Abstracts
47th Annual Symposium

North American Society for Bat Research

Knoxville, TN, USA
October 18-21, 2017

Local Hosts
Gary McCracken & Emma Willcox

Program Directors
Gary Kwiecinski, Frank Bonaccorso, Shahroukh Mistry, Riley Bernard and Luis Viquez-R.

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Abstracts below for both platform and poster presentations are listed alphabetically by first author's last name. Contact information for authors attending the 47th NASBR Symposium is listed in the printed Program.

New Records of Bats from the Southern Kalahari Desert, Kgalagadi Transfrontier Park, South Africa

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Kgalagadi Transfrontier Park stretches across northwestern South Africa eastward into Botswana. The park lies largely within the southern Kalahari Desert ecosystem where the dry river beds of the Auob and Nassob rivers reach confluence. Although these rivers run about once every 100 years, or shortly after large thunderstorms, underground flows and seeps provide consistent water for the parks sparse vegetation and diverse wildlife. No formal studies on bats at Kgalagadi Park have occurred, but molossids were known to occupying several of the chalets at tourist camps. To initiate research in the park, we used SM2 and SM3 Wildlife Acoustics bat detectors to survey 12 sites from 5-16 April 2016. The units recorded 4,401 call sequences that were analyzed using Sonobat 3.1 for call structure attributes [high frequency, low frequency, maximum power frequency (Fc), and call duration]. These data and views of sonograms were compared to published sonar data on African species to derive identifications where possible. We identified 13 species from four families: Molossidae: *Tadarida aegyptiaca*, *Mops condylurus*, *Mops midas*, *Chaerephon pumilus*, *Chaerephon ansorgei*; Vespertilionidae: *Neoromicia capensis*, *Scotophilus dinganii*, *Pipistrellus rueppelli*, *Myotis tricolor*, *Laephotis botswanae*, *Miniopteris schreibersii*; Nycteridae: *Nycteris woodi*; and Rhinolophidae: *Rhinolophus fumigatus*. Although this initial study increases our knowledge of species richness in the southern Kalahari Desert, there are likely more to be discovered in the future.

Bat Diversity and Conservation in Brazil

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Brazil is a mega diverse country with approximately 12% of the world's described species. For bats, there are at least 176 species, 15% of the world's bats, distributed in five large natural regions. Most

bat species here belong to the Neotropical Phyllostomidae family, with frugivorous and nectarivorous bats dominating the assemblages everywhere. Insectivores are less known due to most captures being done with mist nets. Although the country is considered the World's 8th economy, little is invested in basic research, and species and ecosystem conservation. For instance, only 40% of the country has been minimally inventoried for bats and new species have been described in recent years. Also, a continuous substitution of natural vegetation by croplands and pastures, the increasing necessity of energy production, weak environmental policy, and emergent diseases and rabies are related to direct and indirect impacts on bat species conservation. The assessment of species conservation status in response to environmental changes started in the 1960's, but bats were considered only in 1995, when six species were considered threatened. Nowadays the current official Brazilian red list includes only five species as threatened, which represents only 2% of the Brazilian bat fauna. In comparison with the global proportion of threatened bat species, in Brazil bats are considered less threatened than what would be expected by chance. This situation suggests that Brazil needs urgently to invest more in research to evaluate bat populations and their response to environmental changes.

Bat Community Change in Northeastern Iowa

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Bats are important in healthy ecosystems. Effigy Mounds National Monument (EFMO) is a nationally-protected park in northeastern Iowa that contains diverse topography and associated lowland and upland forests interspersed with upland prairie. White-nose Syndrome (WNS) is a deadly fungal pathogen of bats. Since initial detection in the northeastern United States, WNS has spread and caused large population declines in many hibernating bat species including several of those found at EFMO. As part of a multi-year monitoring effort of the bat community, with emphasis on *Myotis septentrionalis*, we have conducted mist-net surveys at EFMO for several years. We deployed 2-4 triple high mist-net systems at every survey site. We have detected dramatic changes in the bat community from 2016 to 2017. First, bat capture success has reduced from 4.43 bats/net-night to 1.43 bats/net-night. Second, bat community composition has changed significantly from 2016 to 2017 ($\chi^2 = 230.38$, $p < 0.001$). In 2016, we captured 5 species within EFMO and the surrounding area. In 2017, we captured only 4 species total and only three species within the EFMO boundaries. In 2016, *Myotis lucifugus* and *M. septentrionalis* represented ~70% of all captures; in 2017 they represent ~23% of all captures with no captures of *M. septentrionalis*. In contrast, *Lasiurus borealis* represented ~6% of 2016 captures and have increased to ~60% of 2017 captures. Our results seem consistent with previously documented community changes due to the impacts of WNS; dramatic declines in myotine bats are driving overall changes in composition.

A Comparison of Body Condition Scoring Systems Validated by DXA and Deuterium Oxide in *Eptesicus fuscus*

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In bats, body condition index (BCI) has historically been assessed by two independent measurements, the bat's mass (grams) and the length of the forearm (mm) defined as mass/forearm. Within a single night, the BCI score of an individual bat can vary based upon the weight before eating and post-prandial. Additionally, measuring forearm length can be variable among observers, resulting in different scores. The purpose of this study was to evaluate body condition score (BCS) obtained by estimating fat (energy reserves) and lean mass composition and compare BCS to composition obtained by dual-energy x-ray absorptiometry (DXA) and deuterium oxide in *Eptesicus fuscus*. Bats were assigned a body condition

score by five independent observers based upon a scale of 1 to 5. Bats were subsequently anesthetized for blood collection, scanned with DXA, and injected with deuterium oxide. Three hours post-injection, a second blood collection was taken to determine deuterium oxide enrichment in the serum after equilibration. Preliminary results from bats (n=15) representing BCS of 2 to 5 indicated average percent body fat ranging from 21.1% to 65.5%. Assigning a BCS score of 5 with 60% fat and decreasing the percent fat by 10 for each whole numerical decrease in BCS, revealed there was a high correlation between percent fat measured by DXA and BCS ($r^2 = 0.86$). Additionally, the independent observers' assignment of BCS were highly correlative to percent body fat ($\rho = 0.93 \pm 0.06$). Our findings suggest that a numeric body condition scoring system can be a useful management tool.

Fluctuations in Colony Size over the Past Decade of the Endangered Mexican Long-nosed Bat in Texas

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The Mexican long-nosed bat, *Leptonycteris nivalis*, is an endangered, migratory, nectarivorous species that occurs throughout much of Mexico, and is known from only two colonies in the United States. We used infrared thermal imaging methods to record the emergence of *L. nivalis* from a cave roost in Big Bend National Park, Texas over a 10-year period (2008-2017) to evaluate trends in colony size. Digital recordings were manually analyzed to determine the number of *Leptonycteris* leaving the cave in early July of each year. The total number of *L. nivalis* counted each year ranged from a low of 294 to as high as 3238 (average of 2085). Colony size fluctuated from year to year and no clear increase or decrease in the size of the colony was observed. On average, emergences began 32 minutes after sunset (range = 20 – 41) and peaked an average of 48.4 minutes after sunset (range = 38 – 61). The highest emergence rate was 146 bats/min in 2011 and the lowest was 25 bats/min in 2008 (average 96 bats/min). Environmental conditions (e.g. drought, hurricanes) and moon phase during each census varied among years and likely influenced the variation in emergence patterns that we observed among years. Unexpectedly there was no significant correlation observed between colony size and annual number of agave in bloom on transects in Big Bend National Park.

On the Move: Westward Expansion of the Evening Bat across the Great Plains

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The general lack of trees in the Great Plains limited colonization by eastern woodland mammals, but the recent expansion of forests in corridors along prairie waterways and in towns has enabled an assortment of woodland species to expand distributional ranges westward. One such species, the evening bat (*Nycticeius humeralis*), historically occurred in woodlands throughout the eastern United States. Following our capture of the first evening bat (*N. humeralis*) in New Mexico, we amassed historic records from published literature and museum voucher records west of the species' historic range published in 1981 and updated the distributional range for this species. We documented that evening bats, including some reproductively active populations, now occur across much of the central and southern Great Plains including southwestern Nebraska, western Kansas, and western Texas. Such records should encourage researchers to factor in the possible occurrence of this and other eastern bat species beyond published historic western limits for mist-netting and acoustic surveys. While it remains unclear if the single capture in southwestern New Mexico represented a wandering individual, these compiled records suggest that established populations might occur west of our updated distribution for the species.

Tissue-level and Whole-bone Biomechanics of the Wing Bones of Bats Compared to Terrestrial Mammals

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The wing bones of bats function in deformation, resulting in the bones twisting and bending with wing beats. The structural innovations driving this unusual performance remain unclear. This study characterized the differences in wing bone performance at the tissue and whole-bone levels of organization in small-bodied taxa including vespertilionids (n=2), phyllostomids (n=2) and the pteropodid *Cynopterus*. Bats are compared to terrestrial mammals of similar body size [rodents (n=4), insectivores (n=3)]. Microindentation tests performed on sectioned bone cortices revealed bats and terrestrial mammals displayed overlapping hardness and elasticity values at the tissue-level. Whole bone experiments on a universal testing machine loaded bones in three-point as well as cantilevered bending. The resulting flexural rigidity and resilience data suggest overlap among bat and terrestrial species. When adjusting for bone length, bat limb elements appear relatively rigid and potentially less resilient compared to terrestrial animals suggesting a key role of bone elongation in wing flexibility observed in flight. Taken together, these tissue-level and whole-bone tests suggest that the flexible phenotype of bat wing bones is influenced by morphological innovations in bone length as nanostructural innovations in bone composition will require further analyses. Future nanostructural analyses via raman spectrophotometry will help characterize potential compositional innovations in the bones of bats that may contribute to their novel bending behaviors.

Effects of Urbanization on Bat Habitat Use in Phoenix, Arizona: A Multi-Scale Landscape Analysis

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Urbanization can have negative effects on bat habitat use through the loss and isolation of habitat. Yet, how bats respond to the changing landscape pattern of our cities remains poorly understood. We examined how landscape composition and configuration affects bat activity, foraging activity, and species richness. We used a multi-scale landscape approach and bat acoustic data to create predictive models that identified key predictor variables across three scales (180 m, 1,500 m, 3,000 m). The examination of multiple scales was necessary to understand how bats perceive the urban landscape. We found that bat habitat use was primarily affected by urban landscape pattern at broad and fine scales. Water (small water bodies, riverbeds and urban waterways) was the most important predictor variable across all response variables. We also found that species richness was high in golf courses, which included the detection of the uncommon pocketed free-tailed bat (*Nyctinomops femorosaccus*), and low in commercial areas. Bat activity was high in native vegetation remnants, and low in outlying desert habitat. Areas with fine-scale land cover heterogeneity had high foraging activity. Our results suggested in hot, arid urban landscapes water is a limiting factor for bats, even in urban landscapes where the availability of water may be greater than in outlying desert habitat. Also, golf courses may serve as important stop-overs or refuges for rare or elusive bats. Golf courses and urban waterways have implications for land-use planning as novel cover types that can serve as important habitat for desert-dwelling bats, and urban biodiversity.

Bat Use of Great Smoky Mountains National Park at Multiple Spatial Scales

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The relationship between nocturnal bat activity and landscape features is poorly understood, especially in the Southern Appalachians, despite how these data may further inform the habitat use of species with special conservation concern. We conducted an acoustic survey at 42 random points (2–8 nights/point) from May–August 2016 in Great Smoky Mountains National Park, a spatially heterogeneous and biologically significant area. Twelve species of bat occupy the park, 6 of which are confirmed susceptible to white-nose syndrome. We used stepwise generalized linear mixed effect models to relate bat activity to landscape characteristics at multiple spatial scales. The effect of landscape characteristics on bat activity varied by species or phonic group. Preliminary analyses of coarse landscape features showed *Lasiurus borealis* were more active in early successional openings, low frequency bats were more likely to be detected in low-elevation, early successional openings near water, and *Myotis* bats showed a preference for mid-elevation northern hardwood forests in late summer. These results suggest landscape characteristics may play an important role in determining bat activity in the Southern Appalachians.

Apicomplexan Parasites of Bats: The Utility of a Bat-Microbe Database

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Many studies focus on viruses infecting bats while neglecting other bat microbes. In order to address this deficiency, I developed a database containing the majority of published reports of viruses, bacteria, fungi, and protozoa associated with bats which includes bat species, family, feeding habits, and location. The present study utilizes this database to examine characteristics of bats associated with Apicomplexa protozoa. All major apicomplexan groups infect bats: Eucoccidiorida (infecting 67 bat species from 9 genera), Haemosporida (51 bat species, 7 genera), Piroplasma (9 bat species, 3 genera), and *Cryptosporidium* (12 bat species, 4 genera). Bats are infected by 23 species of Eucoccidiorida, representing 5 parasite genera, primarily *Toxoplasma* and *Eimeria* species. The eucoccidians *T. gondii*, *Nephroisospora eptesici*, and a *Hepatozoon* species cause respiratory/neurological, kidney, and muscular disease, respectively, in bats. Most eucoccidians are transmitted by ingesting fecal matter. While bats are infected by 30 species of haemosporidians from nine genera, including *Plasmodium* species (causative agents of malaria), none of these parasites are associated with pathology in bats. Additionally, the three *Plasmodium* species in bats do not cause human disease. Four named members of Piroplasma from two parasite genera infect bats. *Babesia* species cause anemia in bats, while *Klosiella* species cause renal damage. While some *Cryptosporidium* genotypes cause severe gastrointestinal disease in immunocompromised humans, no pathology has been reported in bats. Some of these *Cryptosporidium* genotypes are bat-specific. The database utilized in this study may similarly be used to examine other links between bats and microbes.

Bat Behavior in Response to Ultrasonic Signals: Implications for Reducing Mortality at Wind Turbines

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Broadcasting ultrasonic signals has been proposed as a mitigation strategy to prevent bats from coming into close proximity to the rotating blades of wind turbines. Preliminary studies indicate that high frequency noises may deter echolocating bats from entering any area where such sounds are played. Thus if ultrasonic deterrents are deployed effectively, bats should avoid entering the rotor swept zone of wind

turbines, thereby eliminating the risk of collision. Nevertheless, before such deterrents can be applied as mitigation, we need to understand how ultrasonic signals influence bat behavior and determine the conditions under which they will be most effective. We therefore conducted both lab-based and field experiments in which we tested a set of ultrasonic signals that varied in frequency, amplitude and/or distance. We then evaluated the responses of bats to each of these signals to identify which signal characteristics hindered bat activity, and in turn led to avoidance. Using video and acoustic analysis software, we found that responses to ultrasonic signals were 1) species-specific, 2) influenced by distance from the source signal, and 3) dependent on the type of activity bats were conducting (e.g., passing, foraging, drinking, etc.). Our results confirmed that the acoustic properties of the ultrasonic signals and deterrent placement requires careful consideration to effectively and practically reduce bat fatalities at wind turbines.

Being an Honest Broker: Bridging the 'Knowledge-Action' Divide to Inform Disease Management Decisions

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Despite continued calls for improving responses to emerging infectious diseases of wildlife management, actions are often considered after a disease has been introduced and populations are affected. This reactive approach to disease management often results in ineffective control of pathogen introduction, sub-optimal responses to disease spread, and many unintended costs of delayed action while surveillance and research are conducted. Frustration between managers and scientists has been attributed to scientists being deaf to management concerns, and managers not acting on scientific information. Such miscommunication may partially stem from mixing science and values – which have distinct and separate roles in making management decisions. In the context of rational (normative) decision making, scientists must play a role as 'honest brokers' in conducting and communicating research that is guided by what managers identify, through thoughtful and deliberate analysis, as critical uncertainties. Here we discuss the set of management concerns (not limited to bat population persistence) and scientific information needs articulated by resource managers as critical components in deciding on and implementing treatment options. By identifying and understanding these values, managers can more precisely communicate information needs to scientists, who must then act as honest brokers to reduce relevant uncertainties, together identifying the best course of action to slow the spread of white-nose syndrome and maximize bat persistence.

Torpor Use Among Female *Myotis lucifugus* in Bat Boxes in Newfoundland, Canada

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Torpor is a thermoregulatory strategy used by some female bats throughout reproduction. Despite the energy saving benefit of torpor use, it can affect the reproductive success of individuals by delaying parturition and weaning. Regions within the range of *Myotis lucifugus* have different climatic conditions that likely place distinct constraints on thermoregulation. The cool, wet, and windy conditions in Newfoundland, Canada may result in high thermoregulatory costs and influence torpor use and parturition. Bat boxes in this region are used by maternity groups of *M. lucifugus* and are ideal for comparing thermoregulatory strategies among individuals under the same environmental conditions. We tested the hypothesis that reproductive condition, inter-individual variation, and weather conditions explain variation in torpor use in *M. lucifugus* on the Avalon Peninsula in Newfoundland. We used temperature-sensitive radio-transmitters to compare thermoregulatory patterns among females in bat boxes from June-August

2016 and 2017. Additionally, we measured temperature within bat boxes and recorded weather data (e.g. temperature, precipitation, and wind speed) from the nearest weather station. *A priori* candidate models were generated for each torpor pattern (frequency, depth, and duration). Models were ranked using the Bayesian Deviation Information Criterion (DIC) to determine which combination of variables best explain variation in torpor use. The results of this project may provide insight into the relationship between weather conditions, torpor use, and reproductive success of *M. lucifugus*. Bat box success may be explained by the thermoregulatory strategies used by bats in a specific environment.

Does the Framework of Citizen Science Projects Affect Participants' Attitudes Towards Conservation?

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Citizen science (CS) can achieve an important conservation cornerstone: educating the public and inspiring them to protect wildlife. At one extreme of CS projects are top-down initiatives, in which objectives and methods are first determined by researchers, then disseminated to citizens. At the other extreme are bottom-up efforts, in which development of goals and methods are carried out by the citizens themselves. These two approaches have potential tradeoffs regarding their efficacy in fostering investment in conservation. We compared attitudes of participants between two such projects, the Urban Bat Project (UBP) and the Michigan Bat Monitoring Program (MBMP). Both educate members about the importance of conserving bats and provide people with Echo Meter Touch units (Wildlife Acoustics, Inc.) to collect acoustic data. The UBP follows a bottom-up approach, where survey locations, methods, and dates are largely determined by citizens. We sent out 2 units for the UBP and 14 for the MBMP. The MBMP uses a top-down approach, and participants conduct driving surveys in a relatively restricted manner. To measure the degree of impact on participants, we surveyed volunteers from the UBP and MBMP to gauge changes in attitudes towards bats, how meaningful they found the project, and if they were likely to seek out additional ways to support bats. While analyses are ongoing, we will compare participant responses for survey questions. Citizen science collection of acoustic data for bats is becoming increasingly common. Our study will help biologists design projects that drive greater involvement from participants.

Effects of Prescribed Fires on Bat Foraging Behavior and Occupancy in the Ozark Mountains of Arkansas

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Due to the recent spread of white nose syndrome in Arkansas, it is imperative that managers understand the effects their management techniques have on native bat species. Our research aims to determine the availability of insect prey, and spatial and temporal variation in occupancy of bat species native to the Ozark mountains of northwestern Arkansas. Although prescribed burn units in this region are burned on a three-year rotation, it is not currently known how this treatment schedule affects bats. To determine the effects of prescribed burns on bats, acoustic monitors and insect traps were deployed at 20 burned and 20 unburned sites between April and July of 2017. Naïve occupancy was 0.41 for burned sites and 0.22 for unburned sites. However, no significant difference was found in detection of total bat species between burned and unburned sites. On average insect biomass was greater at burned sites (205.6g) than at unburned sites (188.8g). These data seem to show that prescribed fires allow for an increase in total food availability, which may allow for an increase in occupancy by certain bat species. This study will continue throughout 2017, and each site will be resampled to determine seasonal changes in bat occupancy. By comparing bat occupancy and prey availability of sites with different burn regimes, we hope to determine how prescribed fires affect bat foraging efficiency.

Rapid Assessment of Bats on Bougainville Island: Searching for Monkey-faced Fruit Bats and Spare Tires

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We conducted a two-week field assessment of bats across the central region (Wakunai—Mt. Balbi—Torokina) of Bougainville Island from 22 February through 5 March 2017 as part of a conservation initiative jointly hosted by Rotokas Ecotourism (RET) and Bat Conservation International (BCI). Bougainville and neighboring Buka are the two principal islands forming the North Solomons Province of Papua New Guinea but currently local government is under the authority of the Autonomous Bougainville Government which will conduct a plebiscite in 2019 leading to a decision on independence. Our biological assessment was conducted using mist-nets, a harp trap, acoustic recordings, cave and vegetation roost observations, and interviews of local people. We collected wing tissue biopsies, photographic records, and hand release echolocation calls to verify species identifications based on field characters of morphology and echolocation recordings of free-flying bats. We report on the numbers and species of bats surveyed which notably include the first records of *Miniopterus medius* on Bougainville. We report behavioral observations of the IUCN designated endangered species, *Pteralopex anceps* (Bougainville Monkey-faced Fruit Bat). Our species accounts communicate information on body size and morphology, echolocation call characteristics, food habits, roost selections, and conservation status. Finally, we present a summary of conservation outreach and education efforts conducted by RET and BCI at levels of "grassroots" communities (schools, women's groups, and councils of chiefs) through local and national government that promise to importantly facilitate bat conservation on Bougainville into the future.

Disturbances Affect Hibernating Bats: We Don't Know How or How Much It Matters

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The idea that hibernating bats are extremely sensitive to disturbance, and that disturbances cause dramatic energetic and survival consequences, has become paradigm. Unfortunately, the best available science pertaining to costs of disturbance to hibernating bats lags far behind our understanding of other aspects of hibernation physiology and ecology. We review what is known about disturbances to hibernating bats, and the knowledge gaps we need to fill, in the context of hibernaculum management. We will suggest, perhaps provocatively, that a re-evaluation of 20th century hibernaculum management strategies is required to conserve bats in a 21st century landscape.

Bats and Fire: Endangered Florida Bonneted Bats Respond Positively to Prescribed Burns

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The spatio-temporal responses of bats to fire are not well understood. Fire can shape bat habitat through changes to vegetation structure, insect prey, and roost availability. Fire is actively managed across south Florida, home to the endemic, endangered Florida bonneted bat (*Eumops floridanus*). Nonetheless, the effects of prescribed burns on this species are completely unknown. To investigate short-term responses of these bats to fire, we conducted pre-post, treatment-control experiments in four prescribed burns. We surveyed bat activity acoustically for 30 nights pre- and post-burn at three sites within each burn (treatment)

and three adjacent sites (control). Bat activity significantly increased post-burn in treatment sites relative to control sites, with more pronounced effects during dry season spring burns than wet season summer burns. We also detected a negative trend over time in the bats' response post-burn. We suggest that bats are attracted to increases in insect prey immediately following burns, particularly during the dry season when prey may be limited. To investigate long-term responses of Florida bonneted bats to fire, we stratified 144 acoustic survey sites across a landscape gradient of fire frequencies calculated over a 20-year period. We found that bat activity weakly increased with the frequency of burns conducted early in the wet season (April – June), overall burn frequency and years since the last burn. Our results suggest that fire has both short- and long-term positive effects on Florida bonneted bats, with implications regarding the seasonality of burns. We recommend further research on the underlying mechanisms driving these patterns.

Roosting Energetics and Pathogen Transmission in *Myotis lucifugus*

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Pathogen transmission can be influenced by host and environmental characteristics. In the active season, temperate-zone bats select warm roosts, huddle with conspecifics, and/or enter torpor, a state of reduced body temperature and metabolism, to save energy. Torpor reduces the need to be active for foraging which can reduce predation risk and, potentially, risk of contracting pathogens. We tested the hypothesis that torpor and huddling influence pathogen transmission for little brown bats (*Myotis lucifugus*). We predicted that bats relying most heavily on torpor would be least likely to acquire a contact pathogen. We housed groups of bats (n=10 bats/group) in outdoor flight tents and, during 24-hour trials (N=11), manipulated thermoregulation and aggregation using heated and unheated roost-boxes. We quantified torpor expression using skin temperature dataloggers, and used ultraviolet (UV) fluorescent powder as a proxy for a contact pathogen. Transmission dynamics of our proxy pathogen mimicked those of natural pathogens and most bats in each group aggregated in heated rather than un-heated roosts. Roost temperature affected torpor expression ($p=0.0005$) and aggregation ($p<0.0001$) but time in torpor and roosting group size had no effect on infection intensity ($p=0.875$). Our data highlight roost temperature as a driver of torpor expression and aggregation in this species but suggest other factors play a stronger role in pathogen transmission. Aggregation in heated roosts, without an increase in pathogen transmission, suggests that management actions increasing availability of warm roosts on the landscape could support conservation and recovery of this endangered species.

Does the Nose Know? The Link Between Olfactory Tracking Capabilities and Nose Morphology in Bats

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Olfactory tracking is a complex behavior that is dependent upon nasal anatomy, receptor physiology, central sensory integration circuits, and locomotion patterns. Animals exploit behavioral strategies like klinotaxis (sampling odor plumes at one location, moving and resampling) and tropotaxis (sampling odor plumes from two separate points and comparing inputs). Stereo olfaction is known to be important for olfactory tracking in terrestrial animals, such as rodents and carnivores. A larger separation between the nostrils is hypothesized to be an important adaptation to improve perception of odor directionality while tracking an odor plume. As fast, flying mammals, bats face unique challenges with respect to olfactory tracking and the mechanisms by which bats track odors is unknown. We predicted that bats that are more reliant on odor signals in their environment (such as frugivores and nectarivores) would display different nose morphology compared to other species, especially as related to nasal separation. Using museum specimens, we measured seven external morphological characters related to the nose and

cranium across 39 species of bats, encompassing different diets, sizes, and families. We used principal component analysis to create composite orthogonal morphological axes, which were then used to test if morphological traits could predict ecological parameters. Species appear to cluster based on diet, though there is a strong phylogenetic effect. Molossid species are particularly variable, which may be a result of tradeoffs between olfactory and respiratory requirements. These results may help drive new hypotheses in the understudied use of olfaction for foraging in bats.

Foraging Behavior of *Myotis lucifugus* During Summer at High Latitudes

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At high latitudes during summer, day length increases and nights become short or non-existent creating unique challenges. Nocturnally foraging animals must therefore cope by increasing foraging, or relax their nocturnal nature. Previously, we have shown that *Myotis lucifugus* in Alaska have very high foraging rates, as indicated by plasma metabolite analysis. However, studies of bats in northern Europe have reported foraging prior to sunset, thus lengthening their foraging period. Here we report foraging period of *M. lucifugus* in Alaska to determine whether elevated foraging rate is sufficient to compensate for short foraging periods, or whether they must also forage during periods of daylight as observed in other high latitude bats. Our study site was a maternity colony located at an abandoned cabin in Mentasta, AK (62°N). We used an automated telemetry array, consisting of three towers with datalogging receivers placed in the immediate area surrounding the cabin. We attached digitally coded radiotransmitters to 37 bats (33 female, 4 male) and collected data for 45 days in 2015 (August 4 – September 16). Transmitter signal strength changed dramatically as bats entered or exited the roost, allowing us to document emergence and return times for each individual. Contrary to studies in northern Europe, emergence typically occurred after sunset with few emergence events occurring before sunset. Emergence timing varied among individuals and was affected by environmental factors (e.g., temperature, precipitation). We conclude that bats in our study population are able maintain a normal circadian rhythm and compensate for short nights by increasing foraging intensity.

Community Composition of Ectoparasitic Bat Flies (Diptera: Streblidae and Nycteribiidae) from Neotropical Bats of Belize and Brazil

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Community ecology studies have the potential to clarify patterns of host specificity, coevolution, and network structure of parasites and their hosts. Previous studies have shown that ectoparasitic bat flies tend to be highly host specific, but these studies have been geographically limited in their sampling. Comparisons of host-parasite associations across a broad geographic area and range of host taxa may elucidate the degree of host specificity of bat flies at a broader scale. By studying community composition and host-specificity dynamics of bat flies, we can estimate parasite mobility in tropical communities and the potential for cross-population disease transmission by these parasites. Toward this end, we collected streblid and nycteribiid bat flies from bats in Orange Walk, Belize and the Atlantic Forest of Brazil. After identifying the bats and bat flies we constructed unipartite networks of host-parasite associations and examined the modularity and module membership between and within sites in order to evaluate the factors that influence host-parasite associations (e.g., host phylogeny, parasite phylogeny, environmental factors). We additionally analyzed differences in community diversity of both hosts and parasites between the highly fragmented Atlantic Forest and the less fragmented forest in Belize. This is the first time that the influence

of geography and environmental factors (including forest fragmentation) on host specificity has been analyzed on such a broad geographic scale.

Nocturnal Airplane and Ground Telemetry Employed to Determine Foraging Range and Habitat of Townsend's Big-eared Bats

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In August 2016, eight post-lactating females and one juvenile male Townsend's big eared bats (*Corynorhinus townsendii*) were tracked using aircraft and ground-based telemetry for two weeks north of Blythe, California near the now predominantly agricultural Lower Colorado River (LCR) floodplain. Bats were captured exiting an abandoned mine roost where a bat gate was installed by the Bureau of Land Management. Apparently responding to the capture disturbance at the mine portal, the colony relocated the next night to another abandoned mine 1 mile away (1.6 km.) in a Wilderness Area. The bats were tracked a maximum of 9.5 miles (15.2 km) from the roost with a minimum convex polygon for all individuals encompassing 38,355 acres (155.2 km^2.). Their movement after roost emergence was directed to the northeast and east in a broad fan toward the LCR. Foraging habitat was predominantly native vegetation and remnant oxbows of the historic LCR, and included planted trees (possibly cottonwoods) associated with buildings embedded in adjacent agricultural land. Several individuals returned nightly to favored foraging sites, and some bats repeatedly night-roosted in unoccupied buildings in the foraging area distant from the day roost.

Winter Activity Patterns of Bats on the Cumberland Plateau in Relation to Habitat and Environmental Conditions

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As winter is an energetically expensive time for temperate bats, a better understanding of their winter activity can inform conservation strategies in the face of white-nose syndrome and other threats. We investigated winter bat activity in Big South Fork National River and Recreation Area in Tennessee and Kentucky by continuously monitoring bat activity with acoustic detectors from December through February 2014-2015 and 2015-2016. We sampled nine sites: three in recently burned (< 2 years) forests, three in unburned forests, and three in fields containing a pond. We obtained nightly meteorological data from a weather station in the park and recorded temperatures at each sampling site every 30 mins with an iButton data logger. Vegetation surveys were conducted to quantify site-specific structural characteristics. We recorded 2,235 bat passes and identified four species/species groups active on the landscape throughout winter. Winter activity was strongly correlated with temperature, as both the number of nights on which bats were active and the level of nightly activity increased with temperature. Little activity was observed when nightly temperatures were $\leq 0°C$, but all species/species groups were detected at temperatures $< 10°C$. While bats were active at all sites, activity was greatest at sites close to ponds, with significantly less activity recorded in forested sites. Greater activity near water may suggest that bats were arousing to drink during the winter months, as gleaning insects—an important cold-temperature foraging strategy—is likely easier in forested areas. Our findings suggest dehydration may influence winter activity in our study area.

Taxonomy of Large *Anoura* and a Reassessment of the Distribution of *A. latidens*

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The nectar bat genus *Anoura* is one of the most diverse genera within the subfamily Glossophaginae, however despite recent taxonomical revisions species limits and phylogenetic relationships within the genus remain unclear. We present a morphological study of the large species in the genus (*A. geoffroyi*, *A. latidens* and *A. carishina*) using a set of 16 cranial and 11 external measurements. Our sampling represents all subspecies of *A. geoffroyi* and the type series of *A. carishina* and the holotype of *A. latidens.* After conducting the same analyses used in previous research to justify the descriptions of *A. carishina* and elevating to species level *A.g. peruana* (Principal Component Analysis and Discriminant functions) we find little support for elevating *A. g. peruana* to the species level. When analyzed independently *A. carishina, A.g. geoffroyi,* and *A.g. peruana* do not separate in the morphospace as expected to be distinct and discrete morphological clusters, suggesting that their species hypothesis should be revised. Growing evidence suggests that the statistical approaches to explore the morphospace of *Anoura* over estimates diversity in the genus. We propose the use of Mixture Gaussian Models instead of Principal Component Analysis and Discriminant Functions to assess this problem. Finally, we provide an update of the known distribution of *A. latidens* in South America and propose to keep the current taxonomic arrangements following Griffiths and Gardner (2008). Our results suggest that in order to clearly understand the diversity of this genus further genetic work is needed.

Community Compositional Changes Observed in Bat Field Surveys since White-nose Syndrome Arrived in North Carolina

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Epidemiological studies and theoretical modeling have shown that White-nose Syndrome (WNS) has species specific mortality rates. Large-body bats (e.g. big brown bats, *Eptesicus fuscus*) are less susceptible to WNS than small-body bats (e.g. little brown bats, *Myotis lucifugus*). Therefore, compositional changes can be expected in local bat communities impacted by WNS over time. Few studies have examined the compositional change via field surveys. Our goal is to investigate whether community compositional changes would be observed in empirical data in a manner consistent with species-specific WNS mortality rates. We hypothesized that over time species less susceptible to WNS would increase proportionally as compared to species more susceptible to WNS, even though the absolute number of individuals/acoustic activities of all WNS impacted species would decrease. Our study took place in the North Carolina mountain region where WNS was first confirmed in the 2010-2011 winter. We examined 1684 mist-netting captures from 25 sites and 67871 acoustic recordings from 32 transects collected between 2011 and 2016. We found that captures of big brown bats and little brown bats have decreased since 2011. However, proportionally big brown bats have declined less than little brown bats. We also found a similar pattern in the acoustic data when comparing big brown bats and tri-colored bats (*Perimyotis subflavus*). Our results show that species-specific WNS mortality rates can be used to model future community structure and that there is congruence between acoustic and capture data. We recommend that WNS treatments should prioritize species that are more WNS susceptible.

Range-Wide Migratory Patterns of North American Tree-Roosting Bats

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Wind-energy development had led to large-scale mortality of a poorly understood clade of migratory North American bats: *Lasiurus cinereus, L. borealis,* and *Lasionycteris noctivagans*. Understanding potential impacts on bat populations requires an understanding of the migratory behaviors and migration pathways used by these species, information that is largely unknown for these cryptic species. We inferred the summer origins of these species via analysis of their hair δ^2H values within a Bayesian framework. Samples of bat hair were obtained from live-captured, turbine-killed, and museum-specimen individuals, and pooled with hydrogen isotope hair values from the literature. Continuous probability surfaces indicating the likely origin of each individual were compared pairwise using metrics of niche overlap, and hierarchical clustering used to define common summer habitat. Assignment of bats as locals or probable migrants was determined using Monte Carlo simulation of overlaying probability isopleths over sampling locations, which combined with data on the date of mortality enabled inference of seasonal migration timing and intensity. Preliminary results indicate structured migratory behavior in all three species, with individuals summering in similar areas migrating in similar directions. We found evidence of both very long- and very short-distance seasonal movements all three species, with individuals summering further north traveling longer distances than those in the southern reaches of North America. Our results indicate complex migratory patterns, and we hope will inform efforts to conserve these species in the face of emerging threats, including wind-energy development.

Roost Selection by Male Tri-colored Bats in The Great Smoky Mountains National Park

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The tri-colored (*Perimyotis subflavus*) bat was once common across its range but due to the arrival of white-nose syndrome populations have declined significantly, such that tri-colored bats have been recommended for federal listing under the Endangered Species Act. A key component of tri-colored bat habitat is summer roosts, however, not much is known about roost requirements for the species in the southeastern region. We investigated roost selection of tri-colored bats at the micro- and landscape levels within the Great Smoky Mountains National Park (GSMNP) to characterize roost selection for the species within the region. On a microhabitat level, we found that male tri-colored bats selected for taller trees with greater canopy volumes than were proportionately available, and for forest stands that contained fewer overstory trees and fewer overstory conifers, than the surrounding forest. On a landscape level, we saw selection for roost locations that were closer to roads; had lower elevations, shallower slopes, and more north-facing aspects than other areas of GSMNP. As GSMNP contains a uniquely diverse suite of forest types and microclimates, the characteristics identified in our study likely represent true preference for tri-colored bats in the Southern Appalachian region.

Location, Location: Where Bat Roosts Are Installed Can Be an Important Factor in Mitigating Transportation Projects

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Anthropogenic roost sites are increasingly important in the long-term viability of some bat populations; however, bat colonies in bridges can be threatened during bridge widening, seismic retrofit, and replacement projects. Efforts to minimize and mitigate impacts to bats from these projects include creating replacement roosts. Several replacement habitat designs have been implemented successfully in bridges, but few long-term studies have been conducted comparing bat use of different kinds of alternate roost structures. For this project, two types of roost structures were installed along two different kinds of bridge features as mitigation to provide habitat for *Tadarida brasiliensis* and *Myotis yumanensis* at a bridge complex spanning the Santa Ana River in southern California. Data loggers set to collect temperature data hourly were installed within a representative sampling of these structures, and regular surveys were performed from March 2015–August 2017 to determine whether roost structure design and/or where that roost structure was sited had any effect on roost temperature and bat occupancy. The results are consistent with other studies showing that thermal stability and high temperatures are important co-factors in maternity-season roost selection, while during the fall/winter seasons, bats prefer roosts with wider temperature fluctuations rather than simply choosing cooler roosts. In this study, the thermal stability of a roost structure was more correlated with the location of that roost than with its design; consequently, site selection on a given bridge may be an important factor to consider when mitigating for a maternity roost versus a migratory or overwintering roost site.

Do Organismal Traits or Species Range Attributes Offer the Best Predictions of How Species Respond to Climate Change?

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One key finding of phylogeographic research has been the discovery that some species have undergone dramatic changes in population size in response to major climate events. For example, hundreds of studies have suggested that the focal species underwent population expansion or bottleneck at the end of the Pleistocene. However, few investigations have focused on understanding the key factors that influence organismal response to these large-scale climate events. Here, we describe such an investigation. Our goal is to identify the factors that influence the response of bat species to the large-scale changes that they experienced at the end of the last glacial period. Approximate Bayesian Computation was used to calculate the posterior probability of population expansion or bottleneck models in >100 species. Species distribution models were then estimated for each species in order to assess the extent to which their geographic range is expected to have changed between the last glacial climate and the present. Finally, a data table containing organismal trait data was compiled, and a machine-learning ensemble approach was used to build a classification function designed to predict how the species in our dataset responded to the end of the Pleistocene glaciation. After assessing the error rate of this function, we identified body size as the organismal trait that best predicts species response. In contrast, attributes of the environment or species distribution models (either current or historical) had very little predictive value in our framework.

‘Social Bet-hedging’ Reduces Risk in the Snuggle for Survival

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Both reciprocity and biological market theory predict that cooperative social bonds develop from costly investments that are conditional on relative returns, and these returns might involve multiple

interaction types integrated over time. In contrast, alternative models suggest social bonds emerge as simple byproducts of genetic or spatial structure. Here, I first show how nepotism can mask reciprocity, using power analyses of data from vampire bats, mandrills, and macaques. As observations accumulated, kinship effects were always detected before reciprocal help, even when reciprocal help was more predictive than kinship. Next, I review evidence that regurgitated food sharing and allogrooming in vampire bats are cooperative investments influenced by both immediate and long-term factors. Although kin investments yield greater benefits per capita, feeding nonkin appears to create 'backup' partners: feeding more nonkin across previous years predicted receiving more food, but only when we removed a key donor of each bat ($n=14$, $p=0.005$). This supports the 'social bet-hedging' hypothesis that investing in partner quantity over quality is favored by unpredictable social environments. New data on allogrooming decisions show that bats are more likely groom a partner in need that is self-grooming (1100 observations, 36 individuals, $p<0.0001$) or has wetted, disturbed fur (36 paired trials, $p=0.001$). When 13 bats were injected with lipopolysaccharides, mimicking an infection, they reduced their allogrooming ($p=0.0002$), but reduced their self-grooming even more ($p=0.02$). Feeding interactions revealed a subtle female dominance hierarchy, so rank could represent another component of partner 'quality'. Current work tracks how food-sharing bonds form between previous strangers.

Tracheobronchial Tree Reinforcement Due to Flight in Two Species of Phyllostomid Bat

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It has been suggested that the coupling of wing-beat with echolocation call emission not only economizes echolocation but also puts increased mechanical stress on the tracheobronchial tree (TBT). Thus, cartilage rings that support these conducting airways are reinforced through calcification in response to flight development. Currently, this phenomenon has only been described in *Artibeus jamaicensis* and so I set out to assess the timing of TBT ring calcification in the more precocial species, *Carollia perspicillata*. While both these species develop echolocation-like calls soon after birth, *C. perspicillata* develops sustained flight at 23 ± 3.3 days while *A. jamaicensis* at 32 ± 2.7 days. By clearing and staining (alcian blue and alizarin red) removed TBT's from nonvolant neonates, semivolant juveniles, volant subadults, and adult *C. perspicillata* and using existing data on *A. jamaicensis*, I found that TBT rings from *C. perspicillata* calcified 5 days before those of *A. jamaicensis*. Like the pattern in *A. jamaicensis*, calcification of tracheal rings in *C. perspicillata* began after the calcification of the larynx. However, calcification of tracheal rings was less extensive in *C. perspicillata* and there was no evidence of primary or secondary bronchial ring calcification. In both species, TBT ring calcification occurred a few days after sustained flight developed and seemed to occur rapidly. This comparative study is further evidence that sustained flight puts increased loads on the TBT, resulting in reinforcement of rings by calcification. Maintaining an open TBT in the face of powerful compressing flight muscles ensures effective ventilation and vocalization.

Species from Feces Goes Diet: Nicaraguan Bats Reveal All

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Bats occur on almost every continent and their diet is diverse, with species feeding on plants, insects, fish, frogs, birds, other bats, and blood. Genetic tools provide new opportunities to identify aspects of natural history such as diet. In 2015 and 2016 in Nicaragua, we collected guano samples from 21 bat species representing 6 families whose identities were confirmed with our Species from Feces DNA mini-

barcode assay (www.nau.edu/batdna). We used an amplicon-based sequencing approach of the COI gene to identify arthropod diet items to taxonomic order and family. Our data suggested that bats ate a variety of insects; we detected 29 arthropod families from 12 orders. We identified, on average, 3 arthropod orders per bat species (range 1–6). Lepidoptera, Coleoptera, and Diptera were most frequently identified in diets. Genetic approaches also broaden our knowledge of individual bat species. Previous studies for Miller's mastiff bat (*Molossus pretiosus*), for example, described diet as comprised of insects, including beetles and moths, using visual identification of undigested insect parts from fecal pellets. Our genetic analyses for this bat species also included Hemiptera (aphids, cicadas), Isoptera (termites), and Diptera as diet items. Genetic approaches can thus identify taxa that would be underrepresented by visual inspection of fecal pellets such as soft-bodied insects. Although we targeted insects in this analysis, additional genetic analysis can uncover other diet items including plants and other animals. Feces are an incredible source of information to understand ecology of bats as well as other animal taxa.

Spatial Variation in Population Impacts from White-nose Syndrome

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White-nose syndrome (WNS) is an infectious disease of hibernating bats that has caused widespread declines in multiple bat species across North America. We examined patterns of spatial variation in WNS impacts in five bat species. We found that maximum single-year colony declines from WNS occurred at mid-latitudes and mid-longitudes - centered around Indiana and Illinois. We also found strong spatial patterns in pathogen prevalence and loads on bats, with lower prevalence and loads during initial invasion in frontier regions where *Pseudogymnoascus destructans* (Pd) is currently spreading. We investigated three hypotheses to explain variation in WNS impacts: (1) hibernacula temperature, (2) hibernation season length, and (3) colony size. Hibernacula temperature was the strongest predictor of WNS impacts, with a nonlinear relationship peaking around 8 °C and corresponding with a peak in fungal loads. Hibernation season length was less strongly associated with WNS impacts and there was little support for colony size influencing impacts. Surprisingly, we did not find evidence for spatial refugia at southerly latitudes. Instead, our results suggest that WNS impacts may be lessened or delayed in frontier regions where *Pd* is currently spreading. Furthermore, we show that hibernacula temperature is associated with broad spatial patterns of WNS impacts. Our results inform conservation planning by identifying where populations have experienced the most severe declines across North America and provide further support that hibernacula temperature should be investigated further as a potential conservation strategy to improve survival of bats exposed to WNS.

New Geographic and Seasonal Records of Bats in Iowa

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From 2002 to 2017, we conducted 513 events to survey bats (nights of mist-netting, visits to bridges, mines, caves) and captured or observed 6015 bats including all nine species that regularly reside in Iowa. Our captures include a total of 126 new county records, with at least seven records for each species in the state. Since the geographic distributions of most species span the entire state, many of these county records simply fill in gaps within the hypothesized distributions. Records for *Lasionycteris noctivagans*, *Lasiurus borealis*, *Myotis lucifugus*, *Myotis septentrionalis*, *Myotis sodalis*, *Nycticeius humeralis*, and *Perimyotis subflavus*, however, extend the known range for these species or fill large gaps in their suspected distributions. Additionally, our captures provide evidence of reproduction occurring across the state for

most species; previously, little information has been published on the geographic extent of reproduction for bats in Iowa. Lastly, the captures we report substantially increase our knowledge of the timing of seasonal activities for bats in Iowa. We present new early and/or late records for lactation, post-lactation, appearance of flying young, and flight activity outside of hibernation for most species. Collectively, these records expand our knowledge of the biology of bats in Iowa.

Efficacy of Fecal Metabolomics as a Non-Invasive Tool for Age-Determination in Bats with Exceptional Longevity

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Vespertilionid bats live 3-10 x's longer than other mammals of a comparable body size. Physiological adaptations supporting this extended lifespan are poorly understood because the field lacks a reliable and rapid method for age determination. This study tested if mass spectrometry (MS) of feces is a reliable tool for the identification of biomarkers of chronological age in bats. Based on a captive population of known-aged big brown bats (*Eptesicus fuscus*), samples were collected from young (n=22) and elderly (n=6) bats, representing approximately 75% of their lifespan. Spectra were obtained based on an UHD Accurate LC-QTOF-MS. Software identified 65 metabolites with significant concentration differences between age groups, of which 14 were identified as integral to known physiological pathways. Greatest differences in metabolite concentrations were associated with tryptophan metabolism, and metabolism of endogenous metabolites (e.g., indole, 3-Methylindole, 2-Thiazolidine). Results show concentrations in metabolites recovered from feces may serve as biomarkers of age-classes. Application of quantitative fecal metabolomics may provide the means to establish bats as a novel anti-aging model, and explore the physiological mechanisms bats employ to achieve their exceptional longevity.

Hoary Bats (*Lasiurus cinereus*) Use Nearly Undetectable Echolocation in Autumn and May Fly in Silence

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Echolocation allows bats to occupy diverse nocturnal niches. Several decades of research has shown that bats almost always use echolocation, even when other sensory stimuli should be sufficient to guide navigation. Here, using arrays of calibrated infrared cameras and ultrasonic microphones in natural habitats, we show that hoary bats (*Lasiurus cinereus*) have more plasticity in their use of echolocation than previously known. We describe a novel call type ("micro" calls) that has three orders of magnitude less sound energy than normal calls (recorded in 34 of 79 flights over 5 nights). Bats also flew without producing detectable calls in 39 of 79 flights. This indicates that bats either flew in silence, or produced calls having source levels < 70-75 dB at 0.1 m. This level is 30-70 dB lower than levels used other bats in similar habitats. These behaviors reduce echolocation range by 70-96%. We speculate that reduced echolocation may be a strategy to avoid detection by conspecifics during the mating season. Reduced use of echolocation may partly explain why tens of thousands of hoary bats are killed at wind turbines each year. These behaviors also complicate on-going efforts to study hoary bats using passive acoustic monitoring.

Torpor in Neotropical Frugivorous Bats

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As endotherms, bats maintain high internal body temperatures through metabolic processes. Because energetic costs of endothermy increase during inclement weather and/or food scarcity, many bats employ torpor. Torpor is a controlled suppression in metabolic activity and body temperature thus decreasing energy expenditure; it is common in temperate zones where temperatures and food availability are seasonal. Since tropical zones do not experience the same magnitude of seasonality, endotherms of these regions were not believed to have the need or ability to use torpor. However, recent data shows some insectivorous species of tropical and subtropical bats use torpor. Our goal was to determine if frugivorous species of neotropical bats use torpor and, if so, to establish the factors that influence this physiological state. All bat and data collection occurred in Lamanai, Belize. To confirm entry into torpor and relative depth, we measured body temperatures of *Artibeus sp.* and *Sturnira lilium* before and after exposing bats to cool temperatures inside an environmental chamber. Across species, all individuals used torpor, albeit in shallower bouts compared to insectivorous species from the same region and of similar size. Torpor depth was most profound in nonreproductive individuals and negatively correlated with body condition indices ($P<0.01$). We believe that increasing sample sizes would further delineate factors that influence use of torpor. Regardless, this research provides new insight on torpor in hot-climate bats, helping us to better understand this energy saving technique which may shift paradigms in physiological ecology.

Illuminating Diet Shifts in an Insectivorous Bat Community

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Light pollution is increasing worldwide and threatens to disturb natural rhythms of wildlife species. Artificial light impacts the behavior of insectivorous bats in numerous ways, including foraging behavior, which may lead to altered prey selection. In a manipulative field experiment, we collected fecal samples from 6 species of insectivorous bats in naturally dark and artificially lit conditions and identified prey items using molecular methods to investigate effects of light pollution on prey selection. Proportional differences of identified prey were inconsistent and appear to be species specific. Red bats, little brown bats, and gray bats exhibited expected increases in moths at lit sites. Beetle-specialist big brown bats had a sizeable increase in beetle consumption around lights, while tri-colored bats and evening bats showed little change in moth consumption between experimental conditions. Dietary overlap was high between experimental conditions within each species, and dietary breadth only changed significantly between experimental conditions in one species, the little brown bat. Our results, building on others, demonstrate that bat-insect interactions may be more nuanced than the common assertion that moth consumption increases around lights. Thus, no single policy is likely to be universally effective in minimizing effects of light pollution on foraging bats because of differences in bat and insect communities, and their interactions. Our work highlights the need for greater mechanistic understanding of bat-light interactions to predict which species will be most affected by light pollution, and to more effectively craft management strategies to minimize unnatural shifts in prey selection caused by artificial lights.

Summer Roosting Ecology of *Myotis septentrionalis* at Cape Cod National Seashore

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In many parts of eastern North America, our knowledge of bat communities, habitat associations, and other important ecological information is limited. Addressing these knowledge gaps is an essential step in planning for conservation and management of local bat populations, particularly those that have been heavily impacted by White-nose Syndrome. Cape Cod National Seashore is part of a peninsular landscape dominated by mixed evergreen and deciduous forest interspersed with sand dunes, salt marsh, and suburban infrastructure, which experiences a heavy influx of tourism traffic each summer. Previous research within the National Seashore is limited to historic studies dating from the early twentieth century, and there is a need for updated information on regional bat populations, particularly with regard to the federally-threatened northern long-eared bat (*Myotis septentrionalis*). The goal of my research is to better understand the factors that influence roosting habitat selection in the northern Atlantic Coastal Plain by *M. septentrionalis*, which I investigated by conducting radio telemetry on bats captured at Cape Cod National Seashore. During June and July 2015-2016 we conducted 48 nights of mist netting throughout the park, capturing a total of 11 *M. septentrionalis* that included juveniles and lactating females. Nine adult female bats were fitted with radio transmitters and tracked to 21 roosts, more than 90% of which were located in anthropogenic structures. The results of my study suggest that man-made structures may offer suitable alternatives to tree roosts for coastal populations of *M. septentrionalis* during the latter portion of the maternity period.

Jaw-Dropping: Functional Variation in Digastric Muscle Morphology in Noctilionoid Bats

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Cranio-muscular morphology determines how wide, forcefully, and quickly the jaw can be opened or closed, which limits the size and material properties of foods a bat can capture and eat. Most studies of bat feeding performance have focused on skull traits and muscles involved in jaw closure, but few have explored how structures involved in jaw opening relate to feeding performance. We explored the relationship among the morphology of the digastric muscle, the sole jaw-opening muscle in mammals, its associated jaw lever mechanics, and diet in 31 ecomorphologically diverse species of noctilionoid bats. We used dissection to obtain digastric mass, fiber length, and physiological cross-sectional area, and micro-CT scans from associated skulls to quantify jaw lever mechanics. Our results support the hypothesis that digastric and jaw morphology have been shaped by diet in bats. Insectivorous bats have relatively strong digastric muscles associated with elongate jaws, suggesting insectivorous species can open their jaws quickly and powerfully during prey capture and chewing. Short-snouted frugivorous bats show traits that would enable them to open their jaws proportionally wider to accommodate the large fruits that they commonly consume. Nectarivorous and sanguinivorous bats have reduced digastric muscles, suggesting jaw opening is not particularly powerful. However, the digastric muscle of nectarivorous bats inserts on the dentary at an angle that likely facilitates rapid jaw movement during nectar lapping. Our results indicate that structures involved in jaw opening are also specialized for diet, and improve our understanding of the link between cranial morphology and feeding performance.

Context-dependent Interactions Between Bats and the Causative Agent of White-nose Syndrome

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Mitigation of emerging infectious diseases that threaten biodiversity requires treatments that target critical host or pathogen responses to infection. However, these depend strongly on the context of the host-pathogen interaction and both the host and pathogen's response may be highly plastic. We conducted dual RNA-seq of *Pseudogymnoascus destructans* and bats to one another, to test the hypothesis that the pathogen and various bat hosts exhibit reciprocal, context-dependent responses during infection. We found that a tolerant and a susceptible bat species up-regulated entirely different biological responses to the pathogen. We also investigated the role of temperature and humidity on virulence in *P. destructans*, and found that these factors have critical effects on the fungal transcriptome, concurrent with previously described morphological variation. This result suggests that direct comparisons among transcriptomic studies should be made with extreme caution, and also suggests interesting avenues for further research. Based on our study and others that have also identified immune genes upregulated during infection with *P. destructans*, we then designed and applied a sequence capture assay to genetic samples from susceptible *Myotis lucifugus*. We compared samples taken before and after the arrival of white-nose syndrome (WNS) to test whether white-nose syndrome exerts immunogenetic selection on susceptible bats. Our assay of > 140 immune genes revealed signatures of directional selection by the pathogen on Canadian populations of *M. lucifugus*. Directional selection may indicate that this species harbors the genetic potential to adapt to white-nose syndrome, although further research is required to confirm or refute this hypothesis.

Positive Selection in the Antigen Binding Site of the MHC-DRB Gene of *Artibeus jamaicensis*

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The major histocompatibility complex (MHC) loci exhibit an extensive genetic polymorphism in most vertebrate species. The main function of the MHC molecules is to present pathogenic peptides on the cell surface to T cells. Several studies of class I and class II molecules have revealed that the membrane-distal domains of both types of molecules contain a peptide binding site (ABS) in which peptides are bound and recognized by T-cell receptors. These sites display more non-synonymous than synonymous substitutions that change the amino acid sequence under positive selection and maintain the polymorphism in these regions of the MHC. Bats have a long history of association with pathogens. All these factors justify immunogenetics studies to infer evolutionary mechanisms that influence adaptive process across bats distribution. *Artibeus jamaicensis* is one of the most common and well-studied Neotropical abundant bat in highly-fragmented areas. A previous analysis of DRB exon 2 gene in this species, showed high levels of MHC polymorphism. Fifteen localities of *A. jamaicensis* were genetically assessed using one expressed MHC class II locus (DRB) in order to find footprints of positive selection in ABS sites. High allelic diversity was determined, 26 specific positive selected sites (PSS) were shown and located in the α-helix and β-sheet structures. We no found clustering of the MHC class II allomorphs (allele specific proteins) indicating that the high number of alleles are maintain by effect of balancing selection.

Timber Management has Neutral or Positive Effects on Foraging Behaviors of Endangered *Myotis*

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Active timber management and control units on the Hardwood Ecosystem Experiment in central Indiana, a 100-year project in its infancy, provide a unique opportunity to study bat responses. We aimed to track the movements of Indiana (*Myotis sodalis*; MYSO) and northern long-eared (*M. septentrionalis*; MYSE) bats near 9 timber-managed units across a 19,000 ha state forest. Managed units received patch cuts/single-tree selection or clearcutting, shelterwood, and fire. From 2014–2017, we tracked a total of 58 bats: 33 ♀ MYSE, 23 ♀ MYSO, and 2 juvenile ♂ MYSO. All bats were captured at small ½ acre forest ponds and 30–120 locations were collected for each over 1–6 nights. In a preliminary analysis for 37 bats, MYSE foraging ranges averaged 166 ha, whereas MYSO ranges were 391 ha (95% kernel density estimates). We developed management-based habitat types, overlaying foraging areas to perform a probabilistic weighted compositional analysis and rank resource use. MYSO traveled up to 5 km from roost sites to specific foraging areas, while MYSE roosted on ridgetops and foraged along adjacent slopes and typically traveled less than 2 km. Most MYSO and MYSE foraged in recently-harvested or regenerating areas managed primarily with small group selection and single-tree harvesting for stand improvement or harvested for ash salvage. Use of cut areas amidst mature forest suggests timber harvest has a neutral or positive effect on bat foraging space. Strategies to promote heterogeneity of tree species and ages may promote foraging habitat for both *Myotis* species.

Testing Two Potential Treatments for White-nose Syndrome in *Myotis lucifugus*

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White-nose syndrome (WNS) continues to spread and cause rapid declines of North American hibernating bats. Several treatments have been proposed but few have been tested on live bats. WNS treatments should target *Pseudogymnoascus destructans* (Pd) with high specificity to avoid impacting microbiota in bat hibernacula. We tested two treatments that should target Pd with high specificity: 1) Protease inhibitors secreted by Pd during skin invasion; and 2) Polyethylene glycol (PEG), which inhibits the growth of fungi susceptible to water stress. We captured hibernating, WNS-negative little brown bats (*Myotis lucifugus*) from the wild, matched bats for age and mass, and assigned individuals to one of four groups: inoculated with Pd and sham-treated; sham-inoculated with Pd and sham-treated; inoculated with Pd and treated with protease inhibitors (PI); and inoculated with Pd and treated with PEG. Treatment groups were housed in separate cages within incubators maintaining 7°C and 98% relative humidity. In contrast to most laboratory studies of WNS, we replicated the experiment in two incubators. We found no effect of PEG on prevalence of Pd-associated UV fluorescence. There was a significant, 36% reduction in prevalence of fluorescence for bats treated with PI but only in one of two incubators. Our results suggest that topical PIs could improve outcomes for bats with WNS but highlight the importance of replication for experimental studies of the disease. This could be especially important for treatment studies where effect sizes may be smaller than for studies of disease mechanisms quantifying large differences between infected versus un-infected bats.

Respiratory Rate as an Indicator of Response to Smoke during Torpor

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Insectivorous bats employ torpor, a marked reduction in metabolic rate, heart rate (HR), respiratory rate (RR) and body temperature, to save energy when faced with environmental constraints such as food and water shortage. Although torpor is a beneficial strategy to reduce energy expenditure, bats may experience slowed locomotor and sensory capabilities which may interfere with their ability to sense and evade important environmental cues, such as smoke, thus hindering their ability to escape fire. We aimed to determine whether torpid bats can sense smoke and whether RR, HR and reaction time of torpid bats prior to and following smoke exposure is temperature-dependent. To test this we quantified RR and HR of captive Australian tree-roosting bats, *Nyctophilus gouldi* (n = 5, ~10g), in steady-state torpor in response to short-term exposure to smoke from *Eucalyptus* spp. leaves between ambient temperatures (T_a) of 11 and 23°C. Bats at lower T_a took significantly longer to respond to smoke. Following smoke exposure, bats at lower T_a returned to a torpid state more quickly than bats at higher T_a, as shown by the appearance of the first apnoeic period. Interestingly, bats at low T_a never returned to thermoconforming steady-state torpor prior to the end of the experimental day, whereas all bats at high T_a did so, as indicated by apnoeic HR. Our study shows that although bats at low T_a took longer to respond to smoke, they appear to prevent deep torpor and maintain vigilance following exposure.

Preferential Nursing in Brazilian Free-tailed Bats

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Each year, millions of female Brazilian free-tailed bats (*Tadarida brasiliensis*) form maternity colonies and deposit their young in crèches containing up to 4,000 pups per square meter – each pup with a different mother. Despite high pup densities, females preferentially nurse genetically compatible pups, but research in the 1980's also estimated that 17% of nursing bouts involve females and pups that are genetically incompatible. Accurate estimates of relatedness between mothers and the pups they nurse were not possible with 1980's genetic tools and did not exist until now. Using six highly polymorphic microsatellite loci, I estimated relatedness between 100 females and the pups they nurse, looking especially at cases of non-parental nursing. Results of this study answer how often females nurse their own offspring and if nursing is kin-biased when it is not their own pup. These findings examine whether milk stealing, adoptive nursing, and/or indirect fitness benefits explain observed nursing patterns, and ultimately explore whether kin selection has played a role in the evolution of nursing behavior.

The Microbiology of Fresh, Surface, and Deep Bat Guano Samples, Including Detection of Possible Pathogens

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Bat guano plays an integral role in the ecological balance of the cave environment. In addition, guano serves as a food source for microorganisms such as bacteria, potentially including zoonotic pathogens. Past studies on the microbiological populations of guano were limited to isolated pellets or guano from the surface of a pile. Here, we present the first comparison of bacterial populations cultured from fresh, surface, and deep (~ 2m) guano samples from a large maternal colony of Brazilian free-tailed bats (*Tadarida brasiliensis*) in Sierra County, New Mexico. We cultured and isolated bacteria on three

types of nutrient agar: tryptic soy agar, blood agar, and a special recipe consistent with the composition of bat guano ("bat guano medium"). Using 16s rDNA PCR and genetic sequencing technology, we identified 18 species of bacteria including one possible new species. Further research determined that a number of these species that were cultured and sequenced have been present in clinical samples and designated as pathogenic and threatening to cave visitors. The data collected in this research can be utilized to supplement the microbiological knowledge concerning the cave environment and guano as well as to elucidate the health risks involved in cave entry.

Determining the Effectiveness of an Aerial Acoustic Bat Detection Technology for Monitoring Bat Populations

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Current ground-based acoustic methods of bat sampling have limitations that affect the probability of species detection, and in turn determination of species presence, relative abundance, and occupancy. To try and overcome these limitations, we designed a novel Aerial Bat Detection Technology (ABDT) that allows us to deploy an ultrasonic bat detector at various altitudes. During tethered test flights in summer 2016, we used the ABDT to collect ultrasonic acoustic recordings of bat calls at altitudes between 25 and 100 m. Concurrently, we recorded bat calls using a ground-based ultrasonic bat detector. We subsequently identified recorded bat calls to species using SonoBat automated bat call identification software and compared data collected from the ABDT with data collected from the ground-based detectors. Our results indicate that the ground-based detectors did not record bats flying at altitudes above 50 m, but these calls were recorded by the ABDT. As certain bats never flew below 50m, they were never detected by the ground-based detector. Based on data from this ground-based detector alone these species would not have been determined as present. Our initial results suggest that using ground-based monitoring alone for species detection may lead to bias in assessment of bat species presence, relative abundance, and occupancy.

Visitor Attitudes Toward Bats in Buildings of Great Smoky Mountains National Park

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During summer, bats are regularly observed in buildings of Great Smoky Mountains National Park (GRSM), the most visited National Park in the USA. As a result, natural and cultural resources managers seek to ensure public safety and protect historic structures while minimizing impacts on bats, especially in light of declines in bat populations as a result of white-nose syndrome (WNS). However, managers lacked information on visitor perceptions of bats and support for potential management action regarding the taxon. From June to August 2016, we surveyed 420 park visitors at three sites in the Cades Cove area of GRSM on their attitudes toward bats, knowledge about threats to bats and ecosystem services provided by bats, and support for management of bats. Most respondents supported management action to protect bats in buildings in Cades Cove during summer (76%). Standardized parameter estimates from a multiple linear regression developed with survey data indicated that attitudes toward bats and knowledge of threats to bats had the greatest effects on support for bat management. Wildlife management and conservation agencies seeking to further cultivate support for management of bats, in buildings or other locations, may apply these results in the design of tailored programming and outreach materials.

Roost Selection by Bats in Buildings of Great Smoky Mountains National Park

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Bats roosting in buildings are a challenge for wildlife managers due to their conservation needs and potential to transmit diseases to humans. An understanding of roost selection by bats in buildings is essential to effective management, but was lacking in the southeastern United States. During 2015 and 2016, we surveyed 140 buildings in eastern Tennessee and western North Carolina for bats, identifying 48 roost sites and detecting 5 species. We compared the microclimate conditions, building features, and habitat patch characteristics of buildings used and unused by bats using an information-theoretic approach. Averaged parameter estimates from logistic regression models developed with survey data indicated bat presence was more likely in old buildings with dark conditions surrounded by low road density. Of all roost buildings surveyed, 66% were accessed regularly by tourists and 68% were managed as historic structures. We present alternative management strategies that may be implemented to ensure human health and safety and preserve historic sites while protecting bats during the reproductive period.

Factors Influencing Flight Membrane Wound Healing in Big Brown Bats

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The flight membranes of bats can become damaged from impacts with natural or man-made objects, fights with conspecifics, and contact with predators. Bat biologists biopsy the flight membranes of bats for tissue samples and/or to mark animals in the field. Flight membrane damage also occurs in bats that survive an infection with the fungus that causes white-nose syndrome. I will summarize recent studies in my lab comparing flight membrane wound healing times of big brown bats (*Eptesicus fuscus*) in captivity and in the wild. These studies used a sterile biopsy tool to punch circular wounds in the wing (chiropatagium) and/or tail (uropatagium) membranes of male and non-reproductive adult female *E. fuscus*. Despite large environmental and ecological differences, our studies have consistently found that the uropatagium heals faster than the chiropatagium in both free-ranging and captive bats. We have also conducted experiments comparing healing times of healthy *vs* scar tissue, wounds with/without the inclusion of a blood vessel, bats with/without olive oil treatment to assess various factors that may promote/delay cutaneous wound healing in bats.

Decadal Changes Suggest Relaxation of Niche Partitioning After White-nose Syndrome and Climatic Responses in Bat Activity

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Long-term monitoring of animal populations is crucial to ensure the conservation of threatened as well as more common species, by providing early warning signals of population changes. In North America, the greatest and most sudden threat to hibernating bats is White-nose Syndrome (WNS), which has caused massive declines in populations since 2006. The effect of such a reduction of competitors for foraging space on unaffected bat species is poorly known. Moreover, as focus shifts towards future recovery plans, there is a need to investigate how bats respond to variation in climate. To do so, we analyzed acoustic bat surveys conducted in 16 regions in the province of Quebec, Canada, between 2000 and 2015. We used piecewise regressions to describe changes in bat activity over the years for and a meta-analysis approach to investigate

their response to climate variations. As expected, *Myotis* activity declined after the onset of WNS and *Eptesicus fuscus* / *Lasionycteris noctivagans* took up dominance, potentially following a release of competition. *Lasiurus cinereus* also took up dominance but its activity remained stable, and *L. borealis* declined regardless of the onset of WNS. *Myotis* responded positively with a one-year lag to North Atlantic Oscillation (NAO). *E. fuscus / L. noctivagans* and *L. cinereus* responded similarly without the lag. *L. borealis*' activity was negatively correlated to the previous summer's NAO. We suggest that some species other than *Myotis* benefited from a release of niche partitioning following WNS and that climate mostly affects activity through changes in survival and reproduction.

A Hope or a Sprayer? Modeling Implications of Alternative Management Approaches for White-nose Syndrome

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Hibernating bats have suffered enormous declines from white-nose syndrome (WNS) leading to listing of three species as endangered in Canada, and one as threatened in the United States. Media reports about the U.S. listing process highlighted controversy over alternative management strategies. On one hand, what we term "Stuff on Bats" (SOB) approaches (i.e., treatments applied to bats during winter) could improve survival, particularly for bats that are accessible for treatment. On the other hand, SOB could attenuate evolutionary responses of bat populations to WNS, impeding so-called 'evolutionary rescue'. As an alternative or complement to SOB, summer habitat enhancement could help support survival and reproduction by WNS survivors favoring evolutionary rescue. We used population viability analysis to address three questions: 1) How effective does SOB need to be to prevent extirpation of a local bat population? 2) Could SOB impede an evolutionary response to WNS? 3) Could summer habitat enhancement improve the potential for evolutionary rescue and recovery? We extracted estimates of pre- and post-WNS vital rates (i.e., survival, reproduction) and population growth (λ) from the literature to parameterize models. If WNS causes λ to decline to 0.32, SOB would need to improve over-winter survival by at least 40% for a population to return to stability (i.e. λ=1.0). This efficacy is one-third greater than that observed in the most promising treatment trial published to date. Additional analysis will help understand the potential of SOB and habitat enhancement to impede or support evolutionary rescue and population recovery.

Individual Dietary Niche Variation in Female Little Brown Bats on the Avalon Peninsula of Newfoundland

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Niche theory suggests that individuals of the same species may limit competition with conspecifics by consuming available food resources in different proportions. Little brown bats (*Myotis lucifugus*) on the Avalon Peninsula of Newfoundland may provide a unique model to demonstrate the way that inter-individual niche variation may facilitate the persistence of aggregations of adult females and offspring in a potentially competitive, central-place-foraging maternity system. The goal of this study is to discover the incidence and structure of individual foraging niche variation in adult female bats (i.e., do all individuals eat the same proportions of prey on a given night?). To accomplish this goal, we will conduct stable isotope analysis on concurrently collected bat feces and potentially available prey (i.e., nocturnal insects) from May-August 2017. The results of the stable isotope analysis will be run through a Bayesian mixing model analysis (MixSIAR) to determine source (prey) contribution-to-diet posterior probabilities, which in turn will be used to calculate the incidence and structure of individual niche variation in the study population.

Individual foraging niche variation, as it relates to ecological fitness, has important implications in associating foraging behaviors with persistence, adaptation, and speciation. Additionally, this research illustrates that the persistence of these maternity systems requires land-use and management practices that ultimately preserve or expand the diversity and abundance of the prey base.

Promoting Actions to Conserve Bats - batconservationalliance.wikidot.com

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One of the challenges facing conservation scientists is ensuring their information reaches managers undertaking conservation actions. Many practitioners do not stay current with scientific literature and, even if aware of new research, may not link the results to management actions. The North American Bat Conservation Alliance (NABCA) was formed to facilitate coordination and communication among parties interested in bat conservation in North America. To support this mandate we have launched a Wiki (batconservationalliance.wikidot.com) to share information on ways to address threats to bats. A Wiki is a website where any member of the community (including general public) can register and enter or edit existing information (the best-known example being Wikipedia). The NABCA Wiki is organized based on IUCN threat classifications, with a brief overview of each threat and its potential importance. The main feature is a flexible area for discussing and sharing information on ways to address these threats. As with Wikipedia, users are encouraged to contribute new information as well as review, correct or augment existing information. Ideally, information will be presented in plain, easy to read summaries with links to more detailed documents or scientific literature. Scientists could highlight implications of their recently published research; managers could describe what worked (or didn't). Contributors are encouraged to present different perspectives and recognize uncertainty. The success of this venture will depend on whether the scientific community uses it to share information, and whether the conservation community finds it useful to identify options and actions to conserve bats.

The Other End of the Hibernation Phenotype Spectrum: *Myotis velifer* and Hibernation in Mild Environments

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At high latitudes, winters are long and harsh, and bats must deposit large fat stores to survive extended periods of hibernation. Much of our understanding of hibernation physiology is based on studies of the extreme end of the hibernation phenotype: behavioral and physiological adaptations associated with long periods of hibernation. However, more southern populations may not hibernate in the same way. We examined the behavior and physiology of hibernating *Myotis velifer* in Western Oklahoma. We used dataloggers placed throughout the hibernaculum to record temperature and humidity, quantitative magnetic resonance to measure body composition, respirometry to determine the temperature response curve of torpid metabolic rate, radiotelemetry to record torpor arousal dynamics, and passive acoustic monitoring for flight activity outside the hibernaculum. Despite the relatively short winter, *M. velifer* deposit large fat stores prior to hibernation, and do so in a sex-biased manner; males enter hibernation with 19.3% body fat, while females enter with 28.3% body fat. Large energy stores allowed bats to remain active throughout much of the winter, except during notable weather events, and to roost in areas that did not correspond to minimum metabolic rate. This study suggests *M. velifer* fall on the other end of the hibernation phenotype spectrum, where animals experience mild conditions, deposit relatively large energy stores, and hibernate in a manner that does not minimize energy expenditure. We also explore the implications of this energetic strategy for the westward spread of white nose syndrome.

Relating Bat and Insect Communities in the Context of White-nose Syndrome and Prescribed Fire

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Recent studies of North American bats suggest their habitat use is primarily determined by forest structure rather than prey availability, but mortality and behavioral shifts induced by White-nose Syndrome (WNS) may be accompanied by altered bat-insect dynamics. We investigated these effects on bat assemblage composition. Acoustic bat surveys and concurrent insect sampling occurred at Mammoth Cave National Park before and after on-site detection of WNS. We classified echolocation passes by phonic group and identified insects to order. Lepidoptera were identified to species and clustered into six size classes. Mean wingspan differed significantly across Lepidoptera size classes ($P < 0.001$), suggesting classification was effective. Model selection indicated greater evenness in the post-WNS distribution of Lepidoptera size classes ($R^2 = 0.282$, 83% of support). Bat phonic diversity was best predicted by WNS and the relative abundances of prey groups ($R^2 = 0.189$, 53% of support). Distance-based redundancy analysis demonstrated that dominant insect orders, burn history, and WNS influenced bat community composition ($P = 0.01$) and distinguished varied responses of predator and prey groups. These results elucidate subtle relationships between predator, prey, and prescribed fire. We suggest conservation efforts emphasizing prey or land management are unlikely to have quantifiable impacts until bat populations have stabilized, but may still have ecologically meaningful impacts on the long-term viability of local populations of imperiled bat species.

Predator Cues Recognition by Bats: The Effect on Social Communication

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Many potential prey species assess predation risk based on a series of cues, including visual, olfactory, and acoustic. Being able to identify predation risk can be of vital importance to potential prey, since not responding to a signal can often mean death. Likewise, responding to signals emitted by harmless species can increase energetic expenditure during evasive maneuvers and alter normal activities. Some of the activities that predators can influence as they approach prey include the prey's foraging and communication, as prey may cease the emission of signals to reduce conspicuousness. Here we show that predator cues affect the emission of contact calls that species use to locate group members and roosting resources. We conducted a playback experiment to determine how the call-and-response system of Spix's disc-winged bat (*Thyroptera tricolor*) is affected by cues from an important predator species. Our results show that bats cease call production in response to echolocation signals from the False Vampire Bat (*Vampyrum spectrum*) a predatory bat species, but not to signals from other fruit- and insect-eating bat species. Our study shows that *T. tricolor* recognizes potential predators based on echolocation signals. In addition, because this bat relies on acoustic communication to locate the highly ephemeral roosts that they occupy with roost-mates, cues from predators may significantly increase energetic investment and affect group cohesion.

Indiana Bat Occupancy Estimates of Buffalo National River Using a Multi-state Occupancy Model

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The importance of proper management for bats has become paramount in recent years because of the introduction and spread of WNS throughout the eastern United States and Canada. Occupancy modeling is one research/management tool that is widely used among biologists. Occupancy is based on the presence/absence of a species, making it a natural fit with acoustic data recorders, which are unable to address abundance, but do well at producing presence/absence data. Thus it seems that the combination of acoustic data and occupancy modeling is ideal for managing a small, highly mobile species whose population size may be difficult to estimate using traditional techniques (e.g. bats). However, disagreement among automated bat identification programs can make accurate occupancy estimates based upon acoustic recordings difficult to achieve. We performed acoustic bat surveys at 96 sites throughout the Buffalo National River, and then used two USFWS-approved auto-i.d. programs (BCID and Kaleidoscope) to independently identify the calls. We then estimated occupancy using a multi-state occupancy model in which call sequences identified as an Indiana bat by both auto-i.d. programs are considered "certain detections", and call sequences identified as Indiana bat by one program are considered "uncertain detection". We also performed occupancy estimates based on visual identification of bat call sequences and compared the results. Occupancy estimates derived from the multi-state occupancy model were similar to estimates derived from visual identification. As auto-i.d. programs continue to improve their accuracy, an alternative 2-state occupancy model may be the best way to obtain accurate occupancy estimates.

Quantifying Steroid Transfer and Urinary Steroids in Female Big Brown Bats

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Studies have demonstrated that steroids can act as pheromones in mammals. Although most research focuses on the effect of male urinary steroids on female sexual behaviour and physiology, steroids transfer has been documented between female mice leading to changes in the duration of their estrus cycle. In tandem, estradiol (E_2) and progesterone (P_4) tightly regulate sexual maturation, sexual behaviour, blastocyst implantation, and gestation in female mammals. Big brown bats (*Eptesicus fuscus*) are ideal models for sex-related pheromone research because they live in highly social, sexually-competitive harems, and are regularly exposed to conspecific secretions in the close confines of their roost. Experimental analysis revealed absorption of ^{3}H-E_2 and ^{3}H-P_4 (10 µCi) 1 hr after cutaneous and intranasal application to adult females. Additionally, radioactivity was observed in mature female bats caged with an adult female conspecific (for 48 hrs) that was intraperitoneally-injected with ^{3}H-P_4 (50 µCi). Radioactivity was not observed in female bats caged with an adult female conspecific intraperitoneally-injected with ^{3}H-E_2 (50 µCi). Radioactivity measures indicated that P_4, but not E_2, transferred between female conspecifics at physiologically-relevant levels, and may influence the bats reproductive physiology. Additionally, urine was non-invasively collected from female bats and analyzed for steroid content. Analysis showed non-conjugated, bioactive E_2 and P_4 present in the urine of female bats. Collectively, these data show that certain sex steroids transfer between female conspecifics and are bio-actively present in female urine, demonstrating potential for sex steroids to act as pheromones between conspecific female big brown bats.

Diurnal Roost Selection of *Myotis septentrionalis* in Georgia

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Due to recent documented mortality of *Myotis septentrionalis*, land managers and researchers are concerned about the future of the species. An integral component to their ensuing recovery is conservation of and management for quality roosting habitat, which is necessary for successful gestation and rearing of young. Our objective was to discern characteristics of roosting habitat for *Myotis septentrionalis* in Georgia in an effort to better understand and develop management strategies. We compared environmental characteristics at all identified diurnal *Myotis septentrionalis* roost tree locations (n = 30) with randomly generated points within the Chattahoochee National Forest. Covariates were derived from a 10 m elevation raster and 1:24,000 hydrography layer in ArcMap and included: slope, elevation, aspect, distance to water, and topographical exposure. We used logistic regression to determine if any dissimilarities existed between known roosts and randomly generated points. Preliminary results indicate *Myotis septentrionalis* selects roosts on west facing slopes and in areas with higher topological exposures. We contextualize our findings with similar studies conducted in other parts of *Myotis septentrionalis* range and discuss the management implications of regional variation in roost selection.

Modelling the Influence of Evaporative Water Loss on Hibernation Energetics and Implications for White-nose Syndrome

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Evaporative water loss (EWL) during winter torpor is one of the leading hypotheses explaining periodic arousals in hibernating bats (the “dehydration hypothesis”). Increased EWL in bats infected with *Pseudogymnoascus destructans* (*Pd*), the causal agent of white-nose syndrome, has therefore been attributed to the increased arousal frequency and disruption of torpor in infected individuals. However, how EWL contributes to fat loss, and therefore mortality, has yet to be incorporated into predictions of winter energy expenditure. We modified a bioenergetic model to incorporate the influence of increased EWL from *Pd* growth on torpor bout duration. In our model, bats arouse from torpor when a threshold of EWL, as a proportion of lean mass, is reached. We modeled EWL as a function of hibernaculum temperature and humidity, and included a linear increase in response to the percent surface area of a bat covered in *Pd* lesions. We validated the model with measurements from *Myotis lucifugus* and predicted torpor bout duration and energy expenditure over a range of hibernaculum microclimates. Our results indicate that in dry environments, EWL drives energy expenditure, even though *Pd* growth is minimal. In humid environments, when EWL is normally negligible in healthy bats, extensive *Pd* growth exacerbates EWL beyond the threshold and instigates early arousals. These results suggest that temperature and humidity are important predictors of energy expenditure in the context of white-nose syndrome. We conclude that the addition of EWL into energetic models is necessary to predict survival from white-nose syndrome when considering variations in hibernaculum microclimates.

The Influence of Energetic and Time Constraints on Home-range Size in Female *Myotis lucifugus*

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Energetic and time constraints can affect home-ranges of animals. Individuals may be forced to increase home-range size when foraging efficiency is low or energy demand is high, or reduce home range if constrained by the time required for non-foraging activities (e.g., provisioning offspring). For female bats, reproductive status influences energy demand, with high costs during lactation relative to pregnancy. Time constraint may also vary by reproductive stage if lactating females must visit roosts frequently throughout the night to nurse pups. We hypothesized that if home-range size of *Myotis lucifugus* decreases during lactation compared to pregnancy, but nightly visits to roosts increase, then time required for provisioning offspring constrains home-range size. Alternatively, if energetic constraints exert a stronger influence than time limitation, nightly visits to roosts should remain stable between pregnancy and lactation, whereas ambient temperature (T_a), which predicts thermoregulatory costs and food availability, should more strongly influence home-range. We outfitted bats from a colony in northwestern Ontario, Canada with radiotransmitters during pregnancy (n = 7) and lactation (n = 12) and used telemetry to quantify home-range size. At multiple additional colonies in the region, we used passive transponders (PIT tags) and antenna/dataloggers to quantify nightly roost visitations during pregnancy and lactation. Consistent with our hypotheses, preliminary analysis indicates that home-range sizes were smaller during lactation compared to pregnancy. Additional analysis incorporating PIT-tag data and measurements of T_a will help us identify factors influencing home range size and improve understanding of the foraging habitat requirements of this endangered species.

Bats, Bat Flies, and Laboulbeniales Fungi from the Chucantí Nature Reserve in Eastern Panama

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Bats are the second-most diverse group of mammals in the world. They serve as host to various ectoparasites, among them bat flies (Streblidae, Nycteribiidae), which are highly host specific, blood-sucking insects. These parasites, in turn, can carry Laboulbeniales (Fungi: Ascomycota), which are microscopic ectoparasites of many arthropods. Laboulbeniales do not grow hyphae, but form a "reduced hyphal system," or a *thallus*. Only 10% of the described Laboulbeniales species, belonging to eight genera, parasitize Diptera. Three of those genera are exclusive to bat flies: *Arthrorhynchus*, *Gloeandromyces*, and *Nycteromyces*, whereby only the latter two occur on neotropical bat flies. In fact, the study of Laboulbeniales fungi associated with bat flies has been largely neglected for the past 80 years and for Panama thus far only three species have been reported. The aim of this study was to investigate the Laboulbeniales diversity on bat flies collected at the Chucantí Nature Reserve, a protected area of the Eastern Panama montane forests, and to shed light on the relationship of phylogeny and host species traits on the infection patterns. We captured a total of 307 bats belonging to 18 species of which 11 were parasitized by 437 bat flies (mean prevalence 0 – 100%, mean intensity 1 – 12.8). Laboulbeniales fungi have be detected on 30 bat flies (6.8%) and represented 6 species, three of which are new to science. *Pteronotus parnellii* had the highest number of average bat flies per bat individual, while the bat flies from *Trachops cirrhosis* were most-often found with Laboulbeniales fungi.

The Use of Mist-netting Survey Data to Assess Changes in Bat Community Composition

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White-nose Syndrome (WNS) has caused severe regional-scale declines in some cave-hibernating bat species throughout the eastern US. It remains unclear whether populations of relatively unaffected species will expand to fill the niche of heavily affected species on post-WNS landscapes. We compiled historical and current mist-netting survey data to examine temporal changes in the bat community at Fort Indiantown Gap (FIG), a military training facility in Pennsylvania. Additionally, we replicated mist-netting surveys at 12 sites to compare bat capture rates prior to (2004) and after (2017) the onset of WNS. Given species-specific responses to WNS, we hypothesized that capture rates of *Myotis* species would decline between 2004 and 2017, while capture rates of *Eptesicus fuscus* would increase. *Myotis septentrionalis* and *M. lucifugus* comprised 46.8% and 15.6% of total captures, respectively, during pre-WNS (1999-2004) surveys. However, only 1 *M. septentrionalis* and no *M. lucifugus* have been captured at FIG during post-WNS (2014-17) surveys. In contrast, the proportion of *E. fuscus* captured has increased from 22% to 79% between pre- and post-WNS netting surveys. Preliminary results indicate that capture rates (bats/unit of net effort) of *M. septentrionalis* and *M. lucifugus* have declined significantly at sites surveyed in 2004 and again in 2017, whereas capture rates of *E. fuscus* have increased significantly over this time period. These results suggest that *E. fuscus* populations at FIG are expanding in the absence of competition from *Myotis* species that were abundant at the site prior to WNS.

Simulated Bat Populations Erode when Exposed to Climate Change Projections for Western North America

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Recent research suggests that climate conditions correlate with successful reproduction in some insectivorous bat species that live in arid and semiarid regions, and that hot and dry conditions correlate with reduced lactation and reproductive output by females of some species. However, the potential impacts of climate-induced reproductive declines on bat populations in western North America are not well understood. We combined results from long-term field research in our study area with information on vital rates to develop stochastic age-structured population dynamics models and analyzed how simulated fringed myotis (*Myotis thysanodes*) populations changed under projected future climate conditions in our study area near Boulder, Colorado (Boulder Models) and throughout western North America (General Models). Each simulation consisted of an initial population of 2,000 females and an approximately stable age distribution at the beginning of the simulation. We allowed each population to be influenced by the mean annual temperature and annual precipitation for our study area and a generalized range-wide model projected through year 2086, for each of four carbon emission scenarios (representative concentration pathways RCP2.6, RCP4.5, RCP6.0, RCP8.5). Each population simulation was repeated 10,000 times. Of the 8 Boulder Model simulations, 1 increased (+29.10%), 3 stayed approximately stable (+2.45%, +0.05%, -0.03%), and 4 simulations decreased substantially (-44.10%, -44.70%, -44.95%, -78.85%). All General Model simulations for western North America decreased by >90% (-93.75%, -96.70%, -96.70%, -98.75%). These results suggest that a changing climate in western North America has the potential to quickly erode some forest bat populations, including species of conservation concern.

Putting the Leaf-nosed Bats in Context: A Geometric Morphometric Analysis of the Three Largest Bat Families

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Phyllostomids have the most diverse dietary ecology of any mammalian group and the link between their morphology and diet has been well studied. However, phyllostomids have yet to be placed into a greater chiropteran context through a large-scale inter-family shape study. Using geometric morphometrics, we examined shape trends, disparity, and links between shape and diet using skulls and jaws of 181 species from the three largest bat families: Vespertilionidae, Molossidae, and Phyllostomidae. Results indicate that skull shape in insectivorous phyllostomids does not overlap with non-phyllostomid families, suggesting at least two insectivorous skull morphotypes have evolved within Chiroptera and the shape of phyllostomid skulls had already diverged from other bat families prior to developing their broad diet range. Further, phyllostomids have higher skull shape (1.34x) and jaw shape (2.3x) disparity than molossids and vespertilionids, whose jaw and skull shape disparity are roughly equal. While the skull is constrained in many ways (e.g., housing the brain, seeing, smelling), the jaw has evolved specifically for food processing, allowing it to expand into more regions of morphospace. Finally, a dietary analysis based on prey hardness indicates substantial shape overlap between species except for those with extreme diets (e.g. liquid, very hard food). Many bats exhibit generalist behavior, eating a wide variety of food types of varying hardnesses in order to maintain niche flexibility. Therefore, we suggest that eating foods of intermediate hardnesses may not require substantial cranial reorganization.

Changes in Redox State in Different Tissues After Interruption of Hibernation in *Myotis velifer*

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The inability of non-hibernating animals to survive assaults of prolonged hypothermia and metabolic depression, suggests that hibernators must count with physiological strategies to overcome these challenges. During arousal, heart rate, ventilation and metabolism increase before body temperature (T_b) has been completely reestablished, event that potentially intensifies oxidative damage. Here we determined redox state changes and oxidative damage when interrupting the natural hibernation cycle in *Myotis velifer*, a heterothermic bat, which hibernates three months. Bats were captured directly from their hibernacula at the end of the hibernation season (January 2017). Antioxidants: Superoxide dismutase (SOD), catalase (CAT) and glutathione peroxidase (GPx); Tissue damage (carbonyl content) in blood, brain, heart, lungs, liver and brown adipose tissue (BAT), in 5 hibernating bats (11ºC) and in 5 aroused bats (30ºC) were determined to evaluate cellular stress when torpor was interrupted. SOD activity increased after arousal in blood and heart, and decreased in brain and lungs. CAT activity augmented in blood, and diminished in brain, lung and heart. GPX activity decreased in all tissues. No changes were found in liver and BAT. An increase in protein damage was found only in lung and a decrease in liver. SOD and CAT incremented in blood and the decreased in most organs plus the evidence of minimum protein damage, suggests that oxidative burst might be happening before bats reached the euthermic T_b and that antioxidant defenses started working before this. High antioxidant activity in blood suggests that replenishment to organs is also happening.

Comparison of Relative Capture Rates Among Years at a Swarming Site in Eastern Ontario

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White-nose Syndrome (WNS) has caused a significant decrease in population levels for multiple bat species within North America, resulting in *Myotis lucifugus*, *M. septentrionalis, and Perimyotis subflavus* being listed as Endangered in Canada and Ontario, and *M. leibii* being listed as a Species at Risk in Ontario. Although hibernation counts indicate radical declines of these species across many areas of eastern North America, including Ontario, captures at Ontario swarming sites in 2017 indicate persisting, potentially healthy populations of bats. We captured bats at a large hibernaculum and swarming site in Ontario during August and September 2017 and compared these data to capture records from the same site from two time periods: historical records from 1966-1968, and contemporary, pre-WNS capture records from 2005-2009. Results indicate that species composition has changed over time, with the most notable change the decline in relative abundance of *M. septentrionalis* following the arrival of WNS. However, we also noticed a substantial decline in relative abundance of *M. lucifugus* that began prior to the arrival of WNS in Ontario. Our data indicate that conservation efforts for bats that do not take multiple threats into account are insufficient for the effective recovery of populations.

To Kill or Not to Kill? Comparison of Common Sampling Techniques in Bat Microbiome Research

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Gut microbes play instrumental roles in host nutrition, immune function, and development. Research on bat gut microflora is typically accomplished either through collection of guano, or by destructively sampling the intestinal contents of the animal. Studies rarely, if ever, include both sampling techniques, and no comparison of these methods currently exists. Some researchers have postulated that the guano microbial community is only a subset of the intestinal flora, but this hypothesis has never been formally tested. To address these issues, we examined guano and distal colon contents from 22 species representing five families of bats from Lamanai, Belize, using 16S rRNA amplicon sequencing to characterize microbial communities across sampling types. We compared beta diversity, evenness, and species richness of guano and colon microbial communities collected from the same individuals. We further assessed individual variation within species for which we collected at least three representatives. Deviations in microbiome composition ("dysbioses") in mammals are often linked to decreased fitness and may represent novel information for bat conservation. It is thus essential to understand baseline microbiome variation for comparison and identification of true dysbioses in bats. Our study informs future research on the impacts of environmental changes such as habitat degradation and disease on bat microbiomes, and provides the first empirical comparison of two common field sampling methods.

Trophic Position and Reliance on Aquatic Production of Bats along Two Rivers in Yosemite National Park

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Bats use rivers and riparian environments for roosting, migration, and foraging. Insectivorous bats forage on a variety of prey items including both terrestrial invertebrates and emergent aquatic insects. We sampled blood and fur from 72 bats of seven species and used stable isotope analysis to compare the energetic contribution from aquatic and terrestrial primary production and to determine trophic position of bats within two mountain river reaches, one regulated and one unregulated, located in Yosemite National Park, CA. We found similar reliance on aquatic based energetic pathways in both locations, with bats deriving 52% to 98% of their carbon from prey with trophic cascades originating with algal primary production. Bats that relied more heavily on an aquatic energetic pathway generally fed at a higher trophic position (mean 3.44, range 2.60–6.70). In addition, we observed a significant positive relationship between estimates of trophic position and aquatic reliance in both blood and hair analyses. As blood and fur isotope levels provide an indication of foraging activity over the short and long term, respectively, these results indicated consistent dietary selection throughout the season among the bats studied. Results also showed a range of selective preferences among individuals, even within the same species. Together these results indicated that the bats captured in these riparian systems rely disproportionately on food webs supported by photosynthesis occurring within rivers and streams, therefore emphasizing the importance of intact aquatic ecosystem processes to these bats.

Examining the Effect of Torpor and Emergence Behavior on the Susceptibility of Four Bat Species to *Pseudogymnoascus destructans*

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For bats captured outside of caves during winter in the southeastern U.S., research indicates significant variation in *Pseudogymnoascus destructans* prevalence and load within and among species. We hypothesize that differences in susceptibility are linked to variations in winter behavior among individuals and are examining the differences in torpor and emergence behaviors of four bat species (*Myotis leibii*, *M. grisescens*, *M. sodalis*, and *Perimyotis subflavus*) known to hibernate in southeastern caves. For each of our study species, we are assessing *P. destructans* load and prevalence using genetic analysis of skin swabs and ultraviolet examination, and are using temperature sensitive radio-transmitters and passive integrated transponder (PIT) tags to compare torpor bout length, emergence frequency and duration, and foraging behavior. During our first 5 months of data collection (November 2016 – March 2017) in Tennessee, we applied radio-transmitters to and successfully monitored 7 bats (two *M. grisescens*, two *M. leibii*, and three *M. sodalis*), and implanted 748 bats with PIT tags. At NASBR, we will present our research methods and preliminary findings, as well as what we plan to accomplish over the remaining two years of the study.

Mitigating for Noise Near Roosts Based on Noise Frequency and Species of Bats

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Construction noise can negatively impact roosting bats, and mitigation needs to consider the frequency of noise generated and the hearing sensitivity of bat species at risk. We present two case studies for potential noise impacts to bats. At one project, a maternity colony of *Eptesicus fuscus* tolerated high decibel (dB) levels of low frequency sounds generated by chain saws (75—86 dB) and large graders (85—89 dB) within 100 feet of their roost, but the colony abandoned their roost when workers used a high frequency (19–28 kHz) laser surveying instrument, inaudible to the human ear. Most construction noise is low frequency and in a range of low auditory sensitivity for many bat species. To determine buffer zones for drilling >100 wells, we used full spectrum bat detectors at a 192 kHz sample rate to record noise generated by an auger drill at distances of 10, 30, 60 and 90 feet. We graphed noise attenuation based on kHz values and used ambient noise levels to determine buffer zones (e.g., noise recorded at 60 feet attenuated to 22 dB, the ambient noise level for 40 kHz; therefore, the buffer zone would be 60 feet for bats with a peak sensitivity of 40 kHz). Because many bat species are more sensitive to higher frequency sounds, we suggest that careful attention be given to the high frequency noise generated by equipment when planning mitigation. Setting buffer zones solely based on the published dB for low frequency sounds is likely inappropriate.

Urinalysis Indicates Differences in Health between Two Flying Fox Species

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Nutritional stress in flying foxes has been linked to Hendravirus (HeV) spillovers, thus it's important to understand physiological factors that impact HeV shedding. A recent case of HeV in northern New South Wales, Australia prompted sampling from a nearby (>10 km away) flying fox roost composed of Black flying foxes (*Pteropus alecto*) and Grey-headed flying foxes (*P. poliocephalus*). To assess health and potential nutritional stress, we collected morphometric measurements, blood, feces, and urine, which was collected from below the roost on plastic sheeting. We used urinalysis strips to assess biochemical markers in urine pooled from roost cluster. All samples tested negative for nitrates and blood and were within the normal range of pH and urine specific gravity. One sample underneath *P. poliocephalus* had low concentrations of urobilinogen and bilirubin. Urine from a mixed-species cluster contained moderate concentrations of ketones. Three *P. alecto* clusters contained high concentrations of ketones and low to moderate concentrations of proteins. Two *P. alecto* clusters contained low concentrations of glucose and two *P. alecto* samples contained low concentrations of leukocytes. Although captured individuals did not show outward signs of nutritional stress, the presence of ketones, proteins, and leukocytes in urine are indicative of fat metabolism in *P. alecto*, and thus differences in health and nutritional status between *P. alecto* and *P. poliocephalus*. These results warrant further investigation into how interspecific differences in health and nutritional status contribute to HeV shedding.

Evaluating Resource Partitioning Among Post-white-nose Syndrome Bat Communities Using Next Generation Sequencing Technologies

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The decline of cave-dwelling bats since the introduction of white-nose syndrome (WNS) to North America has led to changes in community interactions as evidenced by spatial and temporal partitioning investigations. Indirect effects, such as disease-mediated competition at the community level, can influence the ability of imperiled species to recover because of competitive exclusion. To further investigate community structure following WNS, we assessed the diet of sympatric species with differential WNS susceptibility using molecular techniques. In western Kentucky, *Perimyotis subflavus* (susceptible) populations have severely declined following WNS occurrence. Conversely, *Nycticeius humeralis* (non-susceptible) populations have increased markedly. We collected guano from *N. humeralis* (n=38) and *P. subflavus* (n=9) captured in mist nets during summer 2016. Arthropod DNA was extracted from the guano and a 157 bp target region of insect-COI was amplified. Sequences were analyzed to the lowest taxonomic level provided by the online Barcode of Life Database. *Nycticeius humeralis* consumed 165 genera belonging to 12 arthropod orders, while *P. subflavus* ate 92 genera from 8 arthropod orders. All orders consumed by *P. subflavus* were also eaten by *N. humeralis*, while 33% percent of all orders occurred exclusively in *N. humeralis*. Furthermore, *N. humeralis* consumed 61% of the genera identified in *P. subflavus*. These data support the potential of increased niche overlap between the two species based on 1) the more generalist habits of *N. humeralis* and 2) high dietary similarity between *N. humeralis* and *P. subflavus.* An increase in niche overlap may suppress the recovery of *P. subflavus* populations.

Bats as Reservoirs for *Neorickettsia risticii* (Potomac Horse Fever) in Tennessee

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Potomac Horse Fever is a potentially fatal illness affecting horses during the warmer months of the year (May-September). The causative agent, *Neorickettsia risticii*, is assumed to be transmitted through a fluke. The lifecycle of the fluke finishes in water, where it is ingested by the larval stages of aquatic insects. It is believed that horses will ingest the aquatic insect either in drinking water, dead insects in barns, or dead insects on pastures where the animal grazes. Insectivores bats frequently use creeks as corridors for foraging. It was therefore hypothesized that bats could be ingesting the bacteria from the insects they are eating and passing *N. risticii* in their guano over fields where horses are grazing. We tested guano samples, collected using rectal swabs from live and dead bats captured or collected across the state of Tennessee, for *N. risticii*. Real-time polymerase chain reaction (RT-PCR) is used to detect the agent in feces and whole blood of infected horses, therefore, we used the same process to test the bat guano collected. Of the 118 guano samples collected from dead bats, we had 1 strong positive, 1 positive, and 2 weak positives for *N. risticii*. Although the percentage of positives (3%) is small, it still confirmed our hypothesis that bats could be potential reservoirs for Potomac Horse Fever.

Diversity and Distribution of Bats in the San Juan Archipelago

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Understanding the mechanisms that drive patterns of diversity in time and space is one of the most active research areas in biology. Island Biogeography Theory is one of the most well-known postulations explaining patterns of species richness among oceanic islands, and it has been widely used to inform conservation within human altered landscapes. In this study, we investigate the relative effects of habitat area, isolation, and quality in shaping the diversity and distribution of bats in a naturally fragmented landscape, the San Juan Archipelago. We test whether Pacific Northwest bats follow the equilibrium model of Island Biogeography Theory, and evaluate whether and how differences in species traits influence their patterns of island incidence. We carried out acoustic and mist net surveys of bat communities along the North Washington coast and a subset of the San Juan Islands (n = 20), representing a gradient of habitat size and isolation. In total, we found 10 species inhabiting the islands and mainland, with richness ranging from one to 10 species on each island. Whereas island area strongly influenced patterns of species richness, isolation did not seem to reduce species richness at the scale of our study. We found that the smallest bat species in the region, the California Myotis, had the broadest distribution across the islands, whereas the Little Brown Myotis had one of the most limited distributions. Our study provides insight into how geographic factors affect the diversity and distributions of bat communities in fragmented landscapes.

Roost Selection of Southeastern Myotis in an Old-Growth Bottomland Hardwood Forest

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Little is known about the roosting habits of southeastern myotis, *Myotis austroriparius*, in Coastal Plain forests. Our objective was to quantify characteristics of roosts selected by southeastern myotis in Congaree National Park, an old-growth bottomland hardwood forest in the Upper Coastal Plain of South Carolina during Winter (November-March) 2015-16 and Summer (May-August) 2015 and 2016. We located roosts through opportunistic cavity searches and tracking radio-tagged bats to roosts. We quantified tree characteristics, the herbaceous layer in front of the cavity opening, and the surrounding vegetation of roost and random trees. Winter and summer basal cavity roosts did not differ in any characteristic. Summer and overall roosts had significantly less herb cover in front of the cavity opening than random trees. Diameter at breast height (83.6 ± 3.5 cm) and tree height (29.4 ± 1.2 m) were greater for summer roosts than summer random trees. Cavity volume of winter roosts (3.1 ± 0.9 m^3) was significantly higher than the cavity volume of winter random trees (1.8 ± 0.3m^3). Sixty percent of winter and 68 % of summer roosts were *Nyssa* spp. and percent basal area attributable to *Nyssa* spp. in the area surrounding roost trees was higher for winter (44.6±4.6), summer (48.7±5.6), and overall roost (25.7±4.7) trees than for random trees. Our data suggest that southeastern myotis select roosts with specific tree and habitat features but there is little difference in basal cavity roost selection seasonally.

Cracks in Island Keystones as Threat Synergies and Feedback Loops Push Island *Pteropus* to the Brink

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Following pressure from litchi and mango growers, in late 2015 the Government of Mauritius deployed its Special Mobile Force to shoot > 30,000 individuals of the Mauritius Fruit Bat, *Pteropus niger*,

a threatened island endemic and the last of three *Pteropus* species to survive on the island. Illegal hunting and a second cull at the end of 2016 resulted in a total population reduction of > 50% in less than two years. *Pteropus niger* is just one of 53 island *Pteropus* species, or flying foxes. Intensive hunting and trading of island *Pteropus* in the last century drove one species to extinction and led to the listing of all others under CITES by 1989, but island flying foxes remain the most vulnerable bats in the world. All four of the recent global bat extinctions were island flying foxes, and 57% of species remain threatened (assessed as Critically Endangered, Endangered, Vulnerable by the IUCN). Here we describe the threat synergies and feedback loops driving many species to the brink of extinction. Hunting remains a widespread driver of declines, but stochastic threats like tropical storms and cyclones are of growing concern as populations decline from anthropogenic pressures. Extensive and rapid habitat destruction, and invasion by alien species, reduce natural food resources and precipitate human-bat conflict over fruit crops. A growing hostility against island *Pteropus* compound these threats leading to increased persecution, poaching and culling, alarmingly met with silent indifference when not explicit complicity by authorities in many countries.

Hawks, Ziplines and Drones: New Methods for Recording Echolocation of Bats in Large Groups

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Brazilian free-tailed bats form large maternal colonies numbering in the millions across the American Southwest. Each night, the bats emerge from their roost to travel to foraging locations. During this emergence, individuals fly together in a dense, linear stream and exhibit collective group behavior. Upon morning return to the roost, the flight behavior of bats change and individuals fly in unpredictable paths, with little to no apparent collective group behavior, creating a swarm. To understand the different sensory challenges each of these flight scenarios pose to bats, we recorded the flight behavior and echolocation signals of bats in streams and swarms using four different recording platforms: 1) stationary, ground-based directional and omnidirectional microphones and video cameras, 2) a zip-line microphone that maneuvered through the bat stream and swarm and was monitored by video, 3) a microphone and thermal camera on a quadcopter that recorded bat flight behavior and signals at high altitudes during swarm re-entry, and 4) a trained hawk that flew through the bat stream while carrying a microphone unit and monitored with unique video. We report on the different noise profiles the bats experience during streaming and swarming and the adaptive time-frequency signatures and flight behavior of individuals during group flight.

Bat Diet Reveals Richness in Pest Consumption and High-altitude Insect Migration

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High-altitude nocturnal insect migrations are ubiquitous and represent significant pulses of biomass, which impact large areas and multiple trophic levels, yet are difficult to study and poorly understood. Predation on migratory insects by high-flying bats provides potential for investigating flows of migratory insects across a landscape. Brazilian free-tailed bats, *Tadarida brasiliensis*, provide valuable ecosystem services by consuming migratory pests, and research suggests migratory insects are an important resource to bats in autumn. We sequenced insect DNA from bat feces collected during the 2010-2012

autumn migrations of insects over southern Texas, and tested the utility of predator-prey interactions for monitoring migratory insect populations by asking: 1) how extensively do bats consume migratory insects during autumn? 2) does the prey community reflect known drivers of insect migrations, e.g. cold fronts? and 3) are migratory insects increasingly important to bats when local food resources decline in autumn? Bats consumed at least 21 species of migratory insects and 44 species of agricultural pests. Prey community richness increased with cold front passage. Bats consumed migratory moths over the entire autumn season, and the proportion of migratory moths in the bat diet increased over the course of the autumn season in all 3 years. This study confirms extensive consumption of migratory insects by bats, links patterns in prey communities to mechanisms driving insect migration, and documents a novel approach to tracking patterns of migratory insect movement. As an important resource for *T. brasiliensis* in autumn, migratory insects provide stabilizing effects to the local animal community.

Free Falling or Free Flying? Activity Thermoregulatory Substitution During Rewarming from Torpor in Migratory Bats

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Many bats enter torpor and reduce body temperature (T_b) to conserve energy. Torpid bats use shivering and non-shivering thermogenesis to rewarm to normal T_b but both processes are expensive. During winter, some non-flying mammals substitute heat generated during activity (e.g., while foraging) for thermoregulatory heat production and this can reduce costs of activity. However, the importance of activity-thermoregulatory substitution during rewarming from torpor is not understood. If bats can fly at T_bs below normothermia, the cost of rewarming before departing roosts at dusk could be offset by some of the energy required to commute to foraging areas. We tested two predictions of this hypothesis using silver-haired bats (*Lasionycteris noctivagans*) and eastern red bats (*Lasiurus borealis*): 1) Bats are capable of flight at T_b below normothermia; and 2) Opportunities to fly increase rates of rewarming and, therefore, reduce energetic costs. We captured 70 silver-haired and 18 red bats in southeastern Manitoba, Canada. We housed bats for 12 hours in a temperature-controlled cabinet at 8°C to induce torpor. Half the bats of each species were then allowed to warm passively while the other half were dropped from a height of 1.5m onto a well-padded floor to induce flight. We allowed bats in the flight group to attempt flight every 2 minutes and measured rectal temperature every 2 minutes for both groups. Consistent with our first prediction, bats were capable of flight at T_b as low as 27.5°C. Our results have implications for understanding how bats minimize energetic costs and maintain energy balance.

Overwintering by Silver-haired Bats in the Lake Michigan Basin

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Biologists know little about the ecology and natural history of silver-haired bats (*Lasionycteris noctivagans*), particularly east of the Great Plains, where even the seasonal boundaries of their geographic distribution are uncertain. More than 35 years ago, R. J. Izor postulated that their northern boundary in winter mirrored the -6.7 °C (20 °F) mean daily minimum isotherm for January 1931–1960, based on captures from only 30 sites across the continent. To test his hypothesis, we relied on accidental encounters between silver-haired bats and private citizens, such as bats tested for the rabies virus and reports of wildlife rehabilitators. Using these encounters, we assembled more than 525 new winter (December–February) records of silver-haired bats from the states surrounding Lake Michigan—Illinois, Indiana, Michigan, and

Wisconsin. Although these bats were detected over a broad area, most (75%) were found in the five counties from Milwaukee Co., Wisconsin, to Cook Co., Illinois, along the southwestern shore of Lake Michigan. Silver-haired bats overwintered as far north as the 45th parallel, and neither the -6.7 °C mean daily minimum isotherm for January 1931–1960 or for 1981–2010 approximated the northern limit. The -12.2 °C (10 °F) mean daily minimum isotherm for January, for either period, actually encompassed more records than the -6.7 C isotherm.

Long-eared Bat Taxonomy: Nuclear Genetic Evidence Eliminates the Species Status of Keen's Myotis

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Four species of long-eared myotis bats are recognized in British Columbia: Keen's Myotis (*Myotis keenii*), Northern Myotis (*M. septentrionalis*), Long-eared Myotis (*M. evotis*), and Fringed Myotis (*M. thysanodes*). *Myotis keenii* and *M. evotis* are especially difficult to tell apart in the hand in areas where the species are sympatric. Small differences in skull morphology, colouration, and mitochondrial DNA have been used to distinguish the 2 species, but it has been unclear whether species distinction is biologically warranted. To examine this question, we genotyped 257 long-eared myotis samples at 14 microsatellite loci expanding our base of inference beyond the single marker represented by traditional mtDNA methods and allowing examination of breeding patterns. Samples were obtained from across the range of *M. keenii* along the BC, Alaska and Washington coasts, and long-eared myotis were sampled as far east as Alberta. We also included 24 Little Brown myotis (*M. lucifugus*), as a closely related outgroup. We analyzed all genotypes in several ways, including the clustering programs Genetix (factorial correspondence analysis) and Structure (Monte Carlo Markov Chain) to observe nuclear population genetics relationships. We also looked at relative FST measures between all groups. All 3 analyses supported the conclusion that there were distinct clusters, representing 4 species: *M. septentrionalis, M. thysanodes, M. lucifugus* and a mixed cluster of *M. keenii/M. evotis*. The highly mixed clustering of all potential *M. keenii* and *M. evotis* samples provides clear evidence that these individuals represent a single species that interbreeds.

Long-term Effects of Forest Harvesting on Habitat Use by Insect Eating Bats

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The short-term effects of forest harvesting on forest-dwelling bats have received considerable attention. However, knowledge about long-term effects of forest harvesting are also essential for the development of sustainable forest management practices which will help to preserve forest-dwelling bat populations in Canada. As vegetation regenerates over time in harvested areas, changes created by harvesting (e.g., low-clutter openings and forest edges) will blur and eventually disappear with natural re-growth. Long-term effects of forest harvesting could thus differ from short-term effects on forest-dwelling bat species. To compare short and long-term effects of forest harvesting on insectivorous bat foraging behaviour, in 2016 and 2017 I repeated a study conducted by Grindal and Brigham in 1995 near Nelson, British Columbia. Grindal and Brigham's principal objective was to use acoustic detectors to evaluate bats use of habitats created by clear-cut logging. I revisited the same exact locations 20+ years later to determine how bats treat the re-growth in these habitats. As was done in 1995, I assessed bat activity in the habitats in combination with four different habitat factors: habitat type, stand age-class, elevational zone and prey availability. As was the result in the mid-1990s, I postulate that bat activity will be detected in different

abundance depending on the three habitat features, subject to prey density and structural complexity. I also predict that bat foraging activity will be lower in the revisited locations but still higher along edges when compared to the other habitats.

Threats to Monkey-faced Bats and Flying Foxes in Solomon Islands

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Solomon Islands lies within a globally significant biodiversity hotspot that supports high mammal endemism, especially pteropodid bats. Monkey-faced bats (*Pteralopex*) are iconic to the archipelago. All five known species are categorized as Critically Endangered or Endangered on the IUCN Red List. Solomon Islands has a high rate of human population growth and large-scale widespread commercial logging is rapidly exploiting primary forests. Large island bats are particularly vulnerable to over-hunting associated with burgeoning human populations, and loss of primary forests has been identified as a major threat to *Pteralopex*. Between 2010 and 2016 I surveyed pteropodid bats on all major islands of the Solomon archipelago using mist nets, and investigated cultural drivers of flying-fox hunting pressure on *Pteropus* and *Pteralopex* species. In the Western Province (Kolombangara, Vangunu and New Georgia Islands), I was able to conduct repeat sampling at sites surveyed in 1992, allowing comparisons of capture rates for nine pteropodid bats (including *P. taki*) pre and post widespread logging. Contrary to previous assumptions that *Pteralopex* do not persist in logged forests, *P. taki* and *P. atrata* were recorded in heavily logged areas and on the interfaces between disturbed forests and gardens. However, closer analysis of the data revealed specialist endemics (including *P. taki*) have declined in response to logging at spatial scales that reflected idiosyncrasies of their ecology. Over-hunting does not appear to explain declines of *Pteralopex*, and cultural uses of *Pteropus* do not seem to compound hunting pressure for bushmeat.

Conserving an Endangered Pollinator: Insights for Engaging Communities in "Bat-friendly" Agave Management in Northeast Mexico

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The endangered Mexican long-nosed bat (*Leptonycteris nivalis*) migrates every spring and fall between central Mexico and northeast Mexico and the U.S. Southwest. During this long-distance migration, they feed on the nectar of agaves (*Agave spp.*), particularly in the northern portion of their range. However, agaves are harvested from the wild and cultivated for market products and other cultural uses by rural communities, which may be contributing to the species' decline. "Bat-friendly" agave management, such as replanting wild agaves, can potentially be encouraged within local communities to help conserve the species. This research, which forms part of an integrative approach to addressing this conservation challenge, seeks to identify potential avenues to engage communities and promote adoption of "bat-friendly" agave management practices in northeast Mexico, where two important roosting caves are located. In summer 2016 and 2017, I conducted 27 semi-structured interviews with community leaders, agave harvesters, and elders from 14 communities in the region. These interviews focused on understanding the local contexts of the communities and the current management practices, and identifying potential motivations or barriers to adopting "bat-friendly" practices. Preliminary results show that each community has differing social, political, and economic contexts, and therefore differing incentives and barriers to adoption. This highlights the need for gaining insight into a community's context prior to implementation of "bat-friendly" agave management programs, and tailoring the specific implementation strategies to these

local contexts. Ultimately, this research will provide valuable information for organizations seeking to work with communities to conserve the endangered Mexican long-nosed bat.

Foraging Dispersion and Resource Use of Ryukyu Flying-foxes and Relationships with Fig Abundance on Iriomote Island

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The Ryukyu flying-fox is among the most northerly distributed and least studied pteropodids. Its status has called for a high priority of conservation concerns. We surveyed foraging dispersion of the Yaeyama subspecies along transects covering different types of habitats on Iriomote Island. Tree compositions and heterogeneity were assessed at each transect site. We also collected feeding remains and compiled observational records to evaluate food resource use of bats. Foraging bats were non-randomly distributed among transects. Outskirts generally contributed more frequent bat presence, but the highest mean densities occurred at village sites on the west coast where less proportions of land area were devoted to human use. Mean bat densities were higher in villages and inland forests than in cultivated areas, but were not different among inland forests from different parts of the island. In villages, bat density was correlated to tree heterogeneity and the density of fruiting trees. Yet, in forests bat density was positively dependent on the density of total figs, the basal area coverage of *Ficus septica* and *F. variegate*, and particularly intermediate levels of crop sizes of these figs. These bat-dispersed figs were the most abundant figs in forests and predominant foods of the 40 or so species of plants fed on by bats. Our results support that higher flying-fox abundances occur in areas with less anthropogenic interference, whereas in forests flying-foxes depend on the availability of the most abundant bat-figs. Preserving undisturbed forests containing adequate and suitable resources should be a primary focus for flying-fox conservation.

Morphological Diversity in the Sensory System of Phyllostomid Bats and Implications for Acoustic and Dietary Ecology

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The evolution of novel morphologies in the sensory system can expand ecological niches, allow resource partitioning, and spur diversification. Neotropical leaf-nosed bats (Phyllostomidae) are one of the most ecologically diverse groups of mammals; they evolved a wide range of foraging ecologies and extreme variation in external sensory structures used for echolocation (i.e., nose leaves and pinnae). We examined how the shape of these structures evolves, the mechanisms underlying morphological diversification (e.g., modularity), and how morphological diversity of the sensory apparatus is related to ecological diversity and differences in echolocation calls in phyllostomids. We used 3D geometric morphometrics to quantify the shape of the nose leaf and pinnae of 19 phyllostomid species spanning all the dietary guilds found in the family. We found that the nose leaf consists of two modules, the spear and the horseshoe, which evolve independently and may enable morphological diversity. Nose leaf shape overlaps among dietary guilds, but animalivorous species occupy a larger area of morphospace. This may be related to differences in prey type specificity within each guild. Pinnae morphologies differ between animal-eating and plant-eating species, suggesting functional adaptations to the acoustic cues used by bats to detect prey. We have not found significant differences between morphology and echolocation call characteristics. This may because these structures are dynamic and perhaps behavior plays an important role and echolocation calls can be plastic. Altogether, these results highlight the mechanisms underlying morphological diversification of the sensory apparatus in nasal echolocating bats.

Skin Microbiota Potential in White-nose Syndrome Resistance of Hibernating *Eptesicus fuscus*

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The microbiota (i.e., host-associated microorganisms) is a key component of animal health. Bat skin microbiota almost certainly interacts with *Pseudogymnoascus destructans* (*Pd*), the causative agent of white-nose syndrome (WNS), and variation in the microbiota could help explain differences in WNS susceptibility between species. An anti-fungal strain of *Pseudomonas* bacteria was isolated from the skin of the big brown bat (*Eptesicus fuscus*, EPFU) and this could help explain why EPFU appears not to have declined under WNS. However, the complete skin microbiota of this species when facing *Pd* has never been fully investigated, despite its potential effect in disease persistence. Consequently, our objective was to explore hibernating EPFU skin microbiota to better understand its role in resistance. We hypothesized that antifungal bacteria will be enriched in the skin community following infection. We characterized the skin microbiota of hibernating EPFU not infected and experimentally inoculated with *Pd* at the University of Winnipeg facility during winter 2017 using high-throughput 16S rRNA gene sequencing. We observed an important temporal shift in skin bacterial communities following inoculation, but diversity was weakly affected by the *Pd* infection. Yet, enrichment of the putative antifungal genus *Pseudomonas* was detected in *Pd*-inoculated bats, indicating a significant shift in skin microbiota in response to the fungal infection. Our results support the hypothesis suggesting a protective role of microbiota for bat species facing *Pd* infection and highlight the potential value of the skin bacterial community in the fight against WNS.

Basal Hollow Maternity Roosts of Southeastern Myotis in Alabama

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Southeastern myotis (*Myotis austroriparius*) is an insectivorous bat that occurs in bottomland hardwood forest along the coastal plain and Mississippi River from southern Illinois to Florida. Female southeastern myotis form large maternity roosts containing several hundred to 90,000 individuals during the spring and summer months. These maternity roosts are primarily located in caves, but have also been found in tree cavities. In Alabama, only two known maternity roosts for southeastern myotis exist and both are located in caves along the coastal plain. Southeastern myotis are considered a species of highest conservation concern in Alabama and little is known about their distribution and natural history in the state. We discovered three maternity roosts of southeastern myotis in the southern Appalachians of northeastern Alabama over a hundred miles outside the known range of this species. Over three years of netting at our study site, we captured 47 adult and juvenile southeastern myotis. We radio tagged nine females and tracked their day roost usage. All bats exclusively used one of the three basal hollow roosts. The maternity roosts were located in basal cavities of two tulip popular (Liriodendron tulipifera) and a blackgum (Nyssa sylvatica) in upland riparian forest habitat. Emergence observations revealed several hundred bats were using these roosts during the breeding season. Due to the lack of ecological knowledge of this species, we cannot conclude if their range has extended or has previously been undetected in the area.

Threshold Patterns in the Effect of Residential Urbanization on Bat Diversity

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Urbanization has species-specific effects on bats. For example, big brown bats (*Eptesicus fuscus*) and Mexican free-tailed bats (*Tadarida brasiliensis*) adapt well to cities whereas species from the genus *Myotis* usually do not. Residential developments compose the majority of a city. Species' composition could be different in residential areas as compared to nearby natural areas. Furthermore, the intensity of residential urbanization should have an influence on bat diversity. Using a multiple city comparison approach, we hypothesized that an effect of residential urbanization on local bats would only be found when residential development reached a certain intensity. We used human population density as the index of residential urbanization intensity. In the summers of 2015 and 2016 we established 23 residential–natural area paired sites to monitor bats across the state of North Carolina, USA. We followed the North American Bat Monitoring Program stationary point survey protocol to record bat acoustic activities for 4 consecutive nights at each residential–natural area paired sites, simultaneously. We found that low intensity residential areas had the same number of bat species as in nearby natural areas. Medium intensity residential areas had a lower number of bat species than in nearby natural areas. High intensity residential areas had a higher number of bat species than in nearby natural areas. Our results show that the impact of residential urbanization on bat diversity is not a simple linear relationship. We suggest that conservation efforts should be considered when planning new medium intensity residential developments in regions with endangered species.

Separating the Effects of Water Quality and Urbanization on Temperate Insectivorous Bats at the Landscape Scale

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Many local scale studies have shown that bats respond to water quality degradation or urbanization in a species-specific manner. However, few have separated the effects of urbanization vs water quality degradation on bats in single city or single watershed case studies. Across North Carolina, USA, we used the standardized North American Bat Monitoring Program mobile transect protocol to survey bat activity in 2015 and 2016 at 41 sites. We collected statewide water quality and urban land cover data to disentangle the effects of urbanization and water degradation on bats at the landscape scale. We found that statewide water quality was not correlated with urbanization. Bats responded to water quality degradation and urbanization independently at the landscape scale. *Eptesicus fuscus* and *Lasiurus cinereus* negatively responded to water quality degradation. *Lasiurus borealis* and *Perimyotis subflavus* positively responded to water quality degradation. *Lasionycteris noctivagans* did not respond to water quality change but was more active in more urbanized areas. *Tadarida brasiliensis* positively responded to urbanization and was less active in lower water quality areas. These landscape scale results were generally consistent with local scale study results. Our study demonstrates that bat-water relationships found at the local scale are evident at a landscape scale. We confirm that bats are useful bio-indicators for both urbanization and water degradation. We suggest that water quality can be used to predict the presence of species of conservation concern, such as *P. subflavus* in areas where it has not been studied locally.

Establishing Baseline Data from Bat Monitoring Surveys in Guyana

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An annual biodiversity monitoring program was established in 2011 at Iwokrama Forest and neighbouring Surama Village in Guyana by Operation Wallacea, an organization in England that combines

conservation research at academic institutions with the training of university students. This report on the bat monitoring project will contribute baseline data to the United Nations initiative to incorporate the conservation of biodiversity in Reducing Emissions from Deforestation and Forest Degradation (REDD+) in developing countries. Iwokrama Forest is home to about 90 species of bats, making it one of the better documented and diverse protected areas in the world. Establishing long term monitoring based on standardized survey methods is an essential step in attaining a more complete understanding of this bat community. Six sites were surveyed using 18 understory mist nets arranged in nine pairs positioned at 50 m intervals in a 100-meter grid. There was substantial overall variation on an annual basis ranging from 30% fluctuation in species diversity and 200% change in relative abundance. Among sampling sites, there were two general patterns of biodiversity measures as summarized by species accumulation curves. These differences are attributable in part to climatic patterns, and transient local population densities of large fruit-eating bats and availability of their food resources. Establishing baseline data is needed for differentiating natural background variation from human-induced climate change. Biodiversity research is crucial for basing public policy on long-term scientific information suitable for global initiatives such as REDD+.

Effect of Omnidirectional Microphone Height and Distance from Edge on Call Quality

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Many factors affect the quality of calls collected by field microphones including microphone type and the surrounding environment. Omnidirectional microphones tend to record more calls than directional microphones because they can pick up sound from all directions, but also tend to record more noise which reduces call quality. One way to reduce the amount of noise is to keep the microphone away from vegetation and other echo producing objects such as the ground. Our objective was to determine the best height and distance from clutter required to reduce the amount of noise recorded during regulatory surveys for Indiana bats (*Myotis sodalis*) and northern long-eared bats (*M. septentrionalis*). We set up 9x9 arrays of Anabat Express and Wildlife Acoustics SM4BAT FS detectors with omnidirectional microphones near Indiana bat colonies at two sites in Kentucky during July and August 2016. Detectors were set in open areas 1.5, 5, and 9 m from the ground and 1, 3, and 5 m from the nearest edge for 3-6 nights each month. We used a customized filter to remove noise files and a more restrictive filter and visual examination to remove low quality calls. The total number of bat calls, the number of high quality calls, and the percentage of high quality calls did not differ significantly with height, distance, or the interaction for either detector type, but differed significantly with month. Thus, our preliminary data suggest that distance from clutter may not be an important consideration when deploying detectors with omnidirectional microphones.

The Morphological Variation of the Nose Leaf in the Family Phyllostomidae

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The nose leaf is a soft tissue structure attached to the nasal cavity whose function is commonly associated with the acoustic emission pattern of the bat's echolocation. The Neotropical bat family Phyllostomidae is composed of 43 genera and 92 species. It is the only family that presents a nose leaf. The structure of the nose leaf includes a horseshoe-shaped base with a well-defined vertical projection or lancet. Despite its general format, there is a large variation of nasal leaf shapes among species of the Phyllostomidae family. To describe the morphological variation in the nose leaves within the same family, we analyzed 11 species of five subfamilies using the Elliptic Fourier Analysis (EFA) quantification methodology. The specimens were photographed, and the nose leaf contour was obtained using the TPS

program. Morphometric and statistical analyses were done using the R program. The nose leaf presents a considerable morphological variation, and this is one of the few papers where this variation is accessed using geometric morphometry techniques. We observed a significant phylogenetic signal in the shape of the nose leaves, with species that are phylogenetically close to each other tending to be more similar than distant ones.

Are We Underestimating the Threatened Status of the South American Bats?

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The definition of threatened status is considered the first step toward to a general conservation policy in a country. The International Union for Conservation of Nature - IUCN criteria is used worldwide to define the conservation status of plants and animals, and there are quantifiable parameters that can help such definition. Although some parameters are difficult to obtain or virtually do not exist (e.g., the number of mature individuals), others can be easily obtained for most species. According to the IUCN, 19 bats are considered threatened with extinction in South America, which represents 7,3% of all 258 species listed for the region. The 19 bat species are classified as Vulnerable-VU (10 species) or Endangered-EN (9 species). The proportion of threatened mammals is 18,1% (185 species among 1081 non-bats mammals), and the comparison indicates that bats are proportionally less threatened than other mammals in general ($X2 = 17.107$, $p<0.01$). In this study, we aimed to identify how many South American bat species could be considered threatened using two basic information: the proportion of remaining natural areas and the mean Human Footprint index along the bat's distribution range. We analyzed 258 bat species listed for South America. Based on our analyses, at least 35 of them should be considered threatened with extinction, because they have less than 50% of remaining natural areas and high human pressure. The IUCN criteria are beneficial, although a precautionary approach is necessary mainly in the absence of ideal data.

No Bats in Bat-Baobab Pollination System of South Africa: What Are the Consequences?

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Baobab trees (*Adansonia digitata*) span mainland Africa and have chiropterophilous flowers, and observations and exclusion experiments suggest that bats are the primary pollinators. However, in South Africa, bats do not appear to visit baobabs and hawkmoths are proposed to be the primary pollinator. Because bats should carry greater pollen loads, connect more distant trees, and bring pollen from a greater number of donors, we hypothesized that reproductive output would be greater if trees were pollinated by bats. To test for the potential lack of bat pollinators, we created a hand pollination experiment. We tested the effect of pollinator characteristics on fruit and seed production, mimicking bat and hawkmoth pollination behavior. We manipulated pollen load (small as in hawkmoths vs. large as in bats), distance of donor tree from recipient (near for hawkmoths vs. far for bats, and donor diversity (one vs. four individual donors) in a factorial design. Included also in each of the 45 replicates on 16 unique trees were open flowers, available for natural pollinators, and flowers excluded from pollinators that also received no pollen. The number of seeds, mass of fruit, and size of the fruit were recorded and used to analysis. There was no effect of treatment on any variable (ANOVA, $p > 0.5$), but there was an effect of individual recipient tree. Our results indicate that there is no difference between bat and hawkmoth pollinators in our hand pollination simulation, suggesting that baobabs have adapted to a lack of bat pollinators in South Africa.

Summer Activity of Bat Species at Dyess Air Force Base

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The Dyess Air Force Base (DAFB) Integrated Natural Resources Management Plan is an important managing tool that ensures military operations and natural resources conservation are integrated and consistent with stewardship and legal requirements. Wildlife sampling is being conducted in order to implement management strategies to conserve biological resources. We are currently acoustically monitoring for bat activity at the South Diversion Ditch system at DAFB, Texas. The natural ditch has been channelized during the history of the installation, and flows northeast through the base into a storm drainage channel that feeds offsite. Two Song Meter SM4BAT FS detectors were deployed (one on the ditch bank, the other at the storm drainage channel) for 32 sampling nights during the months of May to June 2017. We used Kaleidoscope Pro 4 to analyze recorded data, and documented Mexican free-tailed bat (*Tadarida brasiliensis*), hoary bat (*Lasiurus cinereus*), eastern red bat (*Lasiurus borealis*), canyon bat (*Parastrellus hesperus*), big brown bat (*Eptesicus fuscus*), pallid bat (*Antrozous pallidus*), and silver-haired bat (*Lasionycteris noctivagans*) utilizing the South Diversion Ditch system. Activity differed among recorded bat species with Mexican free-tailed bat (bat passes = 271) and hoary bat (bat passes = 179) being most active. All bat species documented were recorded at both detectors, and activity was highest at the ditch bank (396 bat passes). Bat activity is still being monitored. These preliminary results suggest that bats routinely utilize the ditch system during nightly activities, and possibly provide insight in how the ditch system should be managed and maintained.

Predicting Susceptibility of Western Bat Species to White-nose Syndrome

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As white-nose syndrome (WNS) continues to spread across North America, there is an immediate need for prioritization of conservation action directed at currently uninfected, at-risk species. However, various constraints (i.e. rough terrain, poor accessibility, limited resources) challenge the conservation community's ability to meet this objective. Powerful modeling tools offer significant advantages over traditional empirical studies in that they use existing data to identify patterns and trends, produce informative results in a short timeframe, can be modified easily as new data become available, and can identify key areas of uncertainty in the system. Combining existing data on bat biology and life history traits with the knowledge gained from WNS research over the last decade, our goal is to quantify the threat of population-level decline for North American bats currently unaffected by WNS. Specifically, we used a machine-learning approach to identify which currently unaffected bat species in North America are most susceptible to WNS. In addition, we produced a profile of traits that best distinguish bats according to their likelihood of developing clinical signs of WNS. The work presented here are the first steps of a larger effort to rank bat species by risk status and make informed recommendation in a detailed report for proactively planning for WNS arrival in currently unaffected areas.

Western Bat Distributions Before and After Exposure to White-nose Syndrome: A Hybrid Correlative-Mechanistic Modeling Approach

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As white-nose syndrome (WNS) advances westward from eastern and central North America, where it has caused widespread bat mortality and threatened several bat species with extinction, it will infect new populations, species, and hibernacula. Western North America's extensive public lands host the highest bat diversity on the continent, so it is critical that western land managers have the information they need to anticipate and address the conservation needs of WNS-susceptible species. We predict changes in several western bat species' probability of occurrence across western North America by integrating spatially explicit estimates of winter survival capacity before and after exposure to WNS with high-resolution maps of key bat habitat characteristics. Winter survival capacity is estimated from a mechanistic survivorship model based on host bioenergetics, climate conditions, and characteristics of the fungal pathogen that causes WNS. Leveraging the Google Earth Engine platform for spatial data processing, we use these estimates, along with landscape attributes, as predictors in hybrid correlative-mechanistic ecological niche models fit to bat occurrence data using a multi-model inference approach. Preliminary results show that, along with topography, winter survival capacity is a primary driver of western bat distributions, where relative probability of occurrence decreases with decreasing winter survival capacity. As winter survival capacity is expected to decline with exposure to WNS, it is crucial that managers anticipate which species are most susceptible to these declines, and where, to implement effective conservation strategies for western bats. We conclude with aims for continued model development, including integration of projected climate change impacts.

Sanctuary: US DOE Oak Ridge Reservation

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The US Department of Energy's Oak Ridge Reservation is an approximately 33,000-acre tract of land located in East Tennessee, and it is the largest continuous undeveloped area within the Ridge and Valley Physiographic Province of the Eastern United States. Most of the undeveloped portion of the Reservation falls within the DOE National Environmental Research Park, which is composed mostly of deciduous forest, undisturbed wetlands, open water and riparian vegetation, areas of native grassland communities, and it is bordered on the south and west by the Clinch River. Caves and cave-like structures exist on the property as well. Acoustic surveys using Wildlife Acoustics SM-3Bat + and SM-4 monitors, followed by analysis using approved USFWS methods allowed us to establish baseline bat species diversity and population density. These surveys were done during the summer season from 2013 through 2017 and during the winter and spring emergence in 2017. Results show that of the sixteen species of bats found in Tennessee, thirteen species are widespread across the Oak Ridge Reservation, one species has been recorded in a protected area of the Reservation, and one additional species was captured during a mist net survey. Natural resources management and conservation of prime forest bat habitat are key efforts in bat population stabilization on the Oak Ridge Reservation.

Temporal Acoustic Detection of Bats in the Piedmont of Paulding County, Georgia

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Restoration of montane longleaf pine (*Pinus palustris*) in the Georgia piedmont may consist of methods such as controlled forest burns, herbicide application, selective cutting, and replanting. These restoration methods affect the activity of wildlife. We have monitored nocturnal activities among insectivorous bat species in two wildlife management areas in the Raccoon Creek Watershed of northwest Georgia locations over several months in 2016 (July to October). The two regions differ in landscape management histories and current long-leaf pine restoration stages. Our preliminary results indicated a significant difference in species presence and activity between regions that differ in landscape management histories ($p < 0.001$), but no significant differences among restoration/ management practices. In addition, we examined the acoustic data (species ID > 5 calls and > 70 % match ratio) to characterized temporal patterns of activity and overlap for the bat species detected (~7 species) during the sampling season. We compared activity patterns and assessed temporal overlap among species to evaluate assemblage-wide temporal overlap. The two habitats have the same species composition. In general, bat species temporal overlap was high (Pianka Index = 0.6303; $p = 0.2806$). Activity peaks of most bat species coincided. A few species (example: Hoary and Silver-haired bats) showed more distinct temporal activity peaks. This work could provide the framework for the generation of hypotheses that explore the potential role of time as a mediator of ecological interactions in southeastern United States bat assemblages.

Stop Using Body Condition Index

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Researchers often use simple body condition indices to estimate the relative size of fat stores in bats. Animals determined to be in better condition are assumed to be more successful and have higher fitness. The most common body condition index (BCI) used in bat research is a ratio index of size-corrected body mass, taking body mass divided by forearm length. We used data from previous and ongoing studies where body composition (fat mass and lean mass) was measured by quantitative magnetic resonance (QMR) to test basic assumptions of BCI, determine whether BCI is an effective proxy of fat mass, and whether other approaches could be more effective. Using data from 1839 individual measurements on 5 species, we found no support for the underlying assumption that bats with longer forearms weigh more than bats with shorter forearms. Intraspecific relationships between body mass and forearm length were very weak ($R^2 < 0.08$ in most cases). BCI was an effective predictor of fat mass, driven entirely by the relationship between fat mass and body mass. Calculation of BCI essentially amounts to dividing body mass by a constant. We evaluated alternative approaches including scaled mass index, using tibia length instead of forearm length, or predicting lean mass, but these alternatives were not more effective at predicting fat mass. The best predictor of fat mass in bats is body mass. We recommend researchers stop using BCI unless it can be demonstrated the approach is effective in the context of their research.

Do Bats Alter Nightly Foraging Activity in Response to Auditory Predation Cues?

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Interactions between foraging bats and nocturnal avian predators are not widely understood. Therefore, the objective of our study was to determine if bats alter nightly foraging activity when exposed to a perceived predation threat in the form of broadcast owl calls. Bat activity was assessed using full-spectrum acoustic monitoring at a U.S. National Guard installment in the Interior River Valleys and Hills Ecoregion of western Kentucky. Survey locations were selected at sites previously identified in 2016 to have relatively high amounts of bat activity. Replicate detectors were deployed for three consecutive nights across four such sites, with different auditory treatments broadcast from water-proof speakers each night. Treatments were broadcast at 80.5 ± 0.8 dB within 1 m of detectors. Auditory treatments were randomly assigned across survey points nightly and included: owl calls (*Strix varia* and *Bubo virginianus*), ambient noise as a mixture of local insect and frog sounds, and a silent control. Auditory treatments were broadcast for 30 sec every 10 min throughout survey nights. Sampling spanned 36 survey locations across four sites, and accounted for 108 detector-nights and approximately 9,300 bat passes. Preliminary analyses indicate that levels of bat activity in this study correspond with previous assessments of bat activity at the sites. While activity was variable across nights, bat activity trended lower at survey points where owl calls were broadcast. These data underscore the importance of understanding the complex role of bats as both insectivorous predators and an opportunistic prey items within food webs.

Putting Eocene Fossils into the Bat Family Tree

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Bats (Order Chiroptera) are unique among mammals in having evolved both powered flight and echolocation. Phylogenies including various combinations of extant species and Eocene fossils (ca. ~47—52.5 Mya) have produced conflicting results concerning relationships of ancient bats to living lineages, and hence conflicting conclusions about patterns of chiropteran evolution. Some analyses have placed Eocene bat lineages as consecutive sister-taxa to the chiropteran crown group, while others (notably the AToL Mammals tree) found that Eocene bats formed a clade that nests within the crown group as sister to a monophyletic Microchiroptera. The latter result is remarkable in part because monophyly of Microchiroptera has been uniformly refuted in numerous multigene analyses over the last decade. However, all past analyses including Eocene fossils have suffered from gaps in taxonomic sampling (e.g., the AToL Mammals project included only two fossil bats) and/or character sampling. No study to date has included all five of the well-preserved fossil bat taxa sampled for all of the phenomic characters known to vary in bats. We tested competing hypotheses using an expanded matrix of morphological data (>600 craniodental and postcranial characters) combined with DNA sequence data from multiple genes. Morphological characters were assembled in a single matrix in the online platform MorphoBank. Phylogenetic analyses of our molecular data produced trees congruent with past analyses based on genes only. In contrast, addition of the morphological data – and Eocene fossils – produced a novel tree that has surprising implications for our understanding of the evolution of ancient bat lineages and echolocation.

Save Our Bats, Save Our Tequila: Industry and Science Working for Pollinators

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Agave plants are very diverse and heavily used by humans to produce alcoholic beverages such as tequila and mezcal. Agave has coevolved with nectar-feeding bats, and often, bats are their main pollinators. But with growth in the demand of agave-derived products, management practices have reduced dependence on bat pollination, using instead clonal shoots to replant fields and harvesting plants before flowering, thereby negatively affecting both bats and agaves. We approached the industry to explain the risks incurred in these practices and describe bat-friendly practices to explore possibilities to incorporate them into the production system. We developed a proposal to producers to allow only 5% of the plants to flower in their fields per hectare (approximately 222 individuals in one hectare). Producers adopting these practices, receive a label indicating that the distilled was produced using bat friendly practices. In 2016 we launched 300,000 bottles of bat friendly tequila. Depending on nectar concentration and total volume, 222 agaves per hectare would allow a minimum of 89 individual bats to feed every night during the flowering period. Extrapolating to the total area of the Tequila Denomination of Origin, allowing 5% of the current total population of *A. tequilana* reproductive agaves to flower could feed over 2 million nectar feeding bats per month. This process may well turn into the industry standard given the reaction obtained from several producers and more are joining the program.

Baseline Data on Overwintering Bats and Hibernacula in Texas

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White-nose syndrome (WNS) has led to precipitous declines in population size of cave-dwelling bat species in eastern Unites States. Of the 33 species documented in Texas, five species have known susceptibility to the fungus. Based on current rates of expansion, we expected that the fungus and potentially WNS could be documented in Texas within the 2016-2019 period. To understand the potential threat of WNS to bats in Texas, we monitored for the fungus and signs of WNS, as well as collected data on bat species distribution, abundance, and environmental characteristics at 20 sites from January-March 2016, and 207 sites for the 2016-2017 winter season. We submitted 142 swabs from bats for testing of *P. destructans* using real-time PCR in the 2016 winter season. All swabs were negative for the fungus. Additionally, we submitted 163 samples for testing between January and March 2017. Of the 10 sites swabbed, 5 produced positive results for *P. destructans* DNA. Throughout our surveys, we documented baseline data for winter roost sites of seven bat species and obtained winter distribution information for one species (*Nycticeius humeralis*). These baseline data will play a critical role in developing management plans prior to the arrival of WNS, and provide guidance on how to proceed should it arrive.

Fine-scale suitability modeling of *Myotis lucifugus* hibernacula in the Ozark Plateau

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Censuses of bats are typically carried out on known roost locations over multiple years. Long-term records indicate that caves known to be used by hibernating bats may become abandoned and recolonized over time. This study uses occurrence records of the little brown bat (*Myotis lucifugus*) from surveys

conducted in the Ozark Plateau of Missouri and Arkansas along with high-resolution environmental layers including climatic, topographic, geological, and hydrological landscape variables to construct a habitat suitability map attuned to hibernacula. A machine-learning approach to model construction is used to compare contributions of different classes of landscape variables to suitability estimates. The most predictive variables were slope and groundwater flow, suggesting that physical landscape features were more predictive than external climate features. Evaluation datasets are used to test model effectiveness over geographically partitioned blocks. Adjustments of model data input and parameterization provide habitat suitability values along with uncertainty estimates across the study landscape, allowing for the identification of caves most likely to host little brown bats. This work is intended to complement broader population models and provide a tool for surveying potential hibernacula sites.

Wildlife Use of Livestock Water Troughs in Several States East of the Mississippi River

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Many factors influence availability and quality of natural water sources that wildlife might use on the landscape. However, when natural water sources are unavailable or undesirable, wildlife may opportunistically exploit artificial water sources provided for livestock. In June 2016, we collected survey data from 269 NRCS employees regarding the incidence of livestock producer reports of wildlife mortalities in livestock water troughs located east of the Mississippi River; 36.8% reported they or their producers observed dead animals in livestock troughs. In addition to the survey, July - September 2016 and June – September 2017, we collected field data at livestock water troughs located in several states east of the Mississippi River. We examined the frequency of wildlife visits to livestock troughs, the type of wildlife using these troughs, and the trough characteristics. During 48-hour sampling periods, we recorded wildlife use at each trough with three Bushnell Trophy Cam HD trail cameras, and recorded bat activity and species richness in the vicinity of the trough with a Wildlife Acoustics SM4BAT detector. Several species of wildlife, the majority of which were either mammalian or avian, were observed using and/or interacting with more than a third of the livestock water troughs in our study. The level of wildlife use of water troughs observed in this study suggests that livestock troughs might be an important alternative source of water for some wildlife species, for whom predation risk might increase as they have to cross the landscape to reach the nearest natural water source.

Density as Indicator of Threat Level and Conservation Needs of Fruit Bats on Islands

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Over 80% (153/187 spp.) of Old World fruit bats live on islands. Half of these are threatened with extinction due to the habitat loss and human disturbance that especially affect island species. Threatened fruit bats remain largely unknown. Only a small fraction (1/10) of published research on fruit bats has been on threatened species, compared to common species. Managers recognize the need to make informed decisions for conservation, but most island populations have not been surveyed. Although population declines are the preferred indicator of threat level, monitoring to detect trends requires more intensive survey effort than most managers can provide. Fruit bats roost in large aggregations making it possible to assess population size for a given area. I used density measures to assess population threat level and inform fruit bat conservation management on two island chains in the Indo-Pacific region. In the Philippines, among 17 roosting populations surveyed, the most protected colonies are 5 to 10 times larger for the same amount of habitat as disturbed colonies. Density of generalist species' populations increased by 6-fold with

agricultural fruit presence suggesting a competitive advantage over specialists. In the Mariana Islands, recovery goals are being set for the federally protected Mariana fruit bat. I used fruit bat density on the most protected island (1.88 bats/ha) in the archipelago to project target population sizes for the other islands. Until monitoring programs are developed for threatened fruit bats on islands, density estimates from population assessment snapshots can provide guidance for urgently needed conservation management.

Insectivorous Bat Activity in Cerrado, a Neotropical Savanna

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Cerrado is a biome that consists of open areas with forests along water courses. It's considered the most diverse savannah in the world and bats are the mammals that most influence richness and diversity in this biome. In order to improve bat conservation, it's important to know their activity during the night and how landscape influences their habitat choices. This work aims to evaluate activity of insectivorous bats and to verify which environmental characteristics influence their activity. We recorded bats with SM2BAT+ detectors installed in ten sampling points at Brasilia National Park. Bat activity was recorded and then related to environmental characteristics (distance from water, temperature, biomass amount, and landscape diversity). Activity pattern differs among points, but bats are active during all night long, showing two activity peaks. Number of passes were positively related to distance to water course ($t=3.092$, $p<0.05$) and biomass volume ($t=2.568$, $p<0.05$). We noticed that landscape context is important for the choice of bat's activity site. The proximity of the water courses and forests diminishes activity of insectivorous bats that prefer to forage in open typical cerrado areas with greater biomass. Our results highlight the importance of landscape for bat activity, even in small scale.

Identifying Important Habitat Characteristics Associated with Eastern Red Bat *(Lasiurus borealis)* Reproduction in Southeast Ohio

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The eastern red bat (*Lasiurus borealis*) is believed to be experiencing population declines due to collisions with commercial wind turbines and habitat loss. To determine the effects of habitat degradation on red bats, and to generate recommendations for land use managers to improve conditions for the species, we studied mist-net capture rates, acoustic activity, and day-roosting habitat at two study locations in southeastern Ohio. We gathered these data within a state dedicated nature preserve and a recently reclaimed mining property to assess effects of habitat degradation. During the summers of 2016 and 2017, we netted a total of 40 nights and captured 63 red bats. Capture rates for adult males were similar between the reclaimed land (0.80 bats per night) and the preserve (0.88), but differed for adult females between locations (0 and 0.4 bats per night, respectively). Day-roosts ($n = 19$) used by females ($n = 8$) at the preserve were similar (47.7 cm dbh, 23.3 m in height) to roosts ($n = 21$) used by males ($n = 8$) at the preserve (51.5 cm dbh, 27.9 m in height). However, roosts ($n = 18$) used by males ($n = 12$) at the reclaimed land were smaller (28.5 cm dbh, 15.7 m in height) than roosts used by both sexes at the preserve. These data suggest that recently degraded habitats lack trees large enough for reproductive female red bats. Additional data to be presented will include measures of stand- and landscape-level habitat use, as well as acoustic detection rates.

Acoustic Analysis of Bat Diversity and Seasonal Activity in Northern California

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California is home to 23 species of bats, yet few long-term acoustic monitoring programs exist, especially in northern California. This study examines the diversity and activity patterns of bats in three distinct habitat types (valley agricultural land, low elevation mixed oak woodland, and high elevation pine-juniper forest) in northern California. These three habitats ranged in elevation from 60m to 1554m. Wildlife Acoustics SM3 recorders were placed at each site and echolocation calls of bats were continuously recorded for the duration of the study. Recorded calls were analyzed using SonoBat software. For the first year of the study, over 3700 calls were manually verified and the software had high identification accuracy for species with adequate sample sizes. Collectively, fourteen species were identified across all habitats with seven being ubiquitous. *Myotis yumanensis* was the most abundant and ubiquitous species. *Parastrellus hesperus* and *Myotis thysanodes* were unique to mixed oak woodland habitat whereas *Myotis volans* was only found at the high elevation site. Peak activity patterns varied with the oak woodland having an early spring peak, the valley agriculture site a late fall peak and the pine-juniper site peak activity during the late summer. Bats showed significant seasonal shifts in activity levels but remained present at the two lower elevation sites throughout the year while absent for three winter months from the high-elevation site. This long-term study will enable us to better understand regional diversity patterns, range distributions, as well as seasonal responses to climate and resource availability.

Thermoregulatory Energetics of *Myotis lucifugus* Recovering from White-nose Syndrome

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White-nose syndrome (WNS) causes hibernating bats to arouse too often in winter and use fat reserves too quickly. Therefore, bats that survive likely emerge in spring in poor body condition making it difficult for females to maintain energy balance and support reproduction. Despite the importance of reproduction, little is known about active season energy balance of WNS survivors. We studied thermoregulatory energetics of reproductive female little brown bats (*Myotis lucifugus*) at the WNS invasion front to test two hypotheses: 1) Females recovering from WNS rely heavily on torpor (an energy-saving state of reduced body temperature and metabolic rate) during both pregnancy and lactation; and 2) Torpor expression by individuals is positively correlated with the severity of WNS-associated wing scarring. We captured bats from a maternity colony in northwestern Ontario, Canada, and assessed wing damage using the Reichard index. We attached temperature-sensitive radio transmitters during pregnancy (June 2017, n=13) and lactation (July 2017, n=14). We then used a datalogging receiver to record 300 bat-days of skin temperature data. Consistent with our first hypothesis, both pregnant and lactating bats used torpor nearly every day. Subsequent analysis will allow us to quantify the relationship between wing damage and torpor expression. Torpor saves energy but delays offspring growth so our study will shed light on potential seasonal carryover effect of WNS on reproduction by survivors. This is critical for understanding the potential of survival traits to evolve in endangered bat populations and help support population recoveries.

Time for Alternative Monitoring Approaches? A Case Study on Eastern Small-footed Bats in Virginia

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Efforts to monitor bat populations have relied heavily on surveys of caves and mines in winter, but such data may be of questionable use for some regions or species. Counts of eastern small-footed bats in winter are typically low and have high variance, making detection of trends difficult. We assessed population trends in Virginia using surveys of 11 hibernacula from 1979 to 2017, and surveys of 3 talus slopes in summer from 2013 to 2017. We also estimated detection error in talus surveys, using trials with radio-tagged bats. Negative binomial models indicate abundance in both winter and summer datasets has been stable or increasing at most sites, even after white-nose syndrome. Surveys on talus slopes overlooked 45% of tagged bats, suggesting mean population density was 93 (95% CI: 57 to 162) bats per ha of talus. The number of bats overlooked in hibernacula is unknown but probably high, based on the size of summer populations. Talus surveys are relatively low cost, non-invasive, and provide information hibernacula surveys do not. Initiating the technique elsewhere in the range of eastern small-footed bats would help to corroborate winter data and allow monitoring in places with few known hibernacula. Such surveys also could be important for monitoring other species of bats that roost in talus, such as in western North America where data from hibernacula are often unavailable.

Genomic Evidence That *Myotis lucifugus* 'Subspecies' Are Five Non-sister Species, Despite Gene Flow

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While genetic exchange between non-sister species was traditionally considered to be rare in mammal species, analyses of molecular data in multiple systems suggest that it may be more common. Such interspecific gene flow, if present, is problematic for phylogenetic inference, particularly for analyses near the species level. Here, we explore how to detect and account for gene flow during phylogeny estimation using data from a clade of North American *Myotis* bats where previous results have led researchers to suspect that gene flow among lineages is present. Initial estimates of phylogenetic networks and species trees indicate that subspecies described within *M. lucifugus* are paraphyletic. In order to explore the extent to which gene flow is likely to interfere with phylogeny estimation, we use posterior predictive simulation and a novel Approximate Bayesian Computation approach. The former indicates that the species tree model is a poor fit to the data, and the latter provides evidence that a species tree with gene flow is a better fit to the data than a species tree without gene flow. Taken together, we present strong evidence that the currently recognized *M. lucifugus* subspecies are paraphyletic, exchange alleles with other *Myotis* species in regions of secondary contact, and should be considered independent evolutionary lineages despite their morphological similarity.

De Novo Transcriptome Assembly and Functional Annotation of Immune Response Genes in Five Species of Bats

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Host-Pathogen interactions have resulted in an evolutionary race due to the selective pressure exerted on each other, in which the host has acquired complex mechanisms of defense carried out by the immune system that increase its resistance and surveillance to pathogens. Bats, as well as all living organisms, have been exposed to a wide range of pathogens throughout their evolutionary history, however many studies indicate that bats seem to be more resistant than other mammals. These observations have led to the hypothesis that bats possess a unique and extremely polymorphic immune system that evolved resistance to pathogens. We intended to understand how immune response genes are expressed in five species (*Artibeus jamaicensis, Mormoops megalophylla, Myotis keaysi, Nyctinomops laticaudatus, Peropteryx macrotis*) from the Yucatan Peninsula, Mexico. For this purpose, we used RNA deep sequencing, which is a powerful tool that allows us to perform gene prediction, detect novel transcripts as well as measure gene expression among species. We sequence the whole transcriptome of liver tissue from three individuals per specie. We obtained fifteen paired-end libraries, getting a total of 403 million of raw reads. *De Novo* Assembly, functional annotation and Gene Ontology analysis were performed for each individual. We obtained between 386,721 and 595,065 transcripts. Gene Ontology results have shown that between 2 and 3% of the genes expressed in the target species are genes corresponding to the innate and the adaptive immune system.

At What Landscape Extent is Habitat Amount Most Relevant to Bats in Urban Environments?

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Urbanization is a major driver of habitat loss globally, leading to population declines of many species. Strategic, landscape-level habitat management is critical for species that rely on remnant habitat patches to persist in urban environments. Although there is a known positive relationship between habitat amount and bat abundance, no studies have determined the landscape extent at which this relationship is strongest in urban environments (i.e. the scale of effect) and thus most informative for habitat management. We hypothesized that the scale of effect of habitat amount on bat abundance would be less than a 3.5-kilometer radius landscape, reflecting the high contrast between natural habitat and non-habitat in urban environments and bat dispersal ranges. To test this, we used Wildlife Acoustic SM2+ recorders to measure bat abundance in 52 backyards in Toronto, Canada, with similar local habitat but different habitat amounts in the surrounding landscape. We did this over two, non-consecutive nights between May 30 and August 10, 2017, while controlling for local variation in temperature and light. To examine the influence of insect abundance on bats, we deployed a blacklight trap eight meters from each recorder to measure nightly insect abundance per site. To find the scale of effect of habitat amount on bat abundance, we will use generalized linear models to determine the landscape scale (with a radius between 0.25 and 3.5 kilometers) where the correlation between these variables is strongest. Landscape-level analyses of the relationship between habitat amount and species abundance will inform habitat management in urban environments.

Survival and Recruitment of a Persisting Colony of Little Brown Myotis in Southern Ontario

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The precipitous decline of bats in response to White-nose Syndrome (WNS) in eastern North America has heightened the need to gain a better understanding of their ecology. The behavior, diet, fecundity, philopatry, adult survival and juvenile recruitment of affected bats are critically important to the conservation and recovery of populations. Through four years of study, the Sandilands Roost has a sustained colony of Little Brown Myotis (*Myotis lucifugus*), despite WNS infection. Bats were captured in mist nets and harp traps, banded, PIT tagged, tested for WNS and radio-tracked to other roosts. The roost is part of a network of at least nine roosts, which bats move among and there are trends in association patterns of individual bats. Significant differences were observed between 9 mm and 12 mm PIT tag retention. Acoustic activity at the roost varied between and within years, but adult and juvenile capture rates in July were relatively constant 2015-2017, with return of some juvenile bats to the natal roost and reproduction in their first year. WNS was identified on bats in May, but not in July, and all showed minimal signs of skin or wing damage. Molecular sequencing of guano revealed that Ephemeroptera were most abundant in the diet followed by Trichoptera. This colony indicates that some Little Brown Myotis, including juveniles, are surviving the effects of WNS and still reproducing. Although the reproductive rate of this species is low, this colony could serve as a source for the rebound of Little Brown Myotis in Southern Ontario.

Skull Shape Diversity among Phyllostomids in Relation to Immediate Outgroups: Phylogeny or Function

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The evolution of New World leaf-nosed bats (Phyllostomidae) has produced greater dietary diversity than any other mammalian clade and is a textbook example of an adaptive radiation. Although many studies have examined skull shape in phyllostomids, none have evaluated the distribution of phyllostomids in shape space within the context of their immediate outgroups. We quantified cranial shape using three-dimensional geometric morphometrics in phyllosotmids, other noctilionoids (Noctilio, Mystacina, Mormoopidae), and Furipterus (142 individuals, 70 species). We found strong divergence in shape between phyllostomids and the other bats. The primary axis of shape largely reflects variation in the degree to which the rostrum is upturned and separates phyllostomids from other bats. Insectivorous phyllostomids plotted near the center of phyllostomid morphospace, which approximates the ancestral condition, but separate from non-phyllostomid insectivores. This opens the possibility that cranial shape in basal, insectivorous phyllostomids diverged from cranial shape in other groups before the evolution of unique diets within the family. Variation in cranial shape among phyllostomids reflected well-known difference in diet. These preliminary results suggest the presence of strong phylogenetic signal in cranial shape within the Noctilionoidea as a whole, but strong functional signal (diet) in cranial shape within phyllostomids. Further, we found significantly different evolutionary trajectories leading from the outgroup to the Noctilionoidea (Mystacina tuberculatum), to mormoopids and to phyllostomids. Our next step will

be to quantify functional and phylogenetic signal in cranial shape and to evaluate the pattern and pace of morphological evolution within this broad sample.

Behavior and Aggression in a Roost of *Eptesicus fuscus*

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For many bat species, interactions between individuals are often difficult to observe and quantify. Individuals may cluster tightly together, and the location of roosts often creates physical constraints to the observation of individuals. This study examines inter-individual behaviors over two seasons in a maternal colony of ~60 big brown bats (*Eptesicus fuscus*) in the southern Appalachian mountains. The colony was filmed with minimal disturbance for extended periods using a remotely activated video camera with infrared illumination. Temperatures within the roost were simultaneously recorded. Not surprisingly, at low temperatures overall activity is minimal, although bouts of torpor were fairly rare and brief in this colony. However, at the warmer temperatures that characterized the roost, overall activity (alertness, movement and self-grooming) is much more frequent. Many individuals appear to be active for much of the day. A few individuals often engage in exploratory behavior around the roost, while the majority of others are clustered together. At very high temperatures, activity declines, but individuals remain alert. Based on proximity between pairs of bats, friendships among individuals may exist, although it is possible that an instinct to cluster may drive these behaviors. Aggressive interactions (biting, vocalizing, displacement) are relatively infrequent prior to the birthing period, but these increase dramatically as females are giving birth and tending to their newborns. Following weaning, the rates of aggression decline again in later summer. Juvenile bats appear to engage in exploratory behavior more than do adult females. Other interesting behaviors will be discussed.

Thermoregulation of *Brachyphylla cavernarum*

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Thermoregulation stands out as one of the main factors related to homeostasis in mammals. The different species of bats present great thermoregulatory variability, compared with other mammals. Inconsistencies in the thermoregulatory capacity of different species within a family, and similar regions, have been attributed to factors such as stress caused by the method used at the time of capture, or nutritional condition. Little is known about this aspect of the ecology of endemic species on islands, where in addition, many species have low metabolic rates. *Brachyphylla cavernarum* (Phyllostomidae) is a species endemic to the West Indies. The analysis of thermoregulation in this species contributes to our understanding of the energetic adaptation of bats on islands. The bats were captured in Cueva Bonita in Toa Alta and Cueva Golondrinas in Vega Baja, Puerto Rico. They were placed in respirometry (SABLE SYSTEM) chambers at 17 °C, 22 °C, 27 °C, 32 °C, and 36 °C for a period of two hours. Body mass, and the change in rectal temperature were measured, as well as conditions such as nutritional state. Our preliminary results suggest that *Brachyphylla cavernarum* has a good thermoregulatory capacity, mainly affected by the mass of each animal.

The Evolution of Thermal Niches in Neotropical Nectar-feeding Bats

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The thermal niche of a species is one of the main determinants of its ecology and biogeography. In this study we determined the thermal niche of 23 species of nectar-feeding bats of the subfamily Glossophaginae (Chiroptera:Phyllostomidae). We calculated their thermal niches using temperature data obtained from collection records, by generating a distribution curve of the maximum and minimum temperatures, and using the inflection points of temperature distributions to estimate the species optimal (STZ) and suboptimal (SRZ) zones of thermal niche. Additionally, by mapping the values of STZ and SRZ on a phylogeny of the group, we generated a hypothesis of the evolution of thermal niches of study species. Finally, we used the characteristics of thermal niches to predict the responses of bats to global warming. We found the upper limits of thermal niches varied little among species, while lower limits differ wildly. The ancestral reconstruction of thermal niche indicated that this group of Neotropical bats evolved under cooler temperatures. The two clades inside the Glossophaginae differ in the evolution of their thermal niches, with most members of the clade Choeronycterines evolving “colder” thermal niches, while the majority of the species in the clade Glossophagines evolving “warmer” thermal niches. By comparing thermal niches with climate change models, we found that all species could be affected by an increase of 1°C in temperature at the end of this century. Our study highlights the value of scientific collections to obtain ecologically significant physiological data for a large number of species.

Species-specific Probability of Winter Activity Across a Temperature Gradient in Bats

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Low winter-temperatures drive hibernation and migration in temperate region bats which in turn can influence mortality via white-nose syndrome (WNS) and wind turbines. However, the low-temperatures at which bats are able to be active remains unknown. The goal of this study was to describe the species-specific winter low-temperature thresholds (T_{LT}) for bat activity across the state of North Carolina (NC), USA. NC has diverse winter climates and is well situated latitudinally to study $T_{LT.}$ We defined the T_{LT} as the mean daily temperature at which there was a 50% probability of activity. We hypothesized that different species of bats would have different $T_{LT.}$ We predicted larger species would have lower T_{LT} due to their smaller surface area to volume ratio. We acoustically monitored winter bat activity from sunset to sunrise nightly from December to February at 11 sites across a large temperature gradient (-10C to 25C). We recorded bat activity in at least one site every night of winter (927 recording nights total). The probability of activity was positively correlated with temperature across species. Silver-haired bats (*Lasionycteris noctivagans*) had a lower T_{LT} than big brown bats (*Eptesicus fuscus*), and tri-colored bats (*Perimyotis subflavus*) had a higher T_{LT} than big brown bats. Our results showed that lower T_{LT} was found in species less affected by WNS, supporting that behavioral adaptations to winter temperatures affect WNS susceptibility. Our results can be used to model winter bat activity in the southeastern USA where WNS affected species may be active in winter.

Effects of Forest Management Techniques on Bat Habitat Use at Fort Indiantown Gap, Pennsylvania

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Bats in the eastern United States currently face a host of threats, including white-nose syndrome. Several species are being evaluated for threatened or endangered status due to dramatic population declines. Recent research suggests that conservation of summer habitat may be one of the most effective conservation strategies for these populations. This approach will require a clearer understanding of how forestry practices affect bat communities. The objective of this study was to assess the impacts of forest management techniques on use of summer bat habitat. We focused on the bat community at Fort Indiantown Gap, a military installation in Pennsylvania, where data on forest composition, management treatments, and bat species presence have been collected since 2003. We collected additional data by mist-netting and acoustic monitoring during the summers of 2016 and 2017, which we compared to historical data to examine changes in the bat community by forest treatment over time. We hypothesized that bat habitat use will positively correlate with higher burning rates from prescribed fire, and higher rates of mechanical thinning. Both techniques are expected to reduce clutter and increase insect abundance, which are generally beneficial to bat species. Investigating these relationships can further our understanding of bat habitat use, and better inform land managers of best practices to manage bat summer roosting and foraging habitats.

Bats of St. Lucia and Species Curves in the Lesser Antilles

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Species richness in the Lesser Antilles is shaped by asynchronous variation in speciation, colonization, and extinction rates among taxa. Such data sit precariously atop differential survey efforts and reporting, idiosyncrasies or a lack of a fossil record, and the influence of humans during the last 2000 years. Eight species of bat have been previously mist netted on the island of Saint Lucia: *Noctilio leporinus*, *Monophyllus plethodon*, *Artibeus jamaicensis*, *Brachyphylla cavernarum*, *Ardops nichollsi*, *Sturnira paulsoni*, *Molossus molossus*, and *Tadarida brasiliensis*. With an additional 1500 captures, we added a ninth species to the fauna in 2007—*Pteronotus davyi*. This fauna is depauperate in comparison to Martinique (11) to the north and St Vincent (12) to the south. This is primarily due to the absence of at least two endemic insectivorous bats. Nevertheless, St. Lucia has the 'correct' number of species relative to its elevation. Despite the dearth of habitat diversity or elevational relief on Anguilla, Barbuda, and Grande-Terre (Guadeloupe), they have far more species than predicted by their elevation. The abundant caves on these flat limestone islands provide critical refugia for bats during the breeding season and in times of natural disaster. As such, these islands are ecological sinks that tend to "collect" species, due in no small part to the presence of these caves.

Bats and the City

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Bats in North America are under grave threat by White-nose Syndrome (WNS), caused by the fungus *Pseudogymnoascus destructans* (Pd). Since Pd requires cold and humid environments to survive, urbanization's "heat island effect" may alter Pd's impact on bat populations. The "heat island effect" results from urbanization's impervious surfaces and manmade structures creating warmer and drier climates. These structures, planted trees, artificial lights, and additional water sources may inadvertently offer bats roosting,

commuting, and foraging habitat. Therefore, I hypothesize that, with the appropriate combination of landscape features, urban areas within WNS-positive region could serve as habitat for WNS-sensitive bats. To test this overarching hypothesis, I deployed bat acoustic detectors, insect traps, light loggers, and sound meters every week from March through October starting in 2015, among three urbanization levels, in Mid-Atlantic States. Approximately 260,000 echolocation calls were recorded over 1,027 nights so far. Calls were identified to species level using Kaleidoscope Pro, Sonobat, and manual verification. WNS-sensitive species calls were converted to presence/absence. Generalized linear mixed modeling (GLMM) and linear regression were used to determine important habitat features. Preliminary results indicate the roosting model performed the best. All three levels of urbanization displayed positive correlation between presence and temperature and humidity; negative correlation between presence and wind and clutter; and little correlation between presence and lunar. Correlation varied among the urbanization levels between presence and light, barometric pressure, sound pollution, and precipitation. Management recommendations will focus on forestry practices. Data collection and analysis continues through October.

Barcoding Genes Reveal High Numbers of Cryptic Species in Bats

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An accurate understanding of species diversity has important implications for understanding evolution and ecology, and implementing constructive conservation strategies. Barcoding genes offer an inexpensive and efficient means to explore species diversity in groups that that lack obvious morphological differences. We collected barcoding genes from over 800 species of bats (80% of those currently described) and found that species diversity is largely underestimated. Using the general mixed Yule coalescent model of species delimitation, we estimated that over 2000 species of bats likely exist. After applying a machine learning approach, using up to 102 geographic, environmental, morphological, and life history traits, we found that cryptic diversity is hard to predict, though home range size might play a role in speciation in bats. These results suggest that there is an important need for basic field and molecular research in systematics and taxonomy.

Documenting Bat Echolocation Calls from Solomon Islands and Bougainville

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Almost nothing is known about the ecology and status of Solomon Island insectivorous bats. Widespread logging, mining, invasive species, intensified land use practices driven by population growth, poverty and civil conflicts are likely threats. Bat detectors offer an opportunity to study bat species of an area quickly and efficiently without the intensive effort required to capture bats in remote undeveloped rainforest islands. However, call detection requires use of reference call libraries to identify species. Prior to this study no bat reference calls from the Solomon Islands had been documented. We recorded 2500 reference calls from 14 bat species from Bougainville, Choiseul, Isabel, New Georgia, Guadalcanal, and Makira Island groups using Echometer 3 or Anabat walkabout detectors. We also recorded unidentified free flying bats in these locations. Parameters from reference calls for each species were extracted using Sonobat and Kaleidoscope software. We found calls of most species were distinguishable based on call type, duration and frequency parameters. Calls of some species varied geographically, both *Hipposideros diadema* and *H. cervinus* recorded on Guadalcanal island called 7 and 10 kHz higher respectively than in other islands. Analysis of the free flying bat recordings revealed *Mosia nigrescens* and *Pipistrellus angulatus* were regularly recorded. We also found an additional 3 distinct call types that did not match any reference calls. We have produced an identification guide to the bat calls of the Solomon Islands which is available as a free download. We hope that this guide will enhance bat research and conservation in the region.

Environmental and Biological Context Modulates the Physiological Stress Response of Bats to Human Disturbance

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Environmental and biological context play significant roles in modulating physiological stress responses of individuals in wildlife populations, yet are often overlooked when predicting consequences of human disturbance on individual health and fitness. Furthermore, most studies gauge individual stress responses based on a single physiological biomarker, typically circulating glucocorticoid concentrations, which limits interpretation of the complex, multifaceted responses of individuals to stressors. We selected four physiological biomarkers to capture short-term and prolonged stress responses in a widespread cave-roosting bat, *Hipposideros diadema*, across multiple gradients of human disturbance in and around caves in the Philippines. We used random forest analysis to determine the role of environmental quality (cave complexity and available roosting area), assemblage dynamics (intra- and interspecific associations and species richness), and intrinsic characteristics of individuals (sex and reproductive status) in modulating responses to disturbance. Direct cave disturbance (hunting pressure and human visitation) was the primary driver of neutrophil-to-lymphocyte ratios, with lower ratios associated with increased disturbance, while context-specific factors were more important in explaining total leukocyte count, body condition, and ectoparasite load. Moreover, conditional inference modelling revealed complex interactions among human disturbance and modulating factors. Cave complexity often ameliorated individual responses to human disturbance whereas conspecific abundance often compounded responses. Our study demonstrates the importance of an integrated approach that incorporates environmental and biological context when identifying drivers of physiological responses, and that assesses responses to gradients of direct and indirect disturbance using multiple complementary biomarkers.

Presence-only Modelling Reveals Future Shifts in Suitable Climate Niches for Bats in Western North America

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Climate change is affecting the distribution and abundance of numerous organisms, including bats. Species with narrow ecological niches may be more greatly affected than generalists. While some bat species could benefit by increasing density or expanding ranges, others, especially those occupying cooler biogeographic regions and or more restricted ranges, may go extinct. We used presence-only modelling to determine how future climate scenarios could affect the distribution, community composition, and suitable climate niches for 19 bat species whose ranges are centered in western North America. We used 5,312 species occurrence records obtained from open-source, proprietary, and government databases. We obtained climactic data from Worldclim and used Maxent and Simapse modelling algorithms to project changes in suitable climate niches over the next 100 years at three greenhouse gas (GHG) scenarios derived by the International Panel on Climate Change; low, moderate, and high. Species diversity and suitable climate niche decreased with increasing GHG emissions, especially at higher altitudes and latitudes. The mean range shift for 18 of the 19 species was approximately 267 km northwest under the moderate emissions scenario and 365 km northwest under the high emissions scenario. Species community composition was best maintained in montane and mid-montane regions. While the suitable climate niche for some species such as *Corynorhinus townsendii*, *Macrotus californicus*, and *Leptonycteris* changed little or expanded slightly, others such as *Myotis thysanodes* and *Antrozous pallidus* contracted significantly.

These results will be used to inform climate adaptation strategies and conservation actions to conserve the most impacted species.

Inventory, Abundance, and Habitat Selection of Chiropterans at Felsenthal National Wildlife Refuge (NWR) in Southeast Arkansas

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Chiropterans (bats) are the second largest taxonomic Order of Class Mammalia on earth, second only to rodents. Felsenthal NWR is a 65,000-acre refuge composed of three distinct habitat types: bottomland hardwood forest, cypress-tupelo swamp, and upland pine forest systems. This study was conducted from October 2015 through May 2017 to provide an inventory of bats on Felsenthal NWR, while also looking at seasonal abundance and habitat selection. Acoustic monitoring and mist netting was utilized to record bat species present throughout different habitat types in and around the refuge. All bats collected in mist nets were screened for white-nose lesions, though no signs of the disease or the fungus were observed. Ten of the eleven species documented in southern Arkansas were recorded either acoustically or via live capture. The sampling methods employed revealed habitat selection by species varied significantly. *Lasiurus borealis, Nycticeius humeralis,* and *Perimyotis subflavus* were the three most abundant species.

Monitoring Site Fidelity and Seasonal Activity of Mexican Long-nosed Bats at Emory Cave Using PIT Tags

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Leptonycteris nivalis (Mexican long-nosed bat) is an endangered nectarivore of conservation concern. In an effort to understand how *L. nivalis* use Emory Cave in Big Bend National Park, Texas during migration, bats were captured and PIT tagged in the summer months of 2014, 2015, and 2017. PIT tags were detected using an antennae cable hung in a serpentine configuration over the cave entrance. Across all years, earliest date of detection was 1 May and latest was 1 September, with highest activity in late-June to mid-July. Out of 206 PIT tags, 81.6% were detected in at least 1 year over the course of the study and 5.8% were detected yearly since tagging. Individuals were in the roost area an average of 23.8 days in 2015, 25.4 days in 2016, and 25.3 days in 2017. Because bats were detected every year since installing the PIT tag system, roost abandonment does not seem to be an issue. The percentage of tagged juvenile males that were detected within a season was higher than tagged females, but very few males returned to the cave the following year. Similarly, juveniles had a greater percentage of detections overall than adults, but juveniles were less likely to be detected outside of capture year. The differences in detection rates could indicate an effect of sex and age on site fidelity or differing survival rates. Continued monitoring of this species in Emory Cave using this PIT tag system will improve our knowledge of the Mexican long-nosed bat's population dynamics.

Effects of Forest Thinning on Bat Foraging Activity in the Northeastern United States

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Many North American bat species are experiencing severe population declines due to white-nose syndrome and other threats. While researchers seek direct solutions to these threats, wildlife managers need

actions they can implement on the landscape to support embattled bat populations. This includes evaluation of the effects of common forest management practices, such as selective tree harvest, on a wide range of bat species. Our study evaluated the effects of forest thinning on nightly bat activity at Fort Indiantown Gap National Guard Training Center in central Pennsylvania. We used acoustic sampling to compare bat activity in forest plots that were thinned in spring 2017 to adjacent unthinned forest plots. We recorded from dusk to dawn for an average of three nights at each location with Pettersson d500x detectors and analyzed calls using Sonobat 4.0.7. We included the following predictors in our generalized linear models of bat activity: thinned vs. unthinned, elevation, distance to road, and distance to water. We used Akaike Information Criterion to select the best model to explain bat activity for eight species/groups: *Eptesicus fuscus*, *Myotis leibii*, *Myotis lucifugus/sodalis*, *Myotis septentrionalis*, *Lasionycteris noctivagans*, *Lasiurus borealis*, *Lasiurus cinereus* and *Perimyotis subflavus*. Results indicated that forest thinning generally has a positive association with foraging activity for these North American bat species. We plan to replicate this study next year to determine whether the benefits of selective forest thinning persist across years.

Does Re-entry Flight Behavior Affect the FM Calls of *Tadarida brasiliensis*?

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Brazilian Free-Tailed bats (*Tadarida brasiliensis*) typically re-enter their cave while using echolocation at very high speeds. Though the species' emergence flight pattern and foraging behavior has been studied extensively, re-entry has been poorly studied. In this study, we used a synchronized array of Wildlife Acoustics SM3 Bat recorders and a FLIR a8300sc high resolution, high frame rate thermal imaging video at a maternal colony in Oklahoma. Single bats entering the cave were isolated from our recordings so we could investigate the acoustic and flight adaptations made during different re-entry behavior profiles. Specifically, we designed an algorithm to analyze the change in bat vocalization characteristics as a function of re-entry speed and deceleration. For all bat calls, we first determined the highest received amplitude on the microphone in our array and used that signal for further analysis. Then, we calculated the frequency, call duration, and call FM shape for the echolocation calls in each extracted video and compared acoustic parameters with flight characteristics. These results help us understand adaptations bats make with echolocation and flight behavior during re-entry at high speeds.

Occupancy Modeling of Foraging Bats in Managed Forests within the Piedmont Region of Georgia

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Data on bat occupancy in public agency-managed forests remains limited despite substantial acreage in this category across the southeastern U.S. Objectives of managed forests may shift depending on current legislation or the goals within the agency responsible for the managed forests. Managed natural systems are monitored to detect changes and develop restorative courses of action to any adverse activity within the natural environment. Evaluating managed forests will assist in the development of occupancy models, thus allowing a better approach in evaluating habitat use of bat species found within the study region. To address the currently limited data, we deployed passive acoustic monitors at several forest edge sites within the Piedmont ecoregion of Georgia. Visits to the same sites were repeated between the months of June and September 2017. The PRESENCE program will be used to analyze the credibility of our occupancy modeling. We hypothesize bat species that use low frequency echolocation and with lower maneuverability will have foraging preferences along linear landscapes, including streams, rivers, tree lines, forest corridors, and roadways. We also expect to see the highest foraging activity in places where mature

tree stands and permanent water bodies are within close proximity. This would suggest habitation preference near food sources, minimizing energy expenditure of long commute distances. These data would support the importance of maintaining a diversity in managed landscapes to provide varied resources for a diverse bat community.

Higher Bat Activity at Organic than Conventional Soybean Fields

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Studies that have compared biodiversity at organic and conventional farms have generally found that there are more species in greater abundances at organic farms. One widespread problem with many previous studies is that most do not control for differences in local and landscape-scale structure at organic and conventional farms. At 16 matched organic/conventional soybean field pairs (a total of 32 sites), we measured relative differences in bat species richness, feeding buzzes and activity using acoustic bat recorders. Within each pair the soybean fields had similar field sizes, hedgerow lengths and surrounding landscape compositions at the 1 km, 2 km and 3 km radius extents around the fields. We predicted that organic soybean fields would have greater bat species richness, feeding buzzes and activity than conventional soybean fields due to their prohibition of synthetic pesticides and longer more diverse crop rotations that would be expected to result in a greater abundance and diversity of bat insect prey. We found that, on average, organic soybean fields had higher total feeding buzzes, total activity and activity levels for most of the bat species in the area than conventional fields, after controlling for the effect of differences in soybean height between conventional and organic fields. Our results suggest that the management practices used at organic farms promote bat activity possibly through a greater abundance and/or diversity of bat prey.

A Spatial Look at Little Brown Myotis Roost Conditions and Reproductive Success Across Alaska

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During 2017 we embarked on a project to document and monitor a network of little brown myotis (*Myotis lucifugus*) maternity colonies throughout Alaska. Fourteen colonies were surveyed during June and July from the Kenai Peninsula up to the Copper and Tanana rivers farther north. All colonies were established in human structures that ranged in size, shape and roof structure. Colony size ranged from two to 568 adults with the smaller colonies occurring farther north. Average internal roost temperatures in July 2017 ranged from 19.0 to 21.4°C and reproductive success ranged from 33% to 100% across colonies. Preliminary analysis suggests that reproductive success was not correlated with roost size or internal temperature but there appears to be a geographic element to these variables. This first year of data provides us with a preliminary look at the spatial distribution of little brown myotis colonies and their reproductive success, climatic differences, and roost characteristics which we will continue to monitor and assess over the next five years. Additional data to be analyzed include acoustic monitoring to assess phenology including spring arrival, fledging and autumn departure of bats at each colony across the landscape.

Genetic Diversity of *Artibeus jamaicensis* (Phyllostomidae) in Forest Fragments Surrounded by Agricultural Matrix in El Salvador

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Effects of habitat fragmentation has been well documented related to species dispersal affectation, leading to genetic structure. El Salvador is the most deforested country in Central America, and forest remnants are immersed in an agricultural matrix (grasslands or shaded coffee), affecting habitat suitability for wildlife. We quantified genetic diversity and genetic structure of *Artibeus jamaicensis*, in order to assess how habitat fragmentation affects its population genetic structure. We selected three tropical forest remnants surrounded by shaded coffee, and three surrounded by grasslands. We took wing tissue samples of 100 individuals (49 in shaded coffee matrix and 51 in grassland), and amplify genomic DNA. Our results showed that heterozygosity index were low compared with other studies of the same species (Ho= 0.554±0.013, He= 0.726±0.008). We found no heterozygosity differences among forest remnants with the transformed habitats (Coffee Ho=0.576±0.013, He=0.766±0.014 / Grassland Ho= 0.535±0.020, He= 0.762±0.012). The genetic structure presented significant values close to zero, meaning there is not genetic differentiation between populations (Fst=0.01, p=0.004), that could be considered with a panmictic arrangement. Lack of genetic structure between populations might be due to the high dispersal capability of the species and its adaptation to transformed environments. However habitat loss, might be affecting other less mobile species, which we are studying at this time. This is the first study of genetic populations with wild mammals in El Salvador, and it will serve as reference for future studies with other mammals in fragmented landscapes in Central America.

Roost Use by *Corynorhinus rafinesquii* in an Upland Forest of South Carolina

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Although roosting ecology of Rafinesque's big-eared bats (*Corynorhinus rafinesquii*) is well documented in the Coastal Plains Regions, few studies have examined roost use in upland habitats. *C. rafinesquii* is known to roost in live trees of bottomland hardwood forests within and adjacent to river floodplains. In the northern part of their range, *C. rafinesquii* often roost in caves, mines, or artificial structures, as well as tree cavities. Our objective was to determine roost use of *C. rafinesquii* in the Andrew Pickens Ranger District, Sumter National Forest, in upstate South Carolina. We mist-netted and radio-tracked two *C. rafinesquii* in June and July 2017 and conducted emergence counts to determine colony size. On 8 June 2017 we tracked a pregnant female to a large, live, tulip poplar (*Liriodendron tulipifera*) with a basal cavity. The roost was 30.7 m tall, 89 cm diameter at breast height (DBH), with an interior cavity height of 9.4 m and contained approximately 44 total bats. On 17 July 2017 we tracked a juvenile male *C. rafinesquii* to another large, live *L. tulipifera* with a chimney cavity opening. This roost was 23.2 m tall, 81 cm DBH, and had an estimated interior cavity height of 11.5 m. Approximately 33 bats were utilizing this roost. Although our sample size was small, our data suggest that in upland areas where *C. rafinesquii* exist, conservation of large hollow tree species that commonly form hollow trunks with basal or chimney openings could aid in the conservation of this species.

Bat Research and Conservation in the National Parks and how it is Changing Public Perception

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The public's perception of bats has long been informed by fear and superstition; however, with increased research, public outreach, and education efforts, opinions on bats are moving in a more constructive direction. This shift is especially important since the spread of the cold-loving-fungus *Pseudogymnoascus destructans* that causes white-nose syndrome (WNS) and additional threats such as energy development, climate change, and habitat loss. At Glen Canyon National Recreation Area (GLCA) we approach these challenges by implementing two projects. In 2016 and 2017 GLCA adopted *A Plan for the North American Bat Monitoring Program* (NABat) (Loeb et al. 2015) monitoring methods and surveyed 10 grid cell sample units to assess the distribution, abundance, trends, and threats of bat species susceptible to WNS. In addition, bats were physically captured to verify species presence and to document any wing damage that may indicate WNS. The second project focused on engaging the public in bat conservation efforts through outreach and education events such as Bat Festivals and Citizen Science. These efforts inform the public and citizen scientists on basic biology of bats, threats, conservation efforts, effects of WNS, and most importantly, ways in which they can contribute to bat conservation. Through citizen science, youth are engaged in acoustic monitoring of bats on river trips along the San Juan and Colorado Rivers. Both of these efforts contribute to continent-wide bat conservation efforts and inform people of all backgrounds on the economic and ecological importance of bats.

Cranial Modularity and its Evolutionary Consequences in the New World Leaf-nosed Bats

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Changes in the patterns and magnitudes of morphological integration may influence the ability of a species to respond to natural selection. Here we analyze morphological integration in the skull of a broad phylogenetic and taxonomically structured sample of New World leaf-nosed bats, a highly speciose clade with unique feeding specialization and extraordinary morphological diversity. We investigate the presence of specific functional/developmental modules and evaluate their potential evolutionary consequences for the phyllostomid skull diversification, in terms of flexibility and constraints. Our database includes 35 cranial measurements taken from 2665 specimens representing all the currently recognized subfamilies. The morphological integration hypothesis includes two major regions (face and neurocranium), and five sub-regions (oral, nasal, zygomatic, cranial vault and base). We investigated the level of integration within and between phenotypic modules, comparing theoretical and observed correlation matrices based on functional/developmental relationships among traits. We used Lande's equation to evaluate the species evolutionary potential in terms of their flexibilities and constraints. The evolutionary consequences were also evaluated in the context of other mammalian orders previously studied. Compared to previous works covering several mammalian orders, phyllostomids presented one of the lowest magnitudes of integration, and also quite evident cranial modules (oral, nasal and cranial vault subregions appearing as dominant). Furthermore, species that exhibit lower overall integration magnitudes are associated with higher flexibilities in terms of their evolutionary response to selection. Overall, phyllostomid bats presented highly modular skulls, with greater potential to respond in the direction of selection (higher evolutionary flexibility) and lower evolutionary constraints.

Population Genetics of *Myotis* in Wrangell-St. Elias National Park, Alaska

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In the summers of 2011 and 2012, numerous sites with up to hundreds of bats were found in buildings within the Copper River valley along the western edge of Wrangell-St. Elias National Park. A total of 96 bats were captured in the 2012 and 2013 field seasons; these bats are present as distinct morphotypes and may represent multiple species lineages. DNA sequence analyses of mitochondrial loci (cytochrome oxidase I and cytochrome *b*) and a nuclear (recombination activating protein I) locus do not distinguish the putative species, but species delimitation of western North American *Myotis* species from such data is notoriously problematic. We combine these sequence data with rapidly evolving microsatellite genotypes for coalescent analyses of species delimitation and for assignment-based analyses of population structure. We combine these new data with previously-published homologous datasets from continent-wide phylogeographic analyses of North American *Myotis* to evaluate patterns of divergence among and differentiation within species, to estimate rates of gene flow across the landscape, and to clarify the contribution of Alaskan *Myotis* populations to source-sink dynamics in western North America.

The Importance of Group Phenotypic Composition in Roost Finding Efficiency

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In group living, individuals can exhibit distinct social roles. Social role specialization is highly beneficial because it can reduce the social conflict and energetic expenditures, as well as increase cooperation. For instance, the Spix's disc-winged bat (*Thyroptera tricolor*), a highly mobile animal that uses ephemeral roosts, is known to have distinct social roles in acoustic signaling, to coordinate roost finding. *T. tricolor* groups are composed by one or few vocal individuals, while the rest of the group members produce none or few calls during roost finding. Such complex collective vocal behaviors often arise from simple interaction rules, such as groups pooling information to make accurate decisions. In this case, having a mix of informed and uninformed individuals (i.e. vocal vs non-vocal bats) can promote better decision-making. However, if the number of vocal bats is large, it might create confusion among group members and thus, decrease coordination in roost finding. In this study, we manipulated the number of roosts with vocal bats inside a flight cage to determine how the number of vocal individuals within groups affects coordination and roost finding efficiency. We found that having multiple vocal individuals within a group increases the time spent finding roosts and creates confusion by splitting group members. This demonstrates that groups composed by a mix or vocal and non-vocal bats are more efficient in roost finding. Our results allow us to understand the importance of group phenotypic composition on individual fitness, as well as evolutionary mechanisms determining group formation.

Bats Navigating the Plant Bouquet: Links Between Bat Diet and Fruit Scent Diversity

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Elucidating the links between an organism's sensory adaptations and its ecology is a fundamental challenge in sensory biology. Frugivorous bats have specialized olfactory systems that allow them to locate ripe fruit, but few studies have identified which plant chemicals allow bats to select suitable food items and particular plant species. Here, we investigated these questions in short-tailed fruit bats (*Carollia* spp.) and their primary fruit resource, neotropical pepper plants (*Piper* spp.). We quantified the annual diet of 3 sympatric *Carollia* species and the volatile organic compounds (VOCs) comprising the scents of 26 *Piper* species consumed by bats in Costa Rica. We tested if *Carollia* dietary preferences are associated with differences in VOC composition and abundances, or if other factors like *Piper* ecology and density are more important. We found that *Carollia* consumes *Piper* species that are phylogenetically and chemically clustered. The scents of ripe fruits differ from vegetation scents in these *Piper*, and are characterized by high abundances of sesquiterpenes and monoterpene compounds such as apiol, cubebene, caryophyllene and safrole. These chemicals are commonly involved in diverse ecological processes such as pollination, herbivory and frugivory in other systems. Consumption of different *Piper* species by *Carollia* does not seem to be predicted by plant abundance, but by fruit scent chemical profiles and physical traits. These results illuminate the sensory signals used by bats to find and select ripe fruit, and the mechanisms underlying food resource partitioning among ecologically similar bat species.

Southeastern Myotis and Rafinesque's Big-eared Bats Make Seasonal Switches in Their Roosting Habits in Arkansas Bottomlands

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Rafinesque's Big-Eared (*Corynorhinus rafinesquii*; CORA) and Southeastern (*Myotis autroriparius*; MYAU) bats use tree roosts in bottomland forests and are considered rare across their range. Little is known about their roost requirements as seasons change from fall to winter. The objective was to characterize roost trees in both seasons in the Cache River National Wildlife Refuge, Arkansas, one of few remaining tracts of unaltered bottomland hardwoods. In October-December 2016, we radio-tracked 15 bats (9 CORAs and 6 MYAUs) to 32 different roost trees. Tree species, cavity type and distance traveled were recorded for each confirmed roost tree. Both species switched their roosting habits after the first freeze. Various tree cavity types were used for roosting by CORAs before they switched to trees with only upper openings. However, MYAUs were roosting in basal cavities exclusively before the freeze and diversified their cavity types afterward. This suggests that both CORAs and MYAUs anticipated seasonal flooding that could potentially trap them inside the cavity. Additionally, the distance between consecutive roosts of MYAU became shorter as the season progressed and CORA doubled the time spent at each roost. These behaviors may coincide with changing priorities from foraging to mating or maintaining homeostatic balance (drink, urinate, etc.).

Impacts of Social Group Composition on Personality in *Eptesicus fuscus*

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In the past fifteen years, the existence of animal personalities and behavioral syndromes have been documented in a wide variety of taxa. Yet, key mechanisms driving the evolution and plasticity of personality and the impacts of ecological and behavioral factors remain relatively understudied. While

many of the focal species of personality research are social (sticklebacks, great tits, guppies, various invertebrates), limited work has addressed how group dynamics impact individual personality. Bats are an ideal system for assessing the impacts of the social environment on animal personality, as these animals are highly social and there is extensive variation across species in social structure. Using a captive colony of female *Eptesicus fuscus*, we manipulated group composition, directly impacting the level of familiarity amongst group members. Over a six-week experiment, two groups were unchanged in group composition (control), two groups were mixed once (single mix) and two groups were mixed twice (double mix). At Weeks 2, 4, and 6, animals were tested in behavioral assays that assessed exploration, aggression, and activity. Variation in behavior was assessed for each animal over the study period in relation to the control or treatment group in which they were included. This work will provide a better understanding of how bat behavior is impacted by the composition of a social group, as well as inform us about the stability of personality characteristics in bats.

Impacts of Sex and Reproductive Condition on Personality in Bats: A Pilot Study

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Individual consistency in behavior, or personality, has been studied in a variety of taxa, yet comparatively little work has focused on bat species, especially in regards to differences in sex or reproductive condition. Frequently in mammals, males tend to display aggressive behavior in higher frequency than females, among other personality differences. In this study, we examined behavioral consistency of captive big brown bats, *Eptesicus fuscus*, by testing three groups of animals - five males, four pre-lactating and four post-lactating females. Behavioral characteristics that were assessed included rates of exploration, activity, production of social calls, and aggressive behavior. Three types of trials were conducted, and repeated four times for the first and second trials, and three times for the third trial, across the summer months on each individual. The first trial type was an open field test, in which an animal was placed in an empty, marked container and recorded for three minutes to assess rates and patterns of movement. The second trial type was a hole-board test in which an animal was given three minutes to explore an arena with six holes, two of which hold mealworms. The third trial type was an assay of aggressive behavior, in which two animals were placed in a triangular arena containing a single mealworm. All videos were analyzed using R script, Noldus Ethovision and Observer. This pilot study will provide us with baseline data for assessing if animals differing in sex and reproductive condition exhibit distinct patterns of personality.

Bat Activity Patterns and Fall Roost Use in Montana Managed Forests

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White-nose syndrome (WNS), a disease that has killed between five and seven million bats, continues to spread westward from the eastern United States and southern Canada, primarily affecting bats during hibernation. Considering the continued spread of WNS and the resultant population declines to formerly common species, understanding the basic ecology, distribution, and habitat use of all bat species is critical, especially when much of the habitat used by these species is in forests commercially managed for multiple uses. We used bat acoustic detectors to document the annual activity patterns of bats at four locations within Sustainable Forestry Initiative certified forests in western Montana from 2014 – 2017. We detected 11 of Montana's 15 bat species, including winter activity for four species. In addition to acoustic monitoring, we conducted telemetry studies during each fall (October and November). During the fall telemetry effort, we tracked four species, but the most numerous species was the California myotis (*Myotis*

californicus). The microclimate temperatures of fall roosts used by this species were below the optimum temperatures for growth of *Pseudogymnoascus destructans*, the fungus responsible for WNS. Results from this study suggest that managed forests provide habitat during all life history stages for some bat species, and that WNS may not impact all species equally during its continued westward spread.

Range-wide Variation in the Summer Habitat of the Eastern Small-footed Myotis

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The eastern small-footed myotis (*Myotis leibii*) is thought to be uncommon within its range in eastern North America. *M. leibii* is known to exhibit the unusual behavior of roosting in talus and rock outcrop habitats, but the species' apparent rarity has made study difficult and relatively little is known about its ecology. Due in part to recent threats associated with white-nose syndrome and loss of foraging habitat, *M. leibii* is listed as a species-at-risk in several jurisdictions (e.g., Ontario, Pennsylvania, Vermont and New Hampshire). The IUCN lists *M. leibii* as least concern, however most states throughout the north-eastern United States, list *M. leibii* as critically imperiled, a species of special concern, or, are in the process of evaluating the species for listing. Therefore, more information is required to identify critical habitats for the species in an effort to conserve them. We have conducted a review of habitats used by *M. leibii* with a focus on its summer life stage. They are considered rare through their range but species status listings and anecdotal evidence suggests local abundance to be more common in south-eastern North America than north-eastern. Throughout the distribution of *M. leibii*, the summertime roost locations (maternity, daytime, nighttime) vary from mountainous or rock barren habitat consisting of caves, rock slabs and crevices to anthropogenic structures such as bridges, tunnels and old buildings. We assess range wide variation in summer habitats, and discuss implications for conservation of the eastern small-footed myotis.

Addressing the Research Needs of a State: Implementing the North American Bat Monitoring Program in Nebraska

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The North American Bat Monitoring Program (NABat) offers a unique opportunity for state wildlife managers to implement a research program that fills knowledge gaps, contributes to a national initiative, and does not require developing a new program from scratch. Like many western states, Nebraska was under sampled due to limited funding and time yet contains a diverse array of ecosystems. We saw an opportunity to benefit both the state and regional bat populations by implementing NABat. We produced a monitoring program that answers state questions while also being financially reasonable through building a sampling protocol within the framework of NABat and utilizing the involvement of citizen scientists. We randomly sampled each dominate habitat type using the Generalized Random Tessellation Stratified (GRTS) sampling method by quantifying the dominate habitat types within each NABat grid. This differs from the basic NABat protocol by focusing on dominate habitats opposed to available bat habitat. After establishing 35 grid cells in 2016 we incorporated citizen scientist involvement in 2017. Fifteen trained volunteers completed over 50% of the sampling for 2017 by using sampling kits placed at key locations. Using NABat's core methodologies we have been able to address state specific questions and establish a methodology that incorporates many of the under-sampled habitats of Nebraska. By including volunteers, we were able to cut costs and educate involved citizens on the importance of bats in Nebraska. This case

study of Nebraska will serve as a successful model for other states to implement large-scale bat research projects.

Metagenomics Indicates Increased Arthropod Consumption in Long-nosed Bats in New Mexico

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Long-nosed bats (*Leptonycteris* spp.) are federally endangered species that migrate to the southwestern U.S. during the summer before returning to Mexico in the fall. This migration is closely tied to the flowering phenology of their main resources—columnar cacti and agaves. Diet of long-nosed bats in Mexico is well understood and includes a wide variety of cacti, succulents, and bombacaceous plants, but less is known of resource use at the northern extent of its range in New Mexico. This information is required to developed successful management plans for the species in the state. We collected fecal samples of bats from a roost in southwestern New Mexico between June and October of 2016 and 2017 to determine diet. Two methods of analysis were compared: 1) fecal samples analyzed visually with a light microscope for pollen and arthropod fragments, and 2) DNA extracted from samples for high-throughput sequencing analysis. *Leptonycteris* spp. arrived at the roost in early June and were absent by early October, with numbers peaking in August. Microscopic analysis showed agave pollen occurred in 100% of samples (2016; n = 110). No other plant species appeared to be consumed. Arthropod fragments occurred in more than 50% of samples. The most common arthropod orders identified were Coleoptera, Lepidoptera, and Diptera. DNA sequencing also identified agave and arthropods as important resources, with greater taxonomic resolution. Arthropod consumption was higher than found in previous studies, suggesting scarce agave in this region drives bats to feed on insects.

"The Neighbourhood Bat Watch", a Canadian Bat Colony Monitoring Network: How It Started and How It's Going

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Following massive declines in bat populations caused by white-nose syndrome (WNS), three species have been listed as federally endangered in Canada (*Myotis lucifugus*, *M. septentrionalis*, and *Perimyotis subflavus*). Monitoring of these species based solely on hibernaculum counts may not provide a complete picture of population trends and, in some sites, cave counts are impossible for safety reasons. Therefore, in 2012 the Government of Québec, Canada, initiated monitoring for summer maternity colonies by asking citizens to report bat colonies on their properties. The database of colonies is now hosted on the bilingual "Neighbourhood Bat Watch and Chauves-souris aux Abris" website (http://batwatch.ca and http://chauve-souris.ca)" and has been expanded to include the provinces of Ontario, Manitoba, Saskatchewan, and Alberta. So far, 422 colonies have been registered, with 351 colonies in Québec, where 360 emergence counts have been made for 141 colonies, with multiple counts from 70 colonies. Patterns based on summer colony counts have mirrored declines observed on winter cave counts. So far the participation of citizens has mostly been limited to reporting colony locations on the website, whereas most emergence counts have been obtained by government employees or local partners. Recently, we made it possible for citizens to report simple observations of bats flying, which could improve our estimates of spring emergence timing during WNS invasion. This could also enhance educational interest, allowing people that do not have bat colonies on their properties to participate. The Bat Watch represents an inter-provincial partnership improving our ability to monitor bats through citizen participation.

Torpor Patterns and Hibernacula Conditions of *Perimyotis subflavus* in White-nose Syndrome Positive and Negative Sites

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Perimyotis subflavus populations have experienced >90% declines in the southeastern U.S. due to white-nose syndrome (WNS), despite milder and shorter winters. Data are lacking on *P. subflavus* response to WNS and hibernacula temperatures in the south; therefore, we initiated a study in the winters of 2015-16 and 2016-17 to compare torpor patterns and hibernacula conditions of *P. subflavus* in WNS+ in South Carolina and WNS- sites in Florida and Mississippi. We used temperature sensitive radio transmitters and Lotek dataloggers to record individual skin temperatures (T_{sk}) and iButtons to record hibernacula temperatures (T_H) and humidity. We collected data on 29 *P. subflavus* in SC, 12 in FL, and 8 in MS. Mean T_H in SC ranged from 9.3°C to 12.1°C and mean T_H was 13.6°C in FL. Bats in MS rarely went into deep torpor. Average torpor T_{sk} in SC (15.5°C) did not differ significantly from average torpor T_{sk} in FL (15.9°C) and were well within the optimal growth range for *Pd* growth. Torpor bout length ranged from 1 to 15 days and numbers of torpor bouts were not significantly different between SC and FL ($P = 0.12$). Arousal length ranged from 30 to 593 minutes and arousal frequency did not differ between SC and FL ($P = 0.22$). Our results suggest similar torpor patterns between SC and FL indicate that bats in the very southern part of the range that use caves are highly susceptible to WNS but bats that use other types of roost may be less susceptible.

Phenotypic Flexibility and Energetic Demand: Insectivorous Bats During the Summer Active Period

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Organisms face variation in energy availability and demand frequently throughout a life cycle. In response, they alter behavior, physiology, and morphology; collectively, described as phenotypic flexibility. Brazilian free-tailed bats (*Tadarida brasiliensis)* are small, volant endotherms that experience wide variation in energy demand. Notably, males and females undergo energy demands associated with reproduction at different times in the annual cycle. Pregnancy and lactation occur during the summer (April-November), while males undergo spermatogenesis over winter. During the summer period, females face both intrinsic (reproduction) and extrinsic (environmental) energy demands, while males have relatively few intrinsic energetic demands. We hypothesized that female phenotypic variation, morphological and behavioral, would be greater than in males, as females experience the greater intrinsic energy demands. During periods of high energy demand (late pregnancy, lactation), we predicted females would increase foraging rate and increase digestive and exercise organ size. Contrastingly, we predicted that males would have relatively little variation in foraging rate and digestive and exercise organ size. We measured plasma metabolites (triglycerides) to quantify foraging rate, and we measured individual organ sizes of bats sampled according to the female reproductive cycle. While there was relatively little change in female triglyceride plasma concentrations throughout the season, female digestive and exercise organs show a pattern of increasing during pregnancy and lactation, followed by declines immediately following lactation. Our results suggest that intrinsic energy demands affect the *T. brasiliensis* flexible phenotype more than environmental factors during the summer active season.

What Bugs Bat Bugs? Factors Influencing the Parasite Communities of Puerto Rican Bats

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Parasites are important players in disease transmission, and different community compositions of parasites can alter disease dynamics. Yet the variables that influence parasite community structure are feebly understood. In this study, we analyzed three factors: host trait, cave type, and parasite co-infections that might be influencing parasite populations on 10 species of Puerto Rican bats. Bats were captured from three study sites using harp traps, mist nets, and hand nets between May 29-July 20, 2017. We found that host weight is significantly correlated with higher ectoparasite richness, and that female bats had higher ectoparasite richness than male bats. Hot caves had significantly higher ectoparasite richness after controlling for host species. We also found that ectoparasite and intestinal parasite abundances were significantly correlated for *Artibeus jamaicensis* and *Pteronotus quadridens*, but not for *Monophyllus redmani.* While the results of the host trait are consistent with previous studies, the indistinct relationship between parasite co-infections was not consistent with previous findings. Future studies should further explore the dynamics of co-parasitic infections to help us understand how parasites are interacting with each other. This information will further our understanding of the factors that influence disease establishment in wildlife populations.

Morphology Predicts Bat Activity at Multiple Scales in a Post-wildfire Landscape

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The frequency and size of wildfires have dramatically increased in southwestern ponderosa pine (*Pinus ponderosa*) forests in the United States. Rapid changes in vegetation resulting from wildfires affects habitat use by bats, but this is not well documented. Our objective was to describe how bats use the landscape at multiple scales over varying fire severities post-wildfire in the 2011 Wallow Fire (217,721 ha) in eastern Arizona. We predicted that species with high wing loading, high aspect ratio, and low echolocation calls (< 35 kHz) would be more active in areas with high severity burn, and that species with low wing loading, low aspect ratio, and high echolocation calls (> 35 kHz) would have higher activity in areas that were less severely burned. We deployed SM3Bat acoustic detectors at 84 locations randomly selected within the fire boundaries. We sampled each location twice during the dry (June-July) and wet (July-August) season in 2014. We used SonoBat to classify echolocation calls to species or species group and calculated an activity index by adjusting the calls per species by hour. We conducted a multi-scale analysis of landscape structure, quantifying fire severity, water density, elevation range, and landform type around each location at a specified scale (from 90 m to 5760 m radius). Burn severity was not as important a predictor as we hypothesized. When it was a predictor, species responded how we hypothesized. In the short term, the patchy forest landscape created by large, intense wildfires provided habitat for different species of bats.

Diversity and Species Richness of Forest Interior Insectivorous Bats along Elevational Gradients in Nigeria

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Bat species richness patterns along elevational gradients vary across mountains and may decrease monotonously, peak at mid-elevation or plateau and decrease sharply. In hierarchical systems, such as

elevational gradients, nestedness of species assemblages is expected but turnover rates may vary across mountains. Despite eastern Nigeria being a bat diversity hotspot, species composition and richness patterns at different elevations of the Cameroon/Nigerian mountain range have not been studied. We conducted bat surveys at five and six elevation strata (at 250 – 400 m intervals) respectively in Afi Mountain Wildlife Sanctuary (AMWS) and Cross River National Park (CRNP) in southeastern Nigeria. Using four-bank harp traps set for two consecutive nights along 200 m transects, we captured bats during 200 and 240 harp trap nights from AMWS and CRNP respectively. A total of 310 and 187 individuals belonging to 14 and 15 species were captured from AMWS and CRNP respectively. We computed diversity statistics, nestedness analysis and dissimilarity indices on both ensembles. We report new country and species elevational range records. Species richness declined monotonously with elevation and sample-based rarefaction curves did not reach an asymptote on either gradient. High ensemble similarity was observed between gradients, while stratum-level pairwise analysis suggest ensemble similarity from low to mid elevations on both mountains. Nestedness temperature (T) metric for both ensembles show that higher ensembles are significantly nested in low level ensembles. The drivers of these diversity, richness and ensemble patterns will be explored in further analysis.

The Effects of White-nose Syndrome on Bat Community Structure in South Carolina

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As part of a larger study of white-nose syndrome (WNS) impacts on bat communities in the eastern U.S., we sought to determine if there was an effect of WNS on niche partitioning among sympatric bat species in South Carolina. We hypothesized that with the decline of WNS-susceptible species, both WNS-resistant and WNS-susceptible bat species would exploit different niche spaces after WNS was detected. We compared data collected with Anabat detectors in summers 2016-2017 to data collected during 2004-2005 (pre-WNS) in the Sumter National Forest, Andrew Pickens District. We identified calls to species using Kaleidoscope Pro and used GLMs to test whether time of night, habitat type, or clutter amount explained bat species presence pre- and post-WNS. Pre-WNS, big brown bat (*Eptesicus fuscus*) presence was negatively associated with mixed habitats and declined during the last four hours of the night. In contrast, post-WNS we found a positive association between big brown bats and mixed and pine habitat types. Pre-WNS red bat (*Lasiurus borealis*) presence was negatively associated with pine habitat and declined during the last three hours of the night but post-WNS neither habitat or time of night were important factors. *Myotis* presence declined during the last six hours of the night pre-WNS but post-WNS presence was negatively associated with pine habitat. Tricolored bat (*Perimyotis subflavus*) presence pre- and post-WNS was not associated with time, habitat, or clutter amount. We conclude that there have been changes in habitat use by WNS-resistant species post-WNS possibly due to the decline of WNS-susceptible species.

Foraging Ecology of *Perimyotis subflavus* in Middle Tennessee

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Tri-colored bats are declining in Tennessee and throughout the temperate portions of their range, primarily from the impacts of white-nose syndrome. The United States Fish and Wildlife Service has been petitioned to protect the species under the Endangered Species Act. However, our limited understanding of

the foraging ecology of the species precludes our ability to identify critical summer habitat for listing. The objective of our research was to determine the size and land cover composition of foraging ranges selected by tri-colored bats. In the summer of 2016, we radio-tagged two male tri-colored bats and biangulated foraging locations for each bat from mobile telemetry stations. For compositional analysis, we compared the proportion of land cover types in a 95% minimum convex polygon (MCP) foraging range for each bat with the proportions of land cover in a 24.4 km buffer around the center of each bat's roost trees. Next, we compared the proportion of foraging locations in each land cover category with the proportion of land cover types in the MCP foraging range. Our preliminary analysis suggests that male tri-colored bats have relatively large MCP foraging ranges (9,655 and 1,783 ha), select foraging areas over open water, and fly relatively long distances (24.4 and 11.5 km) to reach large water bodies. In the summer of 2017, foraging data was collected on five additional male tri-colored bats. This additional data is currently being analyzed and will also be presented at NASBR.

Bats in the City – Science Based Conservation of Bats in the Greater Toronto Area

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Historical population data for bats of Ontario are scarce. This hinders our ability to address conservation threats, such as habitat loss through urbanization, or White-nose Syndrome (WNS). Limited winter count data indicates that WNS has caused devastating declines of cave-hibernating species in Ontario of roughly 92%. Recently, the Toronto Zoo started a monitoring project with partners around the Greater Toronto Area (GTA) to establish species baselines and contribute to science-based conservation and management of bats in urbanized environments and conservation areas, including Rouge National Urban Park. As part of this initiative, we monitor all species but focus on the federally endangered: *Myotis lucifugus*, *M. septentrionalis* and *Perimyotis subflavus*. We investigate local populations using a progression of methods. We deploy static acoustic monitors to assess species presence. We then conduct trapping surveys to understand local populations through factors such as health and breeding status. In the future, we will use radio-telemetry to locate bat roosts and animal movements to determine bat habitats and foraging areas. Here we present results of two years of acoustic monitoring. Our findings indicate the presence of a population of *M. lucifugus* within the GTA, despite heavy urbanization and the presence of WNS in the area. Seasonal activity patterns suggest the presence of reproductive populations of *Lasiurus cinereus* and *Eptesicus fuscus* and migratory activity of *Lasionycteris noctivagans*. We conclude that endangered bats remain present in the GTA, along with other species, despite heavy urbanization and the introduction of WNS in Ontario since 2010.

Long-term Fission-Fusion Dynamics of a *Myotis sodalis* Colony

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We know little about fission-fusion dynamics of bat colonies and the reasons that roost switches occur. Of particular interest are use of primary maternity roosts and the timing of switches between them. Our goal is to better understand the fission-fusion dynamics of a bat colony. We studied a *Myotis sodalis* colony inhabiting trees and bat boxes on mitigation lands in Indiana. To evaluate colony movements, emergence counts, spotlight checks, and radio telemetry were performed from 1997–1999 and 2002–2016. We compiled data from annual reports and a roost database. Over 18 years, this *M. sodalis* colony used 4.4 ± 0.4 (range 1–8) primary roosts/year and 15.7 ± 1.7 (range 1–28) alternate roosts/year while maintaining an average colony size of 169 ±11 (range 70–254) bats. In years following the loss of major primary roosts, we noted that bats used a higher number of primary and secondary roosts. For example, after the loss of the sole primary roost used in 2001, the colony used 4 primary roosts in 2002; likewise, the colony used 12

alternate roosts in 1999, but 25 in 2002. This colony uses multiple primary roosts throughout summer, and often forms subcolonies before and after lactation. In addition, radio telemetry data revealed that individual bats often use more alternate roosts than primary roosts. We found a slight correlation between total number of primary roosts/year and maximum documented population. Understanding colony fission-fusion dynamics should improve our ability to allocate sufficient habitat for *M. sodalis*.

Interactions Between Imperiled Bat Species and a Fire-dependent Ecosystem in the Southern Appalachians

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Longleaf pine (*Pinus palustris*) ecosystems of the southeastern U.S. require low-intensity fire to maintain their open-canopy forest structure. Efforts to restore this once widespread ecosystem are being implemented by use of prescribed fire and forest thinning. These restoration efforts may have negative impacts on the threatened northern myotis (*Myotis septentrionalis*) and the endangered Indiana myotis (*Myotis sodalis*), which are declining due to white-nose syndrome. Our objective is to examine roost site selection and foraging patterns of northern myotis and Indiana myotis across prescribed fire regimes. The study area is located in the Shoal Creek Ranger District of the Talladega National Forest in northeastern Alabama. We mist netted for and radio tagged northern myotis and Indiana myotis during the summers of 2016 and 2017. We tracked tagged individuals daily to find day roosts and obtained foraging points nightly. We measured habitat characteristics for each day roost and a nearby random tree. Our preliminary results suggest that northern myotis and Indiana myotis had greater proportional home range use in areas with more frequent prescribed fire. Indiana myotis used pine snags with large DBH for roosts, whereas northern myotis roosted in a variety of living and dead pine and hardwood trees with a lower DBH. These early results suggest that extensive prescribed fire management associated with longleaf pine ecosystem restoration is compatible with the habitat needs of the northern myotis and Indiana myotis.

Proximate and Landscape Level Resource Use by Rangeland Bats

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Land use change has resulted in shifts in resource distributions throughout the Great Plains of North America. Understanding the factors that drive bat resource use in rangelands is important for effective bat conservation in these landscapes. We investigated bat resource use in the Sheyenne National Grasslands, a working rangeland in southeastern North Dakota. Throughout the summer of 2016, we used acoustic detectors to systematically sample bat activity across the study area on a 1 km point grid. We analyzed calls using Sonobat autoclassification software and developed generalized linear mixed effect models based on the ecology of our focal species. These models included both proximate and landscape level variables. We detected five species using working rangelands, which included *Lasionycteris noctivagans* (2,722 detections), *Lasiurus cinereus* (2,055 detections), *Eptesicus fuscus* (749 detections), *Lasiurus borealis* (62 detections) and *Myotis lucifugus* (1 detection). Our modeling results for the four most commonly detected species highlighted the importance of trees and water at both proximate and landscape scales. The four focal species showed considerable variation in the scale of selection and the importance of other factors, particularly those associated with direct human development. The broad importance of trees to rangeland bats may put their needs at odds with those of obligate grassland species. Focusing rangeland bat conservation on historically treed areas, such as riparian forests, can provide important areas for bat conservation while minimizing negative impacts on other grassland species.

Improving Geographic Range Estimates for Island Endemics

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The genus *Pteropus*, commonly known as flying foxes, consists of primarily island endemic or near-endemic species. *Pteropus* play an important role as seed dispersers and pollinators for hundreds of ecologically and economically important plant species, yet 6 of the 65 species of *Pteropus* have gone extinct since the 17th century and over half are threatened with extinction. We contend that the current IUCN Red List statuses do not reflect the additional degree of threat they face as island species. Four species range estimation methods were compared using geographic calculations in QGIS 2.14: minimum convex polygon (MCP), minimum convex polygon excluding water areas, total land area of all geographic units, and total perimeter of all geographic units where the species is found. The perimeter measurement is hypothesized to be most suitable for species limited to mangrove habitats at the edge of islands, and not anticipated to have particular meaning for continental species. Species location records were obtained from VertNet, iNaturalist, the Field Museum, and the author's recent field expeditions. All species chosen for analyses are partly or entirely island-distributed, with the exception of *Eidolon helvum*, which was included in analysis as a comparative example for the use of these methods on a continental species. We found that species distributed across multiple archipelagoes had significantly different estimated ranges, some of which would affect their IUCN status. Better range estimates can allow for assessment of island species that may be otherwise Data Deficient and bring more conservation attention to bats on remote islands.

Behavioral Responses Associated to Acoustic Roles in Spix's Disc-winged Bats

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Spix's disc-winged bats (*Thyroptera tricolor*) roost in furled leaves that are only available from 5 to 31 hours. Despite the ephemerality of roosts, they form stable social groups, whose composition remains unchanged for several years. To preserve group stability while searching for a roost daily, *T. tricolor* rely on acoustic communication. In fact, they are known to emit two different vocalizations while searching for a new available roost: "inquiry" calls, emitted by flying bats, and "response" calls, produced by individuals that have located a new roost in reply to an inquiry call emitted by flying bats. Furthermore, there is individual consistency and among individual differences in vocal behavior. Thus, within social groups, some bats are consistently very vocal while others do not produce social calls, suggesting the presence of different acoustic roles. Still, to date it is not known what define these roles. In this experiment, we broadcasted inquiry call playbacks to bats inside a furled leaf and constructed behavioral budgets, to determine behavioral differences associated to vocal and non-vocal individuals, that might trigger emission of response calls. We found that non-vocal individuals are less active after inquiry call playbacks, compared to vocal bats. Our study suggests that acoustic roles in *T. tricolor* are associated to different behavioral responses. Currently, we are studying the energetic costs associated to vocal behavior, to better understand how individual energetic expenditures in maintaining constant communication with group members, can influence *T. tricolor* acoustic roles.

From the Shadows of the Southeast: The Population Genetics and Phylogeography of *Myotis austroriparius*

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A notable characteristic of white-nose syndrome (WNS) in North America is its variable infection and mortality rates among species. This project was undertaken to determine the population genetic differences between species of bats in North America that have experienced outbreaks of WNS and those that have not. While affected species such as *Myotis lucifigus* have been widely studied, little is known about the population dynamics of species, such as *Myotis austroriparius*, that are naïve to WNS, or only recently documented as a host to *Pseudogymnoascus destructans* (*Pd*), the fungus that causes WNS. In order to forecast the impact WNS will eventually have on *M. austroriparius*, we are reconstructing the genetic structure and historical demography of a sample of 44 bats from across the species' range. Samples were genotyped at eleven microsatellite loci that were identified from other vespertilionid species in the genera *Myotis* and *Corynorhinus*. We present analyses of population structure, as well as extended Bayesian skyline reconstructions of changes in effective population size through the species' recent history. As a result of this study, bat conservation strategies will be better informed about the ways in which *M. austroriparius* may be affected by the WNS epizootic.

Frequency Tuning of Synaptic Inhibition in Duration-tuned Neurons of the Mammalian Inferior Colliculus

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Duration tuning in the mammalian auditory midbrain is created by the interaction of excitatory and inhibitory synaptic inputs that are offset in time. We used paired-tone stimulation in combination with single-unit extracellular recording to measure the spectral tuning of the synaptic inhibition underlying duration-tuned neurons (DTNs) recorded from the inferior colliculus of the big brown bat (*Eptesicus fuscus*). We stimulated DTNs with a short duration, excitatory probe tone set to the cell's best duration (BD) and best excitatory frequency (BEF) and a longer duration, non-excitatory (NE) tone that was varied in frequency. The onset time of the BD tone was varied relative to the NE tone. Spikes evoked by the BD tone were suppressed by NE tone evoked inhibition when the frequency of the NE tone was near or within the cell's excitatory bandwidth (eBW). The onset of inhibition was independent of stimulus frequency whereas the offset and duration of inhibition systematically decreased as the stimulus de- parted from the cell's BEF. We used the effective duration of the NE tone evoked inhibition to generate an inhibitory frequency response area from which the best inhibitory frequency (BIF) and inhibitory bandwidth (iBW) of each cell was measured. The BIFs of DTNs closely matched their BEFs; however, iBWs were significantly wider than eBWs in the same cell. We conclude that the synaptic inhibition responsible for creating duration-tuned circuits in the IC is broadly tuned in frequency and time-locked to stimulus onset, and these feature help to preserve the temporal selectivity of DTNs.

Evaluating Bat Community Structure in Chickamauga and Chattanooga National Military Park Post-white-nose Syndrome

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White-nose syndrome (WNS) has greatly affected populations of some bat species in the eastern U.S. but, little is known how this is affecting bat communities. Our objective was to determine habitat use of bats in Chickamauga and Chattanooga National Military Park in northern Georgia and southern Tennessee to later compare to pre-WNS data. We surveyed bat activity from June 12 to July 14, 2017 using Anabat Express (Titley Electronics, Ballina, Australia) acoustic detectors. We surveyed a total of 36 sites: 12 in intact forests, 12 in open fields, and 12 at riparian sites. The riparian habitat had the greatest amount of bat activity with an average of 179.6 ± 35.6 bat calls per night. The open habitat averaged 145.4 ± 35.6 bat calls per night while activity in the intact forest habitats averaged 9.4 ± 3.0 bat calls per night. The basal area of the intact forest (16.4 m^2/ha) and riparian habitat (16.2 m^2/ha) were similar but were significantly higher than the basal area in open habitats (0.2 m^2/ha). Our data suggest that conservation of riparian and open habitats may benefit bats in this area. These data will be further analyzed to examine changes in species diversity and population levels pre- and post-WNS.

Filipinos for Flying Foxes: A Model for Integrating Research and Conservation

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The 7,641 islands of the Philippines are the size of Arizona and home to at least 79 species of bats. Building on past efforts, the Filipinos for Flying Foxes (FFF) was launched in 2012 as a collaborative initiative to catalyze and integrate research and promote sustainable conservation the Philippine endemic and globally endangered Golden-crowned flying fox. The scope of the initiative has grown to include all 10 flying foxes in the Philippines. With heightened awareness at a national-level, the leadership of the Department of Environment and Natural Resources in identifying flying fox conservation as a national priority in 2015, and multiple training workshops, have increased capacity and catalyzed additional research and conservation. The FFF efforts have documented over 150 flying fox roosts. To date, at least 6 sanctuaries have been established and more are in development through leadership at local levels. There is a continuing need for additional research to identify and protect new roosts throughout the Philippines to help ensure viable populations of flying foxes are maintained. Further, research is needed that strengthens understanding of habitat associations, the ecosystem services of flying foxes, landscape-scale movements around roosts, population connectivity, and population genetics. There is need and room for members of the North American Bat Research Society to collaborate with robust research programs in the Philippines that will directly contribute to national bat conservation priorities. A collaborative approach will result in greater capacity in the Philippines and prove to be personally and professionally rewarding.

Looking Back to Move Forward: A Quantitative Meta-analysis of *Myotis septentrionalis* Roost Selection

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Previous meta-analyses on bat roosting behavior have described the importance of various roost-tree characteristics such as diameter, canopy closure, and tree height. However due to a prior limitation of available roost studies, these analyses were restricted to pooling studies across all crevice/cavity roosting species despite research showing separate species select different roost characteristics. Because U.S. federal regulations rely partly upon roosting behavior, we compiled quantitative and qualitative data from 36 studies that examined roosting habits of the northern long-eared bat (*Myotis septentrionalis*) in the United States and Canada. From these studies, we extracted 35 unique datasets from 19 different studies that compared roosting selection in a roost vs. random tree design. We calculated the Hedges' g standardized mean difference as an estimate for effect size for ten of the most common habitat variables. We utilized meta-regression and multi-model inference to test the effect of moderator variables to account for between-study heterogeneity in tree diameter. We conducted spatial analysis on study site locations to suggest regions and forest types for future roosting studies. We also qualitatively summarized data on roosting behavior and tree species use. Five variables (bark cover, tree diameter, tree height, decay class, and snag density) were consistent enough to reject the null hypothesis of no difference between roost trees and random trees. Studies were clustered within the Appalachian and northeastern regions with few studies conducted within the western half of the species distribution.

The Threat of Invasive Species to Bats

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Biological invasions are a major driver of biodiversity loss, but no study has described the scope of threats to bats (Chiroptera) by invasive species. We reviewed the literature for negative effects of invasive species to bats and summarized threats according to four categories: predation, disease, competition, and indirect interactions. We identified threats of 37 invasive species to 40 bat species. Ten bat species were threatened by more than one invasion pathway. About 38 percent of cases are speculative and 18 percent circumstantial, many attributed to overlapping ranges, and most accounts do not quantify effects needed to forecast bat population impacts. Evidence of cat predation is frequently cited, constituting the greatest incidence of observational data. Other direct and indirect impacts were documented from goats, dogs, brown tree snake, rainbow lorikeet, rose-ringed parakeet, yellow crazy ant, giant centipede, palm, burdock, avian cholera, and white- nose syndrome. Circumstantial evidence suggests impacts by rats, stoats, coqui frog, common wolf snake, little fire ant, kudzu, and *Lantana camara*. Over 60 percent of bat species reviewed are island-dwelling, corresponding with evidence indicating that most extinctions occur on islands and invasive species' impacts are worse for island than mainland populations. Although appreciable bat population reductions owing to invasive species are often unproven, invasions are likely to exacerbate effects of other vulnerabilities. Multiple invaders and synergistic interactions may ultimately lead to species losses. Managers should exercise the precautionary principle by taking action against non-native species when first detected, even if new species do not appear to be detrimental.

Discerning Migratory Patterns of Bats in Nebraska

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Migratory bats account for the vast majority of observed mortality at wind turbines, however, the migratory patterns of bats across North America remain poorly understood. The majority of studies that describe migration have correlated weather patterns with mortalities at wind turbines or acoustic activity at a few sites. Few studies have been described migratory patterns of bats in the Great Plains, an area with the highest wind energy generation potential in North America. Understanding the migratory patterns of bats in this area before wind energy development could help avoid and mitigate mortality. We placed a systematic grid of acoustic detectors across a 12,500 km^2 area in east-central Nebraska to determine the spatial and temporal patterns of bat activity. We will describe a novel technique to measure and model bat activity in relation to weather patterns.

Trace Elements as a Method for Sourcing Migratory Tree Bats

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Renewable-energy production from wind turbine facilities has recently expanded in the US. This has benefits in reducing production of greenhouse gasses but has negative impacts through increased mortality of tree-roosting bats due to turbine strikes. A key question that would guide management activities is whether bats that are killed are primarily from local populations or migrants. This requires developing methods for sourcing bats using biomarkers. Here we describe an evaluation of the use of trace element analyses in bat fur to identify bats killed at wind facilities in the eastern and mid-western US as being migrants or from local populations. This is based on the idea that the concentration of trace elements in their fur is related to the amount of trace elements present in the soil, which is highly variable across large spatial scales. Using this information, we explore the feasibility of linking trace element profiles from individual bats with trace element reference maps to provide better estimates of the source regions of bats. We used inductively coupled plasma – mass spectrometry to determine the concentration of multiple trace elements in fur, and compared this to publicly available soil trace element concentrations for the US and Canada. We then used a Bayesian probabilistic framework to produce likelihood-of-origin maps for each element for each individual bat, and combined elements using a Bayesian posterior probability framework. Overall, our results suggest that using trace elements may represent a novel type of biomarkers that can be used to source migratory bats.

A Comparative Analysis of Viral Richness and Viral Sharing in Cave-roosting Bats

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Caves provide critical roosting habitats for bats globally, but are increasingly disturbed or destroyed by human activities such as tourism and extractive industries. In addition to degrading the habitat of cave-roosting bats, such activities often promote contact between humans and bats, which may have potential impacts on human health. Cave-roosting bats are hosts to diverse viruses, some of which emerged in humans with severe consequences (e.g., severe acute respiratory syndrome coronavirus and Marburg virus). Characterizing patterns of viral richness and sharing among bat species are therefore important first steps for understanding bat-virus dynamics and mitigating future bat-human spillover. Here we compile a database of bat-virus associations and bat species ecological traits, and investigate the importance of

roosting behavior as a determinant of viral richness and viral sharing among bat species. We show that cave-roosting species do not host greater viral richness, when accounting for publication bias, diet, body mass, and geographic range size. However, our global analyses show that cave-roosting bats do exhibit a greater likelihood of viral sharing, especially those documented in the literature as co-roosting in the same cave. We highlight the importance of caves as critical foci for bat conservation, as well as ideal sites for longitudinal surveillance of bat-virus dynamics.

Boulders, Bats, and Biodiversity: The Influence of Rock Climbing on Cliff-face Ecosystems

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Boulder, Colorado, is a famous rock-climbing destination that has become increasingly popular since the 1980s. At least six species of bat roost in the local cliffs, including Townsend's big-eared bat (*Corynorhinus townsendii*) and the state-threatened fringed myotis (*Myotis thysanodes*). We assessed the impacts of rock climbing on the activity of bats near cliffs, as well as the distribution of roosts on the cliff faces using canonical correspondence analysis (CCA). We also examined whether bats influence the biodiversity of mesofauna and soil microbiota within cliff crevices via microscopy and automated ribosomal intergenic spacer analysis (ARISA), respectively. Lastly, we tested whether the excretion of urine and guano by bats increased levels of macronutrients in cliff crevices. Our CCA suggests that summer closures of rock-climbing sites have a large impact on the number of roosting bats present. The biodiversity of mesofauna was higher in bat roosts ($t = 2.7$; $p = 0.004$), and preliminary results of our ARISA suggest that the biodiversity of soil microbiota with an intergenic-spacer length < 500bp is slightly higher in bat roosts ($t = 1.37$; $p = 0.1$). Analysis of microbiota with an intergenic-spacer length of 501 – 1000bp is being finalized. Guano appears to be a source of phosphate for cliff crevices ($F_{2,94} = 5.37$; $p = 0.006$), and higher levels of usable nitrogen were found in crevices with roosting bats ($F_{2,94} \geq 5.34$; $p \leq 0.006$). By influencing where bats roost, rock climbing may have cascading effects on the mesofauna, microbiota, and nutrient availability of cliff-face ecosystems.

Conserving Connecticut's Natural History: Surviving Bat Communities and Habitat Use Post-white-nose Syndrome

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Population ecology investigates questions related to density, growth/decline and movements of species over time in given geographical regions. This study investigated similar questions regarding populations of endemic bat species in Connecticut. White-nose syndrome (WNS) has recently killed millions of bats in New England, yet no large-scale conservation efforts have occurred in Connecticut and few data have been published on the status of Connecticut bats post-WNS. This study aims to: 1) survey bats persisting in WNS regions to document whether changes have occurred in species biodiversity, distribution and habitat use; and 2) measure seasonality effects from summer through pre-hibernal and winter months. Bat presence and activity were recorded using bat detectors set in grassland and forested habitats, near bodies of water and anthropormorphic structures across Connecticut. Bioacoustic data will be analyzed via Sonobat software and spatial data will be analyzed using geographic information system (GIS) software. Our data will show how bat species diversity, activity and abundance has changed across seasons in a post-WNS environment, and whether persisting bat species are utilizing given habitats and/or adapting to new ecological niches once maintained by now extirpated species. Combined, these data can help drive future wildlife conservation, outreach and management practices.

Impact of Urbanization on Bats in Eastern Iowa

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Our goal was to evaluate the impact of urbanization on bat species in northeast Iowa. It has been suggested that artificial lighting may negatively impact bats. However, the diversity of habitats associated with the urban-suburban-rural-nature matrix may promote greater bat diversity over a larger area even if localized diversity appears low. We tested the Null Hypotheses that there are no differences in bat occurrence (measured as presence or absence) or in bat activity (measured as independent calls per survey) between habitat types in the matrix associated with urbanization. We surveyed bats across a gradient of habitat types, ranging from protected nature parks to highly developed urban industrial areas around Dubuque, Iowa. Sites were visited in a random sequence and bats were recorded for 30 minutes using the Wildlife Acoustics Echo Meter Touch 2 Pro. At each site we recorded GPS coordinates, temperature, humidity, moon phase, lighting conditions, and human activities. *Lasiurus cinereus* accounted for >31% while *Myotis* species accounted for <14% of total vetted calls. Initial results refute our Null Hypotheses. Every species exhibited a variable response to habitats ranging from 100% to 0% presence. Only *Myotis lucifugus* exhibited a 100% detection rate at natural sites while *Eptesicus fuscus* and *Lasiurus cinereus* exhibited 100% detection rates at highly developed sites. Residential areas resulted in the lowest average detection rate (~27%) across all bat species. Our results suggest that urbanization can be suitable for bats and may enhance species diversity over a broader spatial scale.

Performance of Hierarchical Abundance Models on Simulated Bat Capture Data

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The ability to accurately estimate bat abundance is crucial to ecologists, conservationists, and managers to provide insight on species status, population trends, and viability. Acoustic detection and occupancy modeling can provide an understanding of resource use, but these methods do not estimate how many bats are in an area, or how these numbers change over time. There is a heightened need to estimate bat abundance and trends in response to white-nose syndrome (WNS) and other threats to bat populations. We assessed the performance of the N-mixture model for repeated count data and the general multinomial-Poisson model for removal sampling to estimate bat abundance from simulated mist-net capture data. We evaluated performance under varying numbers of sites and visits, detection probabilities, and population sizes. We simulated 4 scenarios with a total of 85 iterations each containing 1000 randomly generated datasets. We used the UNMARKED package in R to fit the N-mixture and removal models. We calculated relative bias (RB), mean absolute error (MAE), and mean absolute percent error (MAPE) from model predictions to evaluate model performance. The removal model outperformed the N-mixture model in all scenarios except when detection probability was 0.05. The mean of estimates from the removal model essentially equaled true abundance and RB, MAE, and MAPE were very low for most scenarios. Use of the removal model with data from repeated mist-net surveys may allow resource managers and conservationists to better quantify how resource management and landscape composition affect bat species abundance and overall populations.

Livin' on a Prair(ie): Bat Foraging in a Mixed Agricultural Landscape

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Increasingly intensive agricultural practices often coincide with declines in native plant and animal populations. Strategies such as encouraging restoration of native plant species have been touted as methods for attracting and supporting native arthropod communities, including those upon which bats may preferentially feed. To understand the extent to which patches of native habitat within a mixed agricultural landscape may support insectivorous bats, we compared diet composition, prey availability, and habitat composition at little brown bat (*Myotis lucifugus*) and big brown bat (*Eptesicus fuscus*) maternity roosts in Southern Wisconsin, USA. Our results demonstrated that the foraging patterns and prey preferences for these bat species differ both temporally and spatially, with inter- and intraspecific differences associated with landscape and prey community composition. Specifically, among big brown bats the taxonomic groups of prey consumed were relatively consistent over time and tended to include arthropod families that remained abundant throughout the summer. In contrast, little brown bats displayed a greater reliance on ephemeral food sources — particularly during times of low prey abundance such as late spring and early summer. Several native plant specialist arthropods were also commonly found in both bat diets, suggesting that even relatively small patches of native vegetation may be effective in attracting important prey. As bats continue to face disease-related population declines, understanding the relationships between landscapes, prey availability, and bat foraging preferences can help inform future habitat management efforts in the key agricultural production areas of the Midwest.