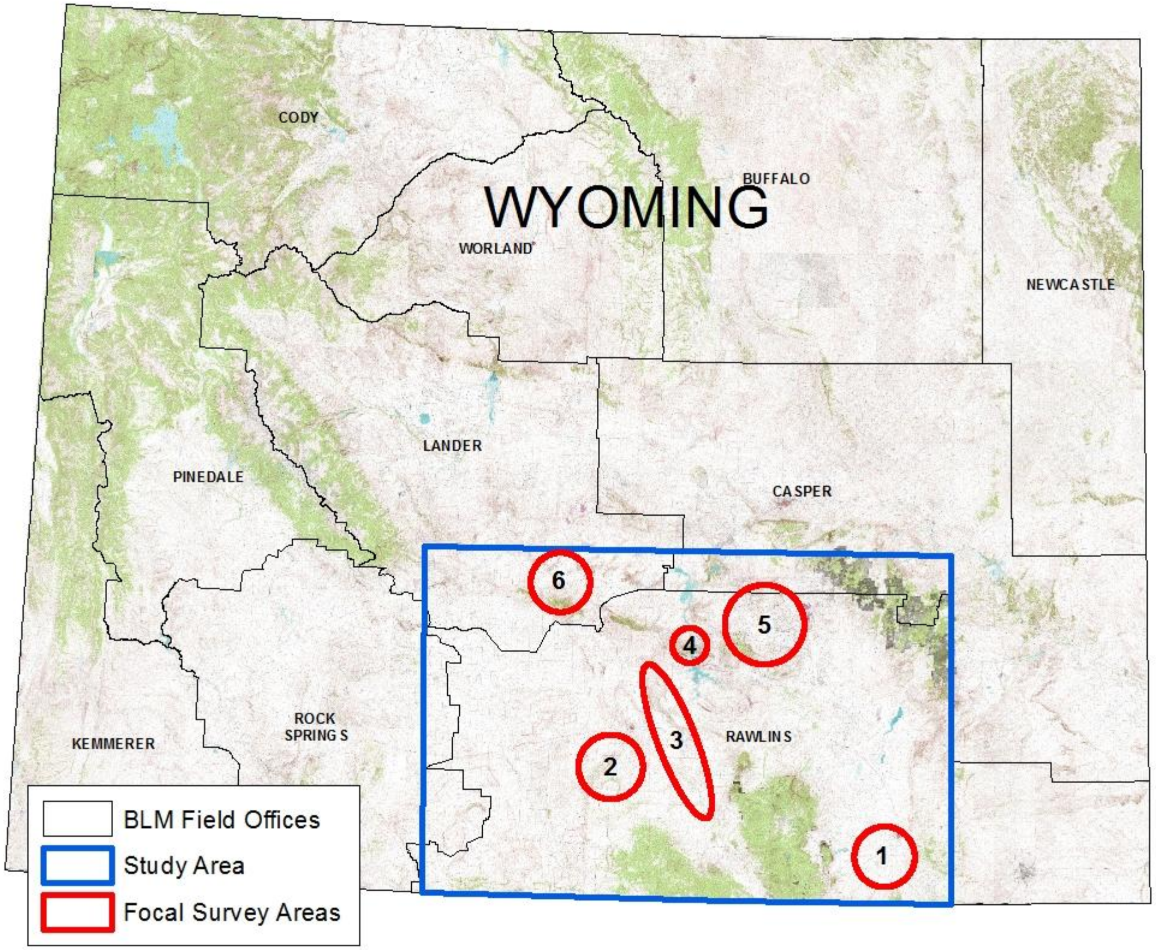


Figure 2. Locations of bat surveys, recordings & captures in 2011.

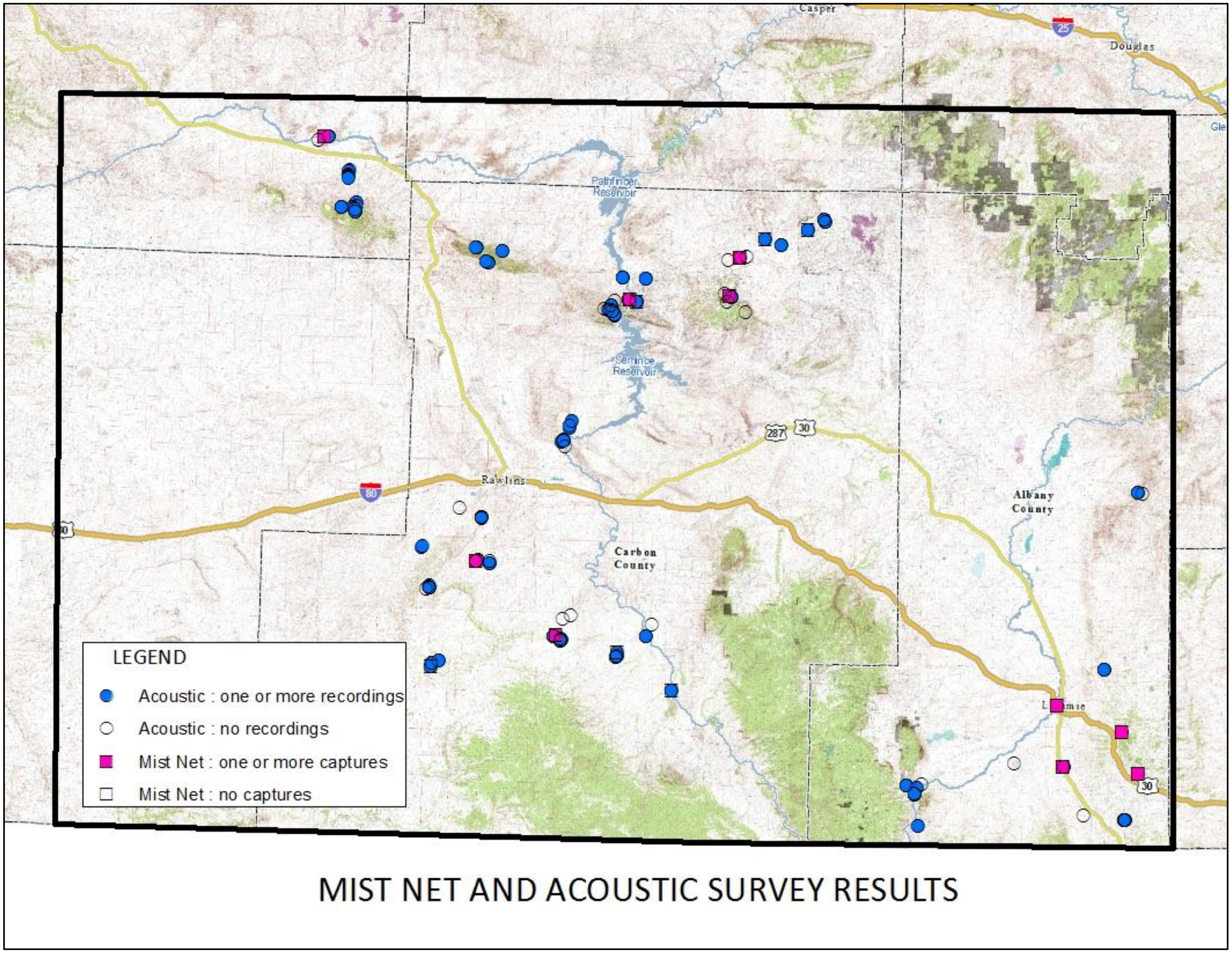


Figure 3. Combined summer distribution model of nine bat species documented in southern Wyoming.

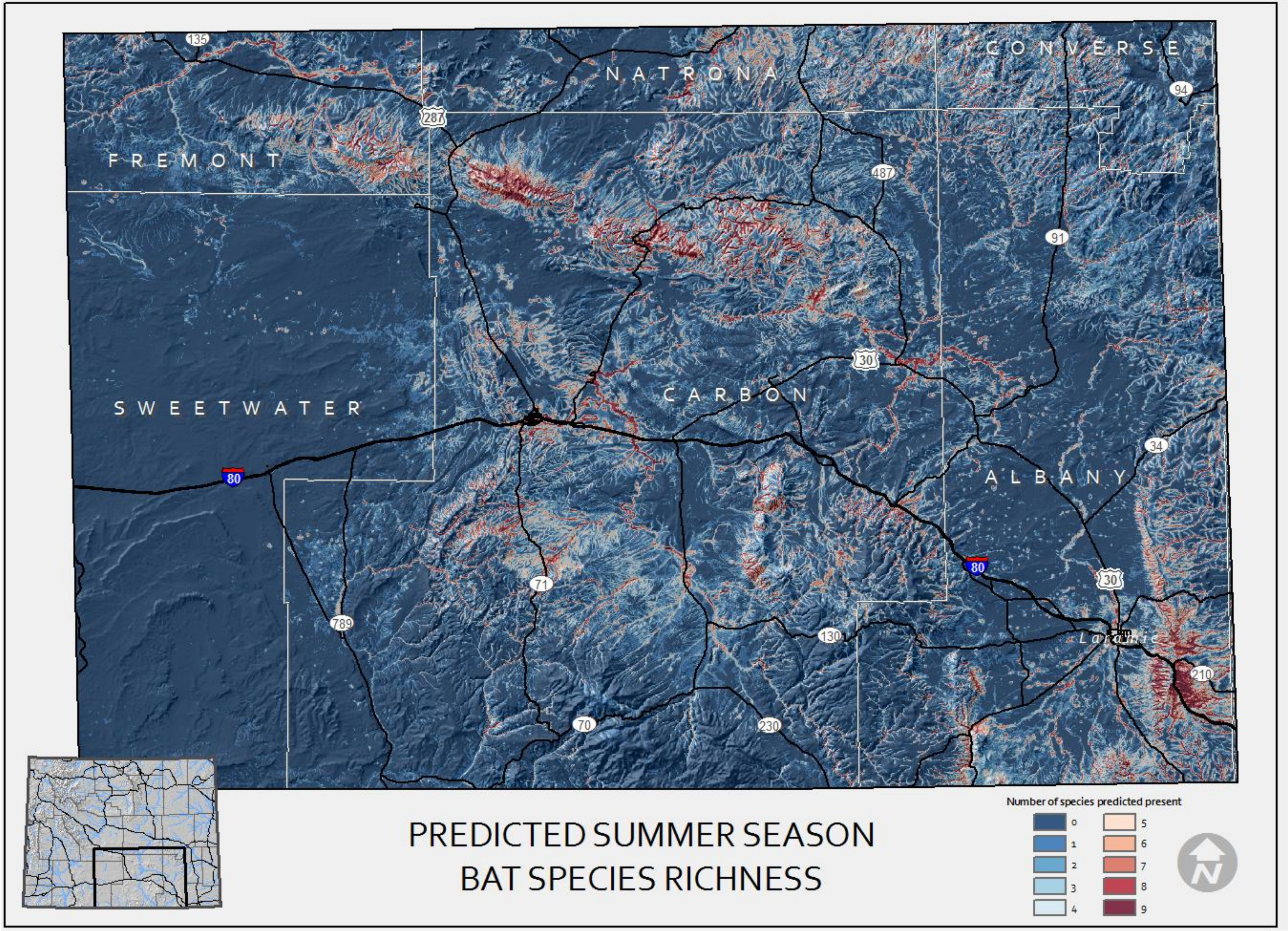


Figure 4. Combined migration stopover model for the three migratory bat species documented in southern Wyoming.

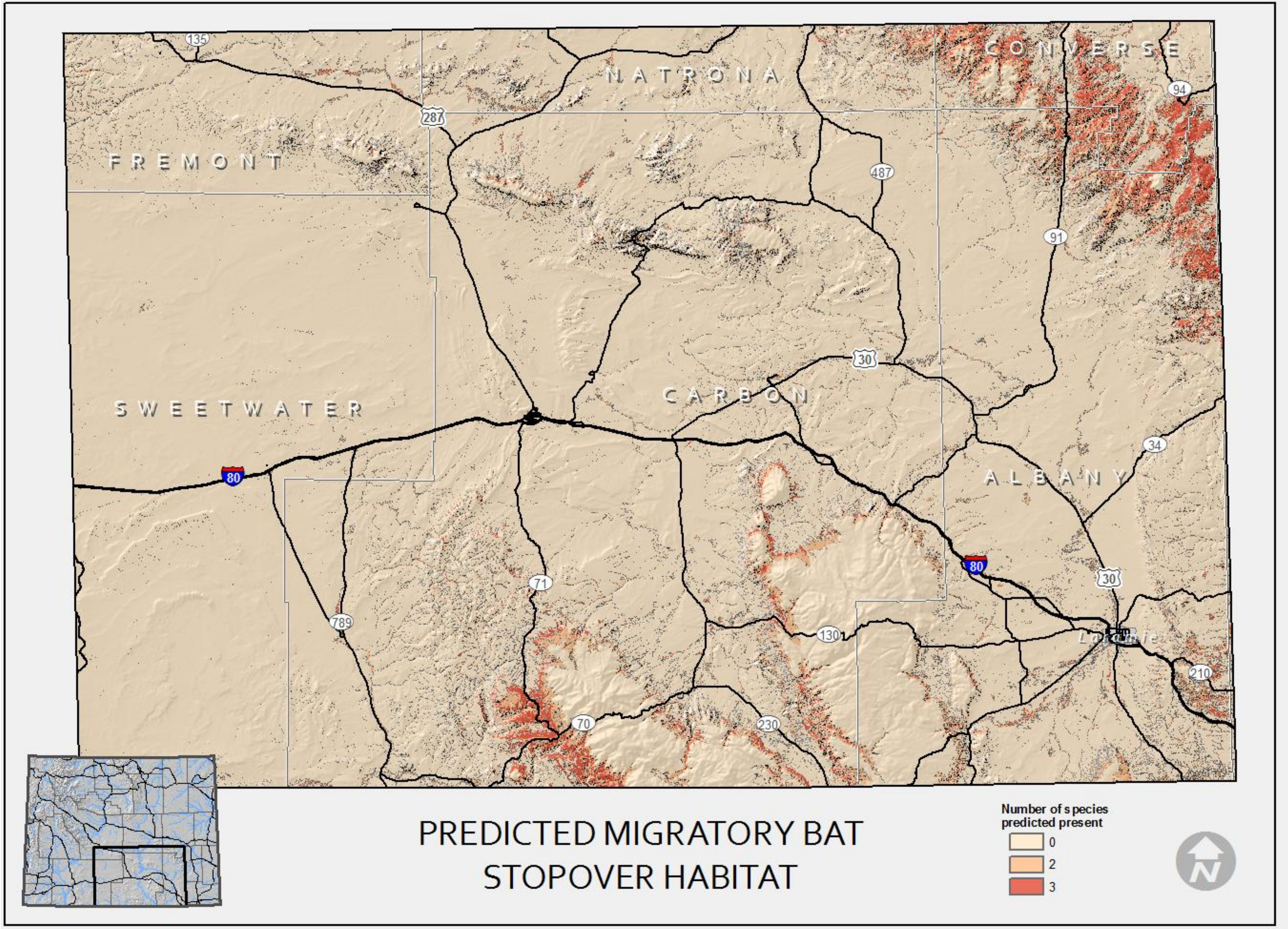


Figure 5. A model of projected wind energy potential in southern Wyoming (source: TNC Wyoming).

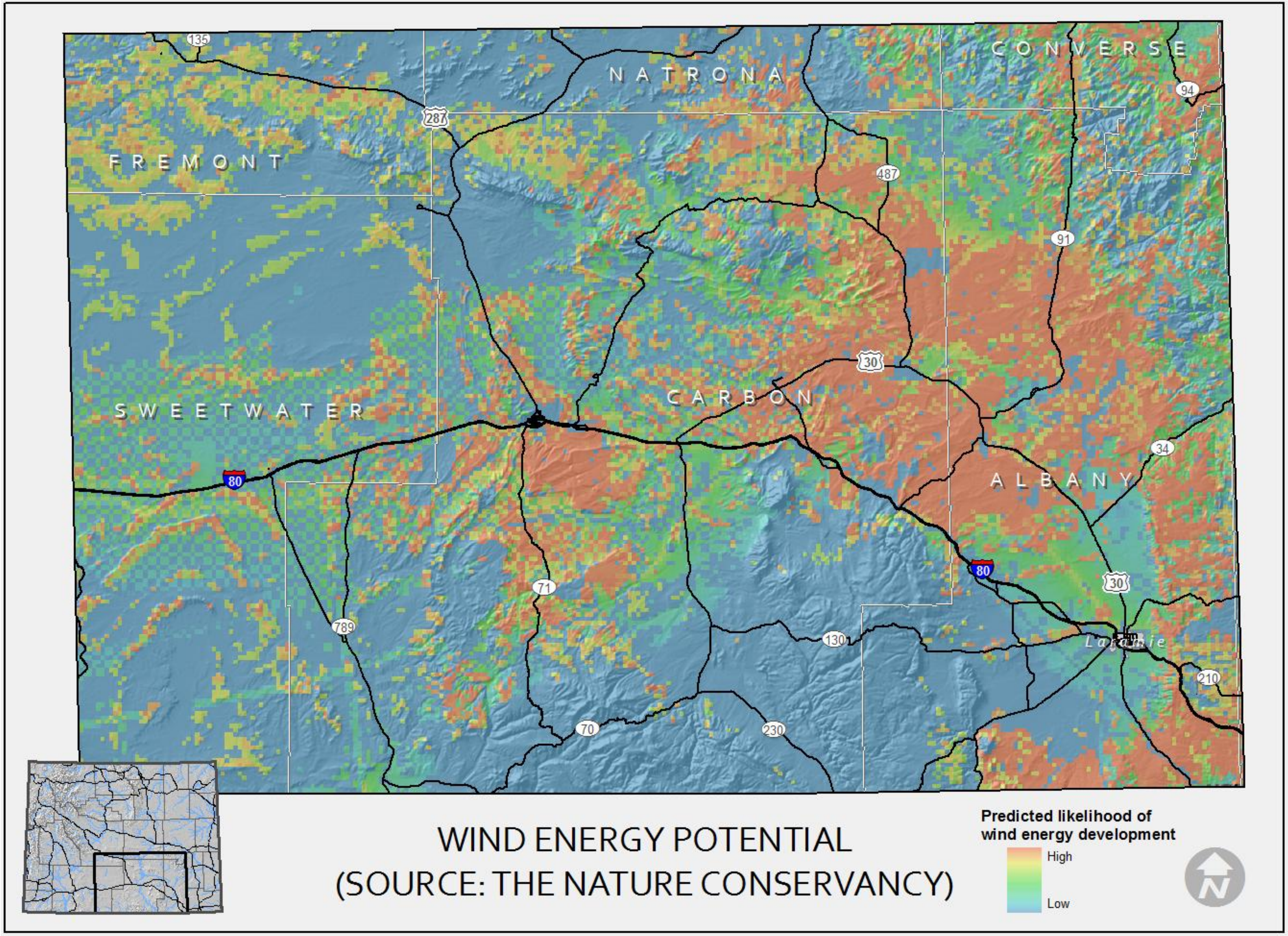
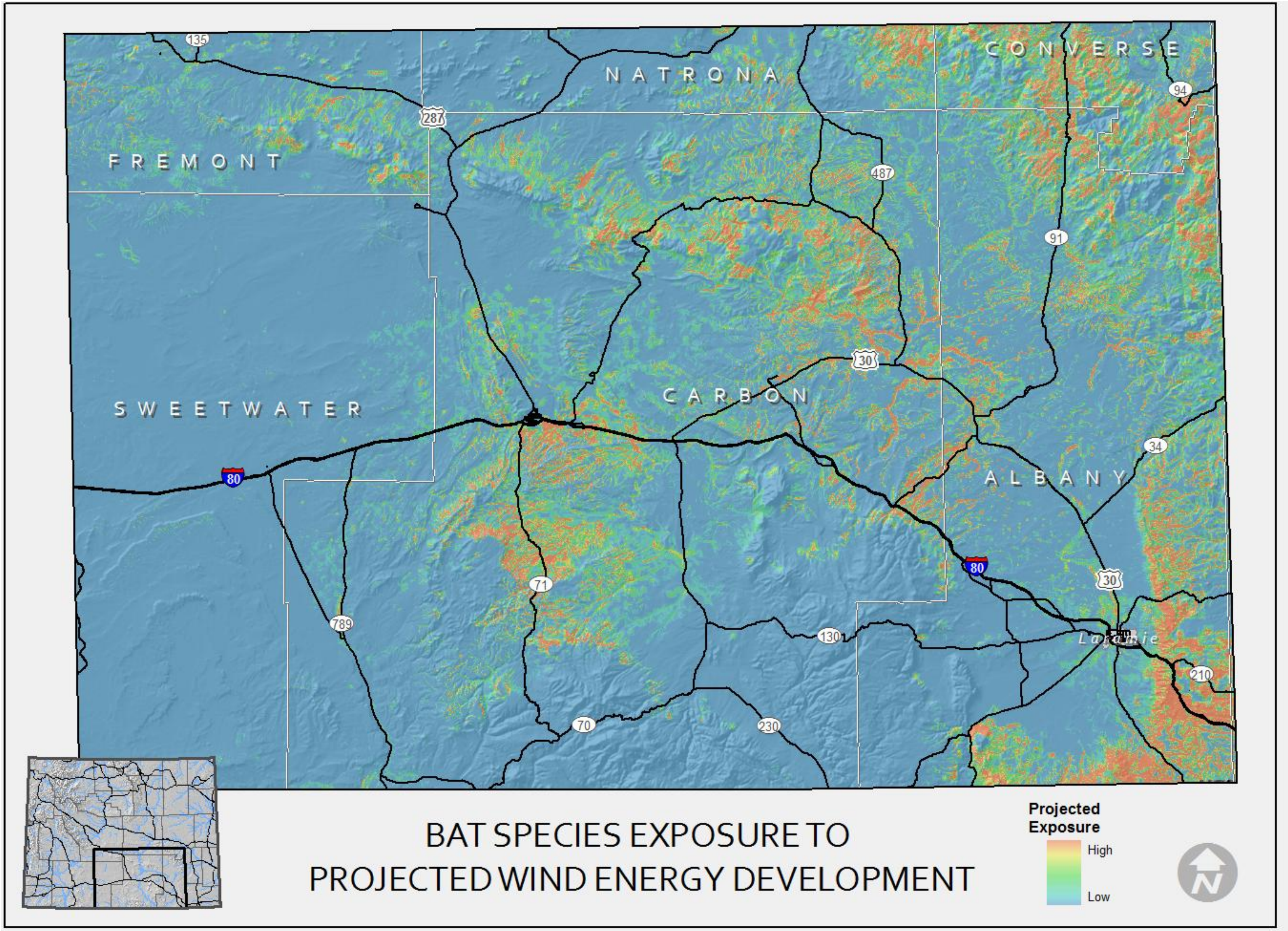


Figure 6. Predicted bat exposure to wind energy development in southern Wyoming. This is an overlay of figures 3-5; predicted summer distribution, migration stopover, and wind energy potential.



APPENDICES

APPENDIX A: SPECIES ACCOUNTS

Little Brown Myotis (*Myotis lucifugus*)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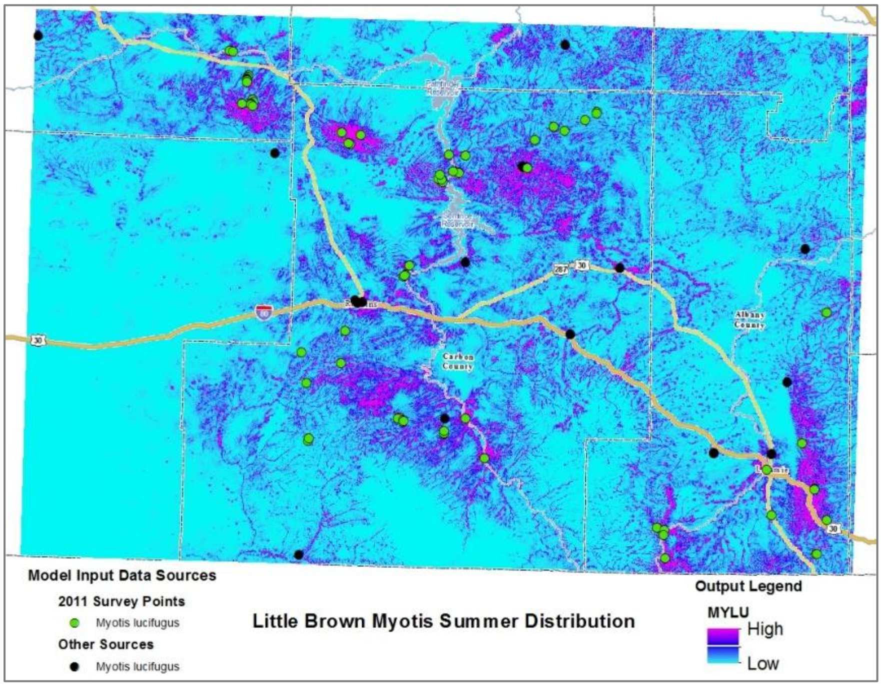
Species Ecology

Because of its behavioral and ecological versatility, the little brown myotis ranges widely across North America and Wyoming. It is a year-round resident, although females are thought to migrate as far as several hundred kilometers between summer maternity and winter hibernating roosts (Adams 2003). The little brown myotis is most common in conifer forest, streamside riparian and urban areas; usually found near open water and absent from hot, arid lowlands. During summer, the little brown bat uses a wide variety of roosts including buildings, trees (cavities and loose bark), bridges, rock crevices, caves, and abandoned mines. It is one of the most common species in Wyoming's buildings. It mainly forages over water, often within a few feet of the surface, but also in open woodlands and forest openings. Although an opportunistic feeder, it mainly eats small, soft-bodied, flying insects, particularly emerging aquatic insects (e.g., caddisflies, mayflies, midges, mosquitoes).

Notes

Little brown myotis was the most common species captured in mist nets (35 individuals) and in acoustic recordings (65 occurrences). It appears to be widespread and common in southern Wyoming, although usually associated with water. Several reproductive females were captured along with young-of-the-year indicating nearby maternity roosts. The presence of permanent water, cliffs, and cave formations were all significant drivers in the species' summer distribution (see map above).



Western Small-footed Myotis (*Myotis ciliolabrum*)

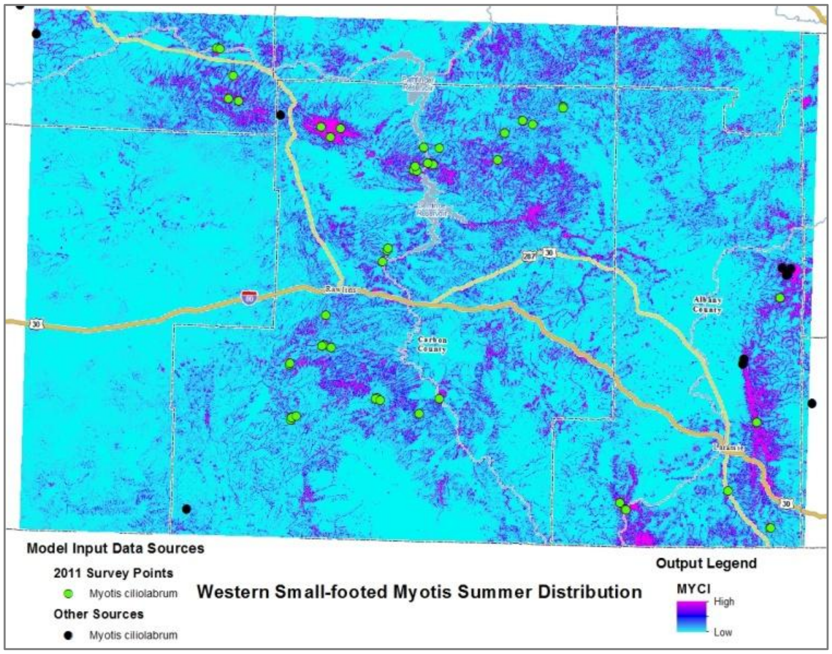

© Doug Keinath, WYNDD

Species Ecology

The western small-footed myotis has a range encompassing southern Canada and extending through the Rocky Mountain states to Arizona and New Mexico. It is found throughout most of Wyoming, but is excluded from high mountains and most of northeastern Wyoming (Keinath et al. 2010). It is commonly associated with middle and low-elevation arid, rocky areas (such as canyons, cliffs, rock outcrops, and badlands) within a variety of habitats (e.g., montane forest, juniper woodlands, sagebrush steppe, shortgrass prairie). It is a year-round resident, known to hibernate is small colonies, a few of which have been identified in north-central and southwestern Wyoming (Adams 2003). Diurnal roosts are varied, but tend to be rock shelters (crevices, overhangs, cliffs, and under rocks), caves, and abandoned mines. Unlike many other species, it will roost at ground level. Small-footed myotis typically forages along cliffs and rocky slopes in dry areas, but can forages over water. It is highly maneuverable, often foraging low to the ground (i.e., <10 ft) among boulders, shrubs, and trees, feeding on a variety of small, soft-bodied insects, especially moths.

Notes

Western small-footed myotis was the second most common species detected (51 acoustic occurrences), although no individuals were captured in mist nets. This might be because they were most often detected in rugged terrain near rock outcrops rather than over open water where mist nets are placed. Although presence of water pulled out as an important predictor of summer distribution (see right), it was less important than the presence of rocks and cliffs.



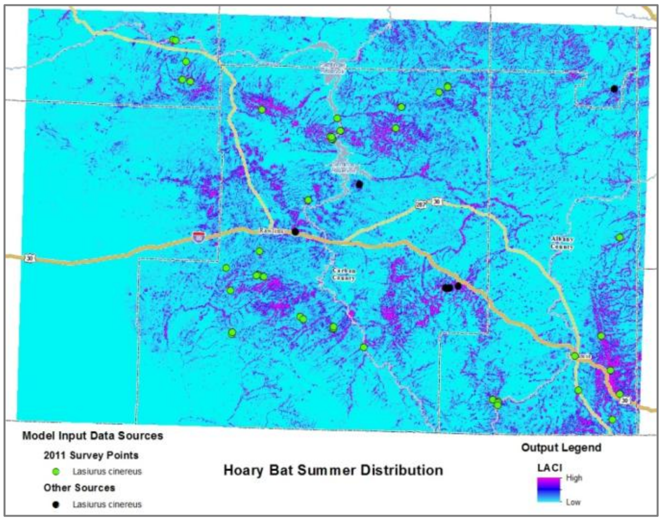
Hoary Bat (*Lasiurus cinereus*)

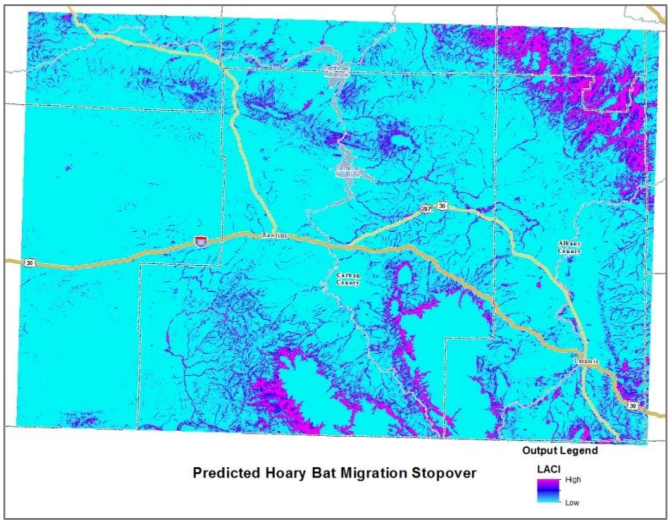
Species Ecology

The hoary bat ranges throughout North America and is considered widespread throughout Wyoming. It is one of Wyoming's few long-distance migrants, spending its winters in the southern and southeastern United States. Hoary bats are large and fast, preferring to forage in open areas where they hunt moths and other large-bodied insects. They usually forage late in the evening, 2 to 5 hours after sunset. They are solitary and roost in the foliage of deciduous and coniferous trees rather than communally in geologic or human structures. Ideal habitat consists of a mixture of trees and open areas because they often roost and forage along forest edges.

Notes

Hoary bats were widespread and the third most common species detected (Table 3). Six males were captured in mist nets and 41 acoustic occurrences were recorded. They appear to forage in a variety of habitats and were found as far as 7km from water and 14km from trees. Of the three long-distance migrants, hoary bats are most often killed by wind turbines (Appendix A) and as a result are of conservation concern in the study area. Summer distribution results indicate that flowing or open water and presence of cliffs and rock formations are important predictors of their distribution. The migration stopover model focused on forested areas and as a result pulled out forested foothills and large riparian areas as important resting and foraging habitat during migration.





Long-legged Myotis (*Myotis volans*)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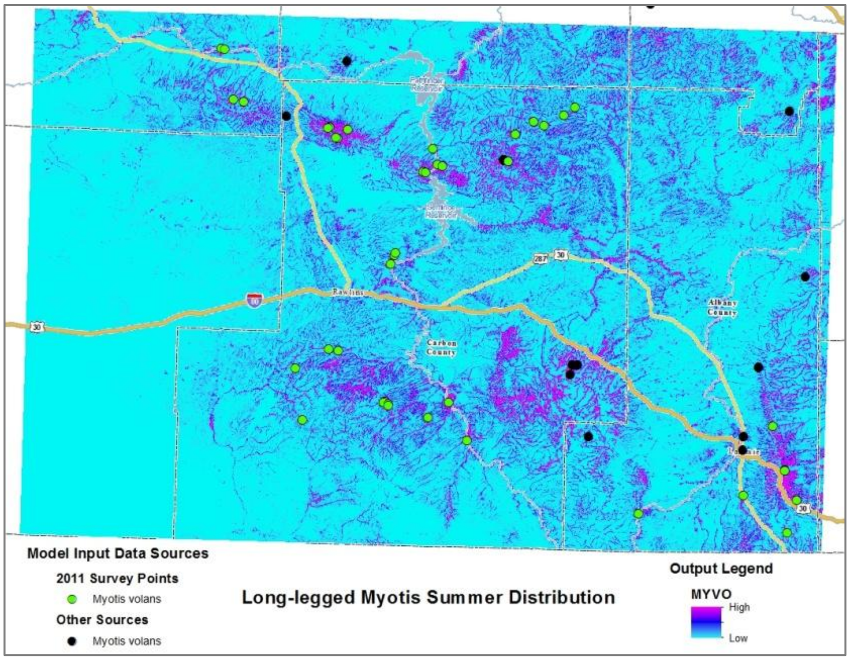
Species Ecology

Long-legged myotis occurs throughout western North America from Alaska to northern Mexico. Prior to these surveys, it was thought to be limited to mid and high elevation forests in Wyoming. Females are known to form maternity colonies in tree cavities, loose bark, and rock crevices near permanent water, however males will roost more broadly. It is considered a year-round Wyoming resident and hibernates in caves and mines. The long-legged myotis is a rapid, direct flier that pursues moths and other insects.

Notes

Typically associated with forests, long-legged myotis were more common than expected in the study area which is dominated by sagebrush and open forests. We caught 5 males in mist nets and collected 44 acoustic occurrences. Distance to water and tree cover were nevertheless important in predicting summer distribution (see right).



Silver-haired Bat (*Lasionycteris noctivagans*)

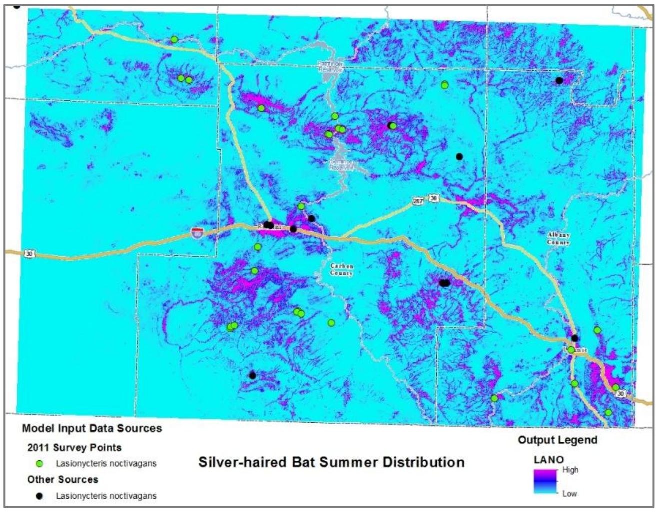

© Doug Keinath, WYNDD

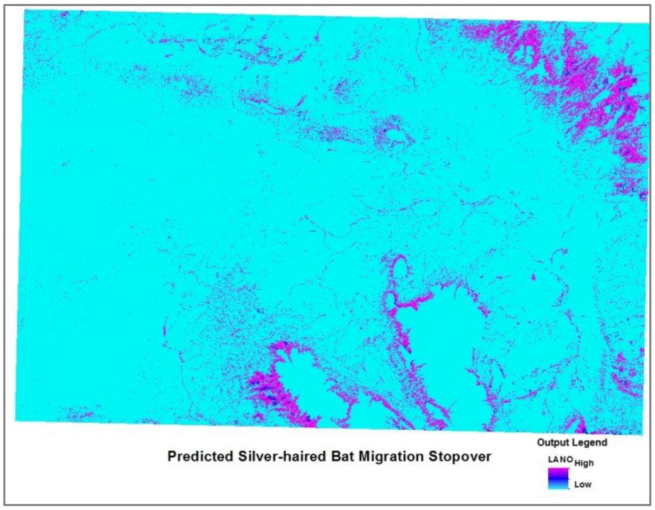
Species Ecology

The silver-haired bat is found in most of North America at varying abundances. It roosts almost exclusively in trees. In Wyoming it occurs state-wide but usually in association with late-successional montane forest (Keinath 2005). High snag density and the availability of open water are other important habitat characteristics. Like the hoary and eastern red bat, it migrates hundreds of miles from southeastern United States to spend its summers in Wyoming. Reproductive females normally roost in small colonies within tree cavities, while males and non-reproductive females roost singly under loose bark or within cracks and crevices. The silver-haired bat usually forages close to the ground (i.e., < 8ft). Although a somewhat generalist feeder, it is a slow and agile flier, making it good at pursuing small, swarming insects at short distances.

Notes

Typically associated with forests, silver-haired bats were more common than expected in the study area which is dominated by sagebrush and open forests. We captured one female and six males in mist nets and recorded 26 acoustic occurrences. The silver-haired bat appears to be pulling out pockets of trees and water as these were important in the summer distribution model (see below). Forested foothills and riparian areas were important in the migration stopover model (see below).


Silver-haired Bat Summer Distribution


Predicted Silver-haired Bat Migration Stopover

Western Long-eared Myotis (*Myotis evotis*)

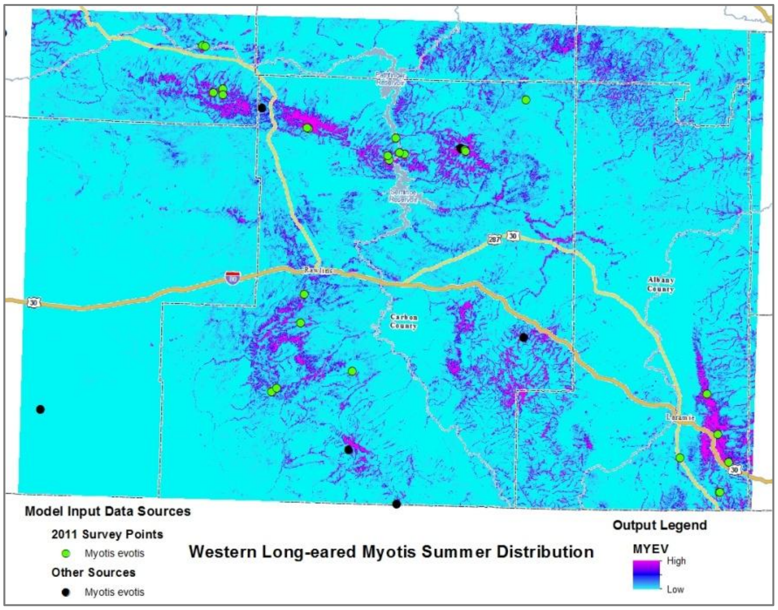

© Paula O'Briant
WYNDD

Species Ecology

Western long-eared myotis looks similar to the northern long-eared myotis but has even longer ears and opaque skin on its tail. It ranges throughout temperate western North America. In Wyoming, the species is most common at intermediate elevations and foothills (Keinath et al. 2010). It is primarily a foliage gleaner, capturing insects on bark and leaves by listening to the flutter of their wings. For this reason, it prospers in vegetatively complex environments ranging from sagebrush shrubland to thick conifer forests (Adams 2003). It roosts in small groups under the bark or in the hollows of snags, in caves, or human structures. Primary food sources are moths and small beetles. Long-eared myotis are colonial and after feeding they often gather in night roosts that are near, but separate from, day roosts. Little is known about the hibernation habits of western long-eared myotis, but it is assumed that they hibernate in relatively small groups in caves or mines (Adams 2003).

Notes

Western long-eared myotis was less common relative to other species (Table 3). . One male was captured and 25 acoustic occurrences recorded. It was positively associated with conifer and deciduous trees (habitat analysis; Table 5) and cliffs and rugged terrain (summer distribution; figure right).



Big Brown Bat (*Eptesicus fuscus*)

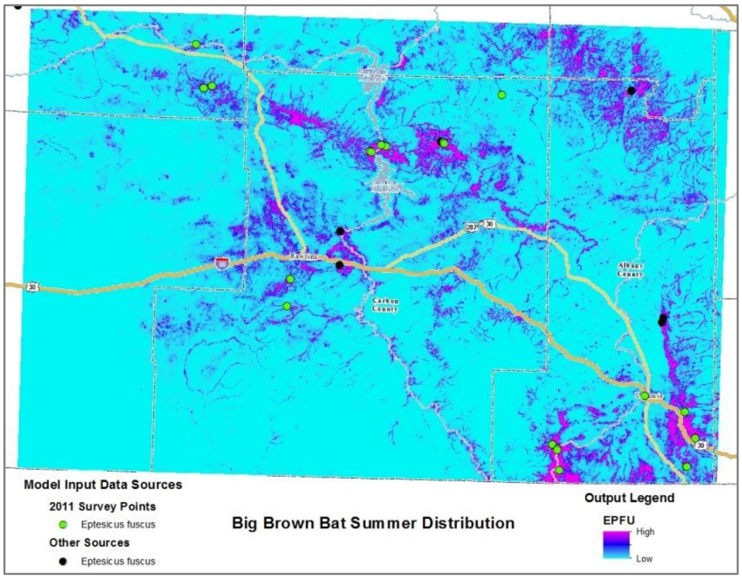
Species Ecology

The big brown bat is found across most of North America. Although it has been documented in sagebrush, it is most often associated with forested habitats and ranges from low-elevation riparian to high-elevation conifer habitats in Wyoming. They are beetle-eating specialists, but will also take other winged insects. Big brown bats are year-round residents and hibernate alone or in small groups in caves, abandoned mines, or human structures. Females form large maternity colonies in the summer which disband in August or September when they join up with the males, mate, and find hibernacula.


© Paula O'Briant, WYNDD

Notes

Big brown bats were positively associated with conifer and deciduous trees (habitat analysis; Table 5) and water and rock formations (summer distribution; figure right). They were the second most abundant species caught in mist nets (13 captures), but relatively few (21) acoustic occurrences were recorded. Of the individuals caught in mist nets, 1 reproductive female was captured, 3 reproductive males, and 9 non-reproductive males. This provides some evidence of juvenile rearing and breeding in the study area.

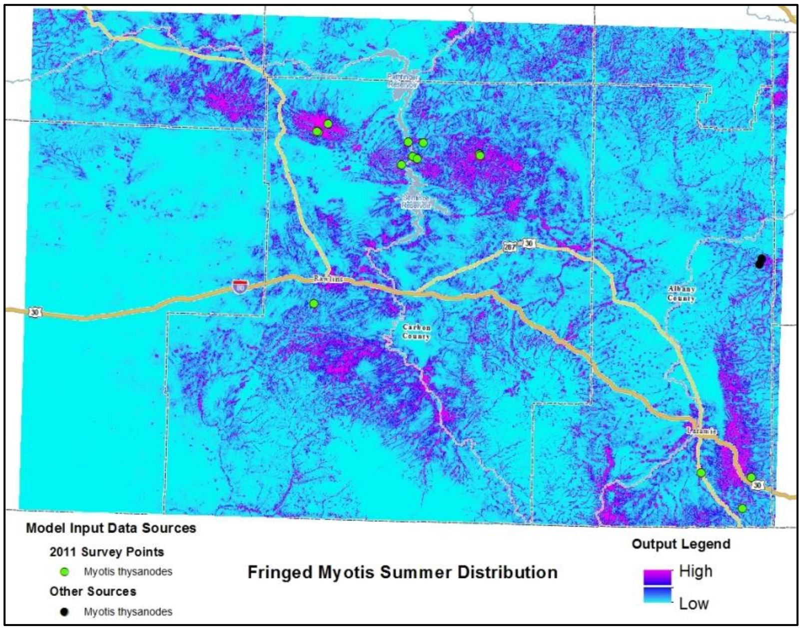


Fringed Myotis (*Myotis thysanodes*)

Species Ecology


© Hannah Griscom, WYNDD

The fringed myotis ranges across most of western North America preferring dry woodlands at mid-elevations. In Wyoming, the species occurs primarily in the sagebrush steppe and open forests of the mountain foothills (Keinath et al., 2010). Fringed myotis are thought to migrate intermediate distances between summer roosts and winter hibernacula, but very little information is available about its migration habits (Adams 2003). It has been documented roosting in rock crevices, caves, mines, and buildings, but it was also found throughout Grand Teton National Park in the apparent absence of such features, leading Keinath (2005) to assume that snags were also used as roosts. Fringed myotis primarily eat beetles and moths which they catch within the forest canopy or along forest edges.



Notes

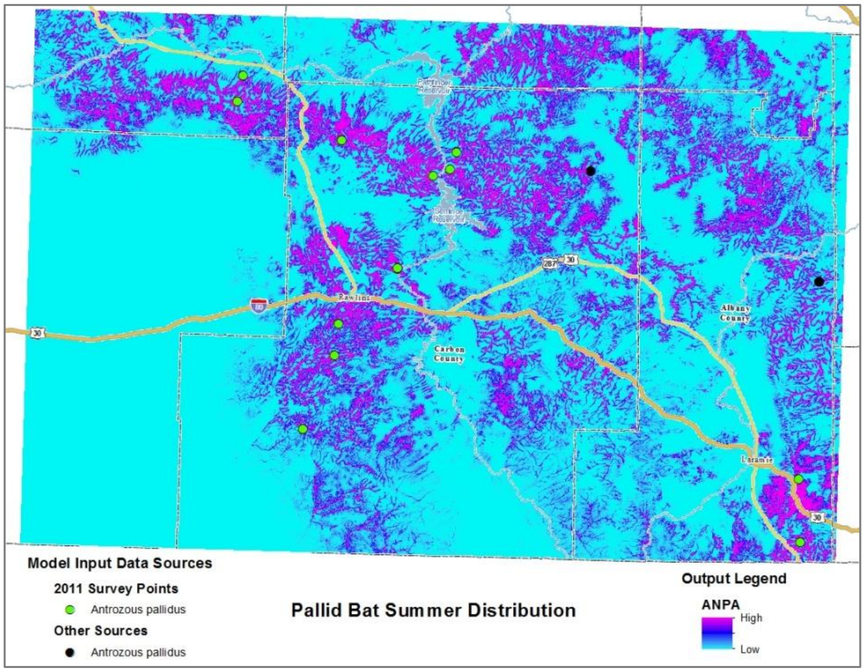
Fringed myotis was somewhat uncommon in the study area. This could be because of its association with conifer trees (see above and Table 5). This preference was reinforced in summer distribution modeling (see left) where it had a negative correlation with sagebrush and a positive correlation with flowing water. No fringed myotis were captured in mist nets but 14 acoustic occurrences were recorded.

Pallid Bat (*Antrozous pallidus*)

© Doug Keinath
WYNDD

Species Ecology

The pallid bat inhabits low desert shrublands, juniper woodlands, grasslands, and nearby cottonwood-riparian zones. It is most common in low, arid regions with rocky outcrops. Roost structures are usually rock crevices and buildings, but also rock piles, tree cavities, shallow caves, and abandoned mines. It likely hibernates in narrow crevices within caves and abandoned mines. The pallid bat emerges about 1 hour after sunset to forage. It primarily gleans large insect prey from the ground and vegetation, but also forages in flight within about 3 m (10 ft) of the ground.



Pallid Bat Summer Distribution

Notes

Pallid bat was somewhat uncommon in southern Wyoming; none were captured in mist nets, and 13 acoustic occurrences were recorded. As further confirmation of habitat preferences discussed above, we found a positive correlation with rock/cliff habitat (Table 5). Areas with bare ground and cliffs pulled out as important predictors in the summer distribution model (see above) in addition to water features.

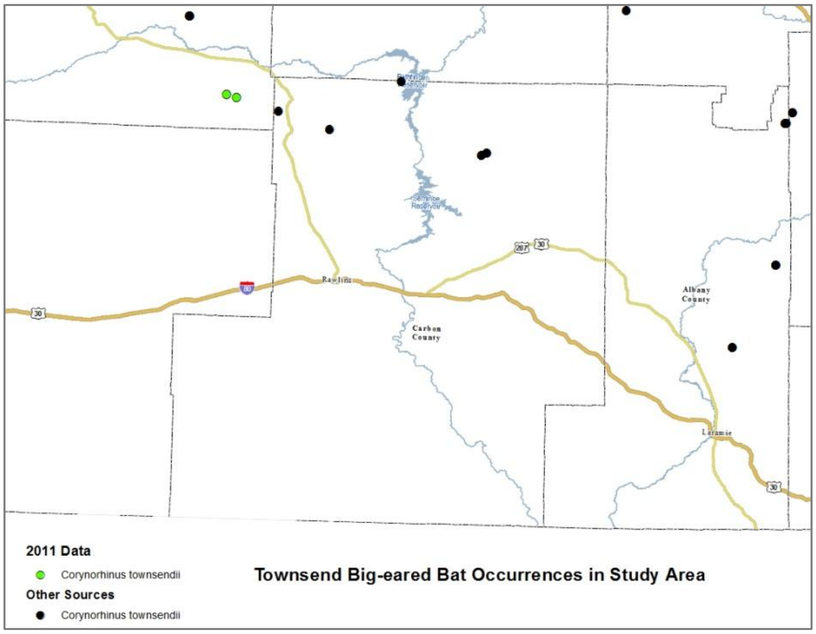
Townsend's Big-eared Bat (*Corynorhinus townsendii*)

Species Ecology

The most critical and restrictive feature of Townsend's big-eared bat ecology is the requirement for large cavern-like structures for roosting during all stages of its life-cycle. Maternity roosts are even more limiting, as they must be consistently warm throughout the breeding season. This results in a general preference for warm, low-mid elevation habitats. Otherwise, habitat use is fairly general and driven by prey availability. Townsend's big-eared bat forages primarily along edge habitats (e.g., forest edges, intermittent streams), but also in forests and along vegetated stream corridors. All reports indicate that it is an agile flier specializing on moths, which it captures on the wing. It occurs in Wyoming year-round, migrating short distances to hibernate in thermally-stable caves.

Survey & Modeling Notes

The range for Townsend's big-eared bat only overlaps with the northern quarter of our study area (Adams 2003, Keinath et al. 2010). Unsurprisingly, we only recorded 2 occurrences of Townsend's big-eared bat and they were both near Green Mountain, indicating that there may be a communal roosting cave in that area. The map to the right shows where these occurrences were in relation to existing data points in WYNDD's database. There was insufficient input data to produce a reliable summer distribution model for Townsend's big-eared bat in southern Wyoming.



Eastern Red Bat (*Lasiurus borealis)*

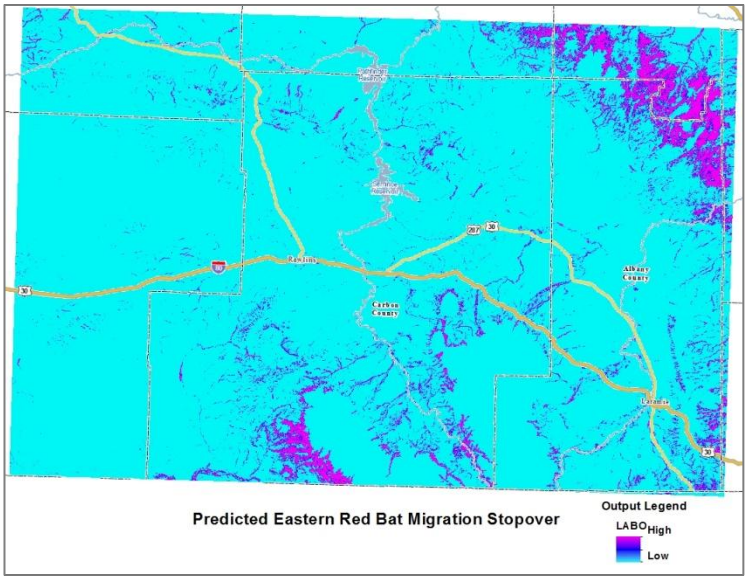
Species Ecology


© Hannah Griscom WYNDD

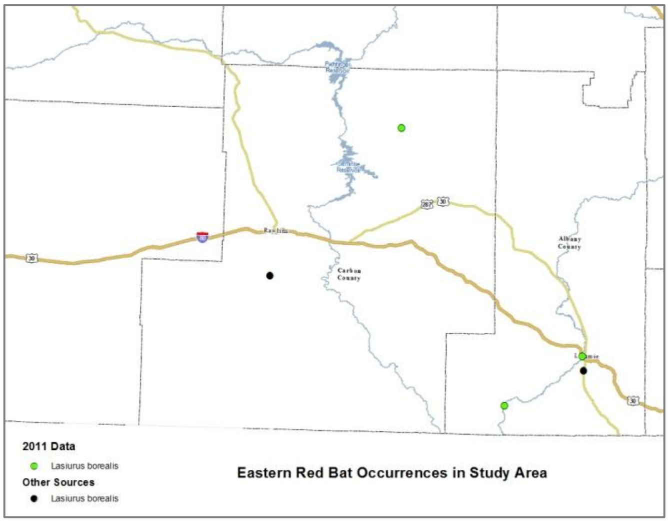
The eastern red bat has a wide range across central and eastern North America, but only occurs in far eastern Wyoming. It is one of three species that migrates from the southern and eastern United States to spend its summers in Wyoming. The red bat primarily roosts in the foliage of deciduous trees, hanging upside down, apparently imitating a dried leaf. It is generally solitary, except during fall migration. In Wyoming, most records are from riparian areas near perennial water where it preys by aerial pursuit on moths and other insects.

Survey & Modeling Notes

Eastern red bats were uncommon in the study area with one mist net capture and two acoustic occurrences (see green points in map below). There were insufficient data overall to produce a summer distribution model, however a migration stopover model was created (right) based on its assumed affinity for deciduous trees and water. The stopover model pulled out extensive areas of aspen in the Sierra Madre and Laramie Mountains that are below 2500m elevation, but it is likely that cottonwood forests along river valleys are more commonly used during migration than the aspen at these higher elevations.



Predicted Eastern Red Bat Migration Stopover



Eastern Red Bat Occurrences in Study Area

APPENDIX B: LITERATURE REVIEW OF BAT MIGRATION & WIND TURBINE FATALITIES

This literature review focuses on the behavior and physiology of migratory bats in relation to wind turbine fatalities. We provide a detailed explanation of the parameters we used to build the migration model (Figure 4) and provide starting points to improve future iterations. Although most of this review is focused on migratory bats, year-round residents are also at risk for being killed by wind turbines (Johnson 2005, Jain et al. 2011). Wind turbines also have the potential to fragment bat habitat by creating ground and air barriers that prevent or restrict movement across the landscape. Because of these potential direct and indirect impacts to migratory and resident bats, we have presented distribution models for all species in the body of this report. Here, however, our focus is only on migratory bats.

Trends in bat fatalities at wind energy facilities

Bat fatalities at wind energy facilities have been documented across North America, and have been the focus of much scientific attention in recent years. By studying the common patterns observed across different facilities, the factors driving bat fatalities and possible mitigation measures have begun to emerge in the literature. We now know that bats are killed by direct impact or internal hemorrhage when they fly too close to moving turbine blades (Baerwald et al. 2008). Although all species are at risk (Kunz et al. 2007, Jain et al. 2011) migratory species represent about 75-83% of the bats killed by turbines (Kunz et al. 2007, Johnson 2005) and hoary bats comprise about half of all fatalities (Arnett et al. 2008). Also, these migratory species are more likely to be killed during fall migration than during spring migration (Arnett et al. 2008, Young et al. 2003, and others). Many studies also show that bat fatalities increase sharply on nights when wind speeds are low, moon illumination is low, cloud cover is high, barometric pressure is low, and temperatures are warm (Baerwald and Barclay 2011, Cryan and Brown 2007). These conditions are probably favorable to mass migration events, and it has been suggested that shutting down wind turbines under such conditions during August and

September would drastically reduce the number of bats killed while having a minimal effect on energy production (Molvar 2008).

Why are migrating bats vulnerable?

Studies are beginning to converge on a set of behavioral explanations for the vulnerability of migrating bats to being struck by turbine blades. First, migrating bats tend to fly higher than locally foraging bats (Tuttle 2009). In late summer and early fall, the number of migratory bats flying between 30-100m above ground (rotor-swept zone) greatly outnumber those flying near ground level (Horn et al. 2008, Baerwald and Barclay 2011). Second, radar surveillance shows that migratory bats sometimes congregate and/or forage around rotor blades (Horn et al. 2008, Cryan and Barclay 2009). The same weather conditions that predict turbine fatalities (bat migration episodes) also predict high insect activity (Rydell et al. 2010, Horn et al. 2008). Indeed, many winged insects in North America migrate at the same time bats do, forming swarms far from the ground in order to pick up wind currents that transport them to new locations (McCracken et al 2008). So swarms of migrating insects may, in essence, be drawing bats into the rotor-swept zone where they are more vulnerable to being hit (Ahlén et al. 2009). The phenomenon of bat swarming during migration may also be due to autumn mating behavior (Cryan and Brown 2007).

How do bats migrate?

The hoary bat (*Lasiurus cinereus*), silver-haired bat (*Lasionycteris noctivagans*), and eastern red bat (*Lasiurus borealis*) are the migratory species that occur in Wyoming. They migrate as far north as the central Rocky Mountains of Canada and as far south as southern Mexico (Cryan 2003). All three species roost and hibernate in the foliage of trees which presumably explains their need to spend winters in warmer regions (Popa-Lisseanu and Voigt 2009). Each species is somewhat different with respect to timing and the degree of sexual segregation during the spring and summer migration seasons (Cryan 2003, Adams 2003). However males and females do overlap to a large extent during fall migration because this is when breeding primarily occurs (Adams 2003). These fall migration periods are generally longer and less synchronized than spring migrations (Cryan 2003, Furnamkiewicz and Kucharska 2009), perhaps as an adaptation to increase breeding opportunities or decrease competition for resources (Flemming and Eby 2003). In any case, the lengthened migration period may be another factor contributing to higher fatality rates during fall migration compared with spring migration.

A bat's journey from summer to winter grounds spans several weeks and is composed of two repeating phases; 'migration flight' and 'stopover' (McGuire et al. 2012, Fleming and Eby 2003, Taylor et al. 2011). Migration flights occur at night and end at a stopover site. For foliage-roosting bats such as our three species of interest, bats find a suitable tree roost and enter torpor during the following day. They then stay near this roost for one or more days, resting and stocking up on food and water until conditions are favorable for another migration flight (McGuire et al. 2012, Taylor et al. 2011, Fleming and Eby 2003). In order to accurately represent bat migration, we need to be able to model both 'migration flight/habitat' and 'stopover habitat'.

Migration Flight

Do bats use 'corridors'?

Because southern Wyoming has few trees, potential stopover habitat is limited and fairly easy to identify. However we know from the fatality studies described above that bats are at least as vulnerable during migration flight as they are while foraging around stopover locations. So how do we model their migration flights? Do they follow established corridors? Do they fly straight south, regardless of terrain, or do they try to stay near patches of feeding and drinking habitat? Unfortunately, there is no clear answer to these questions as there is evidence for and against the 'corridor' concept.

Several studies have documented bats flocking during migration flights (Fleming and Eby 2003) suggesting that they do concentrate together. They may also cluster during stopover periods, as Ruczynski et al. (2007) documented that *N. noctula* relied on conspecific echolocations to identify suitable tree roosts. Furmankiewicz and Kucharska (2009) documented more migratory bats along a major riparian corridor in Poland than in adjacent habitat. In Alberta, Canada, Baerwald and Barclay (2009) showed that turbines placed closer to mountains and trees were more likely to kill migratory bats than turbines in open grasslands. Valdez and Cryan (2009) documented large numbers of hoary bats foraging along cottonwood riparian forests in New Mexico during spring migration. Indeed, it seems logical that foliage-roosting bats would prefer to migrate through mesic and forested habitats in the otherwise dry Rocky Mountain region as this would allow them to stop, rest, and refuel when needed. However a number of studies (summarized by Arnett et al. 2008) looked at the number of turbine fatalities in relation to nearby habitat types and found no relationship, indicating that bats fly somewhat evenly or unpredictably across the landscape. Because of the conflicting results of the aforementioned studies, and lacking empirical data of our own, we are forced to assume that the hoary, silver-haired, and eastern red bat do not use migration corridors in southern Wyoming. For this reason, we elected not to model migration flight in this report.

How far is a typical migration flight?

Bats are capable of sustained flights over 50km when conditions require it. For example, *Pipistrellus nathusii* can fly more than 150km in one night when crossing the Baltic Sea (Ahlén 1997). There are also examples of bats migrating over the open ocean 15-30 miles from the coastline (Ahlén et al. 2009, Cryan and Brown 2007). However, after reviewing many studies, Fleming and Eby (2003) conclude that most migratory bat species travel roughly 30-50km per night, broken up by periodic bouts of feeding and drinking. Unlike birds, migratory bats do not accumulate fat reserves prior to migration, and water loss during flight is about 3% of body mass for every hour of flight (Fleming and Eby 2003). These metabolic demands of flight are the primary limitation on the distance bats can travel before refueling. In a physiological model of optimal migration distance, Hedenström (2009) arrived at 24-46km per night for a 10g bat (similar to the body mass of silver-haired and eastern red bat). Other studies have arrived at similar estimates, with larger bats able to travel further. For example, Petersons (2004) estimated the average flight distance for migratory *Pipistrellus nathusii* (5-15g) to be 48km per night whereas the grey-headed flying fox (*Pteropus poliocephalus*; 500g-1000g) travels 50-

130km in one night (Fleming and Eby 2003). Taken in combination, these studies suggest that 25-50km per night for silver-haired and eastern red bat and slightly more (30-60km) for hoary bats are reasonable estimates for the distance traveled during one migration flight. In the future, this information could be incorporated into a 'least-cost' path model of migration between stopover patches (Figure 4) in southern Wyoming.

Stopover Habitat

Information about the roosting and feeding behavior of hoary, silver-haired, and eastern red bat was used to build the three migration stopover models described in Table 8 and shown in Figure 4. Because all species are foliage-roosters, the presence of trees was the first condition necessary to define stopover habitat. Eastern red bat has predominantly been documented roosting in deciduous trees (Adams 2003, NatureServe 2012), so any deciduous tree cover above 0% was included in its model (Table 8a). Silver-haired and hoary bats use both deciduous and coniferous species (Adams 2003), so any type of tree cover above 0% was included for them (Table 8b & 8c).

Bats can lose up to 30% of their body weight in an eight-hour period, primarily due to metabolic evaporation (Adams 2003). So, although some water can be derived from food, in most cases, bats need to drink water at least once a day. This is especially true during migration when metabolic demands are higher (Fleming and Eby 2003). Therefore, we determined that proximity of perennial water to tree roosts was another condition of stopover habitat. A logarithmically declining relationship between the roost site and distance to perennial water was assumed. In other words, we presumed that, all other variables being equal, a bat would be much more likely to use a water source 100m from its roost than a water source 1000m from its roost.

It was more difficult to determine a 'maximum distance' beyond which a foraging bat was unlikely to seek water. This is because little species-specific home range data exist, and those that do vary between 12ha and over 700ha depending on species, habitat, and reproductive status (Fleming and Eby 2003). In New Hampshire, Veilleux et al. (2009) documented a 156ha foraging range for a hoary bat which equals a 600m circular radius around the roost. In contrast, pregnant little brown myotis only ranged about 300m from their maternity roost site (Henry et al. 2002). The studies cited by Fleming and Eby (2003) indicate that most small-to-medium sized bats range between 300m and 1000m from their roost sites with some species going as far as 3km. We determined, therefore, that 5km was probably the maximum distance that foliage-roosting bats would want to range in search of water. With a lack of species-specific information, we applied this same threshold across all three species (Table 8). Bats also need to eat while stopping over during migration, but because all three species have been documented feeding on insects near water or trees, the first two conditions of the models fulfilled foraging needs.

Based on differences in flight behavior and habitat (Adams 2003), some information is available about the types of water the three species prefer to eat and drink from. Eastern red bats are typically associated with riparian forests and, as a result, usually forage along large rivers (Table 8a.; stream order of 2 or more) and secondarily at large and medium-sized ponds. Hoary bats are fast flyers and pursue prey by aerial hawking. As a result, they are most comfortable foraging and drinking at large, open water bodies, rather than narrow rivers and streams. Silver-haired bats are typically found at ponds or open water in forested environments. They are agile flyers and as such, can also forage within the confines of streams and rivers.

Future Model Improvements

Upcoming surveys in 2012 will focus more on tracking migration activity in different habitats in Southern Wyoming and will hopefully lead to better empirical information about bat migration flight and stopover patterns. This information can be combined with what is known about migration flight behavior and distance (above) to create ‘least-cost’ path models of migration between patches of stopover habitat. In creating future iterations of the ‘bat exposure’ map, it may be more accurate to weigh the migration model higher than the summer distribution model (1.5:1) because migratory bats comprise 75% of turbine fatalities are therefore 1.5 times more vulnerable to turbine fatalities.

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APPENDIX C: 2011 MIST NET CAPTURE RESULTS

Site Name	**UTM Zone (NAD 1983)**	**Easting**	**Northing**	**SPECIES** 4 letter code	**Bat ID #**	**TOC** 24hr	**Sex** (m/f)	**Age** j/a	**Repro** code	**FA** mm	**Th** mm	**E** mm	**Wt** g	**Keel** y/n	**WDI** code	**Photo #**
BvrCrkPond	13	327490	4590447	MYLU	1	2230	f	a	n	39	5.7	11.3	7	n	0-P	1093-1094
BvrCrkPond	13	327490	4590447	MYLU	2	2300	f	a	p	39.2		9.2	10	n	1	1095-1096
BvrCrkPond	13	327490	4590447	MYLU	3	2300	f	a	p	38.7		7.9	12	n	0	1097-1100
BvrCrkPond	13	327490	4590447	MYLU	4	2325	f	a	n	37			8	n	1	1101-1103
Laezenbynets	13	450997	4558334	LACI	1	2215	m	a	n	-	-	-	27	-	0	1072-7074
Laezenbynets	13	450997	4558334	LANO	1	2300	m	a	n	-	-	-	10	n	1-P	1084-1085
Laezenbynets	13	450997	4558334	MYLU	2	2255	f	a	p	39.2	6	9.7	11	n	2	1078-1080
Laezenbynets	13	450997	4558334	MYLU	4	2315	f	a	n	36.8	6.9	11.5	8	-	0-P	1086-1088
Laezenbynets	13	450997	4558334	MYLU	5	0105	f	a	n	38	5.7	10.9	11	n	1	1089-1092
Laezenbynets	13	450997	4558334	MYLU	1	2230	f	a	n	36.6	8.2	12.7	8	n	0-P	1075-1076
Laezenbynets	13	450997	4558334	MYLU	3	2300	m	a	n	41	6.4	10.7	9	n	0	1080-1083
Mirmile	13	345561	4672180	EPFU	4	0015	f	a	l				20	y	0	1117-1118
Mirmile	13	345561	4672180	EPFU	3	2353	m	a	d				13	y	0	1115
Mirmile	13	345561	4672180	EPFU	1	2110	m	a	d				18	y	0	1105
Mirmile	13	345561	4672180	EPFU	2	2319	m	a	n				16.5	y	0	1113
Mirmile	13	345561	4672180	EPFU	5	0015	m	a	n				16	y	1	1119
Mirmile	13	345561	4672180	LACI	1	2110	m	a	n				22	n	0	1110
Mirmile	13	345561	4672180	LANO	1	2335	m	a	n	46.2		13.2	12.5	n	2	1114
Mirmile	13	345561	4672180	MYLU	1	2110	f	a	n	37.5	7	13.8	10	n	1	1104
Mirmile	13	345561	4672180	MYLU	2	2110	m	a	n	36.2	6.2	11.5	7	n	2	1106
Mirmile	13	345561	4672180	MYLU	3	2110	m	a	n	36.5	5.8	11.9	7	n	0	1107
Mirmile	13	345561	4672180	MYLU	4	2110	m	a	d	38.6			7	n	0	1108
Mirmile	13	345561	4672180	MYLU	5	2110	m	a	n	39.3			7	n	0	1109
Mirmile	13	345561	4672180	MYLU	6	2110	m	a	n	37.1			7	n	0	1111
Mirmile	13	345561	4672180	MYLU	7	2110	m	a	n				6	n	0	1112
Mirmile	13	345561	4672180	MYLU	8	0015	m	a	n	37			8	n	1	1116
OptimistNet	13	449339	4573253	LABO	1	2215	f	a	n	41.1	7.2		15	n	0	1167
OptimistNet	13	449339	4573253	LACI	1	2130	m	a	n	55			24	n	0	1166
OptimistNet	13	449339	4573253	MYLU	1	2115	m	a	n	38.7			10.5	n	0	1165
Pole Creek	13	465237	4566890	LACI	1	2345	m	a	n	52.9	10.9	12.9	30	n	0	-
Pole Creek	13	465237	4566890	MYLU	1	2221	m	a	n	36.1	6.5	10	7	n	0-P	1034-1038
QCreekNets	13	369864	4673009	EPFU	1	2200	m	a	d	43.4			17	y	0-P	1132
QCreekNets	13	369864	4673009	EPFU	2	2300	m	a	n	45.7			18	y	1-P	1134

QCreekNets	13	369864	4673009	EPFU	3	0035	m	a	n	45.8			16	y	0	1139
QCreekNets	13	369864	4673009	LANO	2	2200	m	a	n	41.4			8.5	n	0	1131
QCreekNets	13	369864	4673009	LANO	1	2145	m	a	n	43.5			8.5	n	0	1130
QCreekNets	13	369864	4673009	LANO	3	2240	m	a	n	37.9			12		0	1133
QCreekNets	13	369864	4673009	MYEV	1	2145	m	a	n	39	5.2	21.4	13	y	0	1127-1129
QCreekNets	13	369864	4673009	MYLU	1	2306	m	a	n	38.1	7.1	11.8	10	n	0	1135
QCreekNets	13	369864	4673009	MYLU	2	0020	m	a	n	38.3	5.5	14.3	8.5	n	0-P	1137
QCreekNets	13	369864	4673009	MYLU	3	0035	m	a	n	37.9			8	n	P	1138
QCreekNets	13	369864	4673009	MYVO	1	2345	m	a	n	40.6	4.9		8	y	1	1136
SAGE RES NETS	13	308204	4608620	MYLU	4	2200	f	a	n	39.7	5.9		8	n	0	1143-1144
SAGE RES NETS	13	308204	4608620	MYLU	2	2145	f	j	n	39.2	6.2		6	n	0-P	1141
SAGE RES NETS	13	308204	4608620	MYLU	1	2145	m	a	d	38.6	5.9		8	n	0	1140
SAGE RES NETS	13	308204	4608620	MYLU	3	2145	m	a	n	37.7	6.6		8	n	0-P	1142
Sb2	13	372393	4682320	LACI	1	2145	m	a	n	52.7			29	n	0	1120
Sb2	13	372393	4682320	MYLU	1	0015	m	a	n	40.7	6	12.5	9	n	0	1121
Sb2	13	372393	4682320	MYVO	1	0015	m	a	n	39.3	5.9	9.6	7	y	0	1122-1126
SweetWaterNets	13	271116	4711970	MYLU	1	2058	f	a	L	38.9	6.2		7	n	0	1145
SweetWaterNets	13	271116	4711970	MYLU	2	2115	f	a	L	37.8	5.5		7	n	0	1146
SweetWaterNets	13	271116	4711970	MYLU	3	2115	f	a	n	36.6			6.5	n	P	1147
SweetWaterNets	13	271116	4711970	MYLU	4	2115	f	a	L	37.3			6	n	0	1148
SweetWaterNets	13	271116	4711970	MYLU	5	2115	f	a	n	37.4			6	n	0	1149
SweetWaterNets	13	271116	4711970	MYLU	6	2230	f	j	n	37.7	6.4		7	n	0	1150
SweetWaterNets	13	271116	4711970	MYLU	7	0015	f	j	n	39.2		13.3	7	n	0	1151
SweetWaterNets	13	271116	4711970	MYLU?	-	2115	-	-	-	-	-	-	8	-	-	-
Turtle 1	13	469220	4556660	EPFU	3	2215	m	a	n	48.4	8.9	12.1	20	y	1-P	
Turtle 1	13	469220	4556660	EPFU	4	005	m	a	n	45.1	7.5	12.2	17	y	1-P	1062-1063
Turtle 1	13	469220	4556660	EPFU	5	0030	m	a	n				13	y	1-P	1066
Turtle 1	13	469220	4556660	EPFU	1	2145	m	a	n	45	7.6	10.1	14	y	1-P	1043-1046
Turtle 1	13	469220	4556660	EPFU	2	2150	m	a	n	47.8	7	11.5	15	y	0-P	1047-1049
Turtle 1	13	469220	4556660	LACI	1	2335	m	a	n				24		0	1056-1061
Turtle 1	13	469220	4556660	LANO	1	2320	f	a	n				10	n	1-P	
Turtle 1	13	469220	4556660	LANO	2	0015	m	a	n				12		2-P	1064
Turtle 1	13	469220	4556660	MYLU	1	2255	m	a	n	39	6.8	11.8	8	y	0-P	
Turtle 1	13	469220	4556660	MYVO	1	2215	m	a	n	38.6	6.7	8.9	9	y	0	
Turtle 1	13	469220	4556660	MYVO	2	2245	m	a	n	40.3	3.6	5.9	10	y	1-P	
Turtle 1	13	469220	4556660	MYVO	3	0030	m	a	n	37.3			7	y		1065

APPENDIX D: 2011 SPECIES OCCURRENCES

Scientific Name	Common Name	Date	Survey Type	Easting NAD83_13N	Northing NAD83_13N
Antrozous pallidus	Pallid Bat	8/6/2011	Recording-Anabat	277255	4703299
Antrozous pallidus	Pallid Bat	7/5/2011	Recording-Anabat	297416	4583677
Antrozous pallidus	Pallid Bat	7/20/2011	Recording-Anabat	349562	4677205
Antrozous pallidus	Pallid Bat	8/7/2011	Recording-Anabat	329426	4637886
Antrozous pallidus	Pallid Bat	8/22/2011	Recording-Anabat	465850	4545383
Antrozous pallidus	Pallid Bat	8/6/2011	Recording-Anabat	275358	4694592
Antrozous pallidus	Pallid Bat	8/3/2011	Recording-Anabat	308204	4608620
Antrozous pallidus	Pallid Bat	8/21/2011	Recording-Anabat	329558	4638006
Antrozous pallidus	Pallid Bat	7/20/2011	Recording-Anabat	347216	4671545
Antrozous pallidus	Pallid Bat	7/18/2011	Recording-Anabat	341441	4669410
Antrozous pallidus	Pallid Bat	6/22/2011	Recording-Anabat	465196	4566830
Antrozous pallidus	Pallid Bat	6/15/2011	Recording-Anabat	310549	4681335
Antrozous pallidus	Pallid Bat	8/4/2011	Recording-Song Meter	309474	4619358
Corynorhinus townsendii	Townsend's Big-eared Bat	8/4/2010	Capture-mist net	337788	4699352
Corynorhinus townsendii	Townsend's Big-eared Bat	8/6/2011	Recording-Anabat	275358	4694592
Corynorhinus townsendii	Townsend's Big-eared Bat	8/5/2011	Recording-Song Meter	278906	4693595
Eptesicus fuscus	Big Brown Bat	7/24/2011	Capture-mist net	369864	4673009
Eptesicus fuscus	Big Brown Bat	7/18/2011	Capture-mist net	345561	4672180
Eptesicus fuscus	Big Brown Bat	6/23/2011	Capture-mist net	469220	4556660
Eptesicus fuscus	Big Brown Bat	8/21/2011	Recording-Anabat	415787	4543954
Eptesicus fuscus	Big Brown Bat	7/22/2011	Recording-Anabat	370378	4672612
Eptesicus fuscus	Big Brown Bat	7/23/2011	Recording-Anabat	392966	4691619
Eptesicus fuscus	Big Brown Bat	8/22/2011	Recording-Anabat	465850	4545383
Eptesicus fuscus	Big Brown Bat	8/6/2011	Recording-Anabat	275358	4694592
Eptesicus fuscus	Big Brown Bat	8/3/2011	Recording-Anabat	308204	4608620
Eptesicus fuscus	Big Brown Bat	8/5/2011	Recording-Anabat	272447	4711766
Eptesicus fuscus	Big Brown Bat	6/24/2011	Recording-Anabat	412918	4554038
Eptesicus fuscus	Big Brown Bat	8/6/2011	Recording-Anabat	278621	4695383
Eptesicus fuscus	Big Brown Bat	7/19/2011	Recording-Anabat	340939	4669590
Eptesicus fuscus	Big Brown Bat	8/21/2011	Recording-Anabat	414833	4552533
Eptesicus fuscus	Big Brown Bat	8/21/2011	Recording-Anabat	414921	4552028
Eptesicus fuscus	Big Brown Bat	8/22/2011	Recording-Anabat	449339	4573253
Eptesicus fuscus	Big Brown Bat	7/20/2011	Recording-Anabat	347216	4671545
Eptesicus fuscus	Big Brown Bat	7/18/2011	Recording-Anabat	341441	4669410
Eptesicus fuscus	Big Brown Bat	6/22/2011	Recording-Anabat	465237	4566890
Eptesicus fuscus	Big Brown Bat	6/22/2011	Recording-Anabat	465237	4566890
Eptesicus fuscus	Big Brown Bat	8/22/2011	Recording-Song Meter	465961	4545415
Eptesicus fuscus	Big Brown Bat	8/4/2011	Recording-Song Meter	309474	4619358
Eptesicus fuscus	Big Brown Bat	8/3/2011	Recording-Song Meter	308204	4608620
Eptesicus fuscus	Big Brown Bat	7/18/2011	Recording-Song Meter	345337	4672092

Lasionycteris noctivagans	Silver-haired Bat	7/24/2011	Capture-mist net	369864	4673009
Lasionycteris noctivagans	Silver-haired Bat	7/18/2011	Capture-mist net	345561	4672180
Lasionycteris noctivagans	Silver-haired Bat	6/28/2011	Capture-mist net	450997	4558334
Lasionycteris noctivagans	Silver-haired Bat	6/23/2011	Capture-mist net	469220	4556660
Lasionycteris noctivagans	Silver-haired Bat	7/6/2011	Recording-Anabat	327490	4590447
Lasionycteris noctivagans	Silver-haired Bat	7/5/2011	Recording-Anabat	297264	4582951
Lasionycteris noctivagans	Silver-haired Bat	7/5/2011	Recording-Anabat	297416	4583677
Lasionycteris noctivagans	Silver-haired Bat	7/6/2011	Recording-Anabat	327004	4590347
Lasionycteris noctivagans	Silver-haired Bat	6/24/2011	Recording-Anabat	461089	4581959
Lasionycteris noctivagans	Silver-haired Bat	7/5/2011	Recording-Anabat	299142	4584239
Lasionycteris noctivagans	Silver-haired Bat	7/23/2011	Recording-Anabat	392966	4691619
Lasionycteris noctivagans	Silver-haired Bat	8/6/2011	Recording-Anabat	275358	4694592
Lasionycteris noctivagans	Silver-haired Bat	7/9/2011	Recording-Anabat	342362	4585431
Lasionycteris noctivagans	Silver-haired Bat	7/19/2011	Recording-Anabat	343925	4677604
Lasionycteris noctivagans	Silver-haired Bat	8/5/2011	Recording-Anabat	272447	4711766
Lasionycteris noctivagans	Silver-haired Bat	7/19/2011	Recording-Anabat	341483	4669371
Lasionycteris noctivagans	Silver-haired Bat	7/19/2011	Recording-Anabat	340939	4669590
Lasionycteris noctivagans	Silver-haired Bat	8/21/2011	Recording-Anabat	329069	4637415
Lasionycteris noctivagans	Silver-haired Bat	8/21/2011	Recording-Anabat	414983	4551603
Lasionycteris noctivagans	Silver-haired Bat	7/7/2011	Recording-Anabat	328919	4589389
Lasionycteris noctivagans	Silver-haired Bat	8/22/2011	Recording-Anabat	449339	4573253
Lasionycteris noctivagans	Silver-haired Bat	7/18/2011	Recording-Anabat	341441	4669410
Lasionycteris noctivagans	Silver-haired Bat	7/19/2011	Recording-Anabat	347185	4671471
Lasionycteris noctivagans	Silver-haired Bat	6/23/2011	Recording-Anabat	451036	4558319
Lasionycteris noctivagans	Silver-haired Bat	6/15/2011	Recording-Anabat	311197	4681098
Lasionycteris noctivagans	Silver-haired Bat	7/23/2011	Recording-Song Meter	393080	4691157
Lasionycteris noctivagans	Silver-haired Bat	8/22/2011	Recording-Song Meter	465961	4545415
Lasionycteris noctivagans	Silver-haired Bat	8/4/2011	Recording-Song Meter	309474	4619358
Lasionycteris noctivagans	Silver-haired Bat	8/3/2011	Recording-Song Meter	308204	4608620
Lasionycteris noctivagans	Silver-haired Bat	8/5/2011	Recording-Song Meter	278906	4693595
Lasiurus borealis	Eastern Red Bat	8/22/2011	Capture-mist net	449339	4573253
Lasiurus borealis	Eastern Red Bat	7/24/2011	Recording-Anabat	369864	4673009
Lasiurus borealis	Eastern Red Bat	8/21/2011	Recording-Anabat	414983	4551603
Lasiurus cinereus	Hoary Bat	7/21/2011	Capture-mist net	372393	4682320
Lasiurus cinereus	Hoary Bat	8/22/2011	Capture-mist net	449339	4573253
Lasiurus cinereus	Hoary Bat	7/18/2011	Capture-mist net	345561	4672180
Lasiurus cinereus	Hoary Bat	6/28/2011	Capture-mist net	450997	4558334
Lasiurus cinereus	Hoary Bat	6/22/2011	Capture-mist net	465237	4566890
Lasiurus cinereus	Hoary Bat	6/23/2011	Capture-mist net	469220	4556660
Lasiurus cinereus	Hoary Bat	8/3/2011	Recording-Anabat	296769	4602087
Lasiurus cinereus	Hoary Bat	8/4/2011	Recording-Anabat	308675	4608786
Lasiurus cinereus	Hoary Bat	8/6/2011	Recording-Anabat	277076	4702332
Lasiurus cinereus	Hoary Bat	8/21/2011	Recording-Anabat	331081	4641562
Lasiurus cinereus	Hoary Bat	7/6/2011	Recording-Anabat	327490	4590447

Lasiurus cinereus	Hoary Bat	7/5/2011	Recording-Anabat	297264	4582951
Lasiurus cinereus	Hoary Bat	7/5/2011	Recording-Anabat	297416	4583677
Lasiurus cinereus	Hoary Bat	7/23/2011	Recording-Anabat	389015	4688993
Lasiurus cinereus	Hoary Bat	7/24/2011	Recording-Anabat	369864	4673009
Lasiurus cinereus	Hoary Bat	8/5/2011	Recording-Anabat	271116	4711970
Lasiurus cinereus	Hoary Bat	6/24/2011	Recording-Anabat	461089	4581959
Lasiurus cinereus	Hoary Bat	7/9/2011	Recording-Anabat	342224	4585136
Lasiurus cinereus	Hoary Bat	7/23/2011	Recording-Anabat	392966	4691619
Lasiurus cinereus	Hoary Bat	8/6/2011	Recording-Anabat	275358	4694592
Lasiurus cinereus	Hoary Bat	8/4/2011	Recording-Anabat	311442	4608089
Lasiurus cinereus	Hoary Bat	7/9/2011	Recording-Anabat	342362	4585431
Lasiurus cinereus	Hoary Bat	7/9/2011	Recording-Anabat	342391	4586162
Lasiurus cinereus	Hoary Bat	7/19/2011	Recording-Anabat	343925	4677604
Lasiurus cinereus	Hoary Bat	8/5/2011	Recording-Anabat	272447	4711766
Lasiurus cinereus	Hoary Bat	6/24/2011	Recording-Anabat	412918	4554038
Lasiurus cinereus	Hoary Bat	8/2/2011	Recording-Anabat	294873	4611960
Lasiurus cinereus	Hoary Bat	7/19/2011	Recording-Anabat	342042	4668317
Lasiurus cinereus	Hoary Bat	7/19/2011	Recording-Anabat	341943	4668498
Lasiurus cinereus	Hoary Bat	7/19/2011	Recording-Anabat	341620	4668498
Lasiurus cinereus	Hoary Bat	7/19/2011	Recording-Anabat	340939	4669590
Lasiurus cinereus	Hoary Bat	8/21/2011	Recording-Anabat	415428	4553265
Lasiurus cinereus	Hoary Bat	8/21/2011	Recording-Anabat	415095	4552907
Lasiurus cinereus	Hoary Bat	8/21/2011	Recording-Anabat	414983	4551603
Lasiurus cinereus	Hoary Bat	7/7/2011	Recording-Anabat	328919	4589389
Lasiurus cinereus	Hoary Bat	7/18/2011	Recording-Anabat	341441	4669410
Lasiurus cinereus	Hoary Bat	8/1/2011	Recording-Anabat	355807	4577040
Lasiurus cinereus	Hoary Bat	6/23/2011	Recording-Anabat	451036	4558319
Lasiurus cinereus	Hoary Bat	6/15/2011	Recording-Anabat	310549	4681335
Lasiurus cinereus	Hoary Bat	8/3/2011	Recording-Anabat & Song Meter	308204	4608620
Lasiurus cinereus	Hoary Bat	7/23/2011	Recording-Song Meter	393080	4691157
Lasiurus cinereus	Hoary Bat	7/21/2011	Recording-Song Meter	372393	4682320
Lasiurus cinereus	Hoary Bat	8/22/2011	Recording-Song Meter	465961	4545415
Lasiurus cinereus	Hoary Bat	8/4/2011	Recording-Song Meter	309474	4619358
Lasiurus cinereus	Hoary Bat	8/21/2011	Recording-Song Meter	469280	4625256
Lasiurus cinereus	Hoary Bat	7/18/2011	Recording-Song Meter	345337	4672092
Lasiurus cinereus	Hoary Bat	8/5/2011	Recording-Song Meter	278906	4693595
Myotis ciliolabrum	Western Small-footed Myotis	8/3/2011	Recording-Anabat	296769	4602087
Myotis ciliolabrum	Western Small-footed Myotis	8/4/2011	Recording-Anabat	308675	4608786
Myotis ciliolabrum	Western Small-footed Myotis	8/6/2011	Recording-Anabat	277076	4702332
Myotis ciliolabrum	Western Small-footed Myotis	8/21/2011	Recording-Anabat	331081	4641562
Myotis ciliolabrum	Western Small-footed Myotis	8/21/2011	Recording-Anabat	331463	4642617
Myotis ciliolabrum	Western Small-footed Myotis	7/6/2011	Recording-Anabat	327490	4590447
Myotis ciliolabrum	Western Small-footed Myotis	7/5/2011	Recording-Anabat	297264	4582951
Myotis ciliolabrum	Western Small-footed Myotis	7/5/2011	Recording-Anabat	297416	4583677

Myotis ciliolabrum	Western Small-footed Myotis	7/22/2011	Recording-Anabat	378659	4686717
Myotis ciliolabrum	Western Small-footed Myotis	7/6/2011	Recording-Anabat	327004	4590347
Myotis ciliolabrum	Western Small-footed Myotis	7/24/2011	Recording-Anabat	369864	4673009
Myotis ciliolabrum	Western Small-footed Myotis	8/5/2011	Recording-Anabat	271116	4711970
Myotis ciliolabrum	Western Small-footed Myotis	7/20/2011	Recording-Anabat	349562	4677205
Myotis ciliolabrum	Western Small-footed Myotis	6/24/2011	Recording-Anabat	461089	4581959
Myotis ciliolabrum	Western Small-footed Myotis	8/7/2011	Recording-Anabat	329426	4637886
Myotis ciliolabrum	Western Small-footed Myotis	8/1/2011	Recording-Anabat	349500	4590311
Myotis ciliolabrum	Western Small-footed Myotis	7/5/2011	Recording-Anabat	299142	4584239
Myotis ciliolabrum	Western Small-footed Myotis	7/7/2011	Recording-Anabat	328768	4589629
Myotis ciliolabrum	Western Small-footed Myotis	7/9/2011	Recording-Anabat	342224	4585136
Myotis ciliolabrum	Western Small-footed Myotis	7/22/2011	Recording-Anabat	382371	4685547
Myotis ciliolabrum	Western Small-footed Myotis	7/23/2011	Recording-Anabat	392966	4691619
Myotis ciliolabrum	Western Small-footed Myotis	8/22/2011	Recording-Anabat	465850	4545383
Myotis ciliolabrum	Western Small-footed Myotis	8/6/2011	Recording-Anabat	275358	4694592
Myotis ciliolabrum	Western Small-footed Myotis	8/4/2011	Recording-Anabat	311442	4608089
Myotis ciliolabrum	Western Small-footed Myotis	7/19/2011	Recording-Anabat	343925	4677604
Myotis ciliolabrum	Western Small-footed Myotis	8/5/2011	Recording-Anabat	272447	4711766
Myotis ciliolabrum	Western Small-footed Myotis	6/24/2011	Recording-Anabat	412918	4554038
Myotis ciliolabrum	Western Small-footed Myotis	7/19/2011	Recording-Anabat	341483	4669371
Myotis ciliolabrum	Western Small-footed Myotis	7/19/2011	Recording-Anabat	340939	4669590
Myotis ciliolabrum	Western Small-footed Myotis	7/19/2011	Recording-Anabat	340693	4669686
Myotis ciliolabrum	Western Small-footed Myotis	7/19/2011	Recording-Anabat	340425	4669566
Myotis ciliolabrum	Western Small-footed Myotis	8/4/2011	Recording-Anabat	297002	4602678
Myotis ciliolabrum	Western Small-footed Myotis	8/21/2011	Recording-Anabat	414921	4552028
Myotis ciliolabrum	Western Small-footed Myotis	8/21/2011	Recording-Anabat	414983	4551603
Myotis ciliolabrum	Western Small-footed Myotis	7/18/2011	Recording-Anabat	345561	4672180
Myotis ciliolabrum	Western Small-footed Myotis	7/20/2011	Recording-Anabat	347216	4671545
Myotis ciliolabrum	Western Small-footed Myotis	7/18/2011	Recording-Anabat	341441	4669410
Myotis ciliolabrum	Western Small-footed Myotis	7/19/2011	Recording-Anabat	347185	4671471
Myotis ciliolabrum	Western Small-footed Myotis	6/23/2011	Recording-Anabat	451036	4558319
Myotis ciliolabrum	Western Small-footed Myotis	6/10/2011	Recording-Anabat	308011	4684708
Myotis ciliolabrum	Western Small-footed Myotis	6/13/2011	Recording-Anabat	314737	4684002
Myotis ciliolabrum	Western Small-footed Myotis	6/15/2011	Recording-Anabat	311197	4681098
Myotis ciliolabrum	Western Small-footed Myotis	7/21/2011	Recording-Anabat & Song Meter	372393	4682320
Myotis ciliolabrum	Western Small-footed Myotis	8/3/2011	Recording-Anabat & Song Meter	308204	4608620
Myotis ciliolabrum	Western Small-footed Myotis	7/23/2011	Recording-Song Meter	393080	4691157
Myotis ciliolabrum	Western Small-footed Myotis	8/22/2011	Recording-Song Meter	465961	4545415
Myotis ciliolabrum	Western Small-footed Myotis	8/4/2011	Recording-Song Meter	309474	4619358
Myotis ciliolabrum	Western Small-footed Myotis	8/21/2011	Recording-Song Meter	469280	4625256
Myotis ciliolabrum	Western Small-footed Myotis	7/18/2011	Recording-Song Meter	345337	4672092
Myotis ciliolabrum	Western Small-footed Myotis	7/20/2011	Recording-Song Meter	340994	4670875
Myotis ciliolabrum	Western Small-footed Myotis	8/5/2011	Recording-Song Meter	278906	4693595
Myotis evotis	Western Long-eared Myotis	7/24/2011	Capture-mist net	369864	4673009

Myotis evotis	Western Long-eared Myotis	7/6/2011	Recording-Anabat	327490	4590447
Myotis evotis	Western Long-eared Myotis	7/5/2011	Recording-Anabat	297264	4582951
Myotis evotis	Western Long-eared Myotis	8/5/2011	Recording-Anabat	271116	4711970
Myotis evotis	Western Long-eared Myotis	6/24/2011	Recording-Anabat	461089	4581959
Myotis evotis	Western Long-eared Myotis	7/22/2011	Recording-Anabat	370378	4672612
Myotis evotis	Western Long-eared Myotis	7/5/2011	Recording-Anabat	299142	4584239
Myotis evotis	Western Long-eared Myotis	7/23/2011	Recording-Anabat	392966	4691619
Myotis evotis	Western Long-eared Myotis	8/22/2011	Recording-Anabat	465850	4545383
Myotis evotis	Western Long-eared Myotis	8/6/2011	Recording-Anabat	275358	4694592
Myotis evotis	Western Long-eared Myotis	8/3/2011	Recording-Anabat	308204	4608620
Myotis evotis	Western Long-eared Myotis	7/19/2011	Recording-Anabat	343925	4677604
Myotis evotis	Western Long-eared Myotis	8/5/2011	Recording-Anabat	272447	4711766
Myotis evotis	Western Long-eared Myotis	8/6/2011	Recording-Anabat	279018	4695815
Myotis evotis	Western Long-eared Myotis	7/20/2011	Recording-Anabat	347216	4671545
Myotis evotis	Western Long-eared Myotis	7/18/2011	Recording-Anabat	341441	4669410
Myotis evotis	Western Long-eared Myotis	6/28/2011	Recording-Anabat	450997	4558334
Myotis evotis	Western Long-eared Myotis	6/22/2011	Recording-Anabat	465237	4566890
Myotis evotis	Western Long-eared Myotis	6/23/2011	Recording-Anabat	469220	4556660
Myotis evotis	Western Long-eared Myotis	6/15/2011	Recording-Anabat	311197	4681098
Myotis evotis	Western Long-eared Myotis	6/15/2011	Recording-Anabat	310549	4681335
Myotis evotis	Western Long-eared Myotis	8/22/2011	Recording-Song Meter	465961	4545415
Myotis evotis	Western Long-eared Myotis	8/4/2011	Recording-Song Meter	309474	4619358
Myotis evotis	Western Long-eared Myotis	7/18/2011	Recording-Song Meter	345337	4672092
Myotis evotis	Western Long-eared Myotis	7/20/2011	Recording-Song Meter	340994	4670875
Myotis evotis	Western Long-eared Myotis	8/5/2011	Recording-Song Meter	278906	4693595
Myotis lucifugus	Little Brown Myotis	7/6/2011	Capture-mist net	327490	4590447
Myotis lucifugus	Little Brown Myotis	7/24/2011	Capture-mist net	369864	4673009
Myotis lucifugus	Little Brown Myotis	8/5/2011	Capture-mist net	271116	4711970
Myotis lucifugus	Little Brown Myotis	7/21/2011	Capture-mist net	372393	4682320
Myotis lucifugus	Little Brown Myotis	8/3/2011	Capture-mist net	308204	4608620
Myotis lucifugus	Little Brown Myotis	8/22/2011	Capture-mist net	449339	4573253
Myotis lucifugus	Little Brown Myotis	7/18/2011	Capture-mist net	345561	4672180
Myotis lucifugus	Little Brown Myotis	6/28/2011	Capture-mist net	450997	4558334
Myotis lucifugus	Little Brown Myotis	6/22/2011	Capture-mist net	465237	4566890
Myotis lucifugus	Little Brown Myotis	6/23/2011	Capture-mist net	469220	4556660
Myotis lucifugus	Little Brown Myotis	8/3/2011	Recording-Anabat	296769	4602087
Myotis lucifugus	Little Brown Myotis	8/6/2011	Recording-Anabat	277442	4703673
Myotis lucifugus	Little Brown Myotis	8/6/2011	Recording-Anabat	277255	4703299
Myotis lucifugus	Little Brown Myotis	8/6/2011	Recording-Anabat	277033	4702672
Myotis lucifugus	Little Brown Myotis	8/6/2011	Recording-Anabat	277076	4702332
Myotis lucifugus	Little Brown Myotis	8/6/2011	Recording-Anabat	277071	4702003
Myotis lucifugus	Little Brown Myotis	8/6/2011	Recording-Anabat	277067	4701685
Myotis lucifugus	Little Brown Myotis	8/21/2011	Recording-Anabat	330815	4640829
Myotis lucifugus	Little Brown Myotis	8/21/2011	Recording-Anabat	415787	4543954

Myotis lucifugus	Little Brown Myotis	7/6/2011	Recording-Anabat	327490	4590447
Myotis lucifugus	Little Brown Myotis	7/5/2011	Recording-Anabat	297264	4582951
Myotis lucifugus	Little Brown Myotis	7/5/2011	Recording-Anabat	297416	4583677
Myotis lucifugus	Little Brown Myotis	7/23/2011	Recording-Anabat	389015	4688993
Myotis lucifugus	Little Brown Myotis	7/22/2011	Recording-Anabat	378659	4686717
Myotis lucifugus	Little Brown Myotis	7/6/2011	Recording-Anabat	327004	4590347
Myotis lucifugus	Little Brown Myotis	7/20/2011	Recording-Anabat	349562	4677205
Myotis lucifugus	Little Brown Myotis	6/24/2011	Recording-Anabat	461089	4581959
Myotis lucifugus	Little Brown Myotis	8/7/2011	Recording-Anabat	329426	4637886
Myotis lucifugus	Little Brown Myotis	8/1/2011	Recording-Anabat	349500	4590311
Myotis lucifugus	Little Brown Myotis	7/7/2011	Recording-Anabat	328768	4589629
Myotis lucifugus	Little Brown Myotis	7/9/2011	Recording-Anabat	342224	4585136
Myotis lucifugus	Little Brown Myotis	7/22/2011	Recording-Anabat	382371	4685547
Myotis lucifugus	Little Brown Myotis	7/23/2011	Recording-Anabat	392966	4691619
Myotis lucifugus	Little Brown Myotis	8/22/2011	Recording-Anabat	465850	4545383
Myotis lucifugus	Little Brown Myotis	8/6/2011	Recording-Anabat	275358	4694592
Myotis lucifugus	Little Brown Myotis	7/9/2011	Recording-Anabat	342362	4585431
Myotis lucifugus	Little Brown Myotis	7/9/2011	Recording-Anabat	342391	4586162
Myotis lucifugus	Little Brown Myotis	7/19/2011	Recording-Anabat	343925	4677604
Myotis lucifugus	Little Brown Myotis	8/5/2011	Recording-Anabat	272447	4711766
Myotis lucifugus	Little Brown Myotis	6/24/2011	Recording-Anabat	412918	4554038
Myotis lucifugus	Little Brown Myotis	7/7/2011	Recording-Anabat	328808	4589156
Myotis lucifugus	Little Brown Myotis	8/2/2011	Recording-Anabat	295121	4612141
Myotis lucifugus	Little Brown Myotis	8/6/2011	Recording-Anabat	279018	4695815
Myotis lucifugus	Little Brown Myotis	8/6/2011	Recording-Anabat	279202	4694896
Myotis lucifugus	Little Brown Myotis	8/6/2011	Recording-Anabat	278325	4694580
Myotis lucifugus	Little Brown Myotis	8/6/2011	Recording-Anabat	278487	4694291
Myotis lucifugus	Little Brown Myotis	7/19/2011	Recording-Anabat	341685	4669262
Myotis lucifugus	Little Brown Myotis	7/19/2011	Recording-Anabat	341483	4669371
Myotis lucifugus	Little Brown Myotis	7/19/2011	Recording-Anabat	341943	4668498
Myotis lucifugus	Little Brown Myotis	7/19/2011	Recording-Anabat	341220	4669430
Myotis lucifugus	Little Brown Myotis	7/19/2011	Recording-Anabat	340939	4669590
Myotis lucifugus	Little Brown Myotis	7/19/2011	Recording-Anabat	340693	4669686
Myotis lucifugus	Little Brown Myotis	7/19/2011	Recording-Anabat	340425	4669566
Myotis lucifugus	Little Brown Myotis	8/21/2011	Recording-Anabat	329069	4637415
Myotis lucifugus	Little Brown Myotis	8/21/2011	Recording-Anabat	329292	4637700
Myotis lucifugus	Little Brown Myotis	8/21/2011	Recording-Anabat	415428	4553265
Myotis lucifugus	Little Brown Myotis	8/21/2011	Recording-Anabat	414983	4551603
Myotis lucifugus	Little Brown Myotis	7/7/2011	Recording-Anabat	328919	4589389
Myotis lucifugus	Little Brown Myotis	7/20/2011	Recording-Anabat	347216	4671545
Myotis lucifugus	Little Brown Myotis	7/18/2011	Recording-Anabat	341441	4669410
Myotis lucifugus	Little Brown Myotis	7/19/2011	Recording-Anabat	347185	4671471
Myotis lucifugus	Little Brown Myotis	8/1/2011	Recording-Anabat	355807	4577040
Myotis lucifugus	Little Brown Myotis	6/23/2011	Recording-Anabat	451036	4558319

Myotis lucifugus	Little Brown Myotis	6/22/2011	Recording-Anabat	465196	4566830
Myotis lucifugus	Little Brown Myotis	6/9/2011	Recording-Anabat	308553	4684854
Myotis lucifugus	Little Brown Myotis	6/13/2011	Recording-Anabat	314737	4684002
Myotis lucifugus	Little Brown Myotis	6/15/2011	Recording-Anabat	311197	4681098
Myotis lucifugus	Little Brown Myotis	6/15/2011	Recording-Anabat	310549	4681335
Myotis lucifugus	Little Brown Myotis	7/23/2011	Recording-Song Meter	393080	4691157
Myotis lucifugus	Little Brown Myotis	8/22/2011	Recording-Song Meter	465961	4545415
Myotis lucifugus	Little Brown Myotis	8/4/2011	Recording-Song Meter	309474	4619358
Myotis lucifugus	Little Brown Myotis	8/21/2011	Recording-Song Meter	469280	4625256
Myotis lucifugus	Little Brown Myotis	7/18/2011	Recording-Song Meter	345337	4672092
Myotis lucifugus	Little Brown Myotis	7/20/2011	Recording-Song Meter	340994	4670875
Myotis lucifugus	Little Brown Myotis	8/5/2011	Recording-Song Meter	278906	4693595
Myotis thysanodes	Fringed Myotis	7/24/2011	Recording-Anabat	369864	4673009
Myotis thysanodes	Fringed Myotis	7/20/2011	Recording-Anabat	349562	4677205
Myotis thysanodes	Fringed Myotis	7/22/2011	Recording-Anabat	370378	4672612
Myotis thysanodes	Fringed Myotis	7/19/2011	Recording-Anabat	343925	4677604
Myotis thysanodes	Fringed Myotis	7/18/2011	Recording-Anabat	345561	4672180
Myotis thysanodes	Fringed Myotis	7/18/2011	Recording-Anabat	341441	4669410
Myotis thysanodes	Fringed Myotis	7/19/2011	Recording-Anabat	347185	4671471
Myotis thysanodes	Fringed Myotis	6/28/2011	Recording-Anabat	450997	4558334
Myotis thysanodes	Fringed Myotis	6/23/2011	Recording-Anabat	469220	4556660
Myotis thysanodes	Fringed Myotis	6/13/2011	Recording-Anabat	314737	4684002
Myotis thysanodes	Fringed Myotis	6/15/2011	Recording-Anabat	311197	4681098
Myotis thysanodes	Fringed Myotis	6/15/2011	Recording-Anabat	310549	4681335
Myotis thysanodes	Fringed Myotis	8/22/2011	Recording-Song Meter	465961	4545415
Myotis thysanodes	Fringed Myotis	8/4/2011	Recording-Song Meter	309474	4619358
Myotis volans	Long-legged Myotis	7/24/2011	Capture-mist net	369864	4673009
Myotis volans	Long-legged Myotis	7/21/2011	Capture-mist net	372393	4682320
Myotis volans	Long-legged Myotis	6/23/2011	Capture-mist net	469220	4556660
Myotis volans	Long-legged Myotis	8/3/2011	Recording-Anabat	296769	4602087
Myotis volans	Long-legged Myotis	8/21/2011	Recording-Anabat	330815	4640829
Myotis volans	Long-legged Myotis	8/21/2011	Recording-Anabat	331081	4641562
Myotis volans	Long-legged Myotis	7/6/2011	Recording-Anabat	327490	4590447
Myotis volans	Long-legged Myotis	7/23/2011	Recording-Anabat	389015	4688993
Myotis volans	Long-legged Myotis	7/22/2011	Recording-Anabat	378659	4686717
Myotis volans	Long-legged Myotis	7/6/2011	Recording-Anabat	327004	4590347
Myotis volans	Long-legged Myotis	8/5/2011	Recording-Anabat	271116	4711970
Myotis volans	Long-legged Myotis	6/24/2011	Recording-Anabat	461089	4581959
Myotis volans	Long-legged Myotis	8/7/2011	Recording-Anabat	329426	4637886
Myotis volans	Long-legged Myotis	8/1/2011	Recording-Anabat	349500	4590311
Myotis volans	Long-legged Myotis	7/5/2011	Recording-Anabat	299142	4584239
Myotis volans	Long-legged Myotis	7/7/2011	Recording-Anabat	328768	4589629
Myotis volans	Long-legged Myotis	7/9/2011	Recording-Anabat	342224	4585136
Myotis volans	Long-legged Myotis	7/22/2011	Recording-Anabat	382371	4685547

Myotis volans	Long-legged Myotis	7/23/2011	Recording-Anabat	392966	4691619
Myotis volans	Long-legged Myotis	7/21/2011	Recording-Anabat	372393	4682320
Myotis volans	Long-legged Myotis	8/6/2011	Recording-Anabat	275358	4694592
Myotis volans	Long-legged Myotis	8/4/2011	Recording-Anabat	311442	4608089
Myotis volans	Long-legged Myotis	7/19/2011	Recording-Anabat	343925	4677604
Myotis volans	Long-legged Myotis	8/5/2011	Recording-Anabat	272447	4711766
Myotis volans	Long-legged Myotis	7/7/2011	Recording-Anabat	328808	4589156
Myotis volans	Long-legged Myotis	7/19/2011	Recording-Anabat	341483	4669371
Myotis volans	Long-legged Myotis	7/19/2011	Recording-Anabat	341220	4669430
Myotis volans	Long-legged Myotis	7/19/2011	Recording-Anabat	340939	4669590
Myotis volans	Long-legged Myotis	7/19/2011	Recording-Anabat	340693	4669686
Myotis volans	Long-legged Myotis	8/21/2011	Recording-Anabat	414921	4552028
Myotis volans	Long-legged Myotis	7/18/2011	Recording-Anabat	345561	4672180
Myotis volans	Long-legged Myotis	7/20/2011	Recording-Anabat	347216	4671545
Myotis volans	Long-legged Myotis	7/18/2011	Recording-Anabat	341441	4669410
Myotis volans	Long-legged Myotis	7/19/2011	Recording-Anabat	347185	4671471
Myotis volans	Long-legged Myotis	8/1/2011	Recording-Anabat	355807	4577040
Myotis volans	Long-legged Myotis	6/23/2011	Recording-Anabat	451036	4558319
Myotis volans	Long-legged Myotis	6/28/2011	Recording-Anabat	450997	4558334
Myotis volans	Long-legged Myotis	6/22/2011	Recording-Anabat	465237	4566890
Myotis volans	Long-legged Myotis	6/22/2011	Recording-Anabat	465196	4566830
Myotis volans	Long-legged Myotis	6/9/2011	Recording-Anabat	308553	4684854
Myotis volans	Long-legged Myotis	6/10/2011	Recording-Anabat	308011	4684708
Myotis volans	Long-legged Myotis	6/13/2011	Recording-Anabat	314737	4684002
Myotis volans	Long-legged Myotis	6/15/2011	Recording-Anabat	311197	4681098
Myotis volans	Long-legged Myotis	6/15/2011	Recording-Anabat	310549	4681335
Myotis volans	Long-legged Myotis	8/22/2011	Recording-Song Meter	465961	4545415
Myotis volans	Long-legged Myotis	8/3/2011	Recording-Song Meter	308204	4608620
Myotis volans	Long-legged Myotis	8/5/2011	Recording-Song Meter	278906	4693595

APPENDIX E: WYOMING BAT SPECIES IDENTIFICATION KEY

Key to the Bats of Wyoming

Doug Keinath, WYNDD Zoologist

#	If this is true …	… then go to …
1a	Tail extends 1/3 or more beyond rear edge of uropatagium.	2
1b	Tail does not extend more than barely beyond rear edge of uropatagium	3
2a	Forearm > 50mm. [Large bat. Ears join at forehead. Pale-brown to black fur.]	Nyctinomops macrotus
2b	Forearm < 50mm. [Smallish bat. Ears almost joined at forehead. Gray-brown fur.]	Tadarida brasiliensis
3a	Conspicuous pair of white spots on shoulders and one on rump contrast with black dorsal fur. Pink ears.	Euderma maculatum
3b	Lacks white dorsal spots.	4
4a	At least anterior half of dorsal surface of uropatagium heavily furred.	5
4b	Dorsal surface of uropatagium mostly naked or scantily furred.	7
5a	Distinct white patches of fur at dorsal bases of thumbs and often on shoulders. Dorsal surface of uropatagium fully furred.	6
5b	No white patches of fur at dorsal bases of thumbs or on shoulders. Dorsal surface of uropatagium ranging from half to fully furred. Black dorsal fur with silver tips. Black face and uropatagium.	Lasionycteris noctivagans
6a	Light colored ear distinctively edged in black. Dorsal hairs dark gray and tipped with a broad band of white giving a hoary colored appearance. Forearm 46-58mm.	Lasiurus cinereus
6b	Light colored ear never edged in black. Fur bright reddish-orange to yellow in males and tending toward light brownish – grayish in females. Dorsal hairs never dark gray and tipped with white, though possibly frosted. Forearm 35-45mm.	Lasiurus borealis
7a	Dorsal fur lighter at base (pale yellow-blond) than tips (brown). Pale translucent ears 25-33mm long. Forearm 50-55mm. Blunt snout.	Antrozous pallidus
7b	Dorsal fur darker at base than tips. Fur color, ear and forearm lengths highly variable.	8
8a	Prominent pair of lumps above nose on each side of muzzle (see picture). Ear length 30-39mm. Slate-gray fur.	Corynorhinus townsendii
8b	No lumps on nose.	9
9a	Very small bat (mass ≤ 6g; forearm usu. < 33mm). Tragus relatively short and not sharply pointed.	10
9b	Larger (mass > 6g; forearm usu. > 33mm). Tragus longer and somewhat pointed.	11
10a	Small-bodied (3-6g). Tragus short (<5mm), blunt, and club-shaped. Body fur medium to pale brown in contrast to jet black face and ears. Tail membrane sparsely furred on anterior third of dorsal surface. Forearm 27-33mm.	Pipistrellus Hesperus
10b	Hair distinctively tricolored (dark base / light middle / dark tip). Lighter ears and no distinct face mask. Leading edge of wing noticeably paler than rest of membrane. Forearm 30-35mm.	Pipistrellus subflavus
11a	Large, medium to dark brown with keeled calcar. First upper premolar ≥ ½ canine length (see Fig. 11a). Forearm 42-51mm (wingspan 325-350mm). Tragus rounded.	Eptesicus fuscus
11b	Smallish bat. First upper premolar less than ¼ as tall as canine (see Fig. 11b).	12 (myotis spp.)

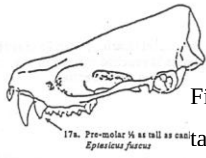


Fig. 11a. First upper premolar ½ as tall as canine (*Eptesicus fuscus*)

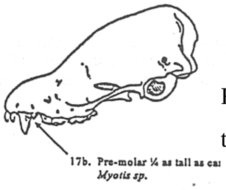


Fig. 11b. First upper premolar < ¼ as tall as canine (*Myotis spp.*)

Myotis species

#	**If this is true …**	**… then go to …**
12a	Calcar keeled. (see Fig. 12a)	13
12b	Calcar NOT keeled. (see Fig. 12b)	15

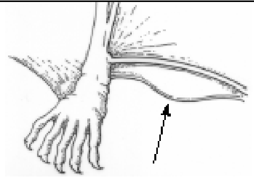


Fig. 12a. Keeled calcar (go to 12)

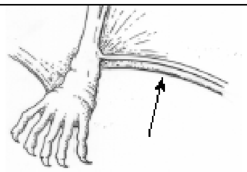


Fig. 12b. Keel absent (go to 14)

Keeled calcar

13a	Forearm 38-42mm (wingspan 250-270mm). Body fur uniformly dark brown or grayish brown with no distinctively darker face mask. [Underside of wing furred from side to elbow.]	Myotis volans
13b	Forearm 29-36mm. Body fur medium to very light tan or reddish brown with clearly darker face mask. [Underside of wing not furred from side to elbow.]	14

14a	Thumb length < 4.2mm. Tail does NOT extend beyond uropatagium. Braincase has an abruptly rising profile (convex forehead). Length of bare snout ≈ width across nostrils. Dorsal fur dull, pale colored, with slightly-contrasting dark brown face mask.(Fig. 14a)	Myotis californicus
14b	Thumb length > 4.2mm. Tail often extends slightly beyond uropatagium. No distinct rise in braincase profile (sloping forehead). Length across snout ≈ 1.5 times width across nostrils. Dorsal fur slightly shiny, pale colored, and sharply contrasting with black face mask. (Fig. 14b)	Myotis ciliolabrum

Fig. 14a. *M. californicus:* Rising braincase. Length of bare snout ≈ width across nostrils.

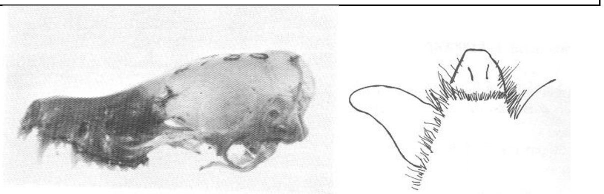


Fig 14b. *M.ciliolabrum*: Shallow braincase. Length across snout ≈ 1.5 times width across nostrils

Long Ears

15a	Distinct fringe of hair extending 1.0-1.5mm beyond edge of uropatagium (picture). Ears darkly pigmented and 16-20mm long. Belly fur light. Forearm 39-46mm.	Myotis thysanodes
15b	Fringe absent (no more than scattered hairs on edge of uropatagium).	16

16a	Ear length ≥17mm.	17
16b	Ear length ≤ 16mm.	18

17a	Ears, wings, and uropatagium are blackish and opaque. Ear length 17-24mm (WY: 17-23mm, but usu. ~20mm). Ears extend past end of nose when laid down. Fur light brown with hairs black at base. [May have an inconspicuous fringe of hairs on the posterior uropatagium.]	Myotis evotis
17b	Ears, wings, and uropatagium are brownish and translucent. Ear length 15-19mm (WY: 15-16mm).	Myotis septentrionalis

18a	Dorsal body fur brown to reddish-brown, long and glossy. Forearm usually 36.5-40.5mm (BC Range: 33.0-40.3mm). Ears dark, 14-16mm long, with short tragus.	Myotis lucifugus

	Forehead with a gradual slope (Fig. 18a), skull usually greater than 14mm. Ventral fur light-tipped but never white. Many foot hairs extend beyond toes.	
18b	Dorsal body fur brown to reddish-brown, short and dull. Forearm usually 32-36mm (BC Range: 30.0-38.0mm). Ears paler, 12-14mm long. Forehead with steep slope (Fig. 18b), skull usually less than 14mm. Ventral fur with whitish tips.	Myotis yumanensis

Fig. 18a. *M. lucifugus*: Forehead with gradual slope

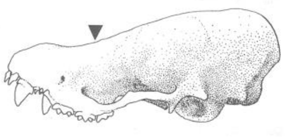
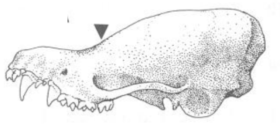
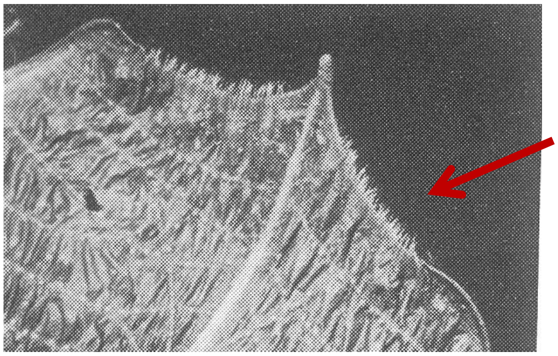
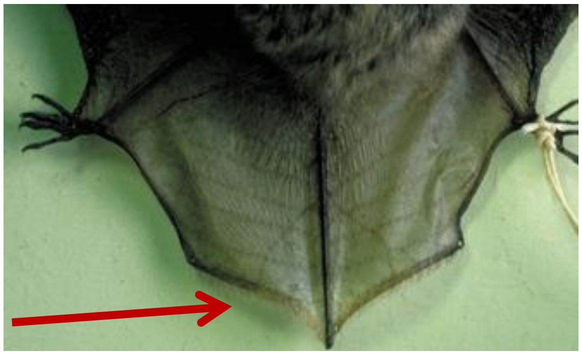


Fig. 18b. *M. yumanensis*: Forehead with steep slope



Supplementary Images for the Wyoming Bat Key

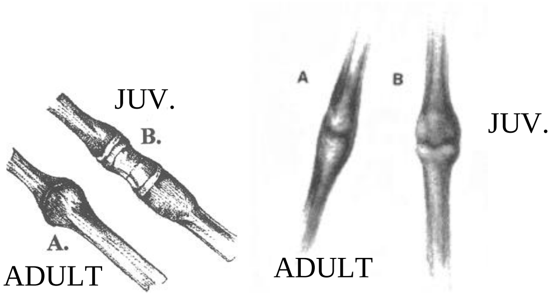




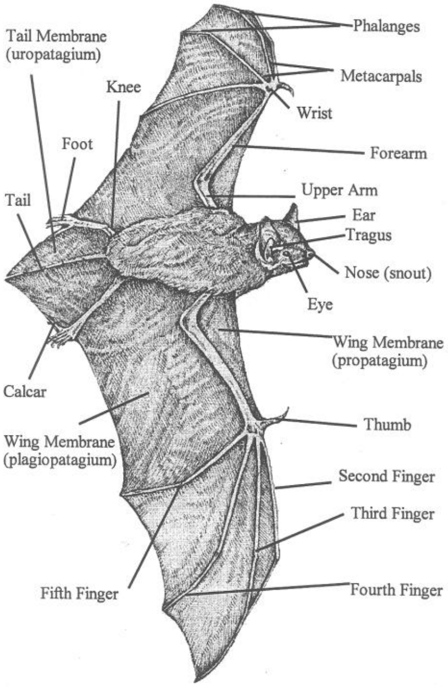
Uropatagial fringe of *Myotis thysanodes*

Face and tragus of *P. hesperus*

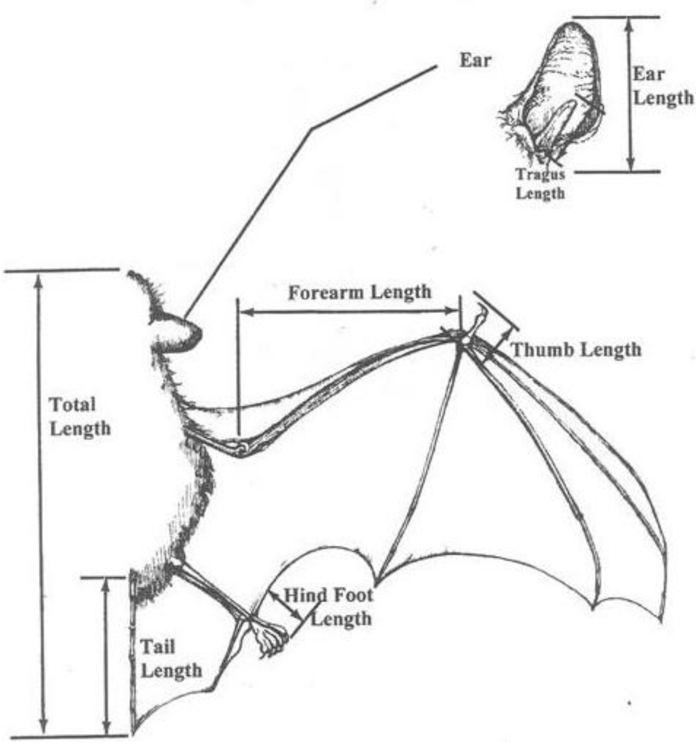
Nose folds of *C. townsendii*



Finger joint of juvenile (tapered, epiphesial plates visible) and adult (nobby and opaque) finger joints, as seen by illuminating the wing from behind (From Nagorsen and Brigham, 1993)



Bat Anatomy (from AZ bat conservation workshop)



Standard Bat Measurements (from The Bats of Texas)

APPENDIX F: WYOMING ANABAT CALL KEY

Wyoming ANABAT Call Key (2011 DRAFT)

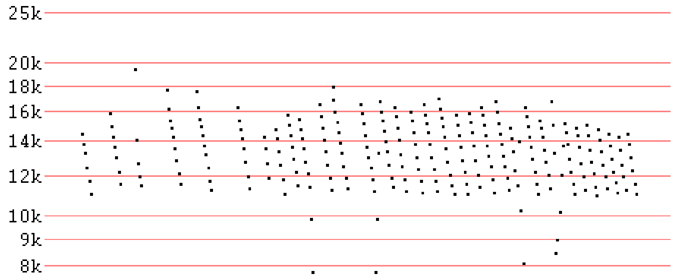
***Developed by** Douglas A. Keinath*

Wyoming Natural Diversity Database, Laramie, Wyoming

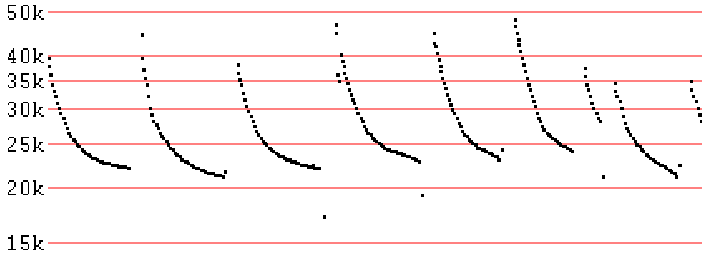
NOTE: Anabat® is a system designed to help users find and identify echolocating bats by digitally recording those calls and plotting them on a computer (for more information see: http://users.lmi.net/corben/anabat.htm #Anabat%20Contents). Before employing this key, users should be familiar with general principals of call analysis (e.g., http://users.lmi.net/corben/glossary.htm #Glossary). With such background information, this key can be used to roughly classify calls. Questionable calls, calls of difficult to distinguish species, or calls that represent new occurrences in an area should always be viewed by local Anabat® experts. In Wyoming, people should contact the Wyoming Natural Diversity Database (Doug Keinath) or the Wyoming Game and Fish Department (Martin Grenier).

Fmin (kHz)	**Description**	**ID**
< 10	1. Calls steep and sparse. Usually beginning above 10 and ending below 8. Calls can be heard audibly with unaided ear; sounds like two pebbles being struck together.	EUMA
16 – 20	2. Calls usually low slope & can be hook-shaped. Calls tend to jump around in Fmin, but typically ~20k or lower. Calls tend to vary in curvature throughout the sequence. Often give several calls at a higher freq, but with same shape.	LACI
~ 25	Fmin ~25 and with distinct tail. Two possibilities (LANO or EPFU), which are difficult to distinguish from each other, especially in clutter. Many call files must be reported simply as “**aB25k**”	a25k
	3. Calls are more bilinear than EPFU. Slope of tail is more variable than EPFU. Min Δslope often ~10 and Δslope plots usually “dribble off” rather than forming “fish-hook” ends. Calls rarely fall below 25k. Calls very regularly spaced (“metronome”).	LANO
	4. Calls are more curvilinear than LANO, but can be more bilinear when they are short in sweep (i.e., ~25-40). Slope of tail is very consistent. On flat calls, Δslope plots may show many calls with “fish-hook” ends. Fmin often not uniform, with some calls falling below 25k. Calls sometimes irregularly spaced (“heart beat”).	EPFU

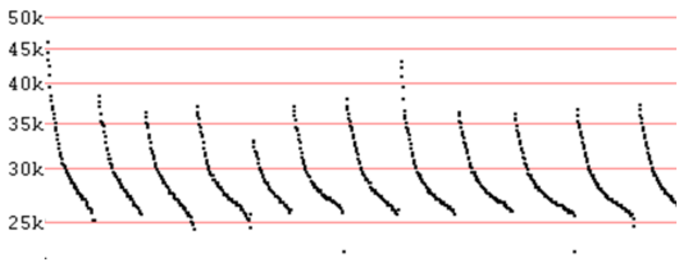
1. EUMA (Div16, F7)



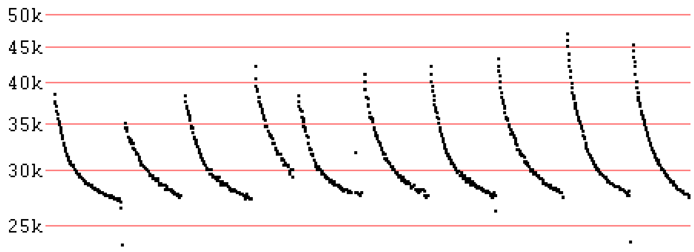
2. LACI (Div16, F7; stock file)



3. LANO (Div16, F6)

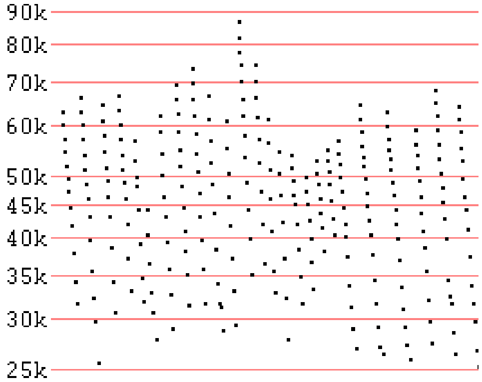


4. EPFU (Div16, F6)

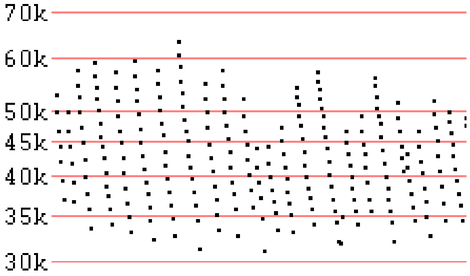


Fmin (kHz)	**Description**	**ID**
~ 25 - 30	F-min 25 – 30 and calls very steep with little tail. Four possibilities (MYTH, MYEV, COTO, ANPA). If sequences are not long and clean, many of these can be difficult to tell apart and must then be reported simply as "**aB30k**".	aB30k
	5. Calls very steep (Δslope ≥ 100) with huge freq. range (usu. > 50 and up to 20-100 in same call) and no tail. Variable Fmin with some calls usu. dropping to or below 25.	MYTH
	6. Calls very steep (Δslope usu > 150; often 300) and very sparse, with no tail. Fmin usu ~35, but varies within sequence, seldom dropping below 30. Freq range usu ~30.	MYEV
	7. Calls steep, but often slightly more curved than MYTH or MYEV and somewhat "thicker". Very little tail, but sometime "dribbling off" in a "lazy S" shape. Fmin ~30k and Fmax ≥50. Can also be difficult to tell from EPFU in clutter, which will usu. have time between calls of <100ms	ANPA
	8. Calls steep, weak, have ***two harmonics***. Fmin usu ~30, but can be ≤25. Harmonic-break often bet. 40-50. Sometimes only one harmonic captured: Upper can look like 50k myotis; lower can look like steep 25k getting thinner at tail	COTO
	9. Unique in its variability; calls vary between flat to steep in same sequence. Flat calls usually sweep 28-25 kHz, while steep usually sweep 60-27kHz. <u>Behavior</u>: open habitat, flying straight for moths and large insects.	TABR

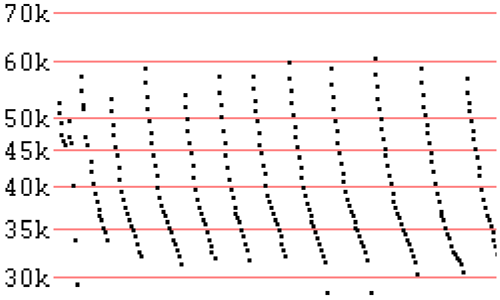
5. MYTH (Div16, F7)



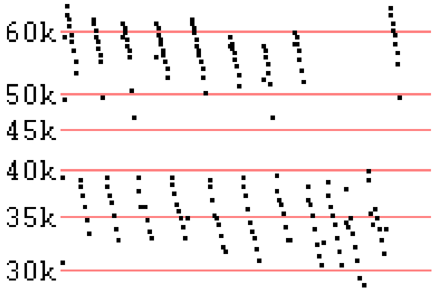
6. MYEV (Div16, F7)



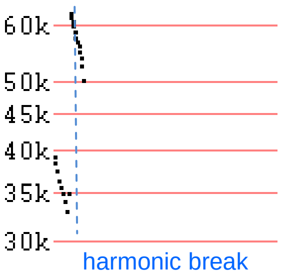
7. ANPA (Div16, F7)



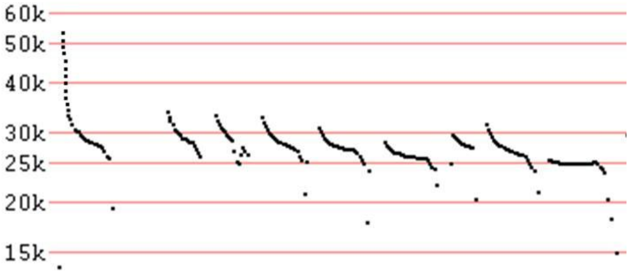
8a. COTO
(Div16, F7, compressed)

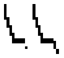


8b. COTO
(Div16, F7, real-time)

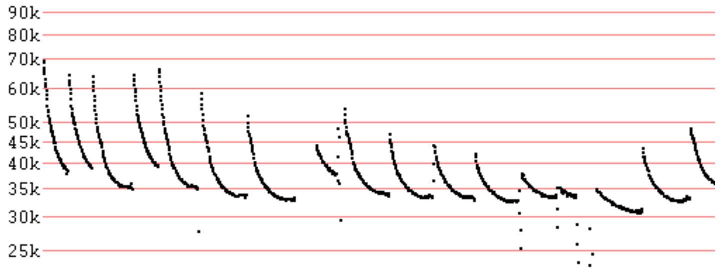


9. TABR
(Div16, F7, stock file)

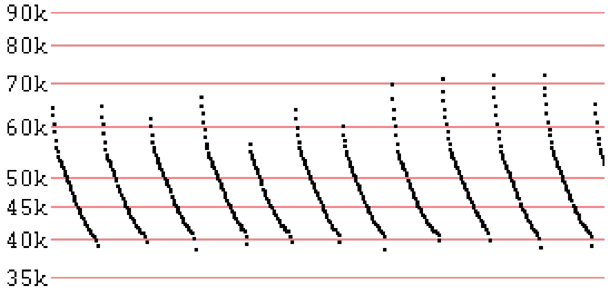


Fmin (kHz)	**Description**	**ID**
~ 27 - 35	10. Calls increases in frequency at end, creating a slight hook shape (like hoary bat). Calls sweep steeply from over 50k to just below 40k, with numerous calls often shifted downward so Fmin can be as low as 27k.	LABO
~ 40	Fmin usually at 40k, with some potentially falling above or below. Four possibilities (MYLU, MYCI, MYSE, MYVO). 40k myotis are very difficult to distinguish from each other, especially in clutter. Many call files must be reported simply as “**aM40k**”.	aM40k
	11. Gently curved slope throughout call (but often get more bilinear in clutter and may “dribble off” at the end). Clean calls often sweep from ~100 to just over 40. On clean calls, Δslopemin can be as low as 40, but usually higher. Sometimes alternate curved call with a more linear one. Behavior: MYLU classically feed over water, which can result in “wobbly” calls.”	MYLU
	12. Calls steep and regularly have a small “toe” at or just before the end, resulting in a “golfclub” or “S” shaped call. Even with a toe, calls usually have Δslopemin near 80. Clean calls usually straighter than MYLU, but can be more curvilinear than MYVO. Calls can have a wobble in the middle of the call (usually ≤50k). Behavior: MYCI feed around vegetation, like MYCA.	MYCI 
	13. Calls look similar to MYEV, but lower frequency limit is roughly 40kHz. Calls typically sweep from 80kHz to just over 40kHz. Clean calls are straighter than MYLU and MYCI and less vertical than MYVO. Behavior: MYSE feed around vegetation, often forests, gleaning and aerially pursuing insects.	MYSE
	14. Calls steep often with “wiggly look”; like MYLU in clutter, but greater call spacing. Calls tend to be more linear (or bilinear) than MYLU and have less “toe” than MYCI. Calls can have a wobble high in the sweep (usually ≥50k). Δslope is usually high (~100) but can drop to ~60. Difficult to distinguish from other 40k myotis	MYVO

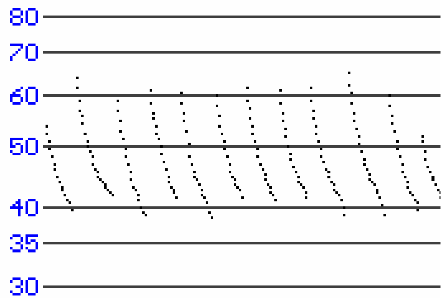
10. LABO (Div8, F7)



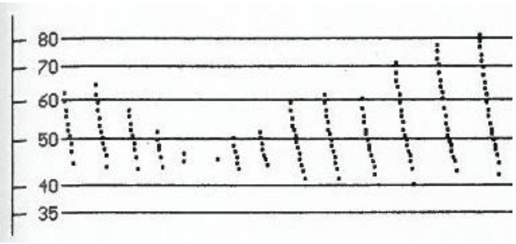
11. MYLU (Div16, F7)



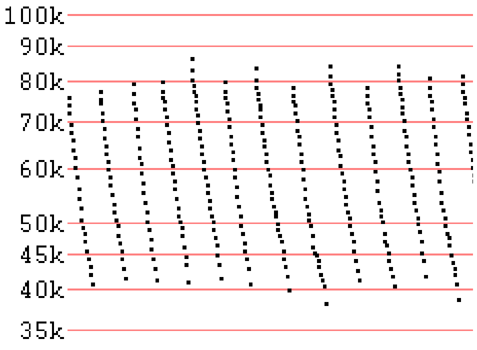
12. MYCI (Div16, F7)



13. MYSE (from Adams 2003)

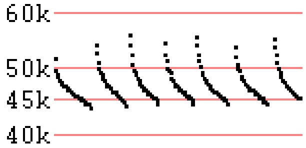


14. MYVO (Div 16, F7)

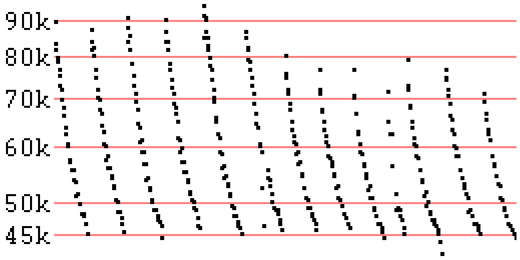


Fmin (kHz)	Description	ID
~50	15. Usually starting around 50 and often ending below (~45). Thick calls with flat tails often with a drooping tail. Duration>5.0ms.	PEHE
~ 50	Steeper than PIHE and usu. Fmin at or just below 50k. Single calls can drop to 40k, but not whole series (consistently above 43k). Difficult to distinguish from each other, especially in clutter, and many must be reported simply as "**aM50k**".	aM50k
	16. Often show calls dropping below 50k (~45k). Call shape similar to MYLU, but thicker tail. Calls often "dribble-off", rather than having constant toes. Dribble calls can have Δslope down to 40. In a series, there is often one call that is flatter than the rest. *Behavior*: MYYU often feed over water.	MYYU
	17. Calls frequently have a flat "toe" at the end, rather than dribbling off. Toed calls usually have Min. Δslope of 30ish. "Dribbling calls" usually have Min. Δslope greater than MYYU (i.e., above 40). Behavior: MYCA typically feed by hugging vegetation.	MYCA

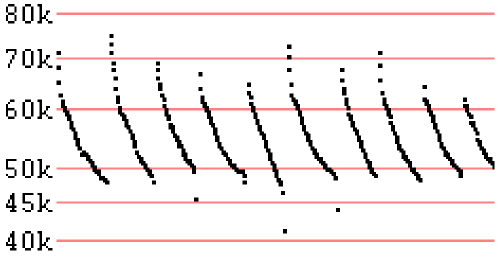
14. PEHE (Div16, F7)



15. MYCA (Div16, F7)



16. MYYU (Div 16, F7)



APPENDIX G: 2011 BLANK DATASHEETS

ANABAT / SONGMETER RECORDING FORM

(307-766-3013; P.O. Box 3381, UW, WYNDD, Laramie, WY 82071)

SITE INFORMATION

Site Name:		**Location (eg. drainage, Hwy):**	
Date:	**Elevation (m):**	**County:**	**Land Owner:**
GPS EPE (m):	**CF Card #:**	**UTM Zone/GPS Datum:**	
Observer Names:			
GPS Location of recording unit (UTM): Easting __________________________; Northing ______________________________			

BAT CALL DOWNLOAD

Download Date:______________________	**Download Location &Folder Name:____**

HABITAT

Site Description:	
Type of habitat where mistnet or recorder placed (choose from below):	
Type of habitat in the surrounding 2 km (choose from below):	
Distance to nearest rock outcrop/cliff:________________**m**	**Distance to nearest open water**:_________________**m**
Distance to nearest conifer stand:________________**m**	**Distance to nearest deciduous tree stand**:________________**m**

SESSION INFORMATION: ANABAT/SONGMETER

Date (mm/dd/yy):	**Time of civil sunset** (24hr):	**Phase of Moon:**
Time Activated:	**Time deactivated** (24hr):	
Division Ratio:	**Sensitivity/Sample Rate:**	**Height above Ground:**

ANABAT Configuration: Sketch (grid cell size: _________m)   Notes

ACOUSTIC ANALYSIS (call file # is of a representative call for that spp)

Species 1 (call file#):	**# of calls:**	**Species 5 (call file#):**	**# of calls:**
Species 2 (call file#):	**# of calls:**	**Species 6 (call file#):**	**# of calls:**
Species 3 (call file#):	**# of calls:**	**Comments:**	
Species 4 (call file#):	**# of calls:**		

Habitat Types
1. Shrubland/ shrub steppe
2. Grassland
3. Wetland/ open water
4. Rock outcrop
5. Cliff (canyon, mountain)
6. Cave
7. Conifer forest
8. Deciduous forest
9. Foothills chaparral
10. Riparian shrub (ex. willows)
11. Badlands
12. Disturbed/ reclaimed/ mined/ oil & gas

MISTNETTING FORM

(307-766-3013; P.O. Box 3381, UW, WYNDD, Laramie, WY 82071)

SITE INFORMATION

Site Name:		**Location (eg. drainage, Hwy):**	
Date:	**Elevation (m):**	**County:**	**Land Owner:**
GPS EPE (m):	**CF Card #:**	**UTM Zone/GPS Datum:**	
Observer Names:			
GPS Location of recording unit (UTM): Easting _________________________; Northing ____________________________			

BAT CALL DOWNLOAD

Download Date:______________________	**Download Location &Folder Name:____**

HABITAT

Site Description:	
Type of habitat where mistnet or recorder placed (choose from below):	
Type of habitat in the surrounding 2 km (choose from below):	
Distance to nearest rock outcrop/cliff:_______________**m**	**Distance to nearest open water**:________________**m**
Distance to nearest conifer stand:_______________**m**	**Distance to nearest deciduous tree stand**:_______________**m**

SESSION INFORMATION:

Date (mm/dd/yy):	**Time of civil sunset** (24hr):	**Phase of Moon:**
Time Nets Open (24 hr):	**Time Nets Closed** (24hr):	
Division Ratio:	**Sensitivity/Sample Rate:**	
Net Configuration and Anabat Placement: Sketch (grid cell size: _________m)	**NOTES**	**No. of Nets Set:** **#6m: _______** **#9m: _______** **#12m: _______** **#18m: _______** **Canopy Net: _____** (circle net size): 6m, 9m, 12m, 18, **Harp Net: _______**

CLIMATE DATA

Beginning Temperature (^{o}C):	**Ending Temperature** (^{o}C):
Beginning Baro. Pressure (**in**Hg):	**Ending Baro. Pressure** (**in**Hg):
Beginning Wind (mph):	**Ending Wind** (mph):
Beginning Relative Humidity (%):	**Ending Relative Humidity** (%):
Beginning Cloud Cover (%):	**Ending Cloud Cover** (%):
Precip in last 24 hrs (Y/N):	**NOTES:**

Habitat Types

1. Shrubland/ shrub steppe
2. Grassland
3. Wetland/ open water
4. Rock outcrop
5. Cliff (canyon, mountain)
6. Cave
7. Conifer forest
8. Deciduous forest
9. Foothills chaparral
10. Riparian shrub (ex. willows)
11. Badlands
12. Disturbed/ reclaimed/ mined/ oil & gas

SPECIES 4 letter code	**Bat ID # ***	**TOC** 24hr	**Sex** m/f	**Age** j/a	**Repro ****	**FA** mm	**Th** mm	**E** mm	**Wt** g	**Keel** y/n	**WDI *****	**Photo #**	**V #**	**Release time**	**Recorded? y/n**	**Notes (fungus?, dentition, fringe, fur, etc)**

*** Bat ID #** = number of that species captured tonight

**** Repro** = Males: **N** (Non-reproductive), **D** (descended); Females: **N** (non-reproductive), **P** (pregnant), **L** (lactating), **PL** (post-lactating)

TOC = Time of Capture, FA = Forearm Length, Th. = thumb length, E = ear length, V# = number of specimen if collected.

***** WDI**: **0**=No damage, **1**=Light damage, **2**=Moderate damage, **3**=Heavy damage; Add “**-P**” to score if there is current physical damage.

CAPTURE TOTALS

	M/F		M/F		M/F		
ANPA	____________	**MYCA**	___________	**MYTH**	__________	**TOTAL BATS**	____________
COTO	____________	**MYCI**	___________	**MYVO**	__________	**TOTAL SPECIES**	____________
EPFU	____________	**MYEV**	___________	**MYYU**	__________	**TOTAL ADULTS**	____________
EUMA	____________	**MYLU**	___________	**PEHE**	__________	**TOTAL JUVENILES**	____________
LABO	____________	**MYSE**	___________	**NYMA**	__________	**TOTAL MALES**	____________
LACI	____________	**LANO**	___________	**TABR**	__________	**TOTAL FEMALES**	____________
PESU	____________		___________		__________		____________

ACOUSTIC ANALYSIS (call file # is of a representative call for that spp)

Species 1 (call file#):	**# of calls:**	**Species 5 (call file#):**	**# of calls:**
Species 2 (call file#):	**# of calls:**	**Species 6 (call file#):**	**# of calls:**
Species 3 (call file#):	**# of calls:**	**Comments:**	
Species 4 (call file#):	**# of calls:**		