BAT RESEARCH NEWS

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Front Cover

Cave bats across the eastern United States have been hit hard by white-nose syndrome, and populations are down. But here is a tri-colored bat (*Perimyotis subflavus*) on the wall of Melrose Caverns in central Virginia. It showed no evidence of the fungus on February 23rd, 2014, so some bats are still making it through the winter. Photo courtesy of Keith Christenson.

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Bat Research News is published four times each year, consisting of one volume of four issues. *Bat Research News* publishes short feature articles and general interest notes that are reviewed by at least two scholars in that field. *Bat Research News* also includes abstracts of presentations at bat conferences around the world, letters to the editors, news submitted by our readers, notices and requests, and announcements of future bat conferences worldwide. In addition, *Bat Research News* provides a listing of recent bat-related articles that were published in English. *Bat Research News* is abstracted in several databases (e.g., BIOSIS).

Communications concerning feature articles and "Letters to the Editor" should be addressed to Dr. Al Kurta (akurta@emich.edu), recent literature items to Dr. Jodi Sedlock, (sedlockj@lawrence.edu), and all other correspondence (e.g., news, conservation, or education items; subscription information; cover art) to Dr. Margaret Griffiths (margaret.griffiths01@gmail.com).

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FROM THE EDITOR

Greetings to each of you! It has been a long, hard, and very cold winter here in central Illinois, as I am sure it has been for many of you, and we are more than ready for spring. We hope that warmer weather will be here soon and stay for a good long while, and that with the appearance of spring, our bats will return as well.

I have a few announcements. First, to all of you who have renewed your subscriptions to *Bat Research News*, thank you very much! We sincerely appreciate your continued support. Also welcome to all of our new subscribers! I hope you enjoy our little journal/newsletter and find it both interesting and helpful.

My next announcement is bittersweet. Dr. Jacques Veilleux is stepping down as Editor for Recent Literature. When Jacques sent me his final Recent Literature section (which appears in this issue), he wrote, "Thanks for the opportunity to work on *BRN*. It has been a lot of fun to see all of the work that everyone does." Please join me in wishing him well in his future endeavors and also in thanking him for his service to *BRN* and to all of you, the subscribers to *BRN*.

I am very pleased to announce that Dr. Jodi Sedlock will be the new Editor for Recent Literature beginning with the 2014 summer issue. Jodi's contact information is listed on the *BRN* website, on the inside front cover, and also at the beginning of the Recent Literature section of this issue. Please welcome Jodi and be sure to send any recent bat-related publications to her for inclusion in the future issues of *BRN*. What better way to welcome her than by sending her some work!

Please consider submitting some of your manuscripts to *BRN*. Original research and speculative review articles, short to moderate length, on a bat-related topic would be most welcomed. If you are interested, submit your manuscripts as .rtf documents to Al Kurta, Editor for Feature Articles. Notes and letters on bat-related topics also are welcome and should be sent to Al. Send news items, announcements, conservation or education items, cover art, and subscription information to me (Margaret). And remember to send reprints of your recent publications to Jodi.

Best wishes for a successful 2014,

Letters to the Editor

Editor's Note: Unlike technical articles, letters are not peer-reviewed, but they are edited for grammar, style, and clarity. Letters provide an outlet for opinions, speculations, anecdotes, and other interesting observations that, by themselves, may not be sufficient or appropriate for a technical article. Letters should be no longer than two manuscript pages and sent to the Feature Editor.

Energetics Alone Is Insufficient for Conservation Recommendations for Hibernating Bats

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We read with concern a new paper on winter energetics of the Indiana bat (*Myotis sodalis*) by Day and Tomasi (2013). These authors calculate winter energy budgets for hibernating Indiana bats using standard laboratory procedures. They rely heavily on older laboratory-based scientific literature but fail to include many relevant field studies, thus giving, we would argue, an outdated view of hibernation by cavernicolous bats. This alone is of little concern, but they then base conservation recommendations on this outdated and incomplete information, which may have serious implications for management of cavernicolous bats and the caves they inhabit.

Briefly, Day and Tomasi use measurements of metabolic rate of individually hibernating and euthermic bats and patterns of body temperature from bats in small groups. Several methodological problems may influence their calculations of winter energy budgets. For example, it is unlikely that patterns of body temperature of individuals within each group are independent (Czenze et al., 2013). Further, measuring the metabolic cost of an arousal, one component of hibernation, by an individual bat is questionable, because evidence suggests that the main reason for clustering is to lessen the cost of arousal (Boyles et al., 2008) and not to buffer against fluctuations in ambient temperatures, as suggested by Day and Tomasi and older literature (Twente, 1955). Although these issues may affect the accuracy of their energy-budget estimates, they are not the major problem with the study.

Day and Tomasi focus almost exclusively on energetic costs of hibernation to reach the conclusion that "Indiana bats should occupy winter hibernacula that provide a mean temperature of 3°–6°C." They briefly mention, but largely ignore, a quickly growing body of literature suggesting that many factors affect depth and length of hibernation and, in turn, the initial choice of a hibernaculum and ultimately the actual hibernating location within a site (e.g., French, 2000; Humphries et al., 2003; Munro et al., 2005; Boyles et al., 2007; Wojciechowski et al., 2007; Zervanos et al., 2010; Jonasson and Willis, 2011). This exclusion leads Day and Tomasi to state that "hibernacula that provide these conditions [i.e., mean temperatures of 3–6°C] deserve extra protection." This is a conservation recommendation that is not only unwarranted but may be harmful to overall management of the Indiana bat. For example, Brack (2007) reported that essentially no Indiana bats hibernate in areas that meet Day and Tomasi's suggested temperature range in a growing population in Ohio (growing at least before white-nose syndrome [WNS] was found there). In addition, Boyles et al. (2008) reported that clusters of hibernating Indiana bats occur between 6.2 and 12.8°C in six caves in southern Indiana, including several caves that contain some of the largest known colonies of Indiana bats.

This is not to say that Indiana bats will not choose temperatures between 3 and 6°C, but rather that it is apparent that Indiana bats elect to hibernate at a wide range of ambient temperatures. Take, as one example, Wyandotte Cave, Indiana, which is a large, thermally stable cave system with mid-winter temperatures that warm slowly and predictably with distance into the cave. During decades of winter disturbance by humans, most Indiana bats clustered in a passage called Washington Avenue, which is an area with very high ceilings that presumably would serve to reduce the impact of human disturbance. Between 2002, when new regulations ended all winter disturbances, and 2009, when the last survey of bats occurred before the discovery of WNS in the cave, the number of Indiana bats hibernating in Wyandotte Cave increased by 50%, from 30,000 to 45,000 bats (Brack et al., 2009). These bats were distributed over a substantial area of the cave with 20% anterior to Washington Avenue (2–5°C), 29.3% in Washington Avenue (5–7.2°C), and 50% posterior to Washington Avenue (9–13°C). Managing this cave to maximize areas with microclimates between 3 and 6°C would be a mistake, because it would disrupt the thermal continuum that clearly is valuable to this species. Our experience suggests that such a pattern of broad distribution with temperature is not unique to this particular cave.

We suggest that no conservation actions be based on protecting hibernacula that contain a specific and limited range of temperatures (e.g., 3–6°C), which is a hallmark of bat management that is based on old, incomplete data. Instead, hibernacula with the widest possible range of stable temperatures should be protected. Larger, more complex cave/mine systems have a wider range of stable temperatures than smaller hibernacula. Likewise, the range of temperatures available within hibernacula will likely vary across the geographic range of the Indiana bat. Protection of caves and mines with the widest possible range of environmental conditions in an area means that hibernacula are available to meet requirements of all individuals in a population (Boyles et al., 2007). We believe that the more modern management approach that we suggest is supported by the current understanding of the physiology, ecology, and behavior of hibernation, and we suggest that simplistic management of hibernacula, based on a single factor influencing hibernation, is harmful to bat conservation as a whole.

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Energy Budgets Are Important to Conservation: a Response to Boyles and Brack

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In their letter to the editor, Boyles and Brack use a significant amount of text to restate what we already said (Day and Tomasi, 2014) and to attack the validity of using energetic data to discuss requirements for hibernacula used by Indiana bats (*Myotis sodalis*) specifically, and other species, in general. However, we end our introduction with this sentence (italics added): "Determining the energetically optimal temperature for winter roost sites, *in conjunction with information on body condition and the ecological and physiological costs of hibernation*, will give conservation agencies insight into which caves or mines are providing the right conditions and therefore deserve extra protection." Furthermore, we conclude the paper with a paragraph that starts: "We acknowledge that the optimal hibernation temperature based on energetic considerations may not be the optimum temperature for other aspects of bat ecology and function…" Therefore, we are confused why Boyles and Brack dismiss our understanding of hibernation by saying that we "briefly mention but largely ignore" the other factors that affect hibernation. We were not presenting data on those other factors. Those who read our entire paper, rather than taking phrases out of context, also will be confused by the statements of Boyles and Brack.

The energetic perspective is crucial, because many other aspects of an animal's ecology depend on the acquisition and expenditure of energy. Because this inter-relationship has been recognized for a long time and energetics have been investigated by a cadre of scientists over the last century, biologists quantitatively understand how temperature affects the energetic cost of hibernation, using those methods that Boyles and Brack call "outdated," whereas this same claim cannot be made for any other factor that might influence the temperature selected by bats (e.g., immune function, threat of freezing, evaporative water loss). It is easy to claim that other issues may be important, but where are the data to describe mathematically the relationship between them and the temperature of a hibernaculum? Hibernation biologists can qualitatively indicate that these factors appear to be important, but can they calculate the magnitude of these effects? Until scientists can, it is premature to discuss whether such matters are more or less important than the energetic perspective.

Even though it has been previously suggested that hibernating in large clusters may make arousals easier (e.g., Boyles et al., 2008; Boyles and Brack, 2009), the data to support this hypothesis are indirect, and saying it more often does not provide additional support. In fact, although such a statement may be true for some bats in a cluster, it clearly cannot be true for all the bats, unless the proponents of this theory are suggesting that the laws of thermodynamics are also outdated. When a bat in a cluster initiates an arousal, the individuals surrounding it indeed benefit from the passive warming. However, unlike other mammals in torpor that use passive warming, for which the source of heat is the external abiotic environment (Geiser et al., 2004), the bats receiving the "external heat" are actually drawing it from the initially-arousing cluster-mate, making it harder for that bat to arouse. Truly synchronous arousals by bats in a cluster could save energy, but we have seen no evidence to suggest that all bats in a cluster initiate thermogenesis at the same time, and Hicks and Novak (2002) indicate that this is clearly not the case for Indiana bats hibernating in the Northeast. Furthermore, Czenze et al. (2013) acknowledge that the pseudo-synchronization of arousals that they observed in little brown bats (*Myotis lucifugus*) may be due to factors other than saving arousal energy.

Another pitfall in debating the underlying causes of complex phenomena is relying on individual occurrences, such as the characteristics observed in a single cave used by Indiana bats. Hicks and Novak (2002) demonstrate that Indiana bats hibernate successfully in mines in New York where temperatures are much lower than those reported for Wyandotte Cave by Boyles and Brack in their letter. Biologists should justify their arguments based on principles and patterns, rather than examples. The big-picture conclusion, which we state and Boyles and Brack restate, is that multiple factors are involved in understanding where bats choose to hibernate, and scientists do not fully understand these factors. Lack of complete understanding does not mean that managers of our natural resources should do nothing. They need data from multiple approaches in the field and the laboratory (not just hypotheses or modeling outputs), to help them make their conservation decisions. Our data were intended to assist in this gap, not to be the sole authority. Ironically, in the lead article in the issue of *Physiology and Biochemical Zoology* containing our paper, Cooke et al. (2014) argue that physiology and behavior should be integrated to make the best decisions for conservation of a species. We agree, and believe that Boyles and Brack would too.

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Attempted Consumption of a Northern Long-eared Bat (*Myotis septentrionalis*) by an American Crow (*Corvus brachyrhynchos*) in Tennessee

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The American crow (*Corvus brachyrhynchos*) is the most common species of crow in the southeastern United States, and it consumes a variety of plants and animal prey, including carrion (Verbeek and Caffrey, 2002). Crows are opportunistic foragers and obtain most food on the ground or by scanning from a perch; however, they use a variety of foraging strategies, such as capturing insects and small birds on the wing (Chamberlain, 1965; Cuccia, 1984; Putnam, 1992; Verbeek and Caffrey, 2002). We report attempted consumption of a northern long-eared bat (*Myotis septentrionalis*) by an American crow in Tennessee.

On 20 January 2014 at about 1600 h (CST), one of us (RB) startled an American crow from its perch and witnessed it fly away and drop a bat-sized object. After searching the area for 15 minutes, the authors found a female northern long-eared bat on the ground. The bat was dead (cool to the touch with slight rigor mortis) and displayed a small region of dried blood on the chest, along with two holes in the right wing, possibly caused by the crow's claws. After taking biological measurements and fungal swabs, the bat was brought to the University of Tennessee and stored in a freezer for further examination.

Many species of birds attack bats. These include members of the Laridae and Corvidae, which opportunistically prey on bats (Estok et al., 2010; Jung 2013; Lee and Kuo, 2001; Speakman, 1991). Two previous papers (Hernandez et al., 2007; Lefevre, 2005) report aerial predation of little brown bats (*M. lucifugus*) by the American crow; however, this is the first documented attempt at consumption of a northern long-eared bat by a crow. Although previous accounts of predation on other species of bats document capture of a bat on the wing, we cannot state with certainty that this was the case for our observation.

Due to the presence of white-nose syndrome in the region, disturbance caused by disease and disease monitoring can trigger increased diurnal activity of bats during winter. Prior to our observation, two surveys had been conducted in caves nearby. Although activity of bats due to disturbance by humans had lessened by the time of our observation, the level of rigor mortis in the bat's extremities indicates that the animal was captured a short time before being dropped by the crow. Unusual diurnal activity caused by white-nose syndrome (Carr et al., in press), as well as disturbance caused by hibernacula surveys or recreational caving, may increase opportunistic predation by wildlife.

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RECENT LITERATURE

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DISTRIBUTION/FAUNAL STUDIES

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ANNOUNCEMENTS

Bat Conservation International and the Tennessee Chapter of the Nature Conservancy Request for Proposals for White-nose Syndrome Research

Bat Conservation International and the Tennessee Chapter of the Nature Conservancy are pleased to announce the availability of funding for research projects that identify mechanisms to control white-nose syndrome (WNS) and the fungus that causes it, *Pseudogymnoascus destructans*. This opportunity is available to all state and federal personnel, non-governmental organizations, universities, and private or independent researchers. Grants of up to **$50,000** are available for high priority research projects. Preference will be given to proposals that use this funding as leverage against other funding sources. **Deadline** for proposals submission is by 5:00 pm CST on **Tuesday April 15, 2014**. Proposals must include: cover page; executive summary; the proposal (introduction, methods, discussion, budget); qualifications of principal investigator. Please submit each proposal via email to Katie Gillies at Bat Conservation International (**kgillies@batcon.org**). For detailed information please see: **http://batcon.org/index.php/what-we-do/white-nose-syndrome/subcategory.html?layout=subcategory**.

Basically Bats Wildlife Conservation Society Announces Student Research Scholarships

Basically Bats Wildlife Conservation Society is offering two student research scholarships for the 2014-2015 academic year. Scholarships of up to **$5,000 each** will be awarded during the Fall of 2014 for research directly related to white-nose syndrome (WNS) in North American bats. All students, including postdoctoral students, who are enrolled in an accredited United States college during the 2014-2015 academic year are eligible to apply. Applications must be in PDF format and include: a brief, one- to three-page description of the WNS-related project; a budget for the project that includes how the funds will be used; the applicant's Curriculum Vitae; and a brief letter of support from the applicant's supervisor. Applications are competitive and will be reviewed by at least two experts in the field of bat biology. **Deadline** for submission of applications is **June 30th, 2014**. Please email the application to Dr. Steve Burnett (**sburnett@clayton.edu**).

Request for Manuscripts — *Bat Research News*

Original research/speculative review articles, short to moderate length, on a bat-related topic would be most welcomed. Please submit manuscripts as .rtf documents to Allen Kurta, Editor for Feature Articles (akurta@emich.edu). If you have questions, please contact Al. Thank you for considering submitting your work to *BRN*.

Change of Address Requested

Will you be moving in the near future? If so, please **send your new postal and e-mail addresses** to Margaret Griffiths (margaret.griffiths01@gmail.com), and include the date on which the change will become effective. Thank you in advance for helping us out!

FUTURE MEETINGS and EVENTS

2014

The 16th Biennial Australasian Bat Society conference will be held 22–25 April 2014 in Townsville, tropical north Queensland, Australia, at the Rydges Hotel in the middle of Townsville The welcoming function will be on Tuesday 22 April, the conference Wednesday 23rd – Friday 25th, followed by a post conference field trip on the weekend. For more information see: http://ausbats.org.au/.

The 44th Annual NASBR will be held 22–25 October 2014 in Albany, New York, at the Hilton Albany. See the NASBR website for future updates — http://www.nasbr.org/.

2015

The 45th Annual NASBR will be held October 28–November 1, 2015, in Monterey, California. See the NASBR website for future updates — http://www.nasbr.org/.

2016

The 46th Annual NASBR will be held in San Antonio, Texas (dates to be determined). See the NASBR website for future updates — http://www.nasbr.org/.

BAT RESEARCH NEWS

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BAT RESEARCH NEWS

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A Godman's Long-tailed Bat (*Choeroniscus godmani*) feeding on the nectar of a garden flower in Paramaribo, Suriname. Photo courtesy of Keith Christenson.

BAT RESEARCH NEWS

Volume 55: Number 2 Summer 2014

Bat Research News is published four times each year, consisting of one volume of four issues. *Bat Research News* publishes short feature articles and general interest notes that are reviewed by at least two scholars in that field. *Bat Research News* also includes abstracts of presentations at bat conferences around the world, letters to the editors, news submitted by our readers, notices and requests, and announcements of future bat conferences worldwide. In addition, *Bat Research News* provides a listing of recent bat-related articles that were published in English. *Bat Research News* is abstracted in several databases (e.g., BIOSIS).

Communications concerning feature articles and "Letters to the Editor" should be addressed to Dr. Al Kurta (akurta@emich.edu), recent literature items to Dr. Jodi Sedlock, (sedlockj@lawrence.edu), and all other correspondence (e.g., news, conservation, or education items; subscription information; cover art) to Dr. Margaret Griffiths (margaret.griffiths01@gmail.com).

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Back issues of *Bat Research News* are available for a small fee. Please contact Dr. Margaret Griffiths (margaret.griffiths01@gmail.com) for more information regarding back issues. Thank you!

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Protection of Water Wells Used as Winter Roosts by Rafinesque's Big-eared Bats

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Old, large-diameter water wells have been known as winter roosting sites for Rafinesque's big-eared bats (*Corynorhinus rafinesquii*) since the 1930s (Blair, 1939). Open wells, however, pose a safety hazard to humans and animals, which could accidentally fall into wells without adequate protective covers. Beginning in the late 1980s, biologists constructed well covers using tin or wooden grids that allowed access for bats, but these materials deteriorated over time (Sasse et al., 2011). In this paper, we describe installation of a new type of cover made from steel that appears to be well tolerated by the bats.

Steel tops were placed on seven wells (Table 1) in southwestern Arkansas in September–December of 2008–2012 (Fig. 1). Covers were constructed from 3.2-mm-thick steel strap and 6.4-mm-thick steel plate and ranged in size from 79 to 127 cm^2. Covers included access hatches (61–76 cm^2) that allowed for researchers to observe bats and made it possible for landowners to draw water from these sites if necessary. The steel tops were secured to the sides of each well with four T-shaped legs that locked into sliding channels on the underside of the cover to allow for proper fit to the well. To maintain access for the bats, a gap of 7–11 cm was left between the top of the casing and the underside of the cover, although damage to one well (Willisville 1) resulted in a gap of 23 cm on one side.

Counts of bats were performed multiple times, between October and March, at each site following installation. Bats continued to use all wells following construction and the number of bats was equal to or higher than recent and/or historic counts with few exceptions (Table 1). Known historic summer roosts linked to the Stagecoach and Oak Grove Church wells were destroyed prior to 2004, perhaps accounting for lower population counts since 2004. In addition, the casing of Willisville 1 was destroyed during timber management operations on 11 November 2013; bats flew out of the well immediately after this occurred, and other bats may have been injured or killed by debris falling into the well, thus accounting for the apparent decrease in bats observed the following year. Use of steel covers apparently keeps these sites available for use as roosts for bats and a source of water for people, while removing human safety concerns.

Funding for construction and installation was provided by Bat Conservation International and the Arkansas Game and Fish Commission. G. Humphreys of Deltic Timber assisted in installation of several covers. We thank Deltic Timber and other landowners for authorization to conduct this project on their property.

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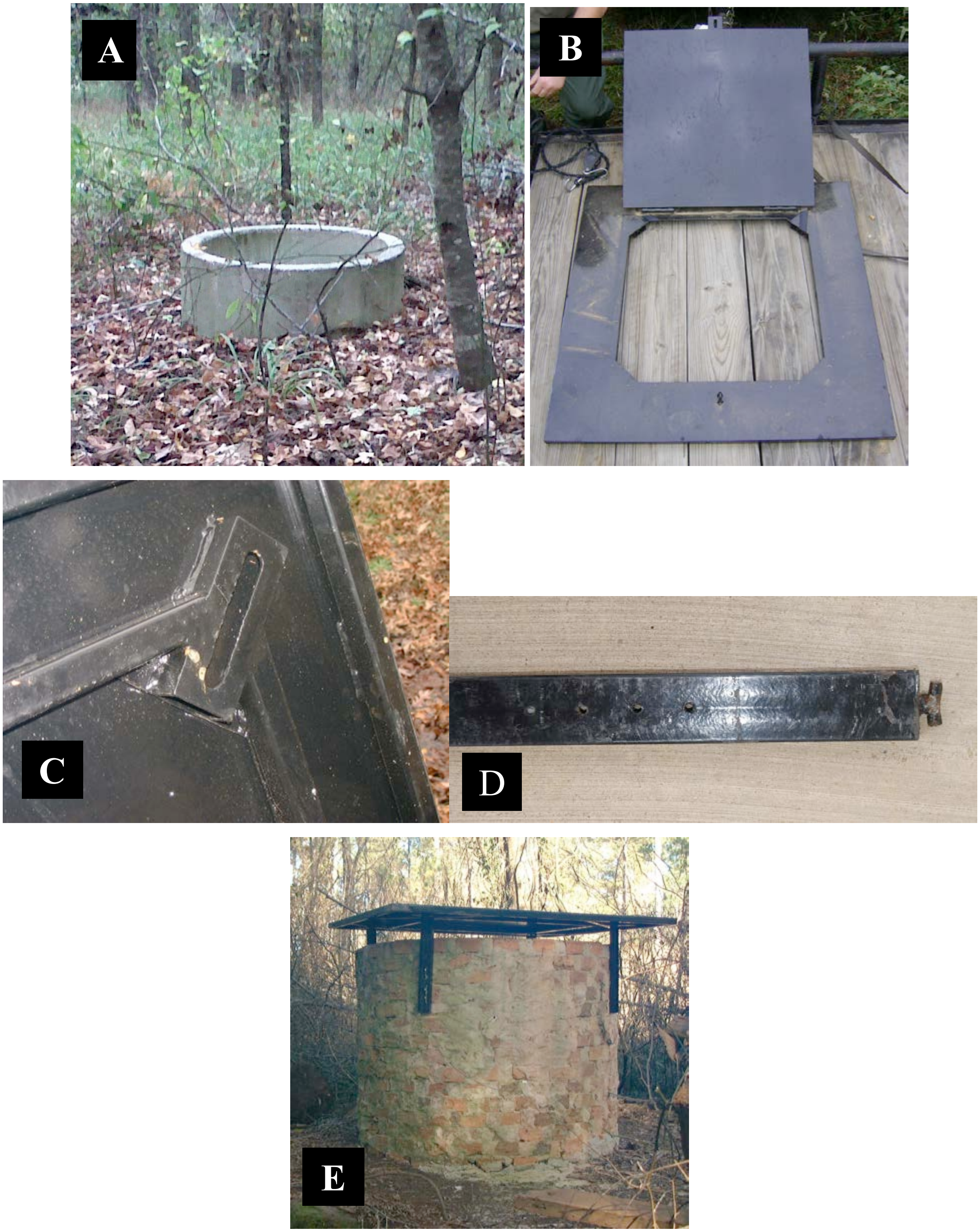

Figure 1. A) Typical uncovered well. B) Well cover showing hatch. C) Channel for leg. D) Leg. E) Well with installed cover.

Table 1. Maximum winter counts of bats at wells in southern Arkansas, before and after (indicated by **bold**) installation of steel covers.

Name of well	Maximum number of bats											
	Pre-2004	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Willisville 1	9	2	-	-	0	-	**9**	**2**	**1**	**7**	**12**	**1**
Willisville 2	5	1	-	-	0	-	**5**	**2**	**0**	**0**	**1**	**3**
Oak Grove Church	32	2	5	-	-	9	**18**	**13**	**11**	**19**	**25**	**11**
Stagecoach	60	6	65	15	-	-	5	**6**	**42**	**13**	**3**	**4**
Sullivan	33	1	-	-	2	15	7	**1**	**1**	**16**	**20**	**31**
Brushy Branch	-	-	-	-	2	-	0	1	**2**	**12**	**13**	**22**
Mt. Holly	-	-	-	-	-	-	-	-	-	1	**1**	**4**

M.J. Lacki, and D.A. Millers, eds.). General Technical Report SRS-145. U.S. Department of Agriculture, Forest Service, Southern Research Station, Asheville, North Carolina.

Letters to the Editor

Editor's Note: Unlike technical articles, letters are not peer-reviewed, but they are edited for grammar, style, and clarity. Letters provide an outlet for opinions, speculations, anecdotes, and other interesting observations that, by themselves, may not be sufficient or appropriate for a technical article. Letters should be no longer than two manuscript pages and sent to the Feature Editor.

Is White-nose Syndrome Causing Insectivory Release and Altering Ecosystem Function in Eastern North America?

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White-nose syndrome, caused by the fungal pathogen *Pseudogymnoascus destructans*, has resulted in catastrophic collapse in populations of cave-hibernating bats in eastern North America (U.S. Fish and Wildlife Service, 2012). First documented in New York in 2006, the fungus has spread to almost all states and provinces east of the Great Plains (U.S. Fish and Wildlife Service, 2014). The epizootic has resulted in a greater than 90% reduction in the formerly predominant species of bat in the Northeast, the little brown bat (*Myotis lucifugus*), and dramatic declines in several other cave-roosting species (Reeder and Moore, 2013).

Biologists have focused most attention on direct effects of the disease on bats, with little consideration to the broader, indirect ecological effects of such rapid and precipitous declines in a formerly abundant mammalian insectivore. Preliminary evidence suggests that remnant populations (i.e., individuals or species less affected) in the Northeast are taking advantage of newly available niche space resulting from the precipitous declines (Jachowski et al., 2014). However, abundance and foraging activity of remnant bats are much lower than before white-nose syndrome (Ford et al., 2011). Thus, it is unlikely that remnant populations are replicating former levels of insectivory in these systems.

In this letter, we estimate the total biomass of insects that is no longer removed as a result of the catastrophic declines in populations of bats in eastern North America. Although the loss of bats was estimated to be at least 5.7 million individuals by 2012 (U.S. Fish and Wildlife Service, 2012), detailed monitoring data from before and after white-nose syndrome is limited to 42 hibernacula in five states—New York, Pennsylvania, Vermont, Virginia, and West Virginia (Reeder and Moore, 2013). We used the proportional rates of declines at these sites to extrapolate the estimated number of total bats lost by species as a result of white-nose syndrome that total to 5.7 million individuals (Table 1).

We created a simple, species-specific, energetics-based model to estimate the annual biomass of insects no longer consumed by bats following white-nose syndrome. Although the biomass of insects that a bat eats

Table 1. Six species of bat impacted by white-nose syndrome in eastern North America and the per-individual, estimated, annual biomass of insects consumed. To calculate an estimate of the total number of bats lost by species, we applied reported species-specific loss percentages that were based on pre- and post-white-nose syndrome surveys at 42 hibernacula in New York, Pennsylvania, Vermont, Virginia, and West Virginia (Reeder and Moore, 2013) to the broader estimate of 5.7 million total bats killed by white-nose syndrome (U.S. Fish and Wildlife Service, 2012). Average body masses were taken from Best and Jennings (1997), Caceres and Barclay (2000), Kunz et al. (1998), Kurta and Baker (1990), Perry and Thill (2007), and Thomson (1982). The per-capita estimated annual biomass of insects consumed (g) was calculated by multiplying average body mass for each species by the average biomass of insects consumed per night as a proportion of the bat's body mass (0.25) and the average number of nights active each year (180 nights).

Species of bat	Estimated contribution (%) to the 5.7 million bats lost	Average body mass (g)	Per-capita estimated annual biomass of insects consumed (g)
Big brown bat, *Eptesicus fuscus*	0.3	17.0	765
Eastern small-footed bat, *Myotis leibii*	0.04	4.4	198
Little brown bat, *Myotis lucifugus*	87.7	8.2	369
Northern long-eared bat, *Myotis septentrionalis*	0.5	6.5	293
Indiana bat, *Myotis sodalis*	10.9	7.3	329
Tricolored bat, *Perimyotis subflavus*	0.6	5.5	248

varies seasonally and with a suite of factors such as individual condition and reproductive state, studies of captive individuals conservatively suggest that bats consume 25% of their body mass in insects each night (Kunz et al., 1998; Kunz et al., 2011). Therefore, we estimated per-capita nightly consumption of insects by multiplying the average weight of a species by 0.25. We then estimated the rate of annual insectivory for an individual by multiplying this nightly value by 180, which is the approximate number of nights that bats are actively foraging between April and October (Davis and Hitchcock, 1965; Table 1). This per-capita estimate of annual insect consumption was then multiplied by our estimate of total individuals lost to produce a species-specific estimate of lost insectivory each year (Table 1).

Our analysis suggests that the yearly consumption of insects has declined by over 2,079 metric tons (Fig. 1). To put this into context, Whitaker (1995) used fecal analysis to estimate that a single big brown bat (*Eptesicus fuscus*), on average, consumes 10.63 stinkbugs (Pentatomidae) per night; therefore, white-nose syndrome has potentially resulted in about 2.3 million fewer stinkbugs being consumed annually by big brown bats alone. In addition, stinkbugs only make up a small (2–16%) proportion of the diet of big brown bats, and declines in the other five species of bats are expected to result in billions of coleopterans, dipterans, hemiopterans, homopterans, hymenopterans, lepidopterans, trichopterans, and arachnids no longer being consumed (Whitaker, 2004), which will have unknown ecosystem-level consequences. Further, as white-nose syndrome spreads across North America, insectivory release is likely to occur across a wider range of taxa, raising the potential for

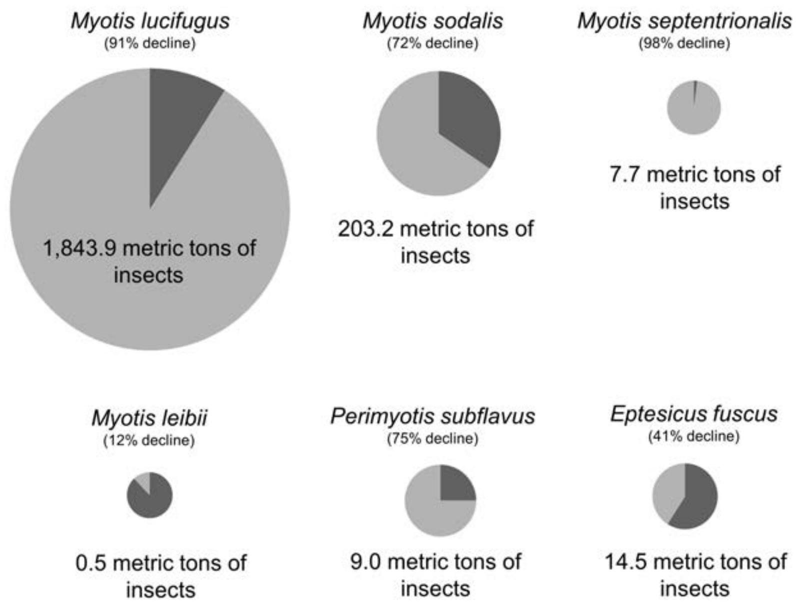

Figure 1. Estimated biomass of insects no longer being consumed because of white-nose syndrome, based on declines in six species of bat in the eastern United States that total to 5.7 million individuals lost. Size of circles represents historical abundance and the fractional percentages in light grey represent the percent population reduction for each species following arrival of the disease, based on data collected from 42 hibernacula in five eastern states where white-nose syndrome has been present for at least 2 years (Reeder and Moore, 2013).

losing important ecosystem-service benefits that bats provide by consuming agricultural and forest pests (Boyles et al., 2011).

In addition to direct predation, communities of insects are also likely being indirectly altered by the relaxation of predation risk. The predation risk posed by bats has led to the evolution of defense mechanisms by insects, ranging from altered activity periods to acoustical jamming (Kunz et al., 2011), and even ultrasonic broadcasts that resemble the calls of bats can reduce mate-seeking behavior and reproductive output of insects (Huang and Subramanyam, 2004). Therefore, in addition to investigations into how white-nose syndrome is causing some level of insectivory release by bats no longer directly consuming insects, research is urgently needed to determine the extent to which the indirect effects of declines in insectivory could be impacting communities of insects and the broader functioning of ecosystems.

Our preliminary analysis highlights the importance of not only directing research toward declining populations of species of conservation concern, but also to considering the potential cascading, indirect, ecological effects of emerging infectious diseases, such as white-nose syndrome. Increasing evidence suggests that emerging infectious diseases have transformative power over ecosystems, shifting the structure and function of biological communities (Cobb et al., 2012; Hartley et al., 2009). To evaluate more effectively the potential role of white-nose syndrome and other emerging infectious diseases as transformative ecological agents, we encourage research into their broader, long-term, direct and indirect ecological effects.

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ANNOUNCEMENTS

In Memoriam

As many of you know, we recently lost one of our dearest colleagues, Dr. Elizabeth (Dixie) Pierson. Our heartfelt sympathy goes out to her husband, Dr. William (Bill) Rainey. Dixie died in April after a long series of hospital-associated infections secondary to various medical treatments. In addition to being a dear friend, Dixie was a long-time supporter of *Bat Research News*, the NASBR, the Bernardo Villa Student Fund, and many, many students throughout her career. And of course she was a real champion of bats worldwide. Dixie will be sorely missed. A complete obituary will be published in a later issue.

Request for Manuscripts — *Bat Research News*

Original research/speculative review articles, short to moderate length, on a bat-related topic would be most welcomed. Please submit manuscripts as .rtf documents to Allen Kurta, Editor for Feature Articles (akurta@emich.edu). If you have questions, please contact Al. Thank you for considering submitting your work to *BRN*.

Change of Address Requested

Will you be moving in the near future? If so, please **send your new postal and e-mail addresses** to Margaret Griffiths (margaret.griffiths01@gmail.com), and include the date on which the change will become effective. Thank you in advance for helping us out!

FUTURE MEETINGS and EVENTS

2014

The 44th Annual NASBR will be held 22–25 October 2014 in Albany, New York, at the Hilton Albany. See the NASBR website for registration details and program information: http://www.nasbr.org/.

2015

The 45th Annual NASBR will be held October 28–November 1, 2015, in Monterey, California. See the NASBR website for future updates — http://www.nasbr.org/.

2016

The 46th Annual NASBR will be held in San Antonio, Texas (dates to be determined). See the NASBR website for future updates — http://www.nasbr.org/.

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A flat-faced fruit-eating bat (*Artibeus planirostris*) from Paramaribo, Suriname. Photo courtesy of Keith Christenson.

BAT RESEARCH NEWS

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Bat Research News is published four times each year, consisting of one volume of four issues. *Bat Research News* publishes short feature articles and general interest notes that are reviewed by at least two scholars in that field. *Bat Research News* also includes abstracts of presentations at bat conferences around the world, letters to the editors, news submitted by our readers, notices and requests, and announcements of future bat conferences worldwide. In addition, *Bat Research News* provides a listing of recent bat-related articles that were published in English. *Bat Research News* is abstracted in several databases (e.g., BIOSIS).

Communications concerning feature articles and "Letters to the Editor" should be addressed to Dr. Al Kurta (akurta@emich.edu), recent literature items to Dr. Jodi Sedlock, (sedlockj@lawrence.edu), and all other correspondence (e.g., news, conservation, or education items; subscription information; cover art) to Dr. Margaret Griffiths (margaret.griffiths01@gmail.com).

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Back issues of *Bat Research News* are available for a small fee. Please contact Dr. Margaret Griffiths (margaret.griffiths01@gmail.com) for more information regarding back issues. Thank you!

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Letters to the Editor

Editor's Note: Unlike technical articles, letters are not peer-reviewed, but they are edited for grammar, style, and clarity. Letters provide an outlet for opinions, speculations, anecdotes, and other interesting observations that, by themselves, may not be sufficient or appropriate for a technical article. Letters should be no longer than two manuscript pages and sent to the Feature Editor.

A Novel Way to Prevent Mist Nets from Snagging Non-target Species during the Day

John Gumbs

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When conducting mist-netting surveys, nets typically are removed from their supporting poles each night to prevent the nets from entrapping non-target species during the day. Removing the nets and re-attaching them the following night is time consuming. However, I stumbled across a way keep the nets attached and prevent them from catching birds and other animals during daytime.

The solution was to furl the nets and then wrap them in a plastic food wrap, such as Saran Wrap (www.saranbrands.com) or Glad Cling Wrap (www.glad.com/food-storage/plastic-wrap/cling-wrap). Each net (2.6- and 6-m wide) was lowered, gathered, and rolled loosely around itself, before being wrapped in plastic wrap, from end to end (Fig. 1). The plastic wrap was overlapped on each revolution to ensure continuity and the result was a snugly rolled "sausage" of netting with no loose strands.

Wrapping is best done by two people—one wrapping and the other preventing the gathered net from rolling, while the wrap is wound around it. The procedure takes only a few minutes to accomplish. Unwrapping is just the reverse—again using two people. The 6-m-wide nets were actually moved to another netting location, while wrapped and with the net loops still attached to the netting poles. The nets were placed on the ground several times, but when the system was reassembled at the new location, they were correctly attached and debris free.

Figure 1. Wrapping a mist net in plastic food wrap.

IN MEMORIAM

Dr. Elizabeth "Dixie" Dixon Pierson 1943–2014

Patricia Brown

With assistance from William Rainey, Paul Racey, Lyle Lewis, and others

When Dixie died on April 2, 2014, from antibiotic resistant bacterial infections associated with cancer treatment, the bat research community lost a valued colleague. For over 30 years, she was an influential personality in bat conservation, particularly in the western United States. Dixie was passionate in her defense of the "under bat", and used her keen intellect and her excellent writing, teaching and organizational skills to promote bat conservation. She was aided in her endeavors by her husband and biologist partner of 31 years, Dr. William (Bill) Rainey.

Originally majoring in English Literature at Mt. Holyoke, Dixie continued with a MAT earned at Yale University after which she taught for several years in Massachusetts. She had a strong love of wilderness, enhanced by a year in Alaska and teaching winter survival for Outward Bound in New England. She decided to change careers to wildlife research and was "converted" to the study of bats in Dr. Tom Kunz's lab at Boston University. She entered the doctoral program at the Museum of Vertebrate Zoology at UC Berkeley. Working with Drs. James Patton and Vincent Sarich, she completed a Ph.D. in 1986 using protein immunology to examine phylogenetic relationships of bat families worldwide. One focus of her dissertation was on the then phylogenetically enigmatic New Zealand short-tailed bat (*Mystacina tuberculata*), a sometimes terrestrial bat species with a diverse diet and a lek-like mating system. Her report linking *Mystacina* most closely to bat families of the superfamily Noctilionoidea of South America appeared in the journal *Nature*.

She was an early supporter of Dr. Merlin Tuttle when he founded Bat Conservation International (BCI), and BCI described Dixie and Bill as "instrumental in gaining passage of a bill through the U.S. Congress" that ultimately created a U.S. National Park in American Samoa to protect flying foxes and their habitat. She collaborated in flying fox studies for several years in Samoa and other Pacific Islands. The population impact of the import of flying foxes as luxury food into Guam led to another collaboration to place *Pteropus* on Appendix II of the International Convention on Trade in Endangered Species. To make this operational, she and Bill developed identification materials after reviewing specimens in U.S. and European collections, provided informal training for field enforcement agents, and sought to intensify Fish and Wildlife Service import monitoring on Guam. She also collaborated with Drs. Paul Racey and Tom Kunz on developing the first symposium on the conservation biology of bats, which was held during the 10th International Bat Research Conference in Boston in 1995 and that resulted in publication of *Bat Biology and Conservation* in 1998. According to Paul, this represented a significant benchmark by signaling the intention of bat biologists to provide a scientific basis for the conservation of their study animals. In tribute, Paul states "Dixie was invariably encouraging and supportive and a greatly valued colleague."

This theme is echoed by colleagues elsewhere. She served on the Board of Directors of the North American Society of Bat Research (NASBR) and worked closely with Drs. Tom and Margaret Griffiths while serving as Treasurer of the society. "Dixie was the driving force behind the Bernardo Villa Student Award," they said. "She cared deeply about students and especially wanted to help Mexican students attend the annual NASBR. She also wanted to honor Dr. Bernardo Villa for his work on bats and for the help he gave to so many students and bat biologists worldwide. Dixie not only helped us set guidelines for the new award, but also provided the initial endowment that established the Villa fund." The current NASBR Board Chair, Dr. Allen Kurta said, "Dixie was a cherished colleague and a mentor to many. She will be dearly missed by the bat-research community."

Dixie was a member of the team that developed the interagency Townsend's big-eared bat Conservation Strategy in 1993-1994 that eventually led to the formation of the Western Bat Working Group in 1996, of which she was a co-founder. According to Lyle Lewis, first chairman of the Western Bat Working Group, "Dixie was an incredibly valuable member of any conference, workshop or meeting. Her ability to cut through falsehoods and niceties of personality and bring forth a simple, candid embodiment of truth was unparalleled. The loss of her dynamic personality, profound influence and advocacy in bat conservation efforts leaves a vacuum in our small community unlikely to ever be filled. Her loyal friendship will be remembered and cherished by all who knew her well."

Dixie and Bill's research added greatly to the knowledge of the distribution and habitat needs of species such as Townsend's big-eared, spotted, western red and greater mastiff bats, particularly in California. Their research and monitoring in Yosemite and Sequoia – Kings Canyon National Parks provided an enhanced baseline on bat fauna and ecology for those diverse protected areas. Their surveys on bats roosting in abandoned mines, caves, anthropogenic structures (including bridges), and forests led to direct conservation efforts for specific bat populations. Dixie also developed a key to Bats of California that found widespread use by biologists across the western United States. Dixie was the lead for the creation of the California Bat Plan, sponsored by the California Department of Fish and Wildlife. She gathered other California bat biologists to collaboratively assess issues and threats, but she was the guiding force for the plan framework. Her cancer diagnosis and treatment limited her involvement at the phase where the final document was being compiled. As a legacy to Dixie, her friends and colleagues will complete this important task in her memory.

Dr. Patricia Brown was a close friend of Dixie's since meeting her at the NASBR meeting in St. Louis in 1979 (as Dixie was beginning her research at UC Berkeley). Pat and her late husband Dr. Bob Berry shared field adventures with Dixie and Bill, where Dixie projected a sense of humor and mischief even in physically trying circumstances. Dixie was a devoted friend and mentor to many aspiring biologists, especially women, who carry on her commitment and passion for bat conservation. Dixie will be sorely missed by all of us.

RECENT LITERATURE

Authors are requested to send reprints or PDF files of their published papers to the Editor for Recent Literature, Dr. Jodi L. Sedlock (Lawrence University, 711 E. Boldt Way, Appleton, WI 54911, U.S.A., e-mail: **sedlockj@lawrence.edu**) for inclusion in this section. Receipt of reprints is preferred, as it will facilitate complete and correct citation. However, if reprints and/or PDF files are unavailable, please send a complete citation (including complete name of journal and corresponding author mailing address) by e-mail. The Recent Literature section is based on several bibliographic sources and for obvious reasons can never be up-to-date. Any error or omission is inadvertent. Voluntary contributions for this section, especially from researchers outside the United States, are most welcome and appreciated.

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ANNOUNCEMENTS

Request for Manuscripts — *Bat Research News*

Original research/speculative review articles, short to moderate length, on a bat-related topic would be most welcomed. Please submit manuscripts as .rtf documents to Allen Kurta, Editor for Feature Articles (akurta@emich.edu). If you have questions, please contact Al. Thank you for considering submitting your work to *BRN*.

Change of Address Requested

Will you be moving in the near future? If so, please **send your new postal and e-mail addresses** to Margaret Griffiths (margaret.griffiths01@gmail.com), and include the date on which the change will become effective. Thank you in advance for helping us out!

FUTURE MEETINGS and EVENTS

2014

The 44th Annual NASBR will be held 22–25 October 2014 in Albany, New York, at the Hilton Albany. See the NASBR website for registration details and program information: http://www.nasbr.org/.

2015

The North American Bat Working Group Meeting will be held March 3–6, 2015, at the Crowne Plaza in downtown St. Louis, Missouri. This will be a joint meeting of the Western and Midwestern Bat Working Groups, and the Southeast Bat Diversity Network.

The 45th Annual NASBR will be held October 28–November 1, 2015, in Monterey, California. See the NASBR website for future updates — http://www.nasbr.org/.

2016

The 46th Annual NASBR will be held in San Antonio, Texas (dates to be determined). See the NASBR website for future updates — http://www.nasbr.org/.

BAT RESEARCH NEWS

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Front Cover

Logo from the 44th Annual North American Symposium on Bat Research held in Albany, NY, 22–25 October 2014. The meeting was hosted by Emily Davis and Mike Warner, and the meeting logo was designed for Emily and Mike by *Eat More Tees*. Many thanks to Emily, Mike, and the NASBR for allowing us to use the logo.

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Bat Research News is published four times each year, consisting of one volume of four issues. *Bat Research News* publishes short feature articles and general interest notes that are reviewed by at least two scholars in that field. *Bat Research News* also includes abstracts of presentations at bat conferences around the world, letters to the editors, news submitted by our readers, notices and requests, and announcements of future bat conferences worldwide. In addition, *Bat Research News* provides a listing of recent bat-related articles that were published in English. *Bat Research News* is abstracted in several databases (e.g., BIOSIS).

Communications concerning feature articles and "Letters to the Editor" should be addressed to Dr. Al Kurta (akurta@emich.edu), recent literature items to Dr. Jodi Sedlock, (sedlockj@lawrence.edu), and all other correspondence (e.g., news, conservation, or education items; subscription information; cover art) to Dr. Margaret Griffiths (margaret.griffiths01@gmail.com).

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Back issues of *Bat Research News* are available for a small fee. Please contact Dr. Margaret Griffiths (margaret.griffiths01@gmail.com) for more information regarding back issues. Thank you!

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Letters to the Editor

Editor's Note: Unlike technical articles, letters are not peer-reviewed, but they are edited for grammar, style, and clarity. Letters provide an outlet for opinions, speculations, anecdotes, and other interesting observations that, by themselves, may not be sufficient or appropriate for a technical article. Letters should be no longer than two manuscript pages and sent to the Feature Editor.

Tents of *Dermanura phaeotis* (Phyllostomidae) in *Genipa americana* (Rubiaceae)

Eduardo Artavia Durán and Oscar Cubero Vázquez

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The pygmy fruit-eating bat (*Dermanura phaeotis)* is a common Neotropical species, found from Mexico to Ecuador and Guyana. In Costa Rica, it is distributed throughout the country, mainly below 1,000 m (LaVal and Rodríguez, 2002). *D. phaeotis* is one of 17 species of bats in the New World that uses tents made from leaves as a roosting site (Rodríguez-Herrera et al., 2007), and in this note, we document the first use of tents by *D. phaeotis* in a new species of Rubiaceae, the guaitil tree (*Genipa americana*).

The study occurred in Barra Honda National Park, located in Nicoya, Guanacaste, Costa Rica (10°10'–10°13'N and 85°18'–85°22'W). The park is mostly covered by secondary forest and lies within two ecozones of (Holdridge, 1987)—premontane moist forest (basal transition) and tropical moist forest (dry transition). Observations were made during September 2012, May and December 2013, and May–August 2014.

In the first 2 years, we recorded only the location, style of architecture, and number of bats using a tent. However, in 2014, we also measured the length of the modified leaf, its height above the ground, and the number of cuts needed to form the tent. In addition, we recorded the angle formed in the modified leaf between the proximal and distal portions of the petiole (apical and boat-apical structure) or the angle formed between the right and left sides of the blade of the leaf (boat structures). The style of architecture was categorized based on Rodríguez-Herrera et al. (2007).

To capture bats for identification, we used mist nets set near occupied tents in 2012 and entomological nets in 2014. We did not attempt to capture bats in 2013. Nevertheless, we assumed that bats roosting in tents in 2013 were *D. phaeotis*, because *Dermanura watsoni* or any other similar species has never been caught in Barra Honda National Park and all bats that we did capture from tents were *D. phaeotis*.

Twenty-three tents were located in 11 *G. americana*. Most tents were either boat or boat-apical in structure, but we also noted two apical and two conical tents (Table 1; Fig. 1). We found three *D. phaeotis* in one tent, but all others sheltered only one or two bats. Only one occupied tent was found at each site, even though several *G. americana* or trees of other species with modified leaves were located within 30 m. During May 2013, one female with a youngster was found in one of the tents, but no other young were noted in the tents during the study.

Kunz and Fenton (2003) indicated that the structure of a tent corresponds more closely to the shape of the leaf than to the ecology of the

Table 1. Characteristics (mean ± SD) of tents of *D. phaeotis* in *G. americana*.

Style of tent	*n*	Length (cm)[1]	Height (m)[1]	Angle (°)[1]	Number of cuts
Boat	12	44 ± 7.0	2.44 ± 0.09	113.5 ± 18.5	25 ± 2.0
Boat-apical	7	58.4 ± 2.4	2.01 ± 0.03	114.3 ± 9.2	25 ± 1.0
Apical	2	44 ± 7.0	2.39 ± 0.3	112 ± 0.0	1 ± 0.0
Conical	2				6 ± 0.0

[1]This characteristic could not be measured on conical tents.

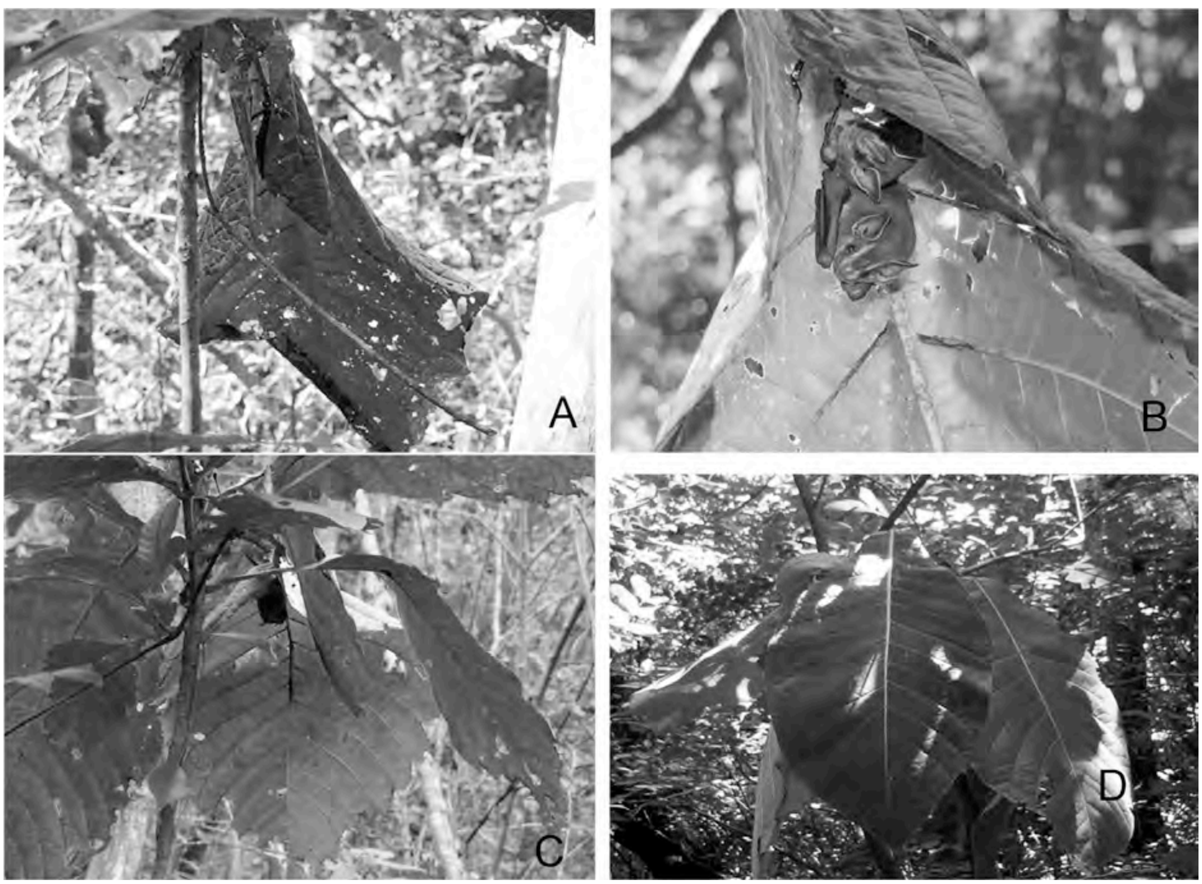

Figure 1. Photographs of tents of different styles in *G. americana*. A) Boat type. B) Boat type occupied by two *D. phaeotis.* C) Boat-apical structure (back) occupied by one bat, with one, unoccupied apical structure to the right of it. D) Conical type.

bat. However, we found four types of structures in leaves of the same species of tree, with similar tree size and height, suggesting that bats select the type of structure they want to build. Unfortunately we have no observations of *D. phaeotis* actually constructing these tents. No other species of bat has been reported using leaves of *G. americana* for roosting.

Acknowledgments

We thank R. LaVal, for reviewing an earlier version of the manuscript, and K. Wilson, for help with translation.

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Rodríguez, B., R. Medellín and R., Timm, R. 2007. Murciélagos neotropicales que acampan en hojas. Neotropical tent-roosting bats. Guía de campo. 1 edición. Instituto Nacional de Biodiversidad, Santo Domingo de Heredia, Costa Rica.

Abstracts of Papers Presented at the

44th Annual Symposium of the
North American Society for Bat Research
Albany, NY
October 22–25, 2014

The following abstracts are from papers presented at the 44th Annual North American Society for Bat Research (NASBR). The local hosts for the meeting were Emily Davis and Mike Warner. Meeting abstracts were submitted by Frank Bonaccorso, Gary Kwiecinski, and Shahroukh Mistry, Program Directors for NASBR. Abstracts are arranged in alphabetical order by first author and, except for minor formatting changes, are published as received. **Student award recipients** are indicated by an asterisk (*) next to the title of their paper. Contact information for authors who attended the 44th Annual NASBR are available in the section following the abstracts.

Olfactory Signals Reveal Body Condition in Male *Phyllostomus hastatus*
Danielle Adams[1], Yue Li[2], and Gerald Wilkinson[1]
[1]Department of Biology, University of Maryland, College Park; [2]Department of Biochemistry, University of Maryland, College Park

Olfactory signals are ubiquitous among mammals and mediate a variety of interactions, including intrasexual competition and mate choice. Here, we examine a sexually dimorphic chemical signal in the greater spear-nosed bat (*Phyllostomus hastatus*). In this harem-forming species, males possess a large sebaceous gland on their chest that produces an odoriferous secretion, which they rub on their mates and roost site. Given this sexual dimorphism, this signal is likely important for mediating male-male competition, especially with regard to harem acquisition and defense, and/or facilitating female mate choice via extra-pair mating. We collected samples from harem males and bachelor males from 3 colonies during the breeding and non-breeding seasons in Trinidad, West Indies. Using Direct Analysis in Real Time mass spectrometry (DART-MS), we quantified the chemical profile of each sample. We found that bachelor and harem males differ in the overall chemical diversity of their scent profiles. In addition, male scent profiles vary with body condition, providing a potential means by which both competitors and potential mates can assess male condition.

Pitfalls of PIT Tagging — Lessons Learned from a Colony of Mexican Long-nosed Bats
Erin Adams and Loren Ammerman
Department of Biology, Angelo State University, San Angelo, TX

The use of Passive Integrated Transponder (PIT) tags is an increasingly popular and effective way to monitor bats at roosts. There are successful examples of PIT tag use with vespertilionids to determine colony activity and dynamics. To our knowledge this was the first study to apply PIT tagging to analyze the nightly and seasonal activities of Mexican long-nosed bats (*Leptonycteris nivalis,* Phyllostomidae), a migratory, nectarivorous bat found in Mexico and a few sites in the southwestern United States. We installed a Biomark IS1001 PIT tag reader with flexible 50-foot antenna in a roost flyway in Big Bend National Park in 2014. We PIT tagged 38 Mexican long-nosed bats from the colony and monitored their activity. Our observations indicated that the antenna deterred the early migrants of the Mexican long-nosed bat colony from using the flyway, while other vespertilionids in the cave passed through the traditional hoop configuration of the antenna regularly. With modifications to reduce high-frequency noise emitted by the equipment and a novel antenna configuration we were able to successfully detect ~58% of tagged individuals on one or more nights. Migratory behaviors of the colony, proximity of undocumented roost sites, previously unknown cave exits, and gaps in flyway detection coverage may have contributed to the lack of detections.

1000 Year Rain, 500 Year Flood: a Natural Experiment for Changes in Water Availability and Bat Activity
Rick Adams
School of Biological Sciences, University of Northern Colorado, Greeley, CO

Many studies have shown the importance of water for bats in arid environments. However, experimental evidence for the importance is scarce. In September 2013, Boulder and Larimer counties, Colorado, experienced 18 inches of rain in a 36-hour period that caused massive rearrangements in canyon drainages. I quantified how bats

responded to post-flood conditions in two canyons that have been monitored for the last four years: Geer Canyon (GC) which has always maintained some water availability throughout the summer, showed an increase in overall bat activity (calculated as sonar passes per night PpN) by 44% in 2014 compared to mean activity of two previous years. In Plumely Canyon (PC), typically a dry canyon, overall bat activity increased dramatically by 73% above the previous three years. Kruskal-Wallis analysis on PpN showed no significant differences in activity among years due to high nightly variation in GC. However, the effects in PC were so strong that despite variable nightly activity, 2014 was significantly higher when compared to the previous three years ($P = 0.001$). Species richness in GC varied between nine and 10 and species in 2014 and evenness hovered around 0.71, but increased to 1.00 in 2014. Species richness in PC showed much higher variation over the years (5–9 species), with nine present in 2014. Species evenness in PC ranged from 0.44 to 0.71 in 2012. In 2014, evenness was 0.62. Thus, the overall response of bats to the 2013 flood event was positive in 2014 apparently due to increases in water availability.

Bat Wing Mites of the Genus *Periglischrus* from Bat *Desmodus rotundus* from the Neotropics

Linda Aldana[1], Juan Morales-Malacara[1], Hugo Ruiz-Piña[2], Enrique Reyes-Novelo[2], and Alan Cuxim-Koyoc[2]
[1]Universidad Nacional Autónoma de México, Unidad Multidisciplinaria de Docencia e Investigación, Facultad de Ciencias, campus Juriquilla, Querétaro, MEX; [2]Universidad Autónoma de Yucatán, Centro de Investigaciones Regionales, "Dr. Hideyo Noguchi", Mérida,Yucatán, MEX

Currently the genus *Periglischrus* represent obligate parasites on naked skin surfaces on Phyllostomid bats. In particular the species *Periglischrus herrerai* is a frequent parasite of the vampire bat *Desmodus rotundus* and represent a unique species in the genus, that have some particular morphological features, and this species belongs to the *hopkinsi* group. The specimens of *Periglischrus herrerai* studied were obtained from field surveys expeditions in four states from central and southeastern regions of Mexico, and we obtain as loan type specimens for comparative purpose from the mite collection of the Central University of Venezuela. We have studied the adults of both sexes of *P. herrerai* using morphometric analysis, in order to elucidate the evolutionary rate of this parasite, related to its host *D. rotundus* distribution. We found that about 12 characters, mainly of Pronotal region and Femora may explain the variation observed in the samples. The cluster analysis performed by ordination data; using the Ward method for clustering, show clearly the separation between sexes. With a non-metric multidimensional scaling method (Bray-Curtis distance) the data showed that females have a separation process in two groups, one with specimens from Yucatan Peninsula, and the other with specimens from the Central region of Mexico. This disjunctive variation in the parasite populations, could explain some geographic variation in this species of parasite, and that could reflect a process of isolation between populations of its host *D. rotundus.*

Acoustic Assessment of the Bats of Devils River State Natural Area — Big Satan Unit, Val Verde County, Texas

Grayson Allred, Loren Ammerman, and Robert Dowler
Department of Biology, Angelo State University, San Angelo, TX

A survey of bats was conducted from July, 2013 to June, 2014 to determine the species diversity and community composition at Devils River State Natural Area (DRSNA) – Big Satan Unit, as part of ongoing research with the Texas Parks and Wildlife Department. DRSNA is a 38,000-acre preserve situated along a 10.8-mile stretch of the Devils River in Val Verde County, 40 miles north of Del Rio, Texas. A handheld acoustic monitoring device, the Echo Meter EM3+ Ultrasonic Recorder (Wildlife Acoustics), was used to detect species based on echolocation calls. Calls were recorded along an 8-mile long transect route that runs generally west to east across DRSNA, and at five stationary netting sites around the survey area. There were a total of 15 transects driven and 10 nights of stationary recording. Kaleidoscope Pro 2.0 (Wildlife Acoustics) was used to analyze the sound files recorded. From a total of 7,248 sound files recorded, 1,429 were recognized as good bat echolocation calls that were used to identify species, while 5,819 were eliminated as noise files. Preliminary results found nine species (*Lasiurus borealis, Lasiurus cinereus, Lasionycteris noctivagans, Nycticeius humeralis, Parastrellus hesperus, Perimyotis subflavus, Tadarida brasiliensis, Antrozous pallidus,* and *Corynorhinus townsendii*) present at DRSNA. Species diversity varied between recordings collected via the transect route and those collected at stationary netting sites. Only five different species were detected along the transect route while nine species were detected at the stationary sites.

How do *Myotis lucifugus* Find Novel Roosts and Can They Discriminate between New and Relocated Roosts? A Proposal

Karissa Appleby and Hugh Broders
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Suitable roosts are a vital resource for bats, and how bats find new roosts is an important area of research that is not yet well understood. The objective of this experiment will be to determine which sensory cues little brown bats (*Myotis lucifigus*) use to find novel roosts, and if this species can distinguish between novel roosts and roosts that have been relocated. Our first hypothesis is that bats will use echolocation to find novel roosts. Our second hypothesis is that providing additional sensory cues (temperature, olfactory, conspecific echolocation calls) will decrease the time it takes for bats to find a new roost. Our third hypothesis is that if little brown bats use additional sensory cues to locate new roosts, these same cues will allow them to distinguish between new roosts and roosts that have been relocated. We know that bats use spatial memory to locate established roosts, but we do not yet know how bats find new roosts. The results of this study could further our understanding of not only how bats find novel roosts, but may provide insights into how well developed memory and other cognitive skills are in bats. Research into how bats find and establish roosts also has important implications for land management and conservation.

Activity of Bats during Migration in the Saginaw Bay Area of Lake Huron

Giorgia Auteri and Allen Kurta
Department of Biology, Eastern Michigan University, Ypsilanti, MI

The Great Lakes region includes species of bats that are long-distance migrants (*Lasiurus borealis, L. cinereus,* and *Lasionycteris noctivagans*), regional migrants (*Myotis septentrionalis* and *M. lucifugus*), and sedentary (*Eptesicus fuscus*). Understanding the seasonal movements of these species may help limit mortality at wind-energy facilities and the spread of white-nose syndrome. To explore how migrating bats deal with the barrier of open water, we set up passive acoustic detectors (Anabat) around the coast of Saginaw Bay in Lake Huron, as well as on Charity Island in Saginaw Bay. We predicted bats would preferentially fly across the narrowest point of the bay (21 km) and over Charity Island, as do many birds, instead of taking the longer route around the coast of the bay (>120 km). We analyzed calls recorded from 14 May to 15 November 2013 and from 1 May to 25 September 2014. Although data collection for 2014 is ongoing, we recorded 97,322 calls in 2013 (mean 8.3 ± 534 (SD) calls per detector per night). Using SaTScan, we performed space-time analyses and found statistically significant clusters in activity between the island and the most proximal mainland detector to the north from 30 August to 5 September, and between the two mainland detectors to the south of the island from 9 to16 September. These results suggest that many bats preferentially cross the water of the bay during migration, because clusters of activity include the narrowest part of the bay and Charity Island rather than other locations around the coast.

Bat Skin Microbial Symbionts: How the Environment and WNS Disease Status Affect the Bat Skin Microbiome

Christine Avena[1], Laura Parfrey[2,3], Holly Archer[1], Winifred Frick[4], Kate Langwig[4], Karen Powers[5], Rob Knight[2,6,] Marm Kilpatrick[2], and Valerie McKenzie[1]
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Bats are a critical component of ecosystems across the globe. They are found in a wide variety of environments—from man-made structures to caves, tree roosts, and rock crevices. The microbial communities that exist in these environments are diverse and may play a role in the development of the symbiont microbiome of bat hosts. During the fall of 2011, 68 bats and their hibernacula in four locations within the white-nose syndrome (WNS) epidemic area were sampled using a sterile skin swabbing technique. After DNA extraction and library preparation, samples were sequenced with Illumina Hi-Seq at the University of Colorado-Boulder and analyzed with the QIIME pipeline. We found significantly distinct microbial assemblages on different bat species. There were 20 named bacterial phyla and 2 archaeal phyla present. Of those, 132 genera of bacteria are unique to the bat hosts, and not found on cave environmental samples. Within bacteria specific to the host, classes included *Gammaproteobacteria*, *Betaproteobacteria, Alphaproteobacteria, Flavobacteria,* and *Actinobacteria*. Cave site is the most important predictor of the composition of microbes living on bat skin, indicating that the environment has a strong influence on the microbes that colonize bats above other biotic host factor. In addition, the presence of the WNS fungal pathogen *Pseudogymnoascus destructans* within the skin microbial community may influence the diversity of bacterial symbionts. The conclusion of our research is that environment, as well as disease status may play an important role in developing and maintaining the bacterial community found on the skin of bats.

Population Structure of Hoary Bats and Silver-haired Bats across Canada

Erin Baerwald and Robert Barclay
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The most common types of bats killed by wind turbines are the migratory tree-bats. In North America, hoary bats (*Lasiurus cinereus*) make up 38% of all bat fatalities and silver-haired bats (*Lasionycteris noctivagans*) make up 18%. While recent cumulative fatality estimates of 840,486 to 1,690,696 from 2000–2012 are disturbing, we have little knowledge of the population structure of these species and how wind turbine-related fatalities may be impacting populations. We used a highly polymorphic portion (HVII) of the mitochondrial DNA control region (D-loop) to investigate the population structures of 151 hoary bats and 215 silver-haired bats from several mist-netting localities and wind energy sites across four Canadian provinces. To address our questions, we used estimates of haplotype diversity (h), nucleotide diversity (π), AMOVAs, exact tests of population differentiation, and Mantel tests. For both species, we found high levels of h coupled with low levels of π. The AMOVA of silver-haired bats suggests population structuring among groups across Canada and among populations within provinces and the Mantel test shows that this population structure is influenced by geographical distance. The AMOVA of hoary bats indicated less structure among groups across Canada than the silver-haired bat, and this structure was not influenced by geographic distance, as determined by a Mantel test. Although there was evidence of population structuring in both species, exact tests show that there is no population differentiation of either species across Canada. Additional analyses using microsatellites will help to further elucidate population structure and movement and help guide conservation strategies.

Using Patterns of Wing Venation to Identify Individuals

Jeanette Bailey[1], Lisa Powers[2], and Allen Kurta[1]
[1]Department of Biology, Eastern Michigan University, Ypsilanti, MI; [2]Department of Biology, University of Illinois, Urbana, IL

Photo-identification, instead of more invasive marking techniques, is commonly used to track cetaceans in the wild by documenting unique external features. When biologists are faced with the challenge of marking newborn bats for later identification, there are only a few temporary options available, such as paint and hair-clipping, but such techniques do not offer enough variability to serve as unique identifiers for the number of pups in a typical maternity colony. In this study, we show that photographs of the transilluminated wing, may be used to identify individuals, based on the branching patterns of the veins. The general branching pattern of patagial veins is common, but each individual bat has unique branching characteristics that can be matched later when the same bat is recaptured and has matured enough to retain a lipped wing band. We photographed 33 non-volant big brown bats (*Eptesicus fuscus*) from a maternity colony in west-central Illinois in mid-June. We then photographed and banded volant pups in early July. By manually comparing several wing-vein patterns, side by side, we were able to identify the newly volant bats as the same individuals that we had examined several weeks earlier.

The Influence of Flight and Effect of Feeding on Plasma Metabolite Profiles of *Myotis lucifugus*

Dylan Baloun[1], Quinn Webber[1], Liam McGuire[2], Anuraag Shrivastav[1], and Craig Willis[1]
[1]Department of Biology, University of Winnipeg, Winnipeg, CAN; [2]Department of Biological Sciences, Texas Tech University, Lubbock, TX

Analysis of plasma metabolites (e.g., triglycerides, β-hydroxybutyrate, glucose) can be used to study nutritional status and foraging behavior in the context of pre-hibernation fattening, migration refueling, and habitat variation. Previous studies have validated these analyses in both field and lab for several taxa. High levels of plasma triglycerides indicate recent feeding and fat accumulation while β-hydroxybutyrate, a product of fat catabolism, reflects fasting. In previous studies of insectivorous bats, triglycerides followed the typical pattern but β-hydroxybutyrate increased after foraging rather than decreased. One hypothesis to explain this difference is that an aerial hawking foraging strategy is demanding energetically and requires catabolism of stored fat even in the midst of food acquisition. We evaluated one prediction of this hypothesis, specifically bats prevented from flying during bouts of feeding would exhibit the typical pattern of reduced β-hydroxybutyrate compared to fasted controls. We also tested whether blood glucose concentrations can be used to infer feeding behavior and quantified the temporal profile of each metabolite following feeding to improve interpretations of the metabolite data collected in the field. We captured *Myotis lucifugus* from a fall swarm in Manitoba, Canada and housed them in captivity for several days before feeding trials. During trials, we housed bats individually in small cages (18x18x18cm) to prevent flight and collected blood samples at set time-points after feeding. Metabolites were later quantified via spectrophotometry using commercially available kits. Our results will enhance the use of plasma metabolite analysis for studies of nutritional status, energetics and foraging ecology in insect-eating bats.

Bat Hibernacula Characterization and Use in the Badlands of North Dakota

Paul Barnhart and Erin Gillam
Department of Biological Sciences, North Dakota State University, Fargo, ND

Extensive work has focused on studying and mitigating the spread of white-nose syndrome; yet, information about hibernating bat populations in some areas of the projected disease path are still lacking. In Winters 2010–2013, we used mist netting, radio telemetry, and ultrasonic detection to determine if the badlands of North Dakota supported winter bat populations. We positively identified three species via ultrasonic detection (*Eptesicus fuscus*, *Lasionycteris noctivagans* and *Myotis lucifugus*) and two species via physical capture (*E. fuscus* and *Myotis ciliolabrum*). We also captured *Corynorhinus townsendii* and *Myotis evotis,* although these may have been late-season summer residents that had not yet migrated. Radio telemetry resulted in the documentation of 3 confirmed hibernacula, and scouting trips guided by a maximum entropy habitat suitability model resulted in the identification of 18 potential hibernacula. Preliminary temperature data showed that all known hibernacula were within the growing range of *Pseudogymnoascus destructans,* but were rarely within the temperature range of optimal fungal growth. Our findings are the first to positively identify bat presence in North Dakota during the winter months. Future work should focus on obtaining baseline ecological information about these winter populations and continue monitoring for *P. destructans* in the region.

Characterization of a Novel Subtilisin-like Serine Protease from *Pseudogymnoascus destructans*, the Causal Agent of White-nose Syndrome in Bats

Chapman Beekman[1], Anthony O'Donoghue[2], Giselle Knudsen[2], Jenna Perry[1] and Richard Bennett[1]
[1]Brown University, Providence, RI; [2]Department of Pharmaceutical Chemistry, University of California San Francisco, San Francisco, CA

Pseudogymnoascus destructans, the causal agent of white-nose syndrome (WNS) is an emerging fungal pathogen that has caused devastating losses to several North American bat species. *P. destructans* is a psychrophilic fungus and therefore targets bats during their hibernation period. During infection, the fungus is able to invade and cause extensive damage to membranous tissues in the wings, ears and muzzle causing premature arousal from stupor with catastrophic consequences. Despite the impact of WNS on bat populations, little is known about the biology of the fungus or how it mediates infection in the mammalian host. In many other pathogenic fungi, secreted hydrolytic enzymes such as proteases represent important virulence factors. Accordingly, we have performed the first in-depth molecular analysis of the *P. destructans* secretome in order to characterize potential secreted virulence factors. One fungal protease was purified and shown to be a serine proteinase of the subtilisin-like S8 family. A recombinant form of this protease, hereby named PdSP1, was subsequently overexpressed and purified, and its proteolytic activity characterized. PdSP1 was inhibited by the serine protease inhibitors chymostatin and antipain, and was able to cleave a collagen substrate. Together, these results provide the first molecular insights into the secretome of P. destructans, and reveal the presence of a serine S8 protease that may contribute to tissue invasion in the mammalian host.

Exploring Potential Hypotheses Behind Bat-Wind Turbine Collisions

Victoria Bennett[1], Amanda Hale[2], Alison Schildt[2], Brenton Cooper[3], Aaron McAlexander[2], and Dean Williams[2]
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Considerable progress has been made toward understanding bat mortality at wind farms, yet we still do not know why bats come into contact with turbines. There are two recognized explanations: 1) fatalities are random and simply reflect bat activity; and 2) bats are attracted to wind turbines. Thus to develop practical solutions to minimize

bat fatalities, we investigated whether proximity to resources and/or attraction hypotheses could be leading to bat-wind turbine collisions. From 2009–2014, we monitored bat mortality and conducted resource mapping, night vision, acoustic monitoring, fecal searches, and invertebrate sampling surveys at a wind facility in Texas, USA. Using resource mapping and fatality data, we found that resource availability could not adequately explain bat mortality as ~40% of the observed fatalities occurred at turbines in areas with no known resources. Our data also confirmed that bats were not attracted to FAA lighting on nacelles. Nevertheless, we found feces in door slats and around the tower bases. Furthermore, night vision and acoustic surveys confirmed that bats were actively coming into contact with turbine towers and exhibited a range of resource-seeking behaviors. Finally, invertebrate sampling at turbines, in combination with DNA barcoding of bat feces, indicated that the invertebrate prey in feces comprised species found on and around turbines. Collectively, these data suggest that wind turbines may provide and/or may be misperceived to be an important resource(s). Mortality may therefore be effectively reduced if turbines can be made less attractive to bats.

***Myotis sodalis* Roost Selection in a Managed Forest**

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There is a growing interest in the effects of timber harvest on forest-dwelling bats, particularly threatened and endangered species. Therefore, our goal was to determine how endangered Indiana bats (*Myotis sodalis*) select for summer roosts in a harvested landscape. In the summers of 2012–2014, we tracked 7 male and 4 female adult Indiana bats to 36 roosts (n_{male} = 23, n_{female} = 12, $n_{male+female}$ = 1) in south-central Indiana. We collected roost, plot, stand, and landscape scale data on roosts and associated random trees. We generated 13 linear regression models based on roosting selection hypotheses and ranked them using Akaike's Information Criteria. Based on preliminary analysis of models for male Indiana bat roosts, 2 models ("ease of discovery + roost availability" and "predator avoidance") were the most biologically relevant. Model averaged parameters for these 2 models showed that male Indiana bats select tall trees surrounded by more live trees and snags than expected. We found no significant effects of our timber harvest parameters (e.g., distance to nearest harvest) on roost selection by male Indiana bats. However, most of our study site was subject to single-tree selection harvest, so we were unable to compare our data to an unharvested control. Male Indiana bats will likely benefit if this study site is managed for large ($\geq$ 22m tall) hickory trees surrounded by large numbers of live trees ($\geq$ 24 trees/0.1ha) and snags ($\geq$ 4 snags/0.1ha).

Variation in Load and Prevalence of *Pseudogymnoascus destructans* on Active Bats during Winter in the Southeastern United States

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In the northeastern U.S., unusual winter activity of bats has been attributed to white-nose syndrome (WNS). Winter activity of bats in the southeastern U.S., where winters are shorter and warmer, may not be unusual, but has received little study. To investigate winter activity and WNS epidemiology on bats in the Southeast, we collected fungal swabs from bats captured outside of several large hibernacula in Tennessee. Samples were collected from 896 captured bats, representing 10 species, during winters 2011–12, 2012–13, and 2013–14. Approximately 46% of the bats captured were found positive for *Pseudogymnoascus destructans* (Pd), with fungal load and prevalence varying among species, between sites and across years. *Myotis lucifugus, M. septentrionalis, M. sodalis,* and *Perimyotis subflavus* had the highest fungal loads and prevalence among all bats captured, with the highest fungal loads in *M. septentrionalis* (n = 176, avg. fungal load 0.0129 ± 0.0021ng). On average, bats positive for Pd had a lower body condition index than those that were Pd negative ($p < 0.0004$). Sites with the highest species diversity had higher fungal loads than sites dominated by one or two species ($p < 0.0485$). Prevalence of Pd was highest during winter 2013−14, with fewer individuals captured in that winter as expected from the population declines seen during hibernacula counts throughout the state. Over the course of three winter seasons, we found that bats in the Southeast remain active throughout winter, regardless of the presence of Pd.

Bat Community Responses to Management-scale Thinning of Forest Regrowth

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Secondary (regrowth) forests are now the dominant type of forest worldwide, with over half of the world's forests managed for production. Early thinning of regrowth forests is a routine practice, affecting ecosystem structure and dependent organisms such as echolocating bats and their prey. We used a community-level chronosequence approach to test the hypothesis that early thinning improves foraging habitat for bats in regrowth forests, and that this effect is variable within bat communities due to their variable tolerance of forest clutter. Using acoustic surveys, we compared overall activity and foraging activity of bat species across unthinned dense regrowth stands; reference (mature open forest) and forest which had been thinned recently and in the medium term. We also quantified prey availability at each site. We found an overall negative response of bat communities to unthinned regrowth, despite increased prey availability within these habitats, and a positive response to thinning. These findings are consistent with the hypothesis that dense regrowth limits the manoeuvrability and foraging ability of bat communities. The change in bat community composition between habitats was largely driven by maneuverable, high echolocation call frequency bats which generally forage against clutter, and which showed considerably lower total and foraging activity in unthinned regrowth. These patterns may indicate that the unthinned dense regrowth of our study placed a constraint on the mobility of against clutter foraging bats, which are less likely to fly over the canopy of cluttered areas to access other habitats than their more open-adapted counterparts.

Kinematics of Recovery from an Aerial Stumble in *Carollia perspicillata*

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Flying animals must skillfully navigate and respond to turbulence from other flyers, discrete perturbations such as gusts of wind, and complex flows that arise from air movement around static structures to safely travel, forage, and migrate. Bats may accomplish this task differently from other flyers because their wings are notably heavier. By coopting the many bones and muscles of the hand, arm, and hindlimb for the skeletal framework of the wing, the wings comprise nearly 30% of total body mass in *Carollia perspicillata*. Theoretically, through rapid and asymmetrical modulation of their relatively heavy wings, bats can use wing inertia to perform complex aerial maneuvers without generating aerodynamic force. To record the kinematics of a perturbation response and to explore the importance of wing inertia during recovery from a gust-induced aerial stumble, we trained several *C. perspicillata* to fly through a window that placed them in the path of a gust of wind from above. A synchronized array of six high-speed cameras recorded both the perturbation and the subsequent wingbeats required to restore flight to that resembling control, unperturbed trials. We performed detailed analysis of kinematics of the body and wings during the perturbation and response. To recover from perturbations that induced body roll, bats flapped their wings asymmetrically and were able to rapidly reorient their bodies within two wingbeats. These findings suggest that through asymmetrical flapping flight, bats may use wing inertia to recover from perturbations and improve flight stability.

Using Behavior to Understand the Pathophysiology of White-nose Syndrome

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White-nose syndrome (WNS) is caused by the invasive fungal pathogen, *Pseudogymnoascus destructans* (Pd) and has devastated bat populations in eastern North America. Infection with Pd disrupts normal hibernation physiology by causing bats to arouse from torpor more frequently than healthy bats, exhaust their fat stores prematurely, and starve before spring. The mechanism underlying this increased arousal frequency is not yet fully understood but there is some support in the literature for two hypotheses. Physiological evidence supports the dehydration hypothesis, which suggests that Pd increases rates of evaporative water loss by disrupting wing tissue. This hypothesis predicts that bats arouse to restore water balance and drink during arousals. The grooming hypothesis is supported by some behavioral evidence and suggests that the fungus causes irritation as it invades the

wing membranes, motivating bats to arouse to groom. We revisited these hypotheses using high-resolution video recordings of captive, healthy (n = 8) and experimentally inoculated (n = 10) *Myotis lucifugus* in the midst of arousals. For each arousal, we quantified the frequency and duration of drinking from a water dish and from condensation on other surfaces inside bats' enclosures. We also quantified the frequency and duration of grooming during each arousal and differentiated grooming behavior likely to reflect irritation at sites of infection (i.e., wings) from grooming less likely to reflect infection (i.e., the body). Our results help improve understanding of mechanisms underlying WNS and, more generally, highlight the value of behavioral measures for studies of wildlife disease.

Winter Distribution, Altitudinal Movements, and Use of High Elevation Caves by the Endangered Hawaiian Hoary Bat

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We examine an altitudinal movement that involves winter and spring presence of Hawaiian hoary bats, *Lasiurus cinereus semotus*, in the Mauna Loa Forest Reserve (MLFR), Hawaii Island. Acoustic detection of hoary bat vocalizations, were recorded with outside 13 lava tube cave entrances situated between 2,200 to 3,600 meters ASL from November 2011 to April 2012. Vocalizations were most numerous in November and December with the number of call events and echolocation pulses decreasing through the following months. Visual searches found no evidence of hibernacula nor do these bats appear to shelter by day in these caves. Nevertheless, many bats fly deep into such caves as evidenced by numerous carcasses found as mummies or skeletons in cave interiors. The occurrence of feeding buzzes produced by hoary bats around cave entrances at air temperature as low as 6 C and observations of hoary bats flying in acrobatic fashion in cave interiors demonstrates the use of these spaces as winter foraging sites. It is very likely that *Peridroma* moth species (Noctuidae), the only numerous nocturnal flying insects sheltering in large numbers in rock rubble and on cave walls in the MLFR, serve as the principle prey attracting hoary bats during winter to the high elevation caves of the MLFR. This unusual daily movement appears to be driven by high elevation winter foraging and not by roosting sites.

The Roots of Bat Social Studies

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Despite the size of the order and bats' well-known gregariousness, research on bat social behavior began much later than studies of their physiologies, taxonomy, and distributions. In some ways, this was fortuitous because the earliest studies coincided with major paradigm shifts in the fields of animal behavior, ecology, and evolution. The new paradigms demanded answers to questions that had largely been ignored in prior bat research, and in each new species studied, bats rose to the occasion by exhibiting surprising social complexity and providing novel insights. These trends have continued in the following decades, and there are still many additional bat species that could be examined with these perspectives. However, there is now a new paradigm shift that is likely to reshape how these studies are undertaken. While reductionist approaches to social systems and communication have dominated past research, they tacitly assume that the whole is the simple sum of the parts (linear systems). Many workers are now treating social and communication networks as complex, often nonlinear, systems with potentially emergent properties. Again, bat social research will come late to this approach when compared to recent advances in ecology, economics, and physics, but the potential for such processes in bats is enormous and I expect many new insights and general principles to come from including them in this endeavor.

Phylogenetic and Demographic Insights into *Pipistrellus kuhlii*, in the Middle East

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Kuhl's pipistrelle is found from Europe and North Africa all of the way to Asia, yet studies have thus far concentrated on the western limit of its distribution. Here we form a multi-marker picture of the diversity of Kuhl's pipistrelle at a mid-point in the Arabian Peninsula in an attempt to redress the western sampling bias and to represent a region from which no genetic data has thus far been presented for this species. The three Arabian Cytochrome b haplotypes showed a clear divergence of 19 substitutions from those found in either Europe or North Africa. Molecular dating suggests the Arabian population split from the remaining Kuhl's somewhere between 0.7 and 1.7

million years before present around the time of a series of aridification events across northern Africa. Well supported lineages within Arabia are typical of that which may be seen after an expansion from multiple Pleistocene refugia, but may also reflect the loss of intermediate haplotypes during historical population fluctuations. A long-term population contraction coincides with climatic changes towards those conditions more typical of contemporary Arabia.

Thermoregulation in Roosting Egyptian Flying Foxes

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Torpor is a common strategy used by a variety of bats to offset energetic constraints. There is evidence that small-bodied tropical and semi-tropical Pteropodidae use this strategy. We tested the hypothesis that the relatively large bodied (~100–160 g) cave roosting *Rousettus aegyptiacus* would also employ torpor in the wild. We measured daytime body temperatures (T_b) of 9 individuals using implanted temperature-sensitive radio-transmitters during winter 2011 (which is typically cool and wet) near Cape Town, South Africa. The bats roosted in a cave (approx. 720 m a.s.l.) on the top of the western side of Table Mountain which ranged in temperature from about 5–13°C with a mean of about 9°C. All individuals exhibited a circadian cycle in T_b with on average about 37.7°C upon returning from foraging and typically falling to about 35.5°C in mid-day. T_b increased to about 37°C before bats left the cave to feed. We found virtually no evidence of individual ever letting Tb fall below 34°C. Video data indicated that bats were active throughout the day in the roost which may be related to how they remain warm. Our data are consistent with those of Noll (1979) who found that the T_b of captive *R. aegyptiacus* also exhibited a circadian cycle in T_b of about 2 degrees. Despite being exposed to cool ambient temperatures during the day in the cave and often relatively cold, wet, windy conditions while foraging, all the *R. aegyptiacus* we tracked left the cave every night and never resorted to using torpor.

Effects of Hierarchical Roost Removal on Northern Long-eared Bat Maternity Colonies

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Although conservation of summer maternity habitat is considered critical for forest-roosting bats, bat response to roost loss is still poorly understood. To address this, we monitored three northern long-eared bat (*Myotis septentrionalis*) maternity colonies on Fort Knox Military Reservation, Kentucky, USA, before and after targeted roost removal. We used two treatments: removal of a single primary roost and removal of a quarter of secondary roosts, and we had an un-manipulated control. Roost removal did not alter the number of roosts used by individual bats, but secondary roost removal may have increased the distances moved between sequentially used roosts. Overall space use by and location of colonies was similar pre- and post-treatment. Patterns of roost use before and after removal treatments also were similar, but treatments may have caused bats to maintain closer social connections. Roost diameter at breast height, height, percent canopy openness at roosts, and roost species composition were similar pre- and post-treatment. We detected some differences in roost decay stage and canopy position pre- and post-roost removal, but this may have been an artifact of temperature differences between treatment years. Our results suggest that loss of limited numbers of roosts in the dormant season will not cause northern long-eared bats to abandon roosting areas or substantially alter roosting behavior in the following active season. Increased understanding of the response of northern long-eared bats to roost loss can be used to improve future conservation efforts by placing focus on determination of thresholds for response to forest disturbances.

Impact of Forest Opening Area and Distance from Edge on Bat Activity in the Southern Appalachian Mountains

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In the Central Hardwoods region, U.S.A., early successional habitat (ESH) is declining due to farmland abandonment and suppression of wildfire. As a result, populations of many ESH dependent species have declined.

This has generated concern among scientists and land managers and has led many to ask how best to restore ESH. Bats, while not dependent on ESH, frequently use ESH for foraging and therefore may be affected by ESH restoration. Our objectives were to determine bat use of ESH in relation to ESH patch area and distance from edge. We placed Anabat SD2 detectors in the Nantahala National Forest, NC at the center and edge of 20 forest openings ranging in size from 0.2 ha to 18.5 ha between June and August 2014. Calls were identified to species using AnalookW and grouped based on bat wing morphology and echolocation call structure (clutter-tolerant, intermediate, and clutter-intolerant). Statistical significance was tested using a mixed model with fixed (size, location, size x location) and random (opening within size) effects. For all species combined, activity was higher ($P = 0.06$) in small (0.20–1.98 ha) than in medium and large openings. A similar trend was observed for intermediate clutter tolerant bats ($P = 0.10$), however there was also a size x location interaction ($P = 0.09$). These results indicate that restoring ESH in small patches may have greater benefit for bats than creating large patches.

Population Ecology of Ectoparasites of Mormoopid Bats from the Osa Peninsula, Costa Rica

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Infection of bat flies, spinturnicids, and other ectoparasites have been observed on tropical bats *(Pteronotus)*, habitants of Central and South American caves (Gannon, Kurta, Rodriguez-Duran, & Willig, 2005). This study was conducted at Proyecto Campanario, Costa Rica during the wet and dry seasons. Collection of ectoparasites were extracted at dusk on captured bats using duct tape and observed under a dissecting microscope (40x) for identification. Bat characteristics were correlated to ectoparasite data for species, time of emergence, sex, relative age, lactation, and forearm length using established field station protocols. Ectoparasites were identified and enumerated at the station's laboratory. Statistical tests suggest that a significant difference exists between *Pteronotus* species for infection of ectoparasites (N=91), $F_{batflies} = 26.75365$ at p=0.0000, $F_{spinturnicids} = 6.90319$ at p= 0.0000, $F_{other} = 6.43209$ at p = 0.0050). A correlation was established for ectoparasite infection and forearm length for *P. parnelli* and *P. gymnonotus*, (N=51, r=0.30661 for spinturnicid infection and r=0.41216 for batfly infection at p=0.028643 and N=28, r=0.34770 at 95% CI, respectively). An additional test involved the difference between parasite infection rates in lactating and non-lactating female bats and was based on a previous study by Krichbaum, Perkins, and Gannon (2009), but did not yield results that matched those of the previous study as is inferred from the insignificant p-value (p=0.028643). These findings are important to better understand ecological relationships between *Pteronotus* species and their ectoparasites to best understand their symbiotic relationships and the potential for vector-borne disease transmission between species in the future.

Rapid Range Expansion of the Brazilian Free-tailed Bat in North Carolina, Tennessee and Virginia, 2008–2014

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Brazilian free-tailed bats (*Tadarida brasili*ensis) are one of the most abundant and widely distributed mammal species in the Western Hemisphere with exceptional mobility and diverse habitat and roost-site preferences. Here we document recent accounts of these bats found year-round in multiple locations in western North Carolina, eastern Tennessee, and Virginia. Until recently, this species was reported only as an occasional extra-limital vagrant in the region. The reports presented here come from local wildlife management professionals, wildlife rehabilitation experts, various community members, and from bats submitted for rabies testing. Their presence in buildings and bat houses indicates that Brazilian free-tailed bats moved into this area as recently as 2008, are now established in year-round colonies, and are rapidly increasing in numbers. Acoustic monitoring in or near urban areas in East Tennessee has identified Brazilian free-tailed bat calls approximately doubled from 2012 to 2014. We expect the expansion of these bats will be highly visible and have implications for public health, ecosystem services, and bat conservation. Their establishment in the same areas as white-nose syndrome affected bat species raises new concerns for the spread of the disease. The reports presented here also emphasize the importance of community outreach and engagement with wildlife management experts.

***Influence of Prescribed Fire on Bat Activity in the Big South Fork National River and Recreation Area**

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* **Leanne Burns** received the **Basically Bats Wildlife Conservation Society Award**.

While prescribed fire is known to maintain forest health and minimize disease, little is known about its impact on bat activity. Past studies suggest the reduction in vegetation as a result of burning may increase access and foraging efficiency. Our objective was to investigate bat activity in relation to burn history and vegetation structure in Big South Fork National River and Recreation Area, in Kentucky and Tennessee. We compared use of forest sites with varying burn histories (frequency, intensity, and burn year) to adjacent unburned forest sites. We used AnabatII detectors to acoustically monitor activity levels for $\geq$ 2 nights from May 19 to August 10, 2014 across 22 paired treatment and control areas. Diameter at breast height (DBH) and evidence of fire were recorded for all trees and snags >1.4 m tall and >3 cm DBH in a 0.1 ha circular plot around each detector. We recorded 4079 bat calls at 66 sites. We separated echolocation files into high ($\geq$36kHz) and low ($\leq$35kHz) phonic groups using a combination of AnalookW software and manual examination. Results indicate the mean number of total bat passes and mean number of high and low frequency calls were significantly higher in burned than in unburned sites. Additional analyses suggest activity was related to presence of recent (<10 years) prescribed burns and stand density. We conclude that prescribed fire and its subsequent effect on forest structure has an effect on the suitability of forested sites for bats in our study area.

Who Swarms With Whom? Group Dynamics of *Myotis* Bats during Autumn Swarming

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For many animal taxa, group-living is a strategy where the togetherness provided by groups confers fitness benefits to individuals. Bats are highly gregarious with many species living in groups that show complex social structures. During the summer, many temperate species are sexually segregated among roosts and females have been found to exhibit dynamic social structures whereas males remain understudied. We studied the group dynamics of little brown and northern Myotis bats (*Myotis lucifugus* and *M. septentrionalis)* during autumn swarming, a period for which social interactions are largely unknown. Using capture-mark-recapture surveys, we characterized the occurrence and frequency of age and sex groups occurring at swarms. Within a night, young-of-the-year (YOY) associated more often with other bats than did adult males and females. Further, they associated more often with other YOY than adults. We found no evidence to support the maternal guidance hypothesis as a dispersal mechanism which predicts that there would be associations between mother-offspring pairs. Adult female and YOY pairs captured together were not related more than randomly generated pairs. Adult male and female bats associated less frequently with each other instead of together and tended to be most often captured alone. When males were captured in groups, these groups were more likely to be composed of multiple males and in *M. lucifugus*, males had preferred male associates they grouped with over multiple nights. Groups formed during the transitional autumn swarming season may reflect dynamic choices of individuals to maximize fitness.

***Describing the Social Behavior of the Indiana Bat at Day Roost Sites**

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* **Caroline Byrne** received the **Titley Electronics Award**.

Bats are highly social, but we do not fully understand how behaviors facilitate sociality. The study of bat social behavior was limited until recently due to technological limitations. Most of bat behavior is imperceptible to our senses, including both their use of ultrasound and their nocturnal activities. Since 1997, Indiana State University has monitored a population of endangered Indiana bats (*Myotis sodalis*) near Indianapolis; this project lends itself to behavioral studies because of the large colony size and high roost fidelity. During the maternity season (May–August), we recorded behaviors with Sony Nightshot HandyCams and IR lights, and Pettersson D500X acoustic detectors deployed together at Indiana bat roosts (115 nights in 2013 and 2014). The objective of this study is to compile a catalog of visual and acoustic behaviors seen at Indiana bat day roost sites. Thus far, we have detected 25

types of visual behavior, including "checking behavior", and 9 types of acoustic behavior. A bat that is "checking" approaches a roost's surface and then flies away; this behavior has also been observed for little brown bats (*Myotis lucifugus*). Several previous studies have documented similar types of acoustic behaviors in *M. lucifugus*, including those used in the contexts of mother to young interactions, agonistic, echolocation, infant isolation, and disturbance. These are some the first systematic observations of social behavior for Indiana bats. Understanding the social behaviors of these highly social bats is crucial to gaining a full understanding of their life cycle and daily requirements.

Effects of Grooming on Pollen Deposition by Nectar Bats
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While nectar bats have been found to carry nearly seven times as much pollen as hummingbirds, many other details of pollen transport by these nocturnal pollinators remain poorly understood. For bees, the majority of the pollen they pick up from a flower is deposited on the following one or two flower visits because they groom heavily, while for hummingbirds, small amounts of pollen continue to be deposited over many visits to subsequent flowers. Thus when pollen transfer is plotted against the flower number in a series of visits (termed a 'pollen carry-over curve'), the curve shape steeply drops for bees and remains long and flat for hummingbirds. How do aspects of bat behavior affect their pollen carry-over curves? To examine this, we placed bats of the species *Anoura caudifer, A. cultrata* and *Lonchophylla robusta* in screen tents and allowed them to visit a single male flower of *Burmeistera glabrata* (with pollen) followed by a series of ten female flowers. During the experiment we recorded time spent flying, resting, feeding, and grooming, and later used a microscope to estimate how much pollen they delivered to each female flower. With this information we constructed pollen carry-over curves, and calculated their slopes as well as the total pollen transferred. Results show that, while all bats transfer large amounts of pollen to multiple flowers, there is much variation between individuals, with the relative amount of time spent grooming, flying, and resting significantly affecting the shape of the pollen carry-over curves.

Bat Occupancy in a Managed Forest: How do Timber Harvests Differ in Species Occupancy?
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Bats exploit forest resources based on species-specific adaptations, resulting in differences in species occupancy across forested landscapes. Forest management practices alter forests, impacting species differently and presumably affecting species occupancy. Application of forest management that promotes bat conservation requires understanding bat response to silvicultural practices. We surveyed timber harvest treatments on two Indiana state forests to compare bat activity across forest management treatments from May to July 2013 and 2014. We used Wildlife Acoustics Song Meter SM2BAT+ detectors to survey bats in relation to four treatment types: clear cut, patch cut, shelterwood cut, and control forest. Detectors were deployed at the center and edge of each treatment and at three points in forest adjacent to treatments. Detectors recorded for three consecutive nights. We developed single-season occupancy models using generalized linear models with binomial distribution and logit link in R to compare species occupancy among treatments. *Lasiurus cinereus* occupancy was higher in clear cuts and patch cuts compared to control forest. *Eptesicus fuscus* occupancy was higher in clear cuts than control forest. *Lasiurus borealis* occupancy was higher in patch cuts, clear cuts, and shelterwood cuts than control forest. *Myotis lucifugus/sodalis* occupancy was higher in patch cuts than clear cuts. *Perimyotis subflavus* and *M. septentrionalis* showed no difference in site occupancy among treatments. Differences in bat occupancy among treatments suggest bat assemblages benefit from management that employs an array of silvicultural methods. These results can be used to predict effects of forest management practices on bat occupancy.

Complex Cooperation: Food Sharing in Vampire Bats is Not Simply "Tit For Tat"
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Food sharing in common vampire bats has long been the textbook example of reciprocity—a well-known but controversial explanation for cooperation. Reciprocity is often modeled by the strategy "tit-for-tat" in the repeated Prisoner's Dilemma game, in which individuals either cooperate or defect based on the actions of their single partner in the previous "round". Many cognition experiments testing the tit-for-tat model place animals in artificial situations (e.g., sharing across cage bars), and ignore partner choice, kinship, long-term relationships, and variation in magnitude of helping. Here, I provide evidence that all these factors can affect the food-sharing decisions of vampire bats. I measured food-sharing networks over a 4-year period by conducting >200 fasting trials (>1,500 food-sharing events) in a captive colony of 34 *Desmodus rotundus* from multiple matrilines (mean kinship= 0.07). To test responses to non-reciprocation, I prevented sharing between females and their top donors by fasting them simultaneously. On these nights, sharing success depended on the size of a subject's partner network (degree centrality; permutation test, p=0.002), but the inability of partners to share food on up to 4 occasions did not reduce subsequent sharing on later nights. Together with past results (Carter & Wilkinson 2013), these findings show that sharing is complex, not driven by a single factor: neither kinship, harassment, nor most recent past help. Cooperative investments in vampire bats appear to depend on long-term social bonds that overshadow single recent events. If so, short-term contingency should be strongest in less bonded partners, as found in simian primates.

Postnatal Ontogeny of the Cochlea and Flight in Jamaican Fruit Bats with Implications for the Evolution of Echolocation

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Recent evidence has shown that the developmental emergence of echolocation calls in young bats 1) follow an independent developmental pathway from other vocalizations and 2) that adult-like aspects of echolocation call structure significantly precede flight ability. These data in combination with new insights into the echolocation ability of some shrews suggest that the evolution of echolocation in bats may involve inheritance of a primitive sonar system that was modified to its current state, rather than the ad hoc evolution of echolocation in the earliest bats. Because the cochlea is crucial in the sensation of echoes returning from sonar pulses, we tracked ontogenetic changes in cochlear morphology. Specifically, we measured cochlear height and width (apical and basal turns) and aspects of the basilar membrane (BM) and secondary spiral lamina (SSL) along the length of the cochlea. Sampled cochleae were taken from individuals that had been classified into one of four flight stages prior to euthanization. Our data show that structures associated with sonar sensitivity (narrower and thicker BM and prominent SSL) of the cochlea significantly precedes the onset of flight in young bats and, in fact, development of cochlear sensitivity is likely complete before parturition. In addition, there were no discernible changes in cochlear morphology with stages of flight development, demonstrating temporal asymmetry between echo-pulse return sensitivity of the cochlea and volancy. These data further corroborate and support the hypothesis that adaptations for sonar and echolocation evolved before flight in mammals.

Flight Membrane Healing in the Winter and Summer with Observations on Tissue Contracture and Impaired Wound Healing

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The flight membranes of bats are essential for locomotion but they also play a vital role in homeostasis. Wound healing is an immunological response that results in increased energy demands following injury. Understanding wound healing in bats is valuable because flight membrane injuries are common in the wild; however, wound healing in bats has recently taken on new importance. Biologists routinely biopsy bat membranes to collect tissue samples or mark animals, and extensive membrane damage occurs in bats that survive infection with *Pseudogymnoascus destructans*—the fungus causing white-nose syndrome (WNS). We inflicted 8 mm diameter circular wounds to the chiropatagium of adult female big brown bats (*Eptesicus fuscus)* from a captive research colony to test the hypothesis that healing times vary with temperature changes between the summer and winter seasons. Wing wounds took significantly longer to heal in the winter *versus* the summer. Bats in the winter did not show wound healing during the first 5 weeks following membrane biopsy, whereas wound healing was observed within 1 week post-biopsy for bats in the summer. If tissue repair serves as an integrative proxy of immune function, then the delayed healing observed in the winter may indicate that hibernating bats are immunologically suppressed. During healing the skin around the wound edges contracts but it is unknown if this influences bat locomotory performance. We also observed impaired wound healing in a few otherwise healthy bats, which demonstrates this is a natural phenomenon unrelated to survival from an infection with the WNS fungus.

Social Roles in Communication Networks: The Case of Spix's Disc-winged Bat

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In successful social aggregations, redundancy is often decreased by individuals fulfilling a specific social role. Communication networks typically include leader-follower roles, such that a few individuals take a leading role in deciding how information will circulate the social network; these roles allow group members to coordinate actions in uncertain environments. Here we provide evidence of social roles in communication networks in bats. We focus our research on Spix's disc-winged bat, a species that forms highly cohesive groups by using two contact calls that advertise an individual's location during flight and while roosting. To determine if individuals within social groups have specific social roles, we first determined if consistent differences in vocal behavior persist across contexts and time by estimating repeatability (R), which compares within-individual to among-individual variance in behavioral traits. Then, we measured vocal behavior of group members to determine if groups were composed of leaders and followers. Our results show that R for call variables was moderate but significant, and individuals that were vocal during flight were not necessarily vocal while roosting. We also observed that 29 of the 30 groups studied were composed of some individuals that were highly vocal and of others that were not. Our results demonstrate important individual differences in the contact calling behavior of *T. Tricolor*, and the presence of diverse social roles within groups; we argue that these roles could be the result of mechanisms such as frequency-dependent selection that favor groups composed of individuals with diverse vocal strategies.

Wing Membrane Muscle Activity in Bats

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Skin makes up the majority of the wing in bats. It is both very compliant and thin, which makes its mechanics in flight distinct from rigid wings. Typically, we think of wing shape determining aerodynamic force, but in bats, the wing changes shape in response to aerodynamic force. Thus, wing shape and aerodynamic force are coupled. Bats possess an array of muscles in the wing skin, the plagiopatagiales proprii, which could serve to stiffen the skin and modulate how the wing interacts with airflow. To test if these muscles could serve this function, we recorded the electromyogram of the plagiopatagiales proprii in *Artibeus jamaicensis* during flight. We found that the muscles activate synchronously during downstroke of both low and moderate speed flight. We estimate that synchronous activation occurs to maximize force production, because each muscle is, by estimation, weak. Thus, the plagiopatagiales proprii behave in a manner consistent with modulating membrane stiffness in flight.

Here's How You Unravel an Ecosystem: DNA and the Largest Interaction Network Ever Made

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Ecosystems are complicated, held together by interactions among species: predators and prey, parasites and hosts, plants and animals. Interaction networks describing these connections are complex and some involve literally thousands of interactions making them difficult to construct. DNA has emerged as a powerful tool to solve this complexity problem and for the last few years I have been applying it to dietary analyses of insectivores. In this project I greatly expand this method and apply DNA techniques to an entire community of bats in a topical ecosystem to create the largest fully resolved network of interactions ever created. I use multiple molecular methods and different genomic targets for plants and animals to generate a web that contains more than 3,300 confirmed interactions among nearly 800 species of plants, bats, arthropods and parasites in Guanacaste Costa Rica. Using modeling techniques I demonstrate that different levels of this web are subject to different degrees of fragility and robustness and extraordinarily different dynamic interactions. I show what might happen if species go extinct, and how we might restore the ecosystem again if it is destroyed. The analysis suggests that insectivores are more flexible than I ever imagined, capable of surviving tremendous disruptions of their insect prey, while frugivores are more fragile and parasites extremely vulnerable. Finally, I highlight the unexpected role of *Glossophaga soricina*, which

appears to be the keystone holding the entire thing together. This web provides insights into how an entire community of bats co-exists with the environment.

Observations of Roost Selection by *Myotis septentrionalis* in the Midwest and Northeast Regions
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The northern long-eared bat (*Myotis septentrionalis)* was recently proposed to be listed as federally endangered, but data regarding the summer ecology and habitats used by this species are limited. Understanding summer roosts used is key to developing conservation efforts that contribute to recovery of this species once it is listed. From May to August 2014, we radio-tracked 56 northern long-eared bats to roosts in the Midwest (Missouri, Michigan, Nebraska, Ohio) and Northeast (New York, Pennsylvania, West Virginia) regions of the United States. One hundred roosts were located, and characteristics and environmental data for each roost were collected and summarized. We found that roost types and environmental conditions of each roost varied remarkably among different individuals as well as within an individual bat, regardless of age or sex. We observed bats in traditional typical roosts, such as large snags, and in atypical roosts, such as human structures. One juvenile female routinely switched roosts from a slash pile in a powerline right-of-way to a dead red oak (*Quercus rubra).* Two pregnant females were tracked to a live black cherry (*Prunus serotina)* from which 50 bats emerged on 20 June, and within four days only two bats remained. Roost selection did not vary significantly between the two regions. Our observations confirm that the northern long-eared bat is a generalist in terms of roost selection, and the task of designating critical habitat for this species may prove to be more cumbersome than expected.

A Method for Estimating Abundance in Indiana Bat Maternity Colonies from Telemetry Data
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Indiana bats (*Myotis sodalis*) residing in maternity colonies are difficult to assess for abundance due to their mobility and hidden roosts. Colonies are typically dispersed among many roosts, so even the primary roost may contain only a minority of the colony. Locating all roosts with certainty may be impossible and methods such as mark-recapture may be impractical. Therefore, we developed an abundance estimator that combines exit counts at known roost sites with coincidence rates estimated from telemetry data. We applied the estimator to simulated data and field data and compared estimated and known abundance. With adequate sample sizes, estimates were unbiased. For example, in the simulated data, if we tracked 8 bats for 20 days, bias was <1% and confidence intervals were <20%. Estimator performance was affected by the number of roosts used, the number of bats tracked, and study duration, as well as social attraction within colonies and Markovian movement. Field data sets were small compared to simulated data and estimates were reasonable, but imprecise. The telemetry data required for the estimator is commonly collected in bat research, and should be feasible. The estimator relies on certain assumptions, such as a closed population and reasonable mixing of colony members. These assumptions are likely less restrictive than those required for mark-recapture studies or N-mixture models. Therefore, the proposed method has the potential to improve abundance estimates in Indiana bat maternity colonies, or in other cryptic taxa with a fission-fusion social structure.

The Collaborative Response to White-nose Syndrome in North America
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White-nose syndrome (WNS) is an infectious disease responsible for decimating hibernating bat populations in eastern North America. Caused by the novel fungus *Pseudogymnoascus destructans*, WNS has spread rapidly since discovery in New York in 2007, and is now present in 25 states and 5 provinces. Seven North American species have been confirmed with the disease and at least 5 others have been identified carrying *P. destructans*. The fungus, possibly of European origin, infects torpid bats resulting in physiological and behavioral impacts, often leading to mortality. Population declines exceeding 90% have been documented in affected hibernacula, and corroborated by counts at maternity colonies and by acoustic and trapping indices during summer. Sister national response plans in both the U.S. and Canada provide the framework for a comprehensive North American response, and establish

working groups to address the research and management needs for the disease. The U.S. Fish and Wildlife Service is the lead federal agency coordinating the response to WNS in the U.S., and since 2008 the agency has provided over $19 million to researchers and state and federal agencies to address WNS. These efforts have led to advances in our understanding of hibernation physiology, bat population dynamics, disease ecology, and general bat behavior. Scientists are investigating all aspects of this fungal disease, including the life history and ecology of this new fungus, the dynamics of fungal infection and transmission, and bat hibernation physiology and immunology in their search for a way to control *P. destructans* and conserve our native bats.

Sensitivity of Hibernation Phenology to Environmental Cues in *Myotis lucifugus*
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Phenology refers to the timing of events in the life cycle and has implications for survival, fitness, and population dynamics. Research on birds has highlighted conservation implications of phenology as climate change has shifted the timing of resource availability away from resource-intensive activities like migration or reproduction for some species. Sensitivity of phenology to environmental cues that predict resource abundance has potential to affect resilience to environmental change but factors influencing phenology have received little attention for hibernating mammals, particularly bats. We used a population of *Myotis lucifugus* marked with passive transponders (PIT-tags) in central Canada to test the hypothesis that differences in hibernation and reproductive energetics of males and females lead to sex differences in the sensitivity of phenology to environmental cues. We predicted that female emergence timing would be relatively insensitive to within- and between-year variation in environmental cues because of selection on females to emerge early and initiate gestation in warm maternity roosts. We predicted that males would be more flexible and emerge in response to environmental cues predictive of flying insect availability (e.g., warm ambient temperature, passing weather fronts). We used a passive PIT-tag antenna/datalogger system at the entrance of one hibernaculum, combined with harp trapping, to quantify emergence timing. We detected 1885 tagged bats (n = 1061 males, 824 females) over three years. Our results will help understand potential responses of bat populations to climate change, as well as to white-nose syndrome, the fungal disease which dramatically impacts emergence phenology by disrupting hibernation energetics.

Five Long Winters of Trying to Watch Bats Hibernate
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White-nose syndrome (WNS) is a disease of hibernating bats. To better understand and respond to WNS we need to better understand bat hibernation. However, discovering the details of what hibernating bats do in cold, dark, undisturbed caves and mines during winter can be difficult. Few studies have continuously observed hibernating bats in their natural habitats over entire winter seasons. This talk will describe the ups and downs of efforts over the past five winters to watch hibernating bats with near-infrared and thermal video surveillance cameras at multiple sites in the eastern United States. Using a combination of custom-made and off-the-shelf equipment, our research group has recorded thousands of hours of imagery with no indication of disturbance. Major challenges associated with this effort have been a dependence on consistent electrical power, computer software and hardware glitches, bats moving out of camera views, an endangered packrat, and the massive amounts of video imagery that need to be "watched". Major benefits include robust data on the presence, activity timing, and detailed winter behaviors of hibernating bats. Video data are still being analyzed in the context of behavioral changes associated with WNS and example imagery will be shown, including mid-winter mating, drinking, wrestling, grooming, and bats interacting with cave insects. Despite the difficulties experienced during this pilot effort, surveillance of this nature is getting easier by the day with rapid developments in off-the-shelf equipment. Watching bats hibernate in the dark using video has tremendous potential for quickly advancing our understanding of hibernation and WNS.

Understanding the Habitat Association of Bats in a Fragmented Landscape—Are Vineyards Important to Bats?
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Understanding the use of vineyards by bats in the South Okanagan Valley will help assess the amount of foraging habitat available to bats in the fragmented landscape. The Okanagan Valley is the second largest wine producing region and supports the highest diversity of bats in Canada, yet no studies have looked at the use of vineyards by bats. Despite the loss of natural habitat there is no evidence of population declines, suggesting that vineyards may provide habitat for bats. I used a radar-acoustic system to assess bat movements in the South Okanagan for 36 days in 2012 post parturition. I surveyed six sites, each containing a natural and vineyard plot, for 14 minutes every 30 minutes from sunset to sunrise. I recorded 1810 bat passes and detected 85 179 tracks. There was 2.6 times more mean bat passes recorded per minute with the acoustic arrays in the natural plots compared with the vineyards with feeding buzzes recorded in four vineyard plots. I obtained 132.5 hr of radar data and recorded an average of 10.7 (SD 13.5) tracks per minute. The radar data is being co-located with acoustic data to determine the percentage of bat activity present in vineyards. Vineyards provide habitat for bats in the South Okanagan Valley, therefore incorporating management strategies with viticulturists can reduce pest management costs while enhancing bat habitat in the area.

Integrating Population Genetic and Quantitative Genetic Models Reveals Selection in Echolocation

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Constant-frequency echolocation with Doppler-shift Compensation facilitates the detection of insect prey in cluttered environments. In the New World, this adaptation has evolved only once in the geographically widespread *Pteronotus parnellii* species complex. Although variation in the frequency of the second harmonic has been recorded throughout the continental and insular range of *Pteronotus parnellii*, previous studies failed to consider random genetic drift as a force shaping echolocation frequency. We obtained standard measurements, resting echolocation frequencies (RF), and sequences from five unlinked loci from 78 *Pteronotus parnellii* individuals from Hispaniola and Puerto Rico. The sequence data were used to fit a Bayesian isolation-with-migration model and estimate current and ancestral effective population sizes, divergence time, and migration from one population to the other. Drawing on these posterior distributions, a drift-based quantitative genetics model was used to estimate the expected null distributions of differences in traits between each population and hypothetical ancestral populations, and standard deviation of descendent traits. A series of regression models were used to test if changes in RF between populations were a function of shifts in body size. Neither changes in body size nor genetic drift are responsible for the differences in RF between Hispaniolan and Puerto Rican *Pteronotus parnellii* populations. Instead, the Hispaniolan population has, in isolation, undergone selection for a higher echolocation frequency. Additionally, we found evidence of stabilizing selection in both RF and body size. This is the first time natural selection has been implicated in the evolution of RF in these bats.

The Long Reach of Temporally-Limited Pathogens: Does *Pd* Exposure in Hibernation Increase Chronic Stress during the Active Season?

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We present a new method to measure chronic stress in small bats through an assay quantifying cortisol in keratinized claw tissue. This assay allows identification of population-level temporal or geographic variation in chronic stress, and tests of hypotheses about the long-term impacts of temporally-limited pressures. We used the assay to test the hypothesis that the physiological impacts of infection with *Pseudogymnoascus destructans* (*Pd*) can extend beyond the recovery period and into the active season. We compared chronic stress in populations of little brown myotis (*Myotis lucifugus*) sampled during the hibernation period, both before and after the arrival of *Pd*. To control for the possibility that differences in wild bats reflected chronic stress experienced during hibernation rather than stress in the active season, we also compared cortisol levels of *Pd*-positive and *Pd*-negative *M. lucifugus* hibernating in captivity under controlled conditions. Our results support the hypothesis that the effects of white-nose syndrome on bats extend well beyond the recovery period and into the active season. Population-level comparisons of chronic stress can be widely applied to investigate the effects of a number of environmental changes on bat populations, including pathogen introductions, declining prey abundance and habitat modifications.

Molecular Variation and Evolutionary Forces Acting on Populations of *Artibeus jamaicensis* in Mexico
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Genetic diversity is widely considered essential for the evolutionary and adaptive potential of populations and species. Several studies in empirical genetics have highlighted the importance of taking into account both neutral and adaptive genetic variation by characterizing microevolutionary dynamics. Genes at the major histocompatibility complex (MHC) have become excellent models for the investigation for adaptive variation and natural selection because their crucial role in fighting off pathogens. *Artibeus jamaicensis* is one of the most common and well-studied Neotropical mammals, showing species with generalist habits and high individual movement. We explored the genetic population structure and the footprints of selection in fifteen collected localities of *Artibeus jamaicensis*, and genetically assayed using ten neutral microsatellites and one expressed MHC class II locus. We report extensive polymorphism at the second exon of MHC class II gene. Overall, 161 alleles were isolated from 193 individuals. Bayesian inference of positive selection suggest that 20 amino acid sites may have experienced positive selection (ω=4.167). Genetic diversity was relatively high in both markers (microsatellites 0.86 and DRB gene 0.978). Observed heterozygosity was 0.756±0.15 (±SD) and expected heterozygosity was 0.885±0.11 (±SD). All localities were in Hardy-Weinberg equilibrium. Pairwise genetic differentiation measures between localities were significant but the overall level of differentiation was lower in DRB gene (Fst=0.039) than microsatellites (Fst=0.154). In general, the distribution of the frequencies of individual MHC alleles does not significantly depart from neutral expectations, which indicates a prominent role for genetic drift over selection.

Bat Specimens Submitted to Department of State Health Services are a Valuable Resource for Documenting Species Distribution
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Bats submitted to the Department of State Health Services for rabies virus testing have been a useful resource in studying the distribution of many species within Texas. Over a ten year period a total of 31,072 bats were submitted to regional Zoonosis Control Offices across the state with each specimen presenting a unique distributional and seasonal locality for its species. Of the bats submitted over 10,000 rabies-negative specimens were collected from 2004 to 2011 and a majority of them were identified using morphological features. We extracted tissues and prepared fluid-preserved vouchers from a subset of these specimens. Each specimen's location was compared to the known distribution of the species to determine new county records or range extensions. Species that had been documented from a county solely based on published literature (no known voucher specimens) were considered country records as well. Herein, we demonstrate the value of rabies-negative specimens in documenting species distributions across states by reporting on 14 species from 70 Texas counties. A total of 103 new county records (including seven range extensions) were documented including one phyllostomid (*Choeronycteris mexicana*), 12 vespertilionids of seven genera (*Myotis*, *Lasiurus*, *Lasionycteris*, *Perimyotis*, *Eptesicus*, *Nycticeius*, and *Antrozous*) and one molossid (*Nyctinomops macrotis*). Although the specimens in this study were not obtained by traditional methods, we suggest they document important occurrences of bat species in the state of Texas and highlight a valuable resource available to other states across the country.

Long-term Sampling of Northern Long-eared Bats — The Hardwood Ecosystem Experiment Case Study
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Since 2006, bat research has been conducted in 9 forest management units on the Hardwood Ecosystem Experiment (HEE) in central Indiana, a 100-year project in its infancy. Mist netting data were collected from May–August each year, but with differing amounts of effort. A total of 464 northern long-eared bats (*Myotis septentrionalis*; NLEB) were captured. We establish a baseline of the local NLEB population to inform the next 91 years of bat research on the HEE and the potential listing of the species by the U.S. Fish & Wildlife Service. To account for variation in effort and sampling technique, we investigate total number of captures, then scale for effort using units of effort (UOE; m^2hr), and subsequently examine captures/UOE by broad habitat designations for sampling sites/year. In 2006, 52 NLEB were captured, 34 in 2010, and 78 in 2014. Scaled for effort, we captured

0.0012 NLEB/UOE in 2006 compared to 0.00087 in 2010 and 0.0063 in 2014, when sampling took place almost exclusively at small forest ponds. Since there has been no standard sampling protocol for NLEB, post hoc UOE calculations are a valuable tool to use with capture data collected annually. This case study also highlights the value of repeated and long-term sampling to strengthen baselines necessary for studies on planned management effects such as timber harvests and prescribed fire, or natural stressors such as white-nose syndrome.

***Huff and Puff or Shut'er Down: How Do Bats Respond to Low Oxygen?**

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* **Yvonne Dzal** received the ***Bat Research News*** **Award**.

Vertebrate species living in low oxygen environments have evolved a variety of strategies for matching oxygen demand and oxygen supply. Although mammals are not typically thought to tolerate low oxygen (hypoxia), bats are exceptional in this regard and maintain normal cellular function at oxygen levels too low for most other mammals. Unfortunately, the basis of this hypoxia tolerance is not well understood, and the strategies bats use to match oxygen demand to supply in hypoxic conditions are essentially unknown. As a first step in elucidating the mechanisms for how bats tolerate hypoxia, we exposed non-hibernating adult big brown bats (Eptesicus fuscus) to a progressive reduction in inspired levels of oxygen (21, 12, 9, 7 and 5% O2) at an ambient temperature within their thermoneutral zone (27.17 ± 0.07 ºC) and measured their metabolic, thermoregulatory, and ventilatory responses. We found that ventilation in hypoxia was not significantly different from normoxic values (21% O2) and as a result, bats did not increase oxygen supply in hypoxic conditions. Instead, bats responded to severe hypoxia by reducing oxygen demand through extreme metabolic suppression (66.92 ± 5.14%), only in in part by lowering their body temperature (4.35 ± 0.40 ºC). Our results suggest that E. fuscus is among the most hypoxia-tolerant mammals identified to date primarily due to its ability to reduce oxygen demand to match supply, rather than by trying to increase supply to match an unchanged demand.

Beyond WNS; When else are Bats Sick? Understanding Disease Effects in Old World Fruit Bats Using Eco-immunological Approaches

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Many questions have been raised on the persistence of viral infections in apparently healthy bats, yet such viruses are highly pathogenic in humans and other vertebrates. Although a number of studies try to seek explanations on the disease modulating behaviors of bats, very little is known about bat immune responses to infections. Preliminary results from our disease ecology studies in South Sudan agree with other research findings that many species of bats are immune tolerant to various pathogens. For instance, 82.8% of healthy-looking epauletted fruit bats (*Epomophorus labiatus*) and several other species surveyed were found to have high parasites loads of active malarial infections. This species, when challenged with lipopolysaccharides (LPS; a pyrogenic bacterial compound), responded by becoming torpid rather than generating a fever; a atypical but perhaps equally adaptive strategy. The ability of bats to host, maintain and transmit viruses and other pathogens is likely related to their health status. However, seasonal, sex, and reproductive differences in health status and their potential relationship to disease spillovers are largely unknown. This study uses an ecoimmunological approach to help understand variations in health status and disease modulation in the less studied fruit bats of the Old World.

Progress Report: The North American Bat Monitoring Program NABat

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Bats in North America are facing unprecedented threats including white-nose syndrome, wind energy development, habitat loss and fragmentation, and climate change. Until now, there has been no coordinated monitoring program to track bat population responses to such threats. The North American Bat Monitoring Program (NABat) is a multi-agency effort spearheaded by U.S. Forest Service, U.S. Fish and Wildlife Service, U.S. Geological Survey, and the National Park Service and has been under development since 2012. NABat integrates several new and ongoing sampling schemes including maternity and hibernacula counts, acoustic surveys along driving transects, and stationary acoustic surveys joined in a common sampling framework. The design for NABat consists of a spatially-balanced master sample drawn from a comprehensive grid spanning Canada and the US. The grid is composed of 10x10km sample units and the master sample approach provides an ordered list of grids to help guide regional survey efforts. GIS files with guidance on selecting appropriate sample units were sent to 24 states and 10 provinces for pilot surveys during the summer of 2014. Greatly expanded surveys will occur in 2015–16 in 8 western states in collaboration with Bat Conservation International (AZ, CA, CO, ID, MT, TX, UT, WA) and in North Carolina and South Carolina. Data will be managed by the USGS Bat Population Data Project and web-based applications are being developed this winter. Once sufficient data are available, NABat will publish "State of North America's Bats" reports, which will provide updates on changes in relative abundance and distributions of bats.

Roost Selection by Bats at a Continental Scale: Meta-analysis and Meta-regressions

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Tree diameter, tree height and canopy closure have been frequently described as important drivers of roost selection by cavity-roosting bats. However, there is substantial variation in the magnitude of effect sizes reported in various studies across North America. We assessed the effect size importance and quantified between-studies heterogeneity of the most common drivers found in the literature on North American bat research. We conducted 9 random-effects meta-analyses including 34 studies which compared random trees to selected trees by cavity-roosting bats. We assessed publication bias and computed $\tau 2$ and Higgins I2 heterogeneity indexes for each driver. Tree diameter, tree height, snag density, elevation, and canopy closure were, by order of importance, the most important drivers for roost selection by cavity-roosting bats. Size and direction of effects varied greatly among studies with respect to distance to water, tree density, slope, and remaining bark on trees. We examined whether heterogeneity for the tree diameter effect size was attributed to categorical and quantitative moderator variables: there were no significant influences of sex, bat species, longitude, or annual mean precipitations on the tree diameter effect size. However, annual mean temperature and latitude further explained heterogeneity compared to other moderator variables. At the continental scale, cavity-roosting bats tend to be more selective towards large trees when the mean annual temperature decreases with increasing latitude. Large trees might have a greater importance for bats in regions with low mean annual temperatures, to reduce thermoregulation cost and ensures juvenile growth.

When It Comes to Bat Activity, Can Fixed Points And Transects Tell a Different Story?

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Acoustic sampling is increasingly used to monitor the activity patterns of bats. It is usually conducted using fixed recording points or transects. Until now, few studies have evaluated the performance and reliability of each method and whether their improper use may yield misleading results. We aimed to compare how each method

detects the effects of variability in habitat structure and weather conditions. We hypothesized that unpaired transects and fixed points give a different picture of the spatial distribution of bat activity when considering landscape structure variables, but that they depict bat response to climatic variables in a similar fashion. During the summer months from 2011 to 2013, we recorded bats in fixed points (n=72) and 2 km-long road transects (n=82). We analyzed call as counts in a generalized least square analysis using the longitudinal structure of our data. As hypothesized, the activity patterns identified by fixed points differed from those identified by transects, but both methods detected climatic variations similarly. These results indicate that when not compared in a paired design, transects are better suited for studies aimed only at assessing periodicity in activity levels, while fixed recording points should be used in studies targeting the effect of landscape structure.

A Proposal about Phonation by Echolocating Bats

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In this paper we present evidence supporting the idea that the lips and snout area of bats that use laryngeal echolocation can play a vital role in the emission phase of echolocation. Specifically, these features may influence the cone of signal broadcast and may be correlated with the strength of echolocation signals. This influence could provide a functional and selective explanations for details of morphology of the skull, mouth, lips, and soft palatal structures of bats that use laryngeal echolocation. We explored this possibility using photographs of the faces of > 50 species of bats in flight, as well as examination of specimens and pictures of the rostral and palatal areas of these species. Our results illustrate multiple patterns of use of the mouth and lips during phonation, and suggest that some previously unexplained features of skull morphology (e.g,, the "free-floating premaxilla" of emballonurids) may play a role in echolocation.. Some bat species emit echolocation calls through the nostrils and fly with their mouths closed (e.g., Rhinolophidae, Hipposideridae, some Phyllostomidae, and some *Plecotus* species). Other species fly with their mouths slightly open, including a variety of phyllostomids (e.g., *Carollia, Chrotopterus, Macrotus, Phyllonycteris, Glossophaga,* and *Sturnira*). Bats that fly with their mouths wide open— presumably for emission of echolocation calls—include most of the species known to produce relatively high-intensity echolocation calls. However, *Desmodus* also falls within this group, suggesting that at least some phyllostomids are oral emitters rather than nasal emitters.

Male and Female Indiana Bats Select Different Roost Trees in the Ontario Lake Plain of Central New York

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Available habitat for the Indiana bat varies widely across the species' broad range and the species' degree of habitat use specificity is not known; therefore, it is necessary to characterize the species' habitat use patterns regionally to provide suitable guidelines for wildlife managers to conserve the species throughout its range. I studied day roosts of 20 female and 7 male Indiana bats in the Ontario Lake Plain northwest of Syracuse, New York, USA during the spring of 2006 and summers of 2007 and 2008 and identified 96 individual Indiana bat roost trees. Indiana bats roosted in 10 species of trees, of which shagbark hickory (*Carya ovata*), maples (*Acer* spp.), and American elm (*Ulmus americana*) were most frequently used. The mean diameter of roost trees was 41.55 ± 7.53 cm, which was similar to roost trees in other regions, but larger than the mean diameter of unused available trees in the same stands used by roosting Indiana bats. Male and female bats used similarly sized trees, but selected tree species differentially. Female Indiana bats selected maple snags more frequently than they were available on the landscape, whereas males selected American elm more frequently than they were available and appeared to avoid maples. I found that size of roost trees in central New York is similar to those throughout the Indiana bat's range, that the most frequently selected tree species differ regionally, and that patterns of male versus female roost selection varies by tree species.

The Resistance of *Eptesicus fuscus* to White-nose Syndrome
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White-nose syndrome (WNS) greatly increases the over-winter mortality of little brown (*Myotis lucifugus*), Indiana (*Myotis sodalis*), northern (*Myotis septentrionalis),* and tricolored (*Perimyotis subflavus*) bats in North American, and is caused by cutaneous infection with the fungus *Pseudogymnoascus destructans*. Cutaneous infection with *P. destructans* causes mortality during hibernation by disrupting their normal torpor patterns, which leads to the premature depletion of body fat reserves. The results of 3 published studies suggest that big brown bats (*Eptesicus fuscus*) are resistant to cutaneous infection with *P. destructans*. We conducted field studies conducted during the winters of 2011–12 and 2012–13 on the torpor patterns of free-ranging *E. fuscus* hibernating where *P. destructans* is found, using temperature-sensitive radio telemetry. Their torpor bouts had a mean duration of 19.4 d, and a mean skin (body) temperature of 12.3° C was maintained during torpor. The mean body fat content of *E. fuscus* in February & April was nearly twice that of *M. lucifugus* hibernating in the same area during this period. No cutaneous fungal infections were observed in hibernating *E. fuscus* using UV trans-illumination. The torpor patterns of *E. fuscus* at this site were within the normal range of bout lengths and body temperatures previously report for this species during hibernation. These findings indicate that *E. fuscus* is more resistant to *P. destructans,* and subsequent WNS, than *M. lucifugus*.

***Bats, Bat Flies and *Bartonella* Bacteria: Complex Parasitism Relationships across a Neotropical Agricultural Landscape**
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* **Hannah Frank** received the **Speleobooks Award**.

Understanding how human actions alter parasitism and disease in natural populations is critical for both conservation and human health, but such relationships are complex and often specific to the host-pathogen system. We tested the impact of tree cover, local bat species richness and host characteristics on the abundance of ectoparasitic, blood-sucking bat flies on 1108 bats (35 species) in an agricultural landscape in southern Costa Rica. Additionally, we screened a subset of these bats and their flies for *Bartonella*, pathogenic bacteria potentially vectored by bat flies, and examined the impact of tree cover, bat species richness and bat characteristics on the probability of *Bartonella* infection. Tree cover did not explain variation in fly abundance or *Bartonella* infection. As bat species richness increased, fly abundance decreased for females but increased for males, likely due to sex-specific differences in roosting behavior during the maternity season. However, as bat species richness increased, bats of both sexes were less likely to have *Bartonella*. This indicates a dilution effect, in which disease or parasitism decreases in more species-rich communities, for both flies and *Bartonella*. Bats that use more permanent roosts had more flies than bats that use ephemeral roosts, however, their flies were less likely to have *Bartonella* and, in general, bats with more flies were less likely to have *Bartonella*. This may result from potential immunological differences between ecologically dissimilar bat species. The complex relationships between bat species richness, fly abundance and *Bartonella* infection underscore the challenges of predicting disease spread in human-altered habitats.

Stable Isotope Investigation of the Latitudinal Migratory Movements of Silver-haired Bats in Eastern North America
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Silver-haired bats (*Lasionycteris noctivagans*) are well-documented as migrants, although their migratory pathways are not well described. Previous research suggests that North American *L. noctivagans* may be split into eastern and western populations, and our objective was to investigate migratory movements across the eastern extent of the species' range. We conducted stable hydrogen isotope analysis on 124 fur samples from museum specimens collected across latitudes and throughout the year. We first estimated moult timing by developing a model associating the stable hydrogen isotope composition of bat fur (δ^2H_{fur}) with local precipitation (δ^2H_{precip}) at the

location of fur growth. We used this model to estimate the latitudinal origins of bats captured outside the season of fur growth. We found that new fur growth occurred between June 20 and August 26 and there was a strong association between δ^2H_{fur} and δ^2H_{precip} in bats collected during this time period. Our study supports previous reports that members of this species engage in latitudinal migration, and we found evidence that females wintering at southern latitudes migrated greater distances than those at more northern latitudes, while no such relationship existed for males. The distance travelled by migrants varied widely among individuals, with a small number of individuals having migrated much more substantial distances than the majority of the bats in the study. This species may mate during the fall migratory period, and we propose that a minority of individuals engaging in substantial migratory movements may play a particularly important role in genetic connectivity at a continental scale.

Transmission, Progression, and Impacts of White-nose Syndrome across North America

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Understanding continental scale patterns of transmission and impacts of white-nose syndrome is critical for predicting the long-term impacts and spread of the disease. We investigate how and why prevalence of infection, infection intensity and disease impacts vary among six species and 230 sites across North America. We examine the influence of geographic factors, such as latitude and elevation, as well as climatic drivers, such as winter season length and hibernacula temperatures, on transmission and impacts. Our results suggest transmission and impacts are influenced by geographic and climatic factors and that progression of disease varies among species and regions. We show macroecological patterns of disease dynamics that have important implications for determining risk of extinction for bat species in North America.

***Leptonycteris yerbabuenae*, a Bat on the Move**

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Movements of *Leptonycteris yerbabuenae* and factors determining migration are still very little understood. The species is in the process of being delisted from Threatened status in Mexico, but many questions remain to be answered about the connectivity of populations and migratory movement of individuals across its range. There is some evidence that *L. yerbabuenae* is invading new areas in eastern Mexico, and hardly anything is known of its natural history in Baja California, a large portion of the range in northwestern Mexico. We report on a new colony in eastern Mexico, which has been growing over the past five years, and also on movements and distribution on the Baja California peninsula. We report on the discovery of four maternity roosts on the Baja peninsula that were previously unknown as well as provide the first evidence of a fall male breeding roost in southern Baja. We show that timing of parturition is asynchronous in the southern part of the peninsula compared to northern locations. In addition, we have inserted pit tags in 212 bats and show seasonal patterns of roost occupancy, with the surprising result that bats return as early as February to a roost located on an island in the Gulf of California. Our results provide the first study on the seasonal and population ecology of *L. yerbabuenae* on the Baja California peninsula and offer new insights about the population expansion, connectivity, and migratory activity of this once endangered species.

Exploring the Recovery Phase of White-nose Syndrome

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Wing damage resulting from WNS is a lasting injury that poses a significant challenge to survivors of the disease. Wings are vital structures to bats in that they facilitate flight, but wing tissue also plays an important physiological role. Wings play a role in cutaneous water loss, thermoregulation, and gas exchange during both torpor and euthermy. Despite the importance of wings to bat survival, the effect of wing damage resulting from

WNS, the physical and physiological changes to wing tissue that accompany healing, and the fate of surviving bats are poorly understood. Our studies over the last three years have touched on some aspects of WNS recovery. We show that 1) bat wing tissue has an exceptional ability to recover from WNS damage; 2) skin surface lipid profiles vary with the extent of wing damage and time after emergence from hibernation; and 3) Pd load drops precipitously after 2 weeks post-emergence, but some bats retain a small load into the latter part of the active season. We have also conducted detailed histological analysis of WNS lesions and quantified how these wounds change over the course of healing. Recovery of surviving bats provides hope that WNS will not totally eliminate affected populations. Thus, research on remnant bat populations, and the recovery phase, is critical so that effective treatment and management strategies can be developed and deployed.

Behavioral Responses to Predator Cues in Tent-making Bats

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Hearing may be an important sensory modality for detecting predators, particularly in organisms such as bats. To date there is little evidence that predator auditory cues influence the behavior of bats, despite the fact that correct assessment of predation risk coupled with an adequate behavioral response should increase survival. Since bats spend half of their lives in day roosts, predatory events that occur at or near roosts should play a major role in driving their ecology and behavior. This study examines the response of bats to several predator auditory cues at their diurnal roosts. We hypothesize that bats' response increases with the perceived risk of the presented stimulus. Using video cameras and ultrasonic microphones, we first recorded the diurnal activity of 3 control groups of the tent-making bat *Dermanura watsoni* (Phyllostomidae: Stenodermatinae) to obtain baseline information regarding normal roosting behavior. We then used auditory playback sounds of a variety of possible predator sounds, used movement of branches as physical cues next to each roost, and created visual cues (i.e., wooden snake) to measure predatory cues responses of 12 different groups. As predicted, each group responded to the different cues, with their response escalating as the risk of predation increased. When using auditory cues, the bats responded mainly by moving their ears. As the predation risk increased with physical and visual stimuli, they opened their eyes and appeared to use visual cues to determine when to flee from the roost.

Finding the Needle in a Hay Stack: Acoustic and Behavioral Strategies for Finding Silent and Motionless Perching Prey

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Echolocating bats foraging in dense vegetation face the problem of severe masking effects due to clutter echoes returning from backgrounds, making the detection of silent and motionless prey on vegetation extremely difficult. Nevertheless, some species manage to detect prey even under these circumstances and in the absence of prey-produced acoustic, olfactory or visual cues, by relying solely on echolocation. A mechanism that helps to detect prey in close proximity to a strong echo reflector is known from trawling bats hunting over water. These bats direct their calls at an optimal angle so that the water surface acts as an acoustic mirror, reflecting background clutter echoes away but prey echoes back to the echolocating bats. We investigated whether gleaning bats hunting for insects perched on leaves use a similar acoustic mirror effect. We ensonified leaves with and without prey items from various angles to predict optimal approach directions for gleaning bats and found that the presence of a prey item on a leaf significantly increased target strength for oblique angles (>30°), especially for frequencies above 80 kHz. In behavioral experiments we tested whether bats actually approached targets from these predicted angles. Flight path reconstruction of bats approaching silent and motionless prey items on leaves confirmed our theoretical considerations and revealed that the animals avoided smaller incidence angles and approached leaves preferentially from oblique angles. This indicates that gleaning bats indeed use the acoustic mirror effect. We argue that this strategy can significantly increase efficiency when foraging on prey perching on vegetation.

Selection of Roost Trees by Female *Myotis septentrionalis* in Lowland, Forested Habitat of the Manistee National Forest, Michigan

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The northern long-eared bat (*Myotis septentrionalis*) is a candidate species for the endangered species list because of white-nose syndrome. Knowledge of the species' roosting ecology would promote informed management decisions and the species' continued survival. We examined the roosting ecology of *M. septentrionalis* during summer 2014 in northwestern Lower Michigan in the Manistee National Forest. We predicted that adult females would congregate in maternity colonies within crevices or cavities or under exfoliating bark of dead or living trees. Transmitters were placed on 7 adult female *M. septentrionalis* (3 pregnant, 3 lactating, and 1 post-lactating). Characteristics of the roost tree and a 0.1-hectare plot around the roost tree were recorded. Emergence counts were conducted whenever possible at roost trees known to contain a bat. All roost trees were located in forested wetlands, and all roosting sites were either in crevices or cavities of dead or almost-dead trees. Of the 13 roosts, 12 were black ashes (*Fraxinus nigra*), and 1 was a red maple (*Acer rubrum*). Bats switched roosts every 1 to 9 nights. On average, 5.9 ± 5.3 (SD) bats exited from a roost each night with a range from 1 to 22 bats (mid-July). The tree with 22 bats was located 16 m from the location of a former roost tree containing 17 bats discovered in July 1999. Our results indicate that, within the study area, *M. septentrionalis* congregates in small maternity groups, roosts in dead black ash trees, and that colonies may show long-term loyalty to a home area.

Experimentally Reduced Food Availability and Competition in a Captive Colony of Phyllostomid Fruit Bats

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Reductions in food availability would predictably lead to increased intra- and interspecific competition. We tested this hypothesis on a free-flying, captive colony consisting of *Carollia perspicillata* and *Artibeus jamaicensis*. In one set of trials we reduced the amount of banana (a preferred food) positioned at an isolated feeding station over a three-day period (Day 1: 5 cups, Day 2: 3 cups, Day 3: 1 cup) while having other food available. We replicated these trails eight times over eight weeks. For the second set of trials we reduced banana availability exactly the same way over a three-day period, but did not provide an alternative food source. We replicated these trials six times over six weeks. We filmed activity at the banana feeding station for 10 minutes after initial placement using a night-vision camera and recorded the number of approaches and landings on the feeding station. We found no significant differences in the number of approaches ($P = 0.08$) or landings ($P = 0.09$) among treatments as bananas were reduced when an alternative food source was present. However, when no alternative food source was available, there were significant differences in both approaches ($P= 0.02$) and landing ($P = 0.01$). In both cases, activity increased on day two when the food resources were cut by 40%, but both significantly declined when food was decreased by 80%. These data suggest that large reductions in food availability may lead to high levels of competitive interactions with only dominant individuals accessing the food resource.

Informal Science Education Project in Puerto Rico to Develop Bat Conservation

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As part of its conservation agenda, the Conservation Trust of Puerto Rico (Para la Naturaleza), in collaboration with several researchers has developed a project on informal science education. One of the sub-projects, "Impact of urban development and ecosystem fragmentation on associations of bats," was developed and is being implemented in collaboration with the Bayamón Campus of the Inter American University of Puerto Rico and the Puerto Rico Program for Bat Conservation (PCMPR in Spanish). The project has three main objectives: 1. Gather information on richness and diversity of bat species in areas with various degrees of human impact; 2. raise awareness on the role played by bats in the ecosystem; and 3. Develop regional bat conservation groups that are part of the PCMPR. We report the results for objectives 2 and 3. At this moment the project is in its second of three years. During the first year we identified bat monitoring localities, trained assistants, purchased equipment and materials and began working with volunteers. During the second year work with volunteers has continued and identified the first core (recurring) volunteers. So far 276 volunteers have been recruited and we have identified two core volunteers. Ten volunteers have repeated the activity from 2 to 9 times. Five percent of the volunteers are over 51 years old, 14%

between 41 and 50 years, 17% between 26 and 40, 30% between 19 and 25, and 34% under 19 years. After field activities, nearly 100% of the participants indicated that their appreciation and knowledge about bats has improved. In addition we present data on strategies and levels of awareness demonstrated by the volunteers.

Environmental Correlates of Winter Activity by Big Brown Bats in Southeastern Alberta
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Correlates of bat activity during summer are well known, but little is understood about predictors of winter activity. Hibernation is not steady state quiescence and all small mammalian hibernators arouse periodically. Bats overwintering at our study site, Dinosaur Provincial Park (DPP), Alberta, arouse and also take flight outside hibernacula, often at temperatures as low as -9°C. Our goal was to assess the influence of environmental variables on winter activity in a population of big brown bats (*Eptesicus fuscus*) hibernating in DPP. We monitored echolocation activity at four stationary sites during the hibernation periods from October 2012 through March 2014. We also radiotagged bats with temperature-sensitive tags to monitor body temperature and marked bats with passive integrated transponders (PIT-tags) to monitor movements in and out of known hibernacula. We compared night-to-night acoustic activity and probability of arousal and emergence in response to environmental predictors, such as daily and nightly mean temperature, change in barometric pressure, and level of lunar illumination. We found a positive correlation between the number of bat passes recorded on detectors and temperature at sunset. We found no relationship between arousal and environmental conditions but did find a positive correlation between emergence and temperature at sunset and increasing amount of lunar light. Our findings suggest that bats arouse within hibernacula independent of environmental cues but do not emerge unless ambient conditions are favourable. Our findings also suggest that, for whatever reason, bats take flight mid-winter in conditions they would otherwise not be found in during summer.

^{3}H-Estradiol Transfer from Male Big Brown Bats to Cohabitating Females
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Recent data have shown that 17β-estradiol (E_2), the most potent estrogen, is capable of passing from male excretions to the reproductive organs, brain, and peripheral tissues of cohabitating female mice. The current study aims to explore the cross-species generality of this phenomenon in big brown bats (*Eptesicus fuscus*), chosen because of their phylogenetic distinction from mice. Upon administrating tritium-labeled estradiol ($^3H\text{-}E_2$) to the nasal region of female bats, radioactivity was reliably measured in the ovaries and uterus, as well as the brain and other tissues. Cutaneous administration of $^3H\text{-}E_2$ to the abdomen yielded measurable radioactivity in the reproductive and peripheral tissues of females. We also injected single male bats with minute quantities of $^3H\text{-}E_2$ and housed each male with a group of three females for 48 hrs; radioactivity was then reliably measured in the uterus (and other tissues) of all females across multiple replications. Males administered $^3H\text{-}E_2$ showed high levels of radioactivity in their reproductive organs, especially the epididymides where sperm is stored and matures. These data demonstrate that E_2 transfers from male to female bats, likely via absorption of the males' excretions and/or possibly intravaginally during copulation. In mammals, estrogens promote and induce female reproductive maturation, sexual response, and fertility. Our data strongly suggest that estradiol acts as a pheromone in bats, with males having evolved the potential for inducing sexual receptivity and ovulation in females.

Year Round Activity of Peripheral Bat Populations in the North Carolina Coastal Plain
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Within a species' distribution there is often a core population that constitutes the majority of individuals. When threats to persistence are present, the core population usually receives most of the conservation effort. However, when a species has the core of its range threatened, such as bats affected by white-nose syndrome (WNS), shifting efforts to peripheral populations may be an effective conservation strategy. Warm temperatures along the Atlantic coastal plain may allow peripheral bat populations there to remain active through winter, thus decreasing their susceptibility to WNS. The objective of our study was to determine activity status of peripheral bat populations in

the North Carolina coastal plain. We established four Song Meter recording stations along a 295 kilometer north-south transect in the coastal plain (peripheral) and two Song Meter recording stations in the piedmont (core) of North Carolina. We recoded activity through the year from sunrise to sunset, 2012–2104. We found differences in relative bat activity between seasons at all sites. However, based on odds ratio testing, the odds of recording a bat during winter at peripheral sites were higher than at the core. Bats, including *Myotis septentrionalis*, on the coast have increased levels of winter activity compared to those found in the piedmont, which could 1) protect them from fungal spores that cause WNS because they may not hibernate, and/or 2) raise their rate of survival from WNS.

Hyoid Anatomy of Bats of the Families Craseonycteridae, Hipposideridae, and Rhinolophidae, with a Phylogeny for Chiroptera

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The hyoid musculature, hyoid apparatus, and adjacent anatomy of the Bumble-bee bat, *Craseonycteris thonglongyai*, and of a taxonomically and geographically broad sample of hipposiderid and rhinolophid bats are described in detail. Data gathered are compared with data on hyoid and adjacent morphologies of bat families described elsewhere. Craseonycterid bats possess a number of hyoid morphology character states that have been described previously only in rhinopomatid bats, and analysis suggests a close phylogenetic relationship between the families. Cladistical analysis of craseonycterid, emballonurid, hipposiderid, megadermatid, nataloid, nycterid, phyllostomid, pteropodid, rhinolophid, rhinopomatid, and vespertilionid bats suggests that rhinolophids and hipposiderids belong in a crown group clade that also contains pteropodids. Megadermatids probably are the sister group to the rhinolophid-hipposiderid-pteropodid clade. Emballonurids may be the sister group of craseonycterids-rhinopomatids at the base of the chiropteran tree. Cladistical analysis suggests that there is one most parsimonious tree with the following topology: ((((((Hipposideridae Rhinolophidae) (Pteropodinae Macroglossinae)) Megadermatidae) ((Phyllostomidae Vespertilionidae) Natalidae)) Nycteridae) ((Rhinopomatidae Craseonycteridae) Emballonuridae)).

The Response of Bats to Introduced Trout in Naturally Fishless Lakes in the Sierra Nevada, California

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Stocking of trout into naturally fishless water bodies in the mountains of western North America has reduced populations of many native species in those systems, with benthic aquatic invertebrates being particularly impacted. Although bats are known consumers of emergent aquatic insects, almost no studies have focused on how changes to these prey populations at lakes subsequent to trout stocking could affect them. This study assessed bat activity, foraging activity, and foraging rate at nine feature-matched pairs of stocked and unstocked high-elevation lakes in the central Sierra Nevada mountains in an effort to determine which provide higher quality foraging habitat for bats. Bats in the 25-kHz and 50-kHz echolocation call categories showed little to no behavioral difference between lakes with trout and lakes without. In contrast, bats in the 40-kHz group had higher levels of activity and higher foraging rates at stocked lakes. Since past studies in this system have found that the introduction of trout results in a reduction in large macroinvertebrates and an increase in small macroinvertebrates (e.g., midges), our results may indicate that bats at those lakes are consuming numerous small insects. If this is the case, it could represent a cost to those bats due to the lower energetic return of small prey items compared to the preferred prey species.

Effect of Food Type and Size on Chewing Performance in *Pteropus vampyrus*

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The efficiency with which an animal eats, an important contributor to survival, can be influenced by the interplay of food physical properties, anatomical morphology, and chewing behaviors. Previous research suggests that food breakdown performance is compromised during the chewing of larger food items. The present study tests whether food size influences the efficiency of the breakdown of foods with varying physical properties, during natural chewing in the Large Flying Fox, *Pteropus vampyrus*. In a preliminary test of feasibility, one *Pteropus* individual was filmed with a high speed camera at the Columbus Zoo and Aquarium while chewing watermelon, grape, cantaloupe, and raw sweet potato in order to examine how food size and type affect chewing performance. The results suggest that chewing performance for each food type is significantly affected by food size, though in different ways depending on food type. Most notably, an increase in the size of raw sweet potato results in a decrease in the duration of the chew, without a subsequent increase in food breakdown. Additionally, the average percent of sweet potato ultimately consumed was significantly lower than the other food types. These results suggest that the physical properties of raw sweet potato (such as its hardness and density) pose a limitation in *Pteropus vampyrus* to the consumption potential of large pieces of this food type. This study lends support to predictions about chewing efficiency derived from mechanical modeling.

Investigating the Benefits of Fine-tuning Curtailment Strategies at Operational Wind Facilities

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Minimizing wind turbine operations by raising cut-in speeds has effectively reduced bat fatalities at wind facilities. As curtailment incurs a loss in power production, there is a need to fine-tune curtailment strategies to maximize benefits while minimizing financial costs. To determine if we could improve the effectiveness of curtailment by incorporating other predictors of bat mortality, we salvaged >600 bat carcasses during daily fatality searches at a wind farm in Texas from July–September 2009 and 2010. We also obtained weather data in 10-min increments from an on-site MET tower. We then used general linear models with an information-theoretic approach to determine which weather variables best fit the observed pattern of bat mortality. We used wind speed, wind direction, temperature, and barometric pressure as these variables can be used to inform curtailment strategies in real-time. We found that wind speed in combination with wind direction best predicted bat mortality at our site: fatality was highest with low to moderate winds from the northeast and southeast. Using these results, we devised a curtailment strategy with variable cut-in speeds, ranging from 3.0–6.5 m/s depending on wind direction. We then tested our customized strategy against a wind speed-only strategy and a control in 2011–2013. Overall, both curtailment groups had significantly lower bat mortality than the control. Bat mortality was 56–82% lower at curtailed turbines compared to controls, yet there was no difference between the two curtailment treatments. Despite a similar reduction in mortality, the financial cost of customized curtailment was higher.

Diet and Foraging Strategy of the Little Brown Bat in Interior Alaska

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Seasonal changes in temperature and water availability affect the availability of invertebrate prey for small mammals including the little brown bat (*Myotis lucifugus*). Bats that forage at high latitudes are constrained by a short summer with variable temperatures. We hypothesized that the little brown bat in interior and northern Alaska has adapted to variable thermal conditions by shifting feeding strategies and consuming a wider variety of prey than southern conspecifics. We tested this hypothesis using microhistology. Guano were collected weekly throughout the summer from roosts in interior and northern Alaska to create a time series of samples that allowed us to identify dietary shifts at each roost throughout the season. We recorded temperature (range: 1 – 35 °C) and length of daylight (range: 16h47min – 21h49min/ day) at roost locations to monitor foraging conditions. Lepidoptera (moths), Araneae (spiders), and Diptera (flies and mosquitoes) were the principal components of the diet of little brown bats in interior Alaska. We found that northern little brown bats consumed a wider variety of prey with more frequent consumption of non-flying arthropods than reported for southern conspecifics. We found shifts in prey selection were closely linked to temperature and not daylight. When temperatures increased, Araneae consumption decreased ($y=-10.109x+105.81$, $R^2=0.306$) and Lepidoptera consumption increased ($y=3.781x+3.78$, $R^2=0.15$). Shannon's diversity index of prey items generally increased with increasing temperatures. The little brown bat's flexibility in feeding strategies may make it well suited to expand its range into thermally variable regions such as the boreal forests.

Modeling and Mapping the Seasonal Whereabouts of a Cryptic Migratory Bat Species Impacted by Wind Energy Development

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Migratory tree bats represent a substantial proportion (> 75%) of bat fatalities at wind energy facilities, and hoary bats (*Lasiurus cinereus*) represent the largest fraction (approximately 40–50%) of all documented bat fatalities in North America. We used species distribution modeling (SDM) to model and map the potential seasonal distributions of North American hoary bats, and to explore the use of SDMs to help describe the seasonal whereabouts of cryptic migratory bat species. We used 2,753 museum occurrence records of hoary bats collected from 1950–2000 in North America, segregated by sex and season. We analyzed potential seasonal distributions of male and female hoary bats using 5 approaches to species distribution modeling: logistic regression, multivariate adaptive regression splines, boosted regression trees, random forest, and maximum entropy. We used these SDM approaches to generate ensemble maps for each sex and season: winter males and females, spring females, spring males, summer females, summer males, autumn females, and autumn males. Our findings suggest that in North America hoary bats winter in locations with relatively long growing seasons and where winter temperatures are moderated by proximity to oceans, and spend summer months in the continental interior. Future field studies are needed to assess our seasonal distribution models and maps, which may indicate that risk of wind energy to these bats might be highest in habitats between interior summering areas and coastal wintering grounds. Our results demonstrate how seasonal SDMs and ensemble mapping can help generate well-justified hypotheses of bat distributions across seasons.

***In-vitro* Tools to Study Anti-viral Immunity in Bats — Differences and Similarities in the Interferons Response to Lyssaviruses**

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Bats are found to be the natural reservoirs for emerging and transmitters of zoonotic viruses, such as lyssaviruses. However, severe clinical signs caused by Lyssaviruses in other hosts (carnivores, humans) are normally not seen in bats. This indicates differences in the virus-host interactions. It is speculated that innate immune mechanisms, especially interferons, are determining the resistance of bats against viral pathogens. However, functions of IFNs against lyssaviruses in bats are not studied yet. Furthermore, due to the strict protection of endangered European bats in-vivo studies are nearly impossible. Cell lines from different tissues of *Myotis myotis* were established after immortalization by SV 40 large T antigen. The transcriptome of lymphoid tissues was sequenced by next generation sequencing. Using these and publicly available databases Type I and Type III interferons were cloned and sequenced. Using the established cell lines, the sequenced interferons were functionally characterized. The immortalized cell lines from brain (*Mm*Br), tonsils (*Mm*To), peritoneal cavity (*Mm*Pca), nasal epithelium (*Mm*Nep) and Nervus olfactorius (*Mm*Nol) of *M. myotis* display different susceptibility to Lyssaviruses. Furthermore, they express different lineage specific markers, different IFN-receptor patterns but do have a complete IFN signaling pathway. The discovered type I IFN's b, k, w and type III IFN's l2, l3 and l4 activates IFN specific signaling pathways and display a cell-type and Lyssavirus specific response pattern. The established cell lines and sequence databases are important tools to analyze antiviral immunity in European bats and for a broad spectrum of future investigations in cellular biology and immunology of bats.

Limb Muscle Activity in the Big Brown Bat during Swimming and Flight

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The big brown bat (*Eptesicus fuscus*) is not only a strong flyer, but also a capable swimmer, propelling itself through water with a wingbeat that resembles its movements during flight. Many animals modify motor pattern when their locomotor mode changes when moving from one fluid medium to another. We investigated the impact of the physical environment on muscle activity patterns of *E. fuscus* during swimming and flight. From

electromyography (EMG) and high-speed video of limb joint kinematics, we examined timing of biceps brachii (short head) and triceps brachii (lateral head) activation relative to elbow joint movement, as well as gracilis activation relative to knee joint movement. Using synchronized kinematic and EMG data, we quantified the relationship between muscle activity and recruitment and joint flexion/extension using cross-correlation analysis. After normalizing our results by stroke duty cycle to accommodate for the different fluid media, the lag times between peak recruitment intensity and peak joint rotation were significantly longer during swimming than during flight. This observation suggests that energy might be stored and released elastically during in the swimming stroke cycle. We hypothesize that energy could be stored in the relatively long and thin tendons of the limb muscles. Future studies of muscle and tendon length dynamics during swimming and flight will allow us to test this hypothesis.

Postnatal Baculum Development in *Pipistrellus pipistrellus*
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The baculum (os penis) is a heterotopic bone in the glans penis, which is probably subject to sexual selection and may play a role in reproductive isolation. The *P. pipistrellus* species complex is a model system for cryptic diversity in European bats. So far, the bat baculum has only been studied by dissecting and macerating penises, but histomorphological studies on baculum development may also complement research on the mechanical function of this bone. In the present study we will compare baculum histomorphology of juvenile and subadult *P. pipistrellus* to that of adults bats, and to *Myotis myotis,* and *M. emarginatus.* Correlative imaging, validating quantitative microCT images with surface stained, undecalcified, serial ground section histomorphology, of our preliminary sample of *P. pipistrellus* (adult n=30, subadult n=15, juvenile n=7), has yielded the following results. The whole baculum of juvenile and subadult *P. pipistrellus* consists of woven bone. While the distal part of the shaft with its forked tip is mostly developed, the proximal base of the baculum is not. The branches are shorter and narrower than in the adult specimens. The base consists of densely packed, large, round osteocytes, which resemble chondrocytes. Our preliminary results show that the distal part of the baculum reaches its adult shape before the proximal part. The different states of medullary cavity development we found suggest an invasion of blood vessels from the ventral side of the baculum. With this sample we could not confirm whether a cartilage precursor to the baculum exists in this species.

Neonatal Roost Mortality in *Eptesicus fuscus* Maternity Roosts Is Not Associated with Declines in *Myotis lucifugus* Populations
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In the wake of white-nose syndrome in the northeast and central New York, we noted expansion of *Eptesicus fuscus* populations in several maternity roosts in our region previously occupied exclusively by *Myotis lucifugus* females. Out of nearly 10 traditional *M. lucifucus* maternity roosts we studied over the past 20 years, we documented a nearly 93% reduction of expected adult population size including the complete absence of *M. lucifugus* from many locations. Running contrary to these trends, we have noted expansion of *E. fuscus* female populations in several barns. However, in 2002 as well as in 2013, we noted significant mortality of newborn *E. fuscus*, and a lessened neonatal mortality in 2014. Should neonatal mortality be considered a norm, or was there a plausible explanation? In 2013 we noted significant mortality of *E. fuscus* neonates in 2 maternity roosts, totaling nearly 12.3% of expected neonatal population sizes. We present analysis relative to temperature and rainfall trends during these field seasons as well as pathologic analysis of recovered carcasses. We believe that maternal abandonment of neonates that fall from the roost is not a likely scenario and that other factors are leading to this pattern of high neonatal mortality. High roost temperatures may be the primary factor in neonatal death, particularly in animals less than 5 days old. Newborn mortality was not as high in 2014, probably due to cooler prevailing temperatures.

Identification of Four Species of *Artibeus* (Chiroptera: Phyllostomidae) by Using Morphometrically Tools

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Since its description in 1897, *Artibeus intermedius* has difficulties to be placed taxonomically, even though some scientists have been considering it is a non-existing species (Allen, 1897; Andersen, 1908; Goodwin, 1969; Davis 1984). A morphometric analysis could clarify its taxonomic status, our goal was to assess the morphological characteristics that place individuals of the genus *Artibeus* within the Mexican distributed species. We analyzed 18 characters (4 standard, 11 cranial and 3 mandibular measures) in a total sample of 275 individuals, belonging to four species: *A. lituratus* (n=57), *A. intermedius* (n=86), *A. jamaicensis* (n=83) and *A. hirsutus* (n=49). We performed a multivariate analysis that found sexual dimorphism between *A. jamaicensis* and *A. intermedius*. We performed a principal component analysis (PCA) with the 18 measures, and we found a continuous gradient of morphometric variation of 82%. Additionally we performed a discriminant analysis (DA) that established 3 discriminant functions to classify the sampled specimens: F1 (Wilk's Lambda=0.020, P=0.00), F2 (Wilk's Lambda=0.242, P=0.00) and F3 (Wilk's Lambda=0.521, P=0.00). Considered traits pull apart *A. intermedius* from the other *Artibeus* species, mainly by the employment of maxillary measures. Despite there is a continuous range of morphometric variation among all, results of both the PCA and the DA support the existence of 4 taxonomic groups and confirm the hypothesis of *A. intermedius* as a valid taxonomic species.

Communicating about White-nose Syndrome with a Unified Voice

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The White-nose Syndrome Communications and Outreach Working Group is one of seven working groups developed under the National White-nose Syndrome Plan to address research and management priorities. Comprised of about 20 members from federal and state agencies and non-governmental groups, the group's mission is to develop and carry out a plan for communicating information about white-nose syndrome to partners involved in the white-nose syndrome response and to the public. As part of this effort, the group developed messages to use when speaking to audiences not familiar with white-nose syndrome. This poster will highlight those messages, introduce members and provide conference attendees with working group updates, handouts and other products.

Band Visibility, Retention, and Band-related Morbidity and Mortality for *Myotis lucifugus*

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To understand the risks to bats from wearing bands, we banded 1,468 bats, primarily little browns (*Myotis lucifugus*) (MYLU), during late March 2012 at seven Midwest hibernacula, using 2.9 mm aluminum alloy bands (Porzana LTD) applied with banding pliers. Half the bats had a band attached to each wing, whereas half had bands attached to either the left or right wing. Banding sites were revisited during late autumn 2012 and late April 2013. A total of 701 (48%) bats were recaptured at least once. We determined the effects of one vs. two bands on annual return rate (survival) using Akaike's Information Criterion (AIC) and the program MARK (White and Burnham 1999). Annual return rate (Phi) for double-banded bats (0.726; SE 0.015) was higher than for single-banded (0.630; SE 0.043) suggesting no additional liability from wearing two bands vs. one. Therefore, the liability associated with the wearing a single band is likely negligible. Searches of additional hibernacula found only 0.8 percent of the recovered bats outside of their banding site. Band retention was 99%. Injuries were associated with 0.5% of examined bands, and there was apparent chewing on 6.5%. A number-letter configuration for bands was developed from the review of images of roosting banded bats that should allow at least 60% of visible bands on MYLU to be identified through photography alone without handling the bats. We recommend photography as a means of greatly reducing the risk of misreading bands on recaptured animals.

White-nose Syndrome and Disease Management — A National Perspective

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The National WNS Plan provides a static framework which outlines the necessary actions for coordination of State and Federal efforts to address white-nose syndrome (WNS). Working groups were created to address the identified seven critical elements and are responsible for developing and maintaining the various actions identified for each element in National WNS Plan. The purpose of the Disease Management Working Group is to identify a range of alternatives and best practices to slow or prevent the introduction of WNS into new areas. This may be accomplished by investigating ways to decrease the virulence of the disease, increase survivorship of infected individuals, and minimize the efficacy of the disease in affected areas while avoiding unacceptable risks to other cave-obligate biota and natural systems. Five subgroups were established to focus on the different goals and actions identified in the National WNS Plan, two of which focus on biological and chemical controls. In recent years, research funding priorities have focused on these control agents because of their potential to slow the spread of WNS. As research has identified potential control agents which show promise in lab trials, the need for evaluating the efficacy and safety of these agents became apparent. A step-by-step process was drafted based on well-established principles combining elements of testing plant biocontrol agents and human drug trials. In addition to this process, a "Control Treatment Panel" was established to address four primary issues: the need for standardized guidance regarding the treatment research process, regulatory concerns for implementation of treatments, key considerations for decision makers, and establishment of a "Treatment Team" to guide the process. Implementing this process for candidate control agents proposed for management of WNS will maximize the likelihood of success while minimizing negative impacts on bat populations and ecosystems.

High Contact Rates Lead to Explosive Amplification of White-nose Syndrome in Bats

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Heterogeneity in host social behavior can have profound impacts on pathogen transmission and thus disease outcome. White-nose syndrome (WNS), caused by the fungal pathogen, *Pseudogymnoascus destructans*, has caused precipitous declines in bat populations across eastern North America. However, impacts from WNS vary considerably among species and populations, and social behavior during hibernation, such as clustering, may contribute to these differences. To investigate the influence of social behavior of bats on transmission, we marked two species of bats (8 bats marked per site) in four sites with a fluorescent tracer dust at the beginning of the hibernation season. We found that contact rates among hibernating individuals increased with colony size in the more social species, *Myotis lucifugus*, but not for the solitary species, *Perimyotis subflavus*. We also found substantial heterogeneity in contact rates among individuals and sites, suggesting that a few individuals can infect a large fraction of the bats in a hibernaculum with *P. destructans*. This provides evidence that high contact rates of *M. lucifugus* may be responsible for driving the explosive transmission of *P. destructans* within hibernacula.

Bats and Caves in 3D: Examining the Effects of Roost Morphology on Colony Dynamics Using Long-range Laser Scanning

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Organisms do not exist in isolation; rather, they are immersed and constantly interact with their surroundings. Understanding the physical properties of the environment is important because such data provide useful insights about the complexity of the natural world and the spatial arrangement of organisms in it. In studying cave roosting bats, much effort to date has been dedicated to recording cave conditions, colony size or physiology of bats to infer roost suitability. Currently, there is little understanding how these variables may be influenced by the morphology of the caves. Existing survey techniques are slow, tedious and can pose a disturbance risk to bats or require expertise in surveying that might not scale well to biological measures of interest. Long-range laser scanning provides an

effective solution to the challenges of traditional cave surveying by capturing the three-dimensional morphology of the roost in stunning accuracy using non-contact measurements. The goal of this work is to reconstruct in detail the roosts of the six largest natural colonies of Brazilian free-tailed bats in south-central United States. Here we present results from five of the six sites that include the largest and smallest caves and colonies by size. The data indicate that there is no relationship between the basic morphometric properties of the caves and the size of bat colonies, however, cave topography influences flight behavior and group dynamics in our sample. Other properties of the roosts such as their unique climatology and proximity to food likely determine the size and dynamics of their resident bat colonies.

Activity and Diversity of Pennsylvania Bat Species during Hibernation and Emergence at Woodward Cave
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Of the eleven species of bats living in Pennsylvania, six are known to hibernate in caves and mines. Normally, individuals from these six species arouse a few times from hibernation during the winter and then emerge in early spring. It is not well-understood if and what environmental factors may trigger their emergence from hibernation. The purpose of this project is: 1) to understand what causes bats to exit hibernation in the spring, 2) to determine the frequency of bat activity during the hibernation period, 3) to identify the bat species utilizing the cave throughout the year, and 4) to test methods for passive ultrasonic acoustic recording inside a cave. We think that barometric pressure may have something to do in determining bats' arousal from hibernation, and we know that all six species of bats have been found hibernating in this cave in past surveys, therefore we expect to see any combination of species utilizing the cave at different times of the year. Preliminary data analysis suggested a limited activity throughout the winter months among the 60+ individuals counted in the cave. However, a complete analysis of data from our SonoBat and Anabat devices should unveil any pattern in bat activity and diversity as well as cave use.

Bats Fat on Ants: Estimating the Energy Expenditure and Storage of *Rhinopoma microphyllum*
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How do animals store energy needed for seasonal migration or hibernation? It is well known that migratory birds quickly store fat by substantially increasing their food intake, known as hyperfagia, however little is known about the physiological and behavioral mechanisms utilized by bats. We examined wild, insectivorous bats, *Rhinopoma microphyllum*, as they explored their environment for ant alates in late fall. Through the use of onboard GPS tracking and ultrasonic audio monitoring devices, we recorded seven individuals over the entire night in Northern Israel. Our methodology allowed for unique insights into the foraging behavior of insectivorous bats by providing data such as the time spent foraging, the distances covered, flight speed, and estimates of the number of insects attacked per night. Integrating this data with measurements of caloric intake per ant, resting and torpor metabolic rates of *R. microphyllum* at different ambient temperatures, and estimates of metabolic rates during flight, we calculated the nightly net caloric gain in the weeks leading up to migration. Our results showed that prey detection can be highly variable, yet the rewards of a few successful nights appear to be enough to allow for the extreme weight shown in this species. Understanding the total energetic investment made before winter may provide clues into the environmental and evolutionary constraints of bat migration and hibernation.

The Effects of Saturated and Monounsaturated Free Fatty Acids on *P. destructans,* the Etiologic Agent of White-nose syndrome
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White-nose syndrome (WNS) is a disease first observed in 2006 which affects hibernating bats in North America. It is caused by cutaneous infection with *Pseudogymnoascus destructans* during hibernation and has led to mass mortality among several bat species in North America. Despite the devastating effects on infected hibernacula, some bat species are more resistant to the fungus than other species. Free fatty acids are found in the mammalian epidermis, and some have been shown to have anti-fungal properties. We thus predicted that: a) certain free fatty acids inhibit the growth of *P. destructans*, and b) bat species that are highly resistant to this fungus have higher concentrations of these fatty acids than those that are relatively more susceptible. We conducted laboratory experiments with cultures of *P. destructans* to test these hypotheses. We also examined the epidermal fatty acid profile of both susceptible and resistant bat species. Pentadecanoic acid has little effect on the growth, but oleic acid greatly inhibited growth. Myristic acid also inhibited growth, but to a lesser extent. Stearic acid was found to actually promote growth. The wing epidermis of *M. lucifugus* (susceptible) has higher levels of pentadecanoic and stearic acids than *E. fuscus* (resistant). Conversely, *E. fuscus* has higher levels of myristic and oleic acids that *M. lucifugus*. Our data thus demonstrates that the ability of *E. fuscus* to resist infection may be due in part to: a) higher myristic and oleic acid concentrations, and, b) a lower concentration of stearic acid.

Roost Tree Use by Female Indiana Bats in Tennessee during the Migratory and Pre-maternity Periods

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The characteristics of trees used as day roosts by the endangered Indiana bat (*Myotis sodalis*) during spring migratory and pre-maternity periods have not been extensively examined. Determining the characteristics of trees used by this species during these periods may help ensure the implementation of habitat management activities that retain or provide roost sites on the landscape. In April 2014, the Tennessee Wildlife Resources Agency and Copperhead Consulting attached radio transmitters to 50 female Indiana bats at a cave hibernaculum in Cumberland County. They tracked seven of these bats by air and road to maternity areas in Benton, McNairy, and Wilson Counties, Tennessee, where we monitored them until May 15, the beginning of the maternity season. We documented these seven bats using 13 trees as day roosts. Two of these trees were still occupied at the beginning of the maternity season. All documented roosts were located underneath exfoliating bark, with all but three in snags. Seven of these snags were identified shagbark hickory (*Carya ovata),* mockernut hickory (*C. tomentosa*)*,* white ash (*Fraxinus americana*)*,* red oak (*Quercus rubra*)*,* or red maple (*Acer rubra*). Three live shagbark hickory were also used as roosts. Six of the roost trees were located on the edge of agricultural fields, three on the border of swampland, and four in the interior of forest patches. We will present additional results from this pilot study and outline avenues for future research that will provide the information needed to maintain Indiana bats roost trees during the migratory and pre-maternity periods.

Engaging Local Communities to Protect Bats through Conservation Education Activities in a Transboundary Biodiversity Corridor

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A key step in any bat conservation strategy includes engaging local communities to protect species in the region. Bats are potentially effective ambassadors for elementary school enrichment activities. The problem lies with availability of materials, which are spread across many sources, challenging educators to find what is available. We addressed this problem by collating available materials, making them accessible on the web, while also finding better ways to engage students. We evaluated: 1) how effectively existing bat conservation materials address essential knowledge and skills needed by educators, and 2) which interactive activities (venues) are more readily obtainable: videos, hands-on, or role-drama. A network of people with knowledge of bat educational materials were contacted, starting with key actors in Bat Conservation International, and snowballing to others who were recommended. Educational materials were collated (n = 24), sorted within venue categories, and scored for essential skills and knowledge. All materials were assembled in an electronic binder, and posted online for easy access through the Biodiversity Stewardship Lab website. The materials gathered consisted of 55% videos, 38% hands-on, and 5% role-drama/stories. The subject matter included: 27% Arts, 25% Science, 16% Language Arts, 22% Social Sciences, 5% Mathematics, and 5% Performance. Since most activities were passive video or individual hands-on, we recommend more interactive role-drama adaptations of stories. Although existing materials address a variety of essential skills and knowledge used by educators, the effectiveness of role drama in engaging students of high priority bat conservation regions needs to be further investigated.

Antibodies to *Pseudogymnoascus destructans* Are Not Sufficient for Protection Against White-nose Syndrome
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White-nose syndrome (WNS) is a fungal disease caused by *Pseudogymnoascus destructans* (*Pd*) that affects bats during hibernation. Although millions of bats have died from WNS in North America, mortality does not occur equally among all North American species or among species of European bats. These differences in susceptibility to WNS may be due to differences in the strength or type of immune response to *Pd*. To test this hypothesis, we quantified antibodies reactive to *Pd* among free-ranging bats in North America and Europe, and captive little brown myotis (*Myotis lucifugus*) immunized against, or surviving infection with, *Pd*. We found that little brown myotis exhibit greater antibody seroprevalence and titers than any other species sampled, with crossreactive antibodies detected in individuals naïve to *Pd*. Greatest titers occurred in populations occupying regions with long histories of WNS and in bats immunized with live *Pd*. These data show that antibody-mediated immunity cannot explain survival of European bats infected with *Pd*, and that little brown myotis respond differently to *Pd* than species with higher survival rates.

Are There Issues Related to Bats at Solar Energy Projects?
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Utility scale solar energy projects are being built throughout much of North America and in many nations around the world, but little is known about their effects on bats. Impacts to bats could potentially occur during construction if the project footprint is graded as opposed to being left ungraded. Likewise projects located on or immediately adjacent to maternity colonies may result in impacts to bats. Our preliminary investigation of the effects of an operating 250-megawatt solar photovoltaic (PV) project on insectivorous bats suggests that most species benefit from solar PV projects. We deployed 26 passive acoustic bat detectors and recorded echolocation calls of bats from sunset to sunrise from July 2012–December 2013. We used general linear models to analyze the effects of operating arrays on the activity of bats as a group and for each bat species. All bats as a group, *Tadarida brasiliensis*, and *Parastrellus hesperus* had higher activity within operating arrays compared to preconstruction and conservation lands activity (0.80, SE= 0.167, $P<0.05$; 0.43, SE=0.203, $P<0.05$; and 0.41, SE=0.152, $P<0.01$, respectively). *Antrozous pallidus*, which specializes in foraging low and on the ground, decreased their activity in array areas (-0.23, SE=0.078, $P<0.01$). No fatalities have been detected during extensive fatality searches for 20 months of the approximate 1,896-hectare site. At a 337-megawatt solar flux project that uses mirrors to concentrate sunlight on a boiler, bat fatalities have been detected within the power block area. Preliminary results suggest that acoustic deterrents will significantly reduce bat fatalities at solar flux project developments.

Migratory Movements of Tree Bats across Southwestern Ontario
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The migratory movements of insectivorous bats are difficult to study because tracking devices small enough for these animals have a limited detection range. We used the MOTUS Wildlife Tracking System, an array of over 50 automated radio-telemetry receivers to track landscape-scale movements of bats during spring migration. In 2014 we captured migrating silver-haired bats (*Lasionycteris noctivagans),* eastern red bats (*Lasiurus borealis*) and hoary bats (*Lasiurus cinereus*) on the northern shore of Lake Erie, Canada, and outfitted them with 0.3 g digital radio transmitters. We hypothesized that bats would travel along linear landscape features, and follow the shorelines of the Great Lakes and the Niagara escarpment. Clearly defined migratory corridors were not observed. Although some bats appeared to travel along the shoreline of the Lake Eire, equal numbers were detected moving inland in a more dispersed front. Future work will examine the migratory movements of fall migrating bats through the same region.

Are Little Brown Bats Ingesting Microcystin through *Hexagenia* Mayflies?

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Microcystis aeruginosa is a type of cyanobacteria that is capable of producing a hepatotoxin called microcystin. Microcystin can cause vomiting, skin irritation, liver cancer, and even death in humans, pets, livestock, and various aquatic organisms. Microcystin has been found to bioaccumulate in many aquatic organisms. Particularly high levels of microcystin have been found in species of *Hexagenia* mayflies. As these mayflies emerge from the water in the summer, they may provide a temporary food source for little brown bats (*Myotis lucifugus*) which feed opportunistically on aquatic insects. To test if microcystin is moving from aquatic to terrestrial ecosystems through this food web, we collected *Hexagenia* mayflies (n = 40), feces from under a *M. lucifugus* roost (n = 20), and a liver from one *M. lucifugus* in June 2013 near Little Traverse Lake, Michigan. We tested the mayflies, liver, and feces for microcystin with an enzyme-linked immunosorbent assay (ELISA) and found that, on average, both the *Hexagenia* mayflies and bat feces contained over 250,000 pg/g of microcystin. However, we found below detectable levels of microcystin in the bat liver. We also tested the bat feces for *Hexagenia* to see if this mayfly is present in the diet of *M. lucifugus*. While we did not find *Hexagenia* in the feces, we did find another type of mayfly, *Stenonema*. Our findings from pilot data suggest that *M. lucifugus* are ingesting microcystin, but the route is still unclear. Continuing research will aid in understanding the route of microcystin ingestion by little brown bats.

Neoichnology and Tracemaking Behavior of *Desmodus rotundus*

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Trace fossils are useful tools for interpreting the behavior of extinct and ancient organisms as well as providing clues to the potential distribution and occurrence of organisms in areas where body fossils are absent. Tracks and trackways of flying organisms are present in the fossil record, including insects, birds, and pterosaurs; bat trace fossils, however, are not known. The absence of bat trace fossils may be due to their small size, unfavorable preservation conditions of the environment, or misidentification. The lack of traces is likely not due to an aversion to terrestrial locomotion, as modern bats display a range of terrestrial abilities from strictly aerial insectivores to the unique terrestrial behaviors of the common vampire bat (*Desmodus rotundus*) and the New Zealand short-tailed bat (*Mystacina tuberculata*). We present the first study of the trackway-making ability of the common vampire bat, and compare it to the terrestrially inept genus *Carollia*. Four *Desmodus rotundus* were captured at Reserva Ecológica Bijagual de Sarapiquí in the Caribbean lowlands of Costa Rica during early summer 2014. A custom-built Plexiglas® and PVC enclosure allowed the bats to walk across sediment but prevented them from flying. The resulting trackmaking behaviors were video recorded and trackways were cast with plaster and analyzed. All *Desmodus* exhibited a more typical quadrupedal gait than did *Carollia*. *Desmodus*, in contrast, did not display the breaststrokelike crawl performed by the less terrestrially-adept species. Trackways produced by *Desmodus* are characterized by deep manus impressions and scattered, more infrequent pedal tracks.

Relatedness of Co-migrating Male Hoary Bats in Northwestern California

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Patterns of migration by bats, even among relatively well-studied communities in Europe and North America, are poorly known. In North America, it has long been known that tree bats of the genera *Lasiurus* and *Lasionycteris* undertake seasonal migrations, but few details are known about the timing and location of movement patterns or about the behavior exhibited by migrating individuals. Historical accounts of flocks of migrating tree bats suggest that these species may travel in groups during migration. Recently, pairs of males were observed flying together during the autumn migration. When one individual was netted, the other member of the pair circled around and remained in the area while the two bats called to one another. This suggests a strong social, and a possible genetic, bond between the two males. To determine whether these males are related, wing tissue samples were collected from 15 male pairs as well as from 76 singleton individuals from the general migrating population. All individuals were genotyped at 14 microsatellite loci. A genetic analysis of relatedness will be performed to assess whether co-migrating individuals are significantly more related than random pairs of individuals in the general population.

A Preliminary Survey of Bat Ecological Communities in the San Juan Archipelago: a New Method for Locating Bat Roosts

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Habitat loss and fragmentation represent two of the greatest threats to bats worldwide. While, it is generally assumed that bats are highly mobile across fragmented, recent research has challenged this assumption. Dispersal in bats may be more closely linked to ecological requirements such as diet and roosting preferences. We present preliminary data testing this hypothesis in bat communities of the San Juan archipelago in the Pacific Northwest. The known geologic history and proximity to the mainland make this region an excellent model to investigate the consequences of habitat fragmentation. To assess community composition and population structure of San Juan bats, we deployed mist nets and harp traps between July and September 2014 on various sites located on the coastal mainland of Washington State and Vendovi, San Juan, and Orcas Islands. For each bat, we collected morphometric data, wing biopsies and fecal samples for functional, population genetics, and dietary analyses. Roosts were surveyed using a newly developed method that employs scent detection dogs to locate bat roosts. Across sites, we documented at least seven species of bats. *Myotis californicus, M. yumanensis,* and *M. lucifugus* were most commonly captured, and *Eptesicus fuscus, Corynorhinus townsendii M. keenii/evotis, and M. volans* most rarely. Roost sites were successfully located by scent detection dogs, highlighting the potential of this technique for future studies. Using this sample, we provide a preliminary assessment of the functional axes characterizing San Juan bat communities, and how their population structure and gene flow may be affected by natural habitat fragmentation.

Mechanisms Allowing Persistence of Remnant Populations and Actions to Restore Them

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White-nose syndrome (WNS) has devastated bat populations across large regions of northeast North America and threatens multiple species with extinction. However, counts at multiple winter hibernacula of little brown myotis have stabilized in New York, while they have declined to zero or near zero in many other locations. The mechanisms enabling these populations to persist in places where WNS has been for more than five years are unknown but understanding them may suggest strategies for managing bat populations, and restoring populations that have been extirpated. We review the currently available strategies for managing WNS, including successes and challenges. We use field data and models to examine the long term outcomes of bat populations under the different mechanisms that could be allowing persistence of populations with WNS. Under even the most optimistic outcome – that remnant populations have developed resistance to or tolerance of WNS – bat populations will take several decades to recover. Under several other mechanisms allowing persistence populations never recover to their former abundance. Results suggest that in areas where substantial populations still exist and are under threat from WNS (i.e., the invasion front), the most promising management action at present is manipulating hibernacula microclimates. Treatment, such as the use of biocontrols, also offers potential, if effective agents can be developed. We outline remaining research questions that need to be answered to manage and restore bat populations affected by WNS.

Microbiota Community Analyses by 454 Pyrosequencing of the Surface of Western Bats

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White-nose syndrome (WNS), a disease caused by the fungus *Pseudogymnoascus destructans* (*P. destructans*) found on the surfaces of bats, has spread west from New York to Missouri and has killed more than six million bats. Although *P. destructans* represents a new species of fungus that may have been introduced, little information exists on the naturally occurring fungi and other microbiota associated with bats. In general, previous studies that identified the microbiota of bats have focused on gut and fecal microbiomes, with little attention given to external microbiota. Similar to gut microbiota, external microbiota may suppress bacteria and fungal infections. For this study, we sampled bats for external microbiota from five locations in the Southwest, including Carlsbad Caverns National Park, Fort Stanton, El Malpais National Monument, and caves near Roswell, New Mexico, as well as Parashant National Monument, Arizona. At these locations, bats were sampled from surface and cave sites. We collected samples from 202 (62 cave, 140 netted) bats belonging to 14 species. Using 454 sequencing of bacterial 16S rDNA and fungal ITS regions, then processed with QIIME, we identified key species of bacteria/fungi found on bats and established a core microbiome shared among the 14 species sampled. Our findings suggest that there appears to be geographic influence on the distribution of bat microbiomes. These results present novel information about the microbiota of bats that may provide insight on differences in vulnerability of bats species to WNS, as well as being useful in future suppression studies of *P. destructans*.

Bat Diversity in Southeast Asia: a 20-year Perspective

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Southeast Asia is a bat diversity hotspot, with the 11 countries home to a quarter of the world's bat fauna. After three summers of bat research in the Neotropics, I first visited Southeast Asia in 1994. Puzzled by empty mist-nets, reclusive fruit bats, and harp-traps bulging with clutter-tolerant insectivorous bats, I have continued to work in Southeast Asia for the past twenty years. Here I provide a personal perspective of how evolutionary and biogeographical processes have shaped the bat diversity and assemblage structure of the region, and how human activities are currently degrading it. I draw comparisons with the diversity and composition of Neotropical assemblages more familiar to the NASBR audience, and highlight the role of key acoustic innovations, dominance of the Dipterocarpaceae in lowland forests, extensive karst systems, and the archipelago structure. I explore the interaction of these factors with increasing population density and development and discuss the consequences for regional bat conservation.

The Acoustics of Emergence: Swarming Mexican Free-tailed Bats Change Vocalizations during Phases of Emergence

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Many bats live in large colonies, numbering up to the millions, and undergo nightly emergence. During the emergence process, bats are often clustered near numerous conspecifics and maintain group cohesion. During this swarming behavior, individuals still perform echolocation. To understand the vocalization of swarming bats, we recorded from a large maternal colony of Mexican Free-tailed bats (*Tadarida brasiliensis*) during the nightly emergence from two caves with a series of ultrasonic microphones at various locations along their emergence pathway. Due to the size of the emerging colony, individual vocalizations were nearly impossible to isolate from the recordings. To determine changes in swarm vocalizations by location, we used Welch's method for spectral density estimates to compare sound recordings from the emergence locations. As the bats emerged from the cave and traveled along their pathway, the spectral estimates of the swarm signals varied substantially, but the same locations measured at the two different caves maintained similar spectral shapes. These results suggest that Mexican Free-tailed bats maintain stereotypical changes in vocalizations during emergence.

Changes in Roosting Behavior of *Uroderma bilobatum* during Pup Rearing

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Female bats incur heavy costs from their offspring. Phyllostomid neonates weigh approximately 26 percent of their mother's body mass at birth and are attached to her nipple and carried during foraging for a period of days to weeks following parturition. This burden likely has a drastic effect on roosting behavior and activity of mothers, especially throughout the period of pup rearing. The burden is even higher for species that may have to commute long distances to find food. To understand if mothers behaviorally compensate for this extra energy expenditure by altering roosting behavior, we studied the fig specialist *Uroderma bilobatum* from May through July 2014 during pup rearing in Gamboa, Panama. *Uroderma bilobatum* can be forced to travel long distances to find figs. Thus, mothers may acquire high energetic costs to commute between feeding trees and offspring left in the roost, or to potentially carry large infants to foraging areas. Bats roosting under the eaves of two houses were video recorded every two to four days across a 24-hour period to capture both diurnal and nocturnal phases of behavior. Infants are always carried away during foraging sessions and were not left in roost until capable of flights at approximately 4 weeks of age. We show changes in maternal, juvenile, and roost-level activity levels as infants age and begin to fledge. Identifying the effects of pup rearing on roosting behavior of mothers may provide insight into costs and benefits of communal roosting for this species.

A Method for PCR-based Identification of Species from Bat Fecal Samples
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The ultimate cause(s) of bat mortality at utility-scale wind facilities remains unclear; however, understanding why bats come into contact with wind turbines is a key component of developing effective strategies to reduce this source of mortality. One possible explanation is that wind turbines may provide resources such as feeding opportunities and roosting sites for bats. Fecal samples found in wind turbine door slats and transformers at a wind farm in Texas suggest that bats may be utilizing wind turbines as night roosts between foraging bouts. We present a fast and reliable method using the polymerase chain reaction (PCR) to identify bat species from fecal DNA samples. We have developed bat-specific primers, as well as primers to identify the six species found at our site: *Lasionycteris noctivagans*, *Lasiurus borealis, L. cinereus*, *Nycticeius humeralis*, *Perimyotis subflavus*, and *Tadarida brasiliensis*. We present data on the species composition of bats utilizing wind turbines as roosting sites. These primer sets may be a cost-effective way to obtain species information from badly degraded bat samples and to confirm identification of recovered carcasses at wind farms without requiring more costly DNA barcoding methods.

USDA Forest Service Southern Region Five-year Cave Closure: What Does it Mean to You?
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On June 2, 2014, the Regional Forester signed a closure order, closing to human entry, all caves and abandoned underground mines in the Forest Service Southern Region for five years. The purpose of the closure is to minimize the human transmission potential of *Pseudogymnoascus destructans,* the fungal agent causing white-nose syndrome. Bats are the primary vector of fungal spread, but evidence suggests humans can also move spores on clothing and gear if not properly decontaminated. The only exceptions to this closure are 1) for caves posted open with official Forest Service signs, 2) for caves with entrances completely underwater, 3) for persons with written authorization by the Forest Service specifically authorizing entry to aid the Forest Service in our cave resources management activities, and 4) for Federal, State or local officers or member of an organized rescue force performing of an official duty. Exception three is critically important to cavers and researchers. During the five-year closure period, the Forest Service Southern Region may authorize entry to gather data to help us better manage our cave and karst resources. This may include cave mapping, white-nose syndrome surveys, bat monitoring, water quality monitoring, biological inventories, placement of data loggers, photo documentation of cave resources, and any other activity deemed mutually beneficial. The closure prohibits caving solely for recreational purposes. You will now have to cave with a purpose and the purpose is to help the Forest Service gather data to better manage cave and karst resources on southern national forests.

Effects of *Lonicera maackii* on Arthropods and Bat Foraging Activity
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Bat activity patterns have been linked to an interplay of factors, including habitat features, climate, prey resources, and seasons. The introduction of invasive plants has the potential to alter some of these factors and influence bat foraging. In this study, we investigated the effect of *Lonicera maackii* (Amur honeysuckle), an invasive shrub, on bat foraging activity in five paired native and invaded plots in forests of St. Louis, Missouri. We hypothesized that invasion by *L. maackii* would reduce bat activity due to increased vegetation density (making it more difficult for bats to forage), and decrease arthropod biomass (reducing food). For each plot we determined vegetation density, recorded bat activity with Anabat SD1 units, and simultaneously sampled arthropods using pitfall, Malaise, and blacklight traps. Our linear mixed effects model showed that honeysuckle invasion was a significant predictor of bat activity (p=0.035, native: $\bar{x}$=34.0, 95%CIs [6.4, 83.8], invaded: $\bar{x}$=16.8, 95%CIs [2.7, 88.8]). Honeysuckle invasion was not a significant predictor of insect biomass or the number of individuals for any trap type. In contrast, vegetation density was a significant predictor of bat activity (p=0.025, native $\bar{x}$= 58.9, SD=34, invaded $\bar{x}$=31.2, SD=27.2). We conclude that honeysuckle has a negative effect on bat activity due to increased vegetation density.

Historical and Present Day Mercury Contamination from Gold Mining in Three Feeding Guilds of Bats from the Peruvian Amazon

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Some artisanal gold miners use mercury as an amalgam to separate gold from river sediments. As the price of gold has risen, artisanal gold mining operations in the Amazon basin have increased. The influx of mercury into river systems has detrimental consequences for organisms, particularly those at higher trophic levels that bioaccumulate mercury. Toxic mercury levels have been shown to impair reproductive, neurological and behavioral functioning of organisms. We used bats as a mammalian model system to study mercury accumulation due to gold mining from field caught and museum collection specimens in Amazonian Perú and showed that: 1) Total mercury concentrations in Amazonian bat species have increased over time since the 1920's; 2) Bat species from sites with current active mining have higher concentrations of mercury than non-mined sites, with some species having levels exceeding those considered toxic for mammals; 3) Higher trophic levels of bats (piscivores and insectivores) bioaccumulate more mercury than bats of lower trophic levels (frugivores); 4) Bats from present day, uncontaminated sites have the same mercury levels as bats collected in the 1920's from the Amazon. The variety of bat feeding guilds allowed for a comparison of how mercury accumulation changes with diet within one taxonomic order. The novel use of museum specimens allowed for a look back into the historical timeline of mercury contamination in the Amazon basin. Bats represent a new and exciting study system since, like humans, they are mammals and should therefore show similar neurochemical and behavioral responses to this toxic element.

Flight Behavior of Individual Brazilian Free-tailed Bats

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The ~2^+-million Brazilian free-tailed bats that emerge and forage nightly from Frio Cave in Texas, USA, are known to have a nightly flight range of up to 50 km and to feed at altitudes of at least 1200 m above ground level. However, most information on the bats' dispersal, flight activity, and foraging behavior has relied on acoustic monitoring and radar observations of mass movements. Little is known of the movements and flight behavior of individual bats, and nothing of their response to winds or local meteorological conditions. The complete nightly flights of seven radio-tagged female Brazilian free-tailed bats were tracked from an aircraft on seven nights (1 bat/night). All bats emerged before dusk and flew continuously for 3 to 6^+ hours. The distances traveled by a bat range from ~54 km to >160 km. Maximum ground speeds range from ~100 km/hr to >160 km/hr. Thus, we document ground speeds and nightly flight distances that exceed all previous estimates for this or any bat species. In response to prevailing winds, bats adjust flight speeds by decreasing flight speed when flight direction is supported by winds, a strategy that optimizes energy use. Flight speeds increase in response to opposing winds. Motion variance analysis of flight trajectories indicates that directional flights are interspersed with apparent Brownian movements (i.e., Levy flight). These observations support the hypothesis that these bats move rapidly and graze within the aerosphere habitat to exploit patches of insects.

Bat Distribution and Species Richness in Conflict-ridden South Sudan: Predicting Responses to a Changing Landscape

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Anthropogenic pressures resulting in habitat loss and landcover changes are leading drivers of biodiversity loss worldwide. Identification of biodiversity hotspots and biogeographical patterns can be used to establish conservation effort priorities, as well as to identify areas that may have undergone significant biodiversity loss. Species richness maps for bats of South Sudan were calculated in DIVA-GIS by stacking species distribution maps from the International Union for the Conservation of Nature (IUCN) and point location data from past surveys compiled by the 2013 African Chiroptera Report. Patterns of species richness map well onto known biogeographical features of South Sudan, with greater numbers of species in tropical and sub-tropical regions. Given that South Sudan has undergone nearly six decades of conflict, significant landscape changes are predicted to have occurred. We demonstrate the ability to visualize and quantify landcover change over time using Landsat remotely sensed satellite imagery. Applying analysis of habitat-level changes to biodiversity hotspot maps can aid in the estimation of how biodiversity may have been affected by habitat changes over time, and what the implications are for bats in South Sudan.

Hibernating Bats and Mines of the Upper Peninsula of Michigan
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Prior to arrival of white-nose syndrome, we found bats hibernating in 82 of 119 abandoned mines in northern Michigan. Unoccupied sites typically were short (19 ± 17 m SD) and/or experienced chimney-effect airflow, which led to temperatures near or below freezing (-0.8 ± 2.9 ºC). Overall, occupied sites were more structurally complex, longer (307 ± 865 m), and warmer (5.7 ± 3.0 ºC) than unoccupied mines. Number of bats varied from 1 to more than 55,000, although the median was 115. Eastern Pipistrelles (*Perimyotis subflavus*) and Big Brown Bats (*Eptesicus fuscus*) accounted for only 0.5% of the total of 244,341 bats that were observed. Ninety percent of hibernating animals were Little Brown Bats (*Myotis lucifugus*), and almost 10% were Northern Bats (*M. septentrionalis*). Relative to Little Brown Bats, Northern Bats were more common in mines of the Upper Peninsula than in hibernacula in the East and Ohio River Valley. Maximum ambient temperature, presence of standing water, and water vapor pressure deficit were potential predictors of the number of *Myotis* that was present. Seventy-five percent of Northern Bats and 22% of Little Brown Bats roosted alone, rather than cluster with other bats. Little Brown Bats in Michigan were solitary much more often than in the East.

Skeletal Kinematics of the Shoulder in *Carollia perspicillata*
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Bats flap their wings in dynamic, three-dimensional patterns during flight. These motions originate from complex interactions between the bones that make up the shoulder and upper arm. Conventional light-based videography is insufficient for fully understanding the skeletal kinematics of flight, as the proximal portions of the wing skeleton are deeply embedded in muscle. We used XROMM (X-Ray Reconstruction of Moving Morphology) to reconstruct *in vivo* scapular and humeral motion in *Carollia perspicillata* at high spatial and temporal resolution. We modeled the glenorral joint as a ball and socket articulation, and carried out rigorous, two-pass validation of this approach. We found that movements of the humerus with respect to the scapula did not account for the full extent of the wing's motion in the transverse plane, indicating substantial contributions by a highly mobile scapula. Intermittent secondary contact between these bones appears to coincide with periods of limited long-axis rotation of the humerus, which is suggestive of a mechanism to intermittently constrain motion at the glenohumeral joint and provide added stability to this crucial articulation during the downstroke.

Department of Defense Efforts to Further Conservation of Threatened, Endangered, and At-Risk Bat Species: Molecular DNA-based Studies
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Over the last decade, scientists with the Environmental Laboratory have used molecular methods in developing monitoring tools for bats and in studying critical components of bat ecology. First, we investigated population genetic patterns among five major *Myotis grisescens* hibernacula using 16 microsatellite DNA loci, complete mitogenomic sequences, and stable isotopes. With microsatellites we found $\bar{A}$ = 6.09 and $\bar{H}_o$ = 0.62, F_{ST} = 0.0231 ($P < 0.05$), and significant population pairwise differentiation among all populations. Stable isotope patterns showed high interpopulation overlap and were uninformative. Mitogenomic results are pending. Second, to better understand food resources used by endangered nectar-feeding *Leptonycteris yerbabuenae*, we collected scat from flyways and night roosts, along with mixed pollen from the fur of captured bats. We subjected both types of samples to next-generation DNA sequencing (NGS) and conventional microscopic analysis. Fecal samples produced a larger diversity of plant DNAs than was expected based on conventional analysis, and was likely a fuller representation of bat diet. In a pilot study, filtrate samples from desert pools, puddles, and streams were NGS assayed for bat DNA barcodes. Though analyses are on-going, bat sequences has been identified from a subset of locations. In our latest study, we are working to combine DNA from numerous bat scat samples into single NGS runs that will provide sample-specific data on each source bat's species, sex, diet, parasite richness, and exposure to *Pseudogymnoascus destructans*, along with microsatellite genotypes, in order to maximize the amount of information that can be obtained from noninvasive, minimally-stressful sampling.

Hibernation Drives Seasonal Dynamics of Fungal Disease, White-nose Syndrome

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Seasonal patterns in disease transmission can influence the impact of disease on populations and the speed of spatial spread. Increases in host contact rates or births frequently drive seasonal epidemics, but changes in other host and pathogen-specific ecological factors may be of greater importance in many systems. White-nose syndrome, caused by the emerging fungal pathogen *Pseudogymnoascus destructans*, is spreading across North America and threatens several bat species with extinction. We determined the patterns and drivers of seasonal transmission of *P. destructans* by measuring infection prevalence and pathogen loads in six species of bats at 30 sites across the eastern U.S. Despite high contact rates and a birth pulse, infection prevalence decreased from 100% in winter to near 0% during summer. Instead, a change in host physiology, specifically hibernation, was the dominant driver of seasonal infection dynamics. The largest increases in infection occurred when bats began hibernating, and peaked in late winter when population sizes were lowest, leading to maximum disease impacts. Our study is the first to describe the seasonal transmission dynamics of this emerging wildlife pathogen, and highlights the importance of understanding both host and pathogen ecology in mitigating impacts from wildlife disease.

Bat Occupancy Modeling Prior to Wind Energy Development: Approach and Preliminary Results

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Bat mortalities at wind energy facilities were estimated at 888,000 bats in the United States throughout 2012 due to direct strikes and barotrauma. How this will impact bat population dynamics throughout North America is unknown. We have initiated a multi-year (2013–2015) acoustic-monitoring, occupancy-modeling project across 21 counties of northern Missouri to document occupancy while incorporating detection probabilities for different species of bats and to see if wind development alters interactions on the community level post development. Sample locations (n=120) were randomly positioned throughout state and federal lands in areas of high potential (n=60) and low potential (n=60) for wind development. Within these categories, we selected sites for high potential (n=40) and low potential (n=20) use by bats based on a combination of trail and water ArcGIS© layers and onsite confirmation by trained bat specialists. Sites are being sampled for nine nights from March 15th – November 15th within defined bat active periods (Spring migration, Summer maternity, and Fall migration). We sampled three nights per season from ½ hour before sunrise to ½ hour after sunset. Each sample location is being monitored with a Wildlife Acoustics SM2Bat+™ echolocation detector outfitted with two microphones, one at 2m above ground level and one mounted on a telescoping pole at 12m above ground level. We have identified calls from all nine species expected in our study area. The high and low microphones recorded similar numbers of calls, but species composition varied. Preliminary results for 2013 and summer 2014 indicate that our methods are effective.

Current Assessment of Bat Populations in Valley Forge NHP and Hopewell Furnace NHS, Pennsylvania

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The US Fish and Wildlife Service (USFWS) has proposed the Northern Long-eared Bat (*Myotis septentrionalis*) for listing as endangered under the Endangered Species Act due to dramatic population declines associated with the spread of white-nose syndrome (WNS). Winter bat surveys provide evidence that *M. septentrionalis* has been particularly hard hit by the spread of WNS since its discovery in 2006, with greater than 90% mortality documented within its core range. Loss or degradation of summer habitat will pose additional threats to this species and so park management plans must be shaped by current bat population data. A summer 2005 inventory by the nature conservancy documented the presence of 4 species of bats (*Myotis lucifugus*, *Eptesicus fuscus*, *Lasiurus borealis* and *M. septentrionalis)* at both Valley Forge NHP (VAFO) and Hopewell Furnace NHS (HOFU). The capture of pregnant females of all species at VAFO (26/32 = 81% of all captures) indicated that maternity colonies were likely supported in the park. At HOFU, *M. septentrionalis* was the most common species captured (7 of 18 bats). These surveys, completed prior to the discovery of WNS, provide a valuable baseline for comparison. This summer, we conducted similar mist-net surveys within the two parks. We captured no *M. lucifugus* at VAFO and only 1 non-reproductive female *M. septentrionalis*. At HOFU, *E. fuscus* and *L. borealis* comprised 95% (35 of 37) of the bats captured, with single pregnant females captured of the two *Myotis* species. These data suggest a striking shift in species composition at these sites.

Responses of Urban Bats to Various Levels of Nighttime Illumination

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Many insects are attracted by night illumination, forming a food source for their predators under city lights. Theoretically, insectivorous bats may follow prey and utilize urban lights as foraging grounds. However, only limited research has attempted to demonstrate how insect communities and bat activity respond to variation in lighting conditions. Whether level of bat activity under nighttime illumination is related mainly to insect prey availability is still not clear. Between September 2011 and October 2012, we conducted an experimental survey to record bat acoustic activity and collect insects at a series of locations with different lighting conditions within a relatively homogenous area. Overall we found that the number of bat passes was somewhat different at sites with different levels of illumination. The proportion of foraging calls, however, was always higher at sites with higher light intensity. Generally the diversity of insects did not vary with light conditions. Insect biomass, however, was greater at brighter sites except during the winter. Regression models showed that both insect biomass and site illumination level affected level of bat foraging activity independently. To a certain extend bats foraged more at sites where prey was more abundant. But bats also preferred to forage more at more illuminated sites regardless of prey abundance. Our findings suggest both prey availability and environmental suitability are important in how bats choose foraging grounds.

Patterns of Genetic Diversification in a Widespread Species, *Molossus molossus*

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The taxonomy and evolutionary relationships of the velvety free-tailed bat, *Molossus molossus*, from Central and South America has long been debated. Within this species, and in fact the entire genus *Molossus*, specimens have been especially difficult to identify and are taxonomically challenging. The objective of this project was to characterize the genetic relationship among individuals representing subspecies of the widespread species, *M. molossus.* We tested the hypothesis that genetic patterns of diversification would reflect subspecies lineages. The mitochondrial gene, cytochrome *b* (cyt*b*) was amplified and sequenced for specimens from across the geographic range. A Bayesian analysis of 678 base pairs of the cyt*b* gene was conducted for 63 specimens with *M. alvarezi* as an outgroup. Genetic divergence was calculated and haplotype analysis was conducted. Overall there was low average divergence across all specimens (4.7%), however a mitochondrial lineage containing the Cuban subspecies, *M. m. tropidorhynchus*, was 7.9% divergent from the other *M. molossus* specimens. This level of divergence and the recovery of a monophyletic lineage containing all Cuban specimens was consistent with recognition of the taxon as a distinct species. Excluding the divergent Cuban specimens ten haplotypes were recovered. The major haplotype was found in 60% of the samples and had a widespread geographic distribution. Our results showed that some subspecies such as *M. m. daulensis* and *M. m. tropidorhynchus,* based on morphology and geographic location, are consistent with the mitochondrial lineages recovered. However, not all currently recognized subspecies of *M. molossus* are recovered by this analysis.

Roost Selection by *Corynorhinus rafinesquii* in Relation to Site Characteristics and Management History

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Rafinesque's big-eared bats (RBEB) in the southeastern Coastal Plains generally roost in large hollow trees in bottomland hardwood forests. I tested the hypothesis that roost selection by RBEB in South Carolina varies with site characteristics, particularly land-use history. The study was conducted at the Savannah River Site (SRS), a site that has experienced considerable disturbance for >100 years, the Webb Wildlife Management Area (WWMA), a relatively undisturbed site, and Groton Plantation (GP), a site that has received intermediate amounts of disturbance. Transects (50 m wide x 1–2-km long) were perpendicular to the floodplain and were searched for trees with cavity volumes >130 dm^3 and the presence of RBEB. Eight logistic models including global and null models were developed and five of those models were also run with a site interaction term. The CavitySite model had the greatest support. Similar to other studies, bats at all 3 sites selected smooth textured cavities with significantly larger volumes than unused cavities. However, cavity volumes of trees used at the WWMA were nearly 4 times as great as those used at SRS and 2.7 times greater than those used at GP. Further, at WWMA only 7.7% of the roosts were in trees other than cypress or tupelo whereas, 31.2% and 31.4% of the trees at SRS and GP, respectively, were in trees other than cypress or tupelo. These data suggest that use and selection of roost trees varies with availability and bats may be less selective in lower quality sites.

Activity Budget and Exhibit Use in *Desmodus rotundus*

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Common vampire bats (*Desmodus rotundus*) have become increasingly popular as zoo exhibit animals, however little is known about the impact that the zoo environment may have on their behavior. We evaluated the activity budget and exhibit location use in a group of captive vampire bats at the Buffalo Zoological Gardens. We collected 54 hours of data on the bats at varying times of the day using instantaneous scan sampling. Using a Wilcoxon signed rank test, we found that there were significant differences in the use of the low wall (the lower half of the wall and includes any vertical space throughout the exhibit) and in the proportion of time spent locomoting, interacting, and resting during high crowd versus low crowd levels. Although we expected the bats to demonstrate avoidance behaviors to high crowd levels, the bats spent more time on the ceiling and therefore further from the front window when low crowd levels were present. This may be an indicator that vampire bat activity might not be heavily influenced by crowd level at the exhibit. When comparing morning (10am–1pm) and afternoon (1pm–4pm) with the same statistical test, we found that the behaviors rest, groom, and clump, and the use of the ceiling, low wall, and upper wall were significantly different during these times which may be a sign of circadian rhythms in these bats. We explore the relevance of these findings to the management of vampire bats in captivity.

Plants Used by Bats as Nectar-pollen Resources in a Tropical Cloud Forest (Cusco-Peru)

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Many tropical plant species are used by bats as food resources, and more than 500 species pollinated by bats. However, in some tropical zones these interactions have been poorly studied. The objective of this study was to analyze pollen ingestion by bats, in order to obtain a list of plants used by bats as nectar-pollen food resources, and potentially pollinated by them as well. The study took place in a tropical cloud forest in the Kosnipata Valley (Cusco) of southeastern Peru. We used palynological techniques to evaluate frequency and abundance of pollen grains in fecal samples. We analyzed 52 samples from the genera *Carollia*, *Sturnira* and *Anoura*. Of the total samples, 58% contained pollen, with 76 different morphotypes; we identified 9 to species level, 31 to genus, 22 to family, 4 to palynological groups and 10 remained as unidentified. Based on plant morphology and review of the

literature, we believe that 25 morphotypes were actively consumed by the bats during flowers visits, 21 were involuntarily ingested during fruit-feeding, and 11 could have been actively or involuntarily consumed, while the mode of ingestion for the remaining morphotypes (19) could not be determined. We registered 36 possible taxa used by bats as nectar-pollen resources, which present characteristics of different pollination syndromes: 44% correspond to chiropterophily, 11% to entomophily, 8% to ornitophily, 3% to anemophily, while the remaining could not be determined. The genera *Abutilon* (Malvaceae), *Cayaponia* (Cucurbitaceae), *Psychotria* (Rubiaceae), and the family Flacourtiaceae showed the highest frequency of occurrence.

Experimental Evaluation of Pest Regulating Services Provided by Bats in Corn

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Recent estimations place the value of pest regulating services provided by bats in North America at greater than $3 billion annually, yet these estimations are built on untested assumptions about top-down effects of bats in row-crops. Specifically, no study has assessed whether bats exert sufficient predation pressure on moth pests to affect 1) density of larvae and 2) herbivory by larvae. To test these assumptions, we constructed six large exclosures and paired control plots in cornfields in the Midwestern United States. The exclosures prevented bats from foraging on insects over corn, but were opened during the day to allow birds to forage. We evaluated larval moth abundance and crop damage on 10 plants in each plot every five to six days. This allowed us to provide the first experimental test of the effect of bats on pest insects and crop damage in row-crop agriculture. Bats appeared to have substantial effects on pest numbers and crop damage. Bats face a variety of threats around the world, but their relevance as predators of insects in a ubiquitous corn-dominated landscape underlines the economic and ecological importance of conserving biodiversity.

Hips Don't Lie: Using Variation in Pelvic Osteology to Inform Bat Relationships

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Morphological studies on bats often rely on the extensive information found in the bat cranium. However, relatively few bat phylogenetic studies have examined the postcranial skeleton. We examined anatomical variation in the pelvic girdle among all bat families to establish informative osteological characters that are useful to build a reconstruction of ancestral states. In addition to developing new characters, previously established characters were reassessed in context. Our goal was to investigate the effect of these characters on branching patterns across bat families by tracing individual character evolution. Character histories were mapped over a molecular tree using Mesquite in order to visualize patterns of phenotypic evolution of pelvic osteology. We assessed correlations between characters, habitat, and foraging modes, to understand whether a trait might indicate an adaptive advantage for the species or if it represents an event of convergent evolution. Tracing character distributions highlighted trends useful to identify bats at the species level, determine higher-level relationships, and distinguish useful postcranial characters that can provide further resolution of bat phylogenies.

Radar Aeroecology of Gray Bats: a Case Study in Missouri and Potential Application Range-wide

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Aerial animals that live in large colonies and fly at sufficient altitude create signatures that can be observed on weather radar. Frick et al. (2012) used weather radar to retroactively study emergence behavior of Brazilian free-tailed bats over an 11-year period. They observed plasticity in emergence times during periods of extreme drought or high surface temperatures. Similar to the Brazilian free-tailed bat, the federally-endangered gray bat is a colonial, cavernicolous species. Summer and winter colonies can range from 10,000 to more than half a million individuals. Maternity colonies are distributed in karst areas throughout the range, but nine hibernacula are considered to contain approximately 95% of the total range-wide population of gray bats. No standardized method for censusing gray bats has been established making an accurate determination of the current status of the species difficult. Furthermore, a lack of understanding about the phenology of gray bats in their summer and winter habitats complicates conservation and recovery efforts and the ability to track the impact of white-nose syndrome. In June 2014, meteorologists in Springfield, Missouri observed a radar signature that was later determined to be a previously undiscovered maternity colony of gray bats. Additional signatures have been observed in Missouri that correspond to known colonies. The ability to view colonies of gray bats by weather radar makes it plausible that this remote sensing technique could be used to study gray bat populations throughout the range to facilitate recovery efforts and monitor populations.

Operational Mitigation Reduces Bat Fatalities at the Sheffield Wind Facility, Vermont

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In response to concerns among conservationists about cumulative population-level impacts of bat fatalities at wind facilities across North America, studies have been conducted to assess the effectiveness of operational mitigation (curtailment) at reducing fatalities. Currently, curtailment has only been implemented in relation to wind speed. Bat activity varies with environmental conditions like temperature and wind speed. Our objectives were to incorporate both temperature and wind speed into a curtailment design in order to fine-tune it to conditions when bats are most active to improve its effectiveness at reducing fatalities. We conducted a two-year study from spring through fall in 2012–2013 at the Sheffield Wind Facility in Sheffield, Vermont. Eight of the 16 turbines were randomly selected each night for an equal number of nights to cut-in at 6.0 m/s rather than 4.0 m/s. Treatments were implemented from half an hour before sunset to sunrise when wind speeds were <6.0 m/s and temperatures were >9.5°C. Bat mortalities at non-curtailed turbines were 2.7 times higher than mortalities at curtailed turbines in 2012, resulting in an estimated 60% (95% CI: 29, 79) decrease in fatalities. In 2013, we found 1.5 times as many fatalities at non-curtailed turbines compared to curtailed turbines. Few fatalities were found in 2013, resulting in small sample sizes which limited statistical power. Analyses still underway will identify combinations of weather parameters where curtailment was most effective at reducing fatalities. We recommend that curtailment be implemented during high risk periods to mitigate cumulative impacts to bat populations.

Seasonal Fluctuations in Roost Use by *Tadarida brasiliensis* in a Highway Overpass, San Angelo, Tom Green County, Texas

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Previous research has documented that populations of Brazilian Free-tailed Bats, *Tadarida brasiliensis,* use highway overpasses as day roosts in the parts of central Texas. Such populations are known to fluctuate in size seasonally, but few colonies in western Texas have been studied. In this study, a large population of *T. brasiliensis* roosting in a highway overpass in San Angelo, Tom Green County, Texas (Central Great Plains) was surveyed to observe changes in roost use since the site was last surveyed in 1995. Population counts and roost use were documented from February through August 2014 by recording the percentage of bridge crevices occupied by bats. An estimate of 2.7 bats per 0.01 m of crevice length was used to calculate the estimated total number of bats. Occupation increased from late February to early April, and showed decline in late April. Numbers began to generally increase again from mid-May through August. The lowest occupancy recorded (12.70%) was during the month of May with an estimated 27,549 bats, and the highest occupancy recorded (82.40%) was during the month of August with an estimated 177,907 bats. Comparison to previous results shows similar trends in occupancy. In 1995, the highest occupancy recorded (94.37%) was in September with an estimated 205,171 bats. It is suggested that the colony is stable and exhibits similar population fluctuations to those seen 20 years ago even though new bridge roosting sites are available locally and some instances of roost switching have been documented.

Management Implications for the Potential Evolutionary Impacts of White-nose Syndrome in Infected Bat Populations

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White-nose syndrome (WNS) is negatively impacting the evolutionary fitness of bats within affected populations and is spreading rapidly throughout North America. Current hypotheses for post-WNS population dynamics are that bats acquire immunity after initial exposure and are altering their social behavior to reduce

infection loading. However, WNS may be acting as an intense bottleneck on already-diverse genotypes that provide differential protection. In this case, selection against susceptible genotypes will lead to initial population declines, but will increase the proportion of genetically robust individuals, and subsequent population growth trajectories will reflect the new-majority phenotype. Combining methods from Population Viability Analysis (PVA) and Population Genetics, we construct a mathematical model that incorporates this *evolutionary rescue* (ER) into PVA and apply it to observed *Myotis lucifugus* populations across multiple infected hibernacula. We compare both short- and long-term predicted population trajectories under ER with those predicted for the case of acquired immunity. Our results offer qualitative support for consideration of ER as an explanation of post-WNS *M. lucifugus* population trajectories. Our subsequent sensitivity analyses demonstrate that management approaches to support recovery are drastically different for each population response. Under ER, WNS management should target short-term growth by increasing adult survival (e.g., anti-fungal treatments). Under acquired immunity, recovery efforts should focus on long-term growth by increasing adult reproduction (e.g., assisted reproduction programs). We show that determination of the appropriate phenomenon is critical for effectively managing infected and at-risk populations, and we highlight important knowledge gaps that can deepen our understanding of bat response to WNS.

Supporting Endangered Species Protection for the Northern Long-eared Bat

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Biologists may choose to utilize their particular expertise about species, or general knowledge about population ecology, extinction dynamics, and other fields of study, to clarify public decision-making processes related to species protection. The federal Endangered Species Act (ESA) requires that decisions to list species under the law be based strictly on scientific knowledge, not on economics, politics, culture or other considerations. The U.S. Fish and Wildlife Service's 2013 proposed listing of the northern long-eared bat (*Myotis septentrionalis*) as endangered, and subsequent political resistance from certain sectors, including the timber and oil and gas industries, presents an opportunity for biologists to facilitate the resolution of a challenging policy issue and to be of service in the arena of species conservation. The Fish and Wildlife Service's pronouncement on June 30, 2014 that it would delay a final decision on protecting the bat to April 2015, rather than sticking with its originally scheduled decision date of Oct. 2, 2014, is indicative of the contentious political dynamics surrounding this issue. In an effort to bring the authority of science back to the listing decision, a scientists' sign-on letter has been created. The letter supports designation of the northern long-eared bat as endangered, and it briefly explains both the scientific information that compels the listing, as well as the conservation benefits it will confer. The letter will be delivered to the Secretary of the Interior and the Director of the Fish and Wildlife Service in late winter 2015. Scientists are encouraged to review the letter, and if they are in agreement, to sign it as well as share it with colleagues. The letter will provide an authoritative and influential voice for a science-based listing decision on the northern long-eared bat.

Hibernating Bats Offset Arousal Costs by Not Warming Up to Normal Body Temperatures: Implications for WNS Energy Budgeting

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Periodic arousals account for the majority of the energy cost of hibernation. With WNS, increased arousal frequency depletes energy stores leading bats to die of starvation. We hypothesized that bats could use physiological mechanisms to reduce arousal energy expenditures. Bats sometimes use heterothermy (lowering body temperature) during arousals, therefore we predicted bats could save energy by arousing without increasing body temperature. Furthermore, we predicted non-warming arousals would be associated with extreme energy distress at the end of hibernation. To test these predictions, we collected hibernating bats from a WNS-negative cave in Manitoba. Bats were inoculated with either *Pd* or a sham control, and placed in temperature and humidity controlled environmental chambers for hibernation. We recorded activity with motion-sensitive IR video cameras, and skin temperature (T_{sk}) with iButtons affixed to the bats. We observed some bats experiencing slow, shaky and uncoordinated movements during arousals which were strikingly different from typical arousal activities. These abnormal arousals corresponded with T_{sk} <15°C, whereas normal arousals occurred at T_{sk} >25°C. These "cold arousals" were observed in both inoculated and control animals, suggesting it is not a physiological response to disease. As we predicted, "cold arousals" typically occurred in the final days of hibernation, when energy stores were nearing exhaustion. However, we also observed "cold arousals" associated with disturbance in mid-hibernation. Therefore we suggest that "cold arousals" are a facultative strategy that may be used to manage energy stores, rather than being related to disease and extreme energy distress.

Metabolic Rate and Evaporative Water Loss in Hibernating Little Brown Bats Inoculated with *Pseudogymnoascus destructans*

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Bats with white-nose syndrome (WNS) experience increased arousal frequencies leading to exhaustion of energy stores and death by starvation. However the cause of the increased arousal frequency is not known. In healthy bats, dehydration has been proposed as a cue for periodic arousals. Torpid bats lose water at a greater rate than can be replenished by metabolic processes, therefore bats must arouse to drink. The 'dehydration hypothesis' proposes that wing damage caused by WNS leads to increased evaporative water loss (EWL), and therefore more frequent arousals. Furthermore, WNS may lead to increased torpid metabolic rate which would also contribute to premature exhaustion of fat stores. We used respirometry to test the predictions that bats inoculated with *Pseudogymnoascus destructans* (*Pd*) would 1) have elevated rates of EWL, and 2) have elevated torpid metabolic rates compared to healthy control bats. We collected wild bats from a WNS-negative cave in central Manitoba, inoculated them with *Pd* (or sham inoculated controls), and held them in cages in a temperature and humidity controlled environmental chamber for hibernation. After > 114 days of hibernation, we transferred bats to respirometry chambers to measure torpid metabolic rate and EWL in dry and humid air. Consistent with the predictions arising from the dehydration hypothesis, bats inoculated with *Pd* had higher rates of EWL. Inoculated bats also had higher torpid metabolic rates. Therefore bats with WNS use more energy during torpor bouts, and suffer increased EWL which may be the trigger for increased arousal frequency, further depleting energy stores.

Western Coordinated Multi-state Response to a Deadly Emerging Threat: White-nose Syndrome in Bats

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White-nose syndrome (WNS) is associated with extensive bat mortality in Eastern North America. Currently, the disease, or the fungus that causes it has been confirmed in 25 states and 5 Canadian provinces. It may appear that the West has an advantage in dealing with WNS in that there is time to prepare, but little is known about the winter ecology of bats in the West and how the disease could affect our species, which are highly dispersed on a large landscape. From what we can determine in the West, bats susceptible to WNS tend not to hibernate in large colonies. Yet, WNS surveillance and early diagnosis of the disease are essential for management decisions. For this project, Arizona partnered with 5 Western states (CA, ID, MT, NV, and WA) and Bat Conservation International to conduct a regionally coordinated approach to WNS surveillance in 2012–2014 as part of a Multi-State Wildlife Grant. Partner states identified an approach to increase surveillance efforts within their jurisdictional boundaries using a variety of investigative methods to gather baseline data. Traditional methods, including internal roost surveys, emergence surveys, data-logger deployment and fixed and mobile acoustic surveys were employed. At least 258 sites, including 91 hibernacula were surveyed within partner states and over 3,032,955 acoustic files collected to help western states understand western bat winter ecology.

Landscape modifications driving reduction in bat abundance and richness

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Bats spend less time crossing an altered matrix when compared with same-sized vertebrates. Consequently, their response to landscape changes is an interesting subject to be explored. We tested the hypothesis that habitat amount will be more important driver of bat diversity than landscape configuration. We also expected that herbivorous species will respond in a higher scale than animalivorous bats (except Desmodontinae), because herbivorous species tend to search out for new forage areas. We sampled 18 forest patches (similar size), using 20

mistnets (6 hour duration), for 4 nights. We classified Landsat 8 satellite images and measured the loss of natural areas (LNA) and number of patches (NP). Buffers of analysis ranged between 500 m and 10 km. Partial coefficients of multiple regressions were used to verify the importance of the LNA and NP. The best relationship between bat abundance with LNA and NP occurred for 7-km buffer (F=3.62, df=2.15, p= 0.05, betaLNA=0.65, betaNP=0.27). Richness (Chao1 index) is related with LNA and NP to 3-km buffer (F=7.63,df=2.15, p<0.01,betaLNA=0.42,betaNP=-0.41). We corroborated our hypothesis regarding bat abundance, but it not for bat richness. Herbivorous abundance responded to LNA and NP in the 6-km buffer (F=3.92,df=2.15, p=0.04,betaLNA=0.62,betaNP=0.49), while animalivorous richness responded in the 2-km buffer (F=4.61,df=2.15,p=0.03,betaLNA=0.52,betaNP=-0.16). Although we find that herbivorous would have a higher response scale, these answers occurred in different components of diversity. For both hypotheses, differences for abundance and richness responses may suggest that conservation programs should consider the scale of effect for local persistence and colonization capacity.

A Comparison of Bat Activity between Edge and Interior Portions of Timber Harvests

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Forest management techniques such as timber harvest have been shown to influence habitat use of several bat species. In recent years, the implementation of forest management guidelines to create breeding habitat for the imperiled Golden-winged Warbler have intensified on public and private lands in Pennsylvania. The objective of our study was to compare bat activity levels between two timber harvest methods: overstory removals (n=6) and shelterwoods (n=6) used to create golden-winged warbler habitat. Our study was conducted in northeastern Pennsylvania. Stand size averages were 40.1 and 35.4 hectares for overstory removals and shelterwoods, respectively. Anabat detectors were placed within timber harvests, and edge-timber harvest ecotones. We conducted two 3-day sampling bouts in each stand. We identified bat calls to species using Analook program and neural networks in Program R. We compared bat activity to the location within a harvest and timber harvest method using a Chi-square analysis. *Eptesicus fuscus* selected the interior of timber harvests, while *Lasiurus borealis* selected edge-timber harvest ecotones. Based on a limited number of calls (n=15) *Myotis sodalis* also appeared to select edge-timber harvest ecotones. *Eptesicus fuscus* and *Myotis lucifugus*, selected for overstory removal treatments, and *Lasiurus borealis* and selected for shelterwood treatments. Furthermore, we found that *Eptesicus fuscus* and *Lasiurus borealis* had a greater detection probability than other species. Our results will help inform land managers about species-specific responses of bats to forest management prescriptions currently used to create golden-winged breeding habitat.

How Do Diverse Sensory Structures Drive Ecological Diversity in Neotropical Leaf-nosed Bats (Chiroptera: Phyllostomidae)?

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The evolution of differences in the sensory system can create new dimensions to ecological niches and allow for resource partitioning and potentially diversification in bats. Neotropical leaf-nosed bats (Phyllostomidae) are one of the most ecologically diverse groups of mammals. They have a wide range of diets, foraging styles and extreme morphological variation in their sensory structures (i.e., nose leaves and ears). To date, there have been very few broad comparative analyses focusing on how morphological differences of the sensory system evolve, and how they functionally affect echolocation parameters in foraging bats. This is a significant knowledge gap because morphological differences can affect fitness via their effect on prey capture performance. Here we use phyllostomid bats to address one important question about the sensory evolution of bats: how does the morphological diversity of external sensory structures map onto ecological diversity? We assess the role of foraging ecology as a selective force on the morphology of nose leaves and ears, and use these data to illuminate the drivers of ecological diversity in this group. Our analyses contrast the results from two- and three-dimensional morphometric data, collected using traditional methods and micro-CT scanning for a varied sample of phyllostomid species. We find the dimensions of the horseshoe, one section of the nose leaf, explains most of the variation between species and we predict dietary ecology correlates with this variation. This study provides insight into how the morphology of the sensory system could shape bat ecology in an extremely diverse lineage of bats.

Effect of farmland heterogeneity on bat activity and diversity
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Previous studies have documented the relationships between forest amount and configuration in agricultural landscapes effect bat diversity and activity. However there has been little research how to enhance agricultural landscapes for bats without reducing production areas. We focused on investigating bat responses to the heterogeneity of the farmland itself, specifically the configurational heterogeneity of crops and compositional heterogeneity of crop types. This information can influence farming guidelines seeking to promote bat activity while maintaining productive area. As bats use linear landscape elements for foraging and commuting, we predicted that landscapes with more configurational heterogeneity would have more diverse and active bat communities. We also predicted that increasing compositional heterogeneity would have a positive effect on bat communities. We conducted acoustic surveys in 40 agricultural landscapes in Eastern Ontario which were selected to minimize correlations between the two types of heterogeneity at 1, 2, and 3km scales. We used model averaging to assess the relative effects of configurational and compositional heterogeneity on bat diversity and abundance. Configurational heterogeneity at several spatial scales had a positive effect on species richness, total bat activity, and activity of *Eptesicus fuscus*. Compositional heterogeneity had a negative effect on total bat activity and *E. fuscus* activity at the 1km scale. In general configurational heterogeneity had two or more times greater an effect than compositional heterogeneity. Our results suggest that bat communities may benefit from increasing configurational heterogeneity of agriculture and that these relationships can be managed at the 1km scale, a size typical of many farms.

Uncovering Skin Immune Proteins as Predictors of Resistance to White-nose Syndrome
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We are launching a new study to investigate the composition of bat skin immune proteins as predictors of resistance to white-nose syndrome (WNS), and to discover the mechanisms underlying the survival of remnant populations in the WNS-affected area. The project uses proteomics to characterize and compare the diversity and relative abundance of skin immune proteins of five bat species that vary in observed rates of WNS-associated mortality (*Myotis lucifugus*, *Eptesicus fuscus*, *M. austroriparius*, *M. grisescens*, and *Corynorhinus townsendii virginianus*). We will compare protein profiles among species to test the prediction that certain proteins related to anti-fungal responses are more prevalent in species that appear to suffer less from the effects of WNS, such as *M. grisescens* and *C. townsendii virginianus.* To test the prediction that proteins prevalent in survivors of more highly susceptible species are similar to those found in resistant species, *M. lucifugus* and *E. fuscus* are being more extensively sampled both within and outside of the WNS-affected area and their protein profiles will be compared between sites. Microsatellite genotyping will be used to quantify levels of relatedness among sampled individuals, which will allow for functional and adaptive similarity in immunological proteins to be differentiated from similarity due to common ancestry. We focus on antimicrobial peptides (AMPs), a set of proteins that is known to kill or inhibit the growth of invading microorganisms such as fungi. Finally, we will investigate these peptides as a control for WNS.

Potential for Monitoring Bats that Roost on Talus Slopes
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Most efforts to monitor temperate bat populations rely on winter hibernacula counts, but this may be ill suited for some species. Despite decades of winter surveys of caves and mines status of the eastern small-footed bat (*Myotis leibii*) is unclear. We used novel methods to study *M. leibii* on talus slopes in Virginia, including: capturing bats in mist-nets placed directly on boulder fields, conducting daytime visual searches, and using body temperature sensitive radio transmitters to infer timing of migration and hibernation. We also surveyed random quadrats to estimate local population size. Netting on talus slopes resulted in 4.1±2.5 bats per 1.25-h visit (±SD) and visual searches documented 3.1±1.1 bats per person-hour of searching, making both methods preferable over standard mist-net protocols. Bats used crevices near the surface of talus slopes until the end of October, and we did not find them again until brief warm spells in early March. Patterns of torpor in March resembled those of bats hibernating in stable thermal refugia, supporting the notion they might hibernate outside of caves and mines. Quadrat surveys

indicated bats occupied 0.6±1.0% of searched crevices, and a particularly large (3 ha) talus slope may have had 174–261 bats in July. Results suggest monitoring *M. leibii* is more feasible than has previously been assumed. Although the quadrat method will need to be refined to reduce error, the method is promising and should be initiated elsewhere to resolve uncertainty over population trends in *M. leibii*, and perhaps other species that roost on talus slopes.

Analysis of Chiropteran Humeri from Late Pleistocene Talara Tar Seeps of Northwestern Peru with Applications to Paleoenvironmental Studies

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The fauna of the Talara tar seeps of northwestern Peru is one of the most diverse late Pleistocene deposits in South America. However, the mammalian order Chiroptera is poorly represented in these deposits. We morphologically assessed seven humeri that were previously unreported from the original excavation in 1958 of the Talara tar seeps and compared them to the humeri of extant bat families with ranges that extend into northwestern South America. Previous research on the Talara tar seeps has found species in the families of Vespertilionidae and Phyllostomidae. Based on comparison of morphology and measurements, our results identified six humeri as being the first fossil records of *Lasiurus egregius*, which is a species that typically occurs in Neotropical rainforest and is not currently known from the drier open desert habitats of northwestern Peru. This supports earlier suggestions that the late Pleistocene environment of Talara was moister and resembled a woodland savannah. One smaller humerus was of the genus *Eptesicus*, most closely resembling *Eptesicus furinalis* and *Eptesicus andinus*. These results further elucidate the existence and distributions of bats from the Pleistocene Talara tar seeps and importantly contribute information to assist with the reconstruction of paleoenvironments dating back to 14,000 years ago.

Assessing Changes in Genetic Variation of *Myotis lucifugus* Population(s) in the Eastern US Due to White-nose Syndrome Mortality

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Pseudogymnoascus destructans is the causative agent of white-nose syndrome (WNS), a potentially fatal fungal infection in bats. This disease is responsible for the death of ~70–90% of cave hibernating bats of the genus *Myotis* in New York (NY) since 2006. *Myotis lucifigus* was once the most common bat species in NY, but WNS has caused hibernacula in NY to lose ~95% of resident bats. Currently, the impact of this mortality event on the genetic diversity of northeastern *M. lucifugus* population(s) is unknown. I calculated the genetic diversity of the *M. lucifugus* population in NY prior to the introduction of *P. destructans* using both mitochondrial and microsatellite DNA, and aimed to determine the effects of WNS mortality and historical geology on the present genetic variation of this population. A lack of diversity and low Garza-Williamson Index value among samples taken from the epicenter of the outbreak during 2008–2011 in NY indicate that this population has been subject to a genetic bottleneck. However, results from samples collected in 2003–2005 indicate diversity in this region was depauperate prior to the estimated arrival of WNS. I postulate that the bats in this region are still recovering from founder effects resulting from the glacial coverage during the Last Glacial Maximum. I am currently analyzing samples from other states to determine if the low genetic diversity can be attributed to glacial coverage, or if the arrival of WNS in NY may have occurred prior to 2005 and is responsible for the earlier loss of diversity.

The Effects of White-nose Syndrome on Bat Populations in Southern Ontario during the Maternity Roosting Season

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Bat populations have been dramatically affected by the introduction of white-nose syndrome (WNS) in much of the northeastern United States and eastern Canada. However, the magnitude of these effects on activity levels of bats during the maternity roosting season (May to July) has not been well quantified. Further, changes in activity levels of bats not known to be directly affected by WNS may indicate a competitive release. Acoustic bat monitoring data was collected at 9 locations in Southern Ontario and 2 locations in central Michigan from 2009 to 2011, prior to the population decline of WNS-effected bats, using AR125 bat detectors and analyzed using the Sonobat 3.2.1 NNE automated classifier. This data collection was replicated in the same time periods, using the same technology and analysis procedure in 2014. For each species, mean bat passes per night for each month at each station was compared from pre-WNS decline to post-WNS decline. The change in bat activity levels within stations was also compared to changes in bat activity levels at the stations in central Michigan where WNS has not yet been documented. In total, 870 detector-nights of data across six years and over a large geographic extent will provide strong inference on maternity season bat population changes in southern Ontario.

Nectar Extraction Efficiency in Three Species of Lonchophyllinae and Glossophaginae Bats in a Tropical Cloud Forest (Napo, Ecuador)

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The specialized tongue morphology adapted to extract nectar efficiently from flowers differs in lonchophylline and glossophagine bats. Lonchophyllines have one deep ventro-lateral longitudinal groove at each side of the tongue, while glossophagines have anterodorsal keratinized papillae forming a brush-like tip to the tongue. We tested how efficient different species of bats are at extracting nectar from a variety of artificial and real flowers with different floral morphologies. Species tested included two glossophagines, *Anoura caudifer* and *A. cultrata*, and one lonchophylline, *Lonchophylla robusta*. Bats were captured and held temporarily in flight cages. We assessed tongue lengths using a straw filled with nectar, measuring how deep nectar was consumed. Bats were presented with each different "flower" type, including flowers of *Marcgravia* and *Burmeistera*, and plastic tubes of six different depths and two different widths. We recorded bats visits to obtain time per visit, and weighed "flower" types before and after visits to document the amount of nectar consumed. *Anoura cultrata* possesses a surprisingly long tongue given its jaw length, and was able to extract relatively large amounts of nectar from deeper tubes. In general, glossophagine and lonchophylline tongue morphologies perform similarly in terms of nectar extraction for all flower widths at intermediate nectar depths. However, for *Burmeistera* flowers *L. robusta* was able to extract much less nectar. This could be due to the relatively narrow floral mouths and wide bases holding the nectar; perhaps the anterodorsal papillae of glossophagine tongues are better adapted to mop up nectar from these corollas.

The Complexity of Background Clutter Affects Nectar Bat Use of Flower Odor and Shape Cues While Foraging

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Nectar bats are small, have a high metabolism, and cannot store much energy in fat, thus they need to rapidly and efficiently locate the flowers they feed from. Botanists have noted various floral traits associated with chiropterophily, but little is known about whether and how nectar bats actually use these traits during foraging. In this study, we ran flight cage experiments with *Anoura geoffroyi*, *A. caudifer*, and artificial flowers to explore whether odor or shape are more important cues. In a training phase, each bat visited a flower with a specific shape and odor, whose position was constantly shifted to force the bats to actively search, rather than simply relying on spatial memory to return to the same spot. In the experimental phase, two flowers were presented, one with the 'correct' shape (i.e., the shape used with the training flower) and one with the 'correct' odor. For each experimental repetition, we recorded which flower was located first, and then shifted flower positions. The experiments were repeated for two backgrounds: simple (with nothing behind the flowers) and complex (with leaves and branches behind). In simple backgrounds there was no significant difference in which of the two flowers was visited. In contrast, in complex backgrounds flowers with the odor were most frequently visited. Bats also learned to rely more on odor over time. This study suggests that echolocation and/or vision are sufficient for locating flowers in the absence of obstructing clutter, while in cluttered habitats bats rely more on olfaction.

Eat, Prey, Love: Pre-hibernation Foraging Behavior in a Northern Population of *Myotis lucifugus*

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During autumn, temperate bats must deposit fat stores to survive winter hibernation. Populations at high latitudes face four challenges: a shorter active season (less time to accumulate fat), a longer hibernation period (larger fat store needed), colder nighttime temperatures during pre-hibernation (reduced prey availability), and shorter nights during the active season. Mating also occurs during the pre-hibernation period, placing further time constraints on populations near the northern range limit. We tested the hypothesis that these factors constrain pre-hibernation foraging in a northern populations of little brown bats (*Myotis lucifugus*). We used plasma metabolite analysis (plasma triglyceride concentration) to study pre-hibernation fuelling rates of little brown bats in central Manitoba, Canada, and compared our results with a previously published study of a more southern population. Little brown bats in central Manitoba have the longest known hibernation period of any bats, making this population ideal for testing our hypothesis. In contrast to lower-latitude bats, we found consistently low concentrations of plasma triglycerides, indicating a low fuelling rate throughout the pre-hibernation period. However, despite an apparently low fuelling rate, body mass increased dramatically and the bats ultimately achieved a substantially greater body mass than the southern population. The discrepancy between populations suggests that northern bats employ different behavioral or physiological strategies to cope with the constraints imposed by high latitude and indicate that regional differences in environmental conditions should influence time allocation and energy balance of hibernating mammals.

Testing the Efficacy of Coalescent-based Estimates of Eastern Red Bat Populations in Decline Using Msvar

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Reliable estimates of current population size are crucial for making effective decisions about how to manage populations and allocate resources to support populations in decline. In the absence of population counts, genetic-based estimates of effective population size have been used as a population monitoring tool. Here, we use simulated genetic datasets to evaluate the efficacy of one analytical tool for monitoring populations in decline. Microsatellite data sets of varying sizes were simulated under demographic scenarios consistent with that estimated for eastern red bats (*Lasiurus borealis*), a species which is currently suffering ongoing losses due to wind turbines. Simulated data sets were analyzed using Msvar to produce estimates of current effective population size, ancestral effective population size, mutation rate, and generations since decline. Results were compared to known values for each parameter. Analyses consistently arrived at highly accurate estimates of ancestral effective population size as well as narrow confidence intervals indicating a high level of precision. Estimates of time since decline were reasonably precise but tended to underestimate the generations since decline. Estimates of current effective population size showed the least precision and consistently overestimated population sizes by an order of magnitude or more. Additionally, greater precision was not seen in current effective population size as time since decline increased in the scenarios tested. Overall, our results indicate that Msvar's estimates of effective population sizes from microsatellite data are reasonably accurate and precise for ancestral populations but are inaccurate, imprecise, and significantly overestimate current effective size in populations undergoing demographic decline.

Air Traffic Control by Pallas' Long-tongued Bats at Nectar Feeders

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When several nectar-feeding bats converge on a food source, they may rely on vocal signals to minimize the chances of mid-air collision and interference by other individuals. To explore this possibility, we conducted presentation experiments among a captive all-male population of Pallas' long-tongued bats (*Glossophaga soricina)* exploiting the same point sources of nectar at the Montreal Biodome. We presented a variety of randomized playbacks every 15s over several days using an UltraSoundGate Player BL Light speaker (Avisoft Bioacoustics) under light and dark conditions. We hypothesized that these bats might use echolocation calls and/or social calls for air traffic control while feeding. Playbacks included calls from unfamiliar individual female and male long-tongued bats as well as calls produced by familiar long-tongued males from the Biodome. As controls we presented recorded echolocation and social calls from insectivorous and nectarivorous heterospecifics. We used infrared GoPro video cameras set to 60fps to record behavioral responses to playbacks, as well as a four-microphone array of UltraSoundGate microphones to record vocalizations with Recorder USGH (Avisoft Bioacoustics). We visually scored behavioral responses during and after approximately 3,000 presentations. We analyzed the duration of feeding hits and timing between feeding approaches using video, and analyzed flight speed from acoustic recordings using MATLAB Moonshine (Lasse Jakobsen). We also compared video and audio recordings to previous recordings of wild long-tongued bats feeding from a banana plant in Belize, to determine any differences between wild and captive bats.

Holes in the Digital Mist-net: Exploring Uncertainty Associated with Acousitc Identification

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Identification of bat echolocation calls to species is becoming increasingly important in North American bat research, particularly in monitoring the spread and long-term effects of white-nose syndrome and in assessing the risk to sensitive bat species posed by various types of development. However, bat call identification is a complex process, often made difficult by highly-variable echolocation calls and overlap in call characteristics among species. Acoustic identification typically relies upon recognizing "vocal signatures", i.e., echolocation calls that are characteristic of a particular species. However, bats produce a variety of calls in their echolocation repertoires aside from vocal signatures and this can lead to call misidentifications, especially in certain acoustic environments. For example, the echolocation calls of the eastern red bat (*Lasiurus borealis*) have been described by many authors and are generally thought to be relatively easy to identify. However, the eastern red bat has an extremely variable echolocation repertoire, and can emit calls that resemble several other bat species. I examine how call variation in the eastern red bat and other species can lead to uncertainty in acoustic identification. I also discuss how factors such as recording situation, incomplete characterization of the acoustic landscape, and call analysis methodology can further complicate the process of accurately identifying the echolocation calls of bats.

Changes in Bat Populations in a WNS Positive Region: Four Years of Acoustic Data from Western Maryland

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Western Maryland has been white-nose syndrome positive since the winter of 2009–2010. In order to monitor the effects of this disease on bat populations in the region, we conducted acoustic surveys between 1 June and 15 July each year from 2010 to 2013. This timing was chosen to target local adult bats, since young of the year are not yet volant. We chose eight routes, between 32 and 40 km in length, and surveyed each one four times per year. Surveyors drove the routes at 32 kph. A roof-mounted microphone, ultrasonic receiver, GPS unit, and computer were used to record bat calls continuously. Compared to 2010 levels, bat passes per minute have decreased by 31.5% overall. The largest declines occurred in *Myotis lucifugus/sodalis* (82.4%), *Perimyotis subflavus* (79.9%), and *M. septentrionalis* (64.4%). *Eptesicus fuscus/Lasionycteris noctivagans* activity levels changed only slightly since 2010, increasing by 8.2%. This group exhibited the most bat passes, accounting for 36.2% of those recorded. Both *Lasiurus borealis* and *L. cinereus* activity levels increased since surveys began in 2010; *L. borealis* by 61.3% and *L. cinereus* by 104.5%. Most of the increase in *L. borealis* occurred along routes in Allegany and Washington counties, while the increase in *L. cinereus* was more widespread. *Myotis leibii* continued to increase along the one route in Green Ridge State Forest, but decreased elsewhere, resulting in an overall increase of only 2.5% since 2010.

Autonomous Telemetry of *Myotis lucifugus* Foraging with Data Loggers

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While autonomous telemetry via data logging receivers has been used to assess bat migration and group cohesion during flight, the technology may prove useful for other research objectives. Autonomous telemetry allows for simultaneous, long term data collection on multiple bats with minimal researcher effort. We used Lotek SRX DL telemetry receivers to assess foraging habitat selection of *Myotis lucifugus* in the badlands of North Dakota. Multiple receivers were placed encircling a known roost with antennae oriented outward to separate portions of the surrounding habitat. Bats were captured at the roost, fitted with coded ID transmitters, and telemetry data was collected for 11 nights. Bat activity was also acoustically monitored at 11 sites near the roost for 6 nights per site over a 2-year period. Habitat selection for both telemetry and acoustic data was subsequently assessed based on selection ratios of used and available proportions of habitat for 13 habitat types. Telemetry results indicate that foraging *M. lucifugus* selected for deciduous forest and shrubland. Acoustic survey results indicate more generalist habitat use with some selection for habitats with available water. It is important to understand the technological limitations of autonomous telemetry for ecological applications, however, our study found consistent results, indicating that it can be a valuable tool for studying aspects of the ecology and behavior of bats.

Assessing Bats' Use of Swimming Pools as an Alternative Water Source in the United States
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Anecdotal reports suggest that as clean natural water becomes scarce, bats are using man-made water sources to satisfy their drinking needs. Our aim was to determine if bats use swimming pools as an alternative water source, if bats drown in pools, if certain pool features make them more/less accessible to bats, and if there are specific areas of the country where bats use pools more often. We created an online survey with 29 questions for pool owners and users across the U.S. The survey was open in 2013 and 2014, with 512 responses nationwide by August 23rd. Most responses were from the eastern U.S. as well as the west coast and southern states, with gaps in northern Great Plains and Rocky Mountain regions. Many (82%) respondents observed bats around their pools, and 68% of those observing bats have seen bats drinking. Of 512 respondents, 83 (16%) reported finding a drowned bat. Drowned bat responses are concentrated in southern regions of the U.S., particularly in the southeastern states. As habitat loss and urbanization pressure bats to roost in or near human dwellings, swimming pools could become a main water source for these bats. If swimming pools have negative effects on bats, this could raise conservation concerns for species already at risk. This survey will be available through the end of 2014. In spring 2015, the results will be compiled and analyzed to gain knowledge on this novel interaction between wildlife and urban society.

The Effect of Holocene Climate Change on Caribbean Mormoopid Bats
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There are three mormoopid species of bat in the Caribbean and all of them strictly roost in caves. As cave-dwelling bats, *Mormoops blainvillii, Pteronotus parnellii,* and *P. quadridens*, predominantly roost in hot chambers where temperature may reach 40°C and humidity is over 90%. We developed ecological niche models (ENMs) to estimate the present and mid-Holocene distributions of these three Caribbean mormoopid bats. Additionally, we estimated the intersection of the suitable climate conditions and karst areas to examine the hypothesis that mormoopid bat extirpations were due to microclimatic changes in cave environments after the late Pleistocene to Holocene (ca. 10 ka) climate change transition. Climate ENMs show that mormoopid bat distributions in the Caribbean have remained stable over the past 6 ka with up to a 19% expansion in the amount of suitable habitat from past to present. Karst-climate ENMs resulted in over-fit estimates of distribution in all cases and on average had a false negative rate of 50%. Previous fossil evidence shows that some populations of mormoopids became extirpated as recently as 3600 ka. Our results confirm that suitable climate habitat for mormoopid bats existed in the Caribbean beyond late Pleistocene to Holocene transition and indicate that these bats may have survived this climate change event outside their characteristic hot cave environment.

North American Bat Conservation Alliance Survey Results
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The North American Bat Conservation Alliance is a federation of groups working to address common priorities on a continental scale. NABCA is not intended to replace or direct regional working groups or topic-driven response teams, but rather provides a forum for addressing issues that cross regional and international boundaries. We polled bat biologists across the continent about conservation issues, species of concern, and roadblocks to conservation success, and asked respondents about areas lacking bat data and unique efforts to protect bats and their habitats. We received >200 responses from Canada (15% of total), the U.S. (75%), Mexico (9%), and peripheral islands (1%). Over 50% of responses came from the Midwest and eastern U.S. In Canada, most responses were from Manitoba and other western provinces. White-nose syndrome is a conservation concern for biologists in all regions except Mexico and the peripheral islands. Wind energy was a concern mainly for respondents in Canada and the Midwestern U.S. Importantly, in all regions, >65% of respondents listed habitat loss and disturbance/persecution as major threats to bats. Major roadblocks to conservation include limited funding, lack of information about bats and how they will respond to threats such as WNS or wind, and limited collaboration amongst stakeholders. Many respondents pointed to the need to educate policy makers and the public about the significance of bats and the need for conservation measures to protect both common and rare species. These data will guide NABCA's future efforts to promote bat conservation at regional, national, and international levels.

Viral Discovery in Bats: a Quantitative Review from the Last Decade
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Viral discovery in bats has increased dramatically in the past decade, yet a rigorous synthesis of the published data is lacking. We extract, synthesize, and analyze data published from nearly 100 viral discovery studies published since 2007, and identify specific variables of importance to better target future discovery efforts in bats. A total of 60,018 samples from 44,322 bats comprising 17 families, 110 genera, and 340 species were taken across 94 studies. Overall, a total of 5,946 (9.91%) of all samples tested were found to be virus or antibody positive, with 24 viral families identified overall and >200 described as "novel" viruses. We report prevalence by host family and sample type for each viral family. We found that 44% (19,484) of individual bats were killed across studies, but that this factor was never significant in models that explain number of novel viruses found or number of total viruses found. Our quantitative review has important implications for how future viral discovery studies in bats are designed, how samples are collected, and whether lethal sampling should be used. We discuss the overarching value of these studies and how they can co-exist with conservation efforts.

Spines and Sperm Storage: Genital Evolution in Bats in the Context of Reproductive Physiology
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Genitalia are extraordinarily diverse and likely evolve via several processes, primarily sexual selection. Mechanisms of sexual selection might include male-male competition (sperm competition), selection for female stimulation (cryptic female choice) or sexually antagonistic coevolution (conflict between the sexes for control of fertilization). How these processes shape genital evolution when mating system and reproductive physiology vary independently is unclear. Bats present an excellent group within which to investigate how male genital elaborations might vary in the context not only of sexual selection but also physiology and phylogeny. Amid the assorted ecologies and mating systems of bats are three types of reproductive delays including; delayed fertilization, implantation and development. Delayed fertilization (DF) occurs when females store sperm for extended periods before ovulating. By increasing the time over which fertilization occurs, species with DF may experience increased sperm competition and females may store and select among sperm from multiple mates. Previous studies concluded that baculum morphology is not associated with level of promiscuity, thus we investigated glans elaboration. We expected taxa with DF to have more elaborations (spines) to allow locking, sperm removal, sperm transfer or female stimulation. Using Scanning Electron Microscopy we examined the glans penis surface of multiple bat species to determine if the presence of penile spines relates to DF, mating system and/or phylogenetic relationships. Although there are some phylogenetic relationships in the presence and type of penile spines (e.g., Phyllostomids lack spines, Mollossids usually have spines) the relationship is complicated by both physiological mode and other biological attributes. We discuss these complications and present the results of this study integrating behavior and physiology to evaluate genital evolution.

Seasonality in the Immune Response of *Myotis vivesi* in the Gulf of California
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Animals that live in seasonal environments must cope with variation in food availability and climate, and their biological cycles are generally coupled with seasonality. *Myotis vivesi* is an endemic species restricted to the Gulf of California, Mexico, which is characterized by high seasonal fluctuations in oceanographic conditions and environmental temperature. We hypothesized that climatic seasonality would dictate general immune response patterns in this bat species, and we predicted that immune response would be lower in spring and summer than in autumn and winter. We injected phytohemagglutinin (PHA) into the footpad of bats to estimate the inflammatory response (IR), and we estimated bactericidal ability (BA) using blood plasma to determine innate immune response. Both IR and BA were estimated for males and females in each climatic season during two years. According to our hypothesis IR and BA were significantly different among seasons. Inflammatory response was significantly lower in spring than in summer, autumn and winter, and BA was significantly lower in spring and summer. Our findings suggest that both inflammatory and innate immune responses in *M. vivesi* vary seasonally. Variations in IR and BA might be related to bat´s reproductive pattern, because gestation takes place in spring and lactation in summer.

Green Roofs Provide Foraging Habitat for Bats in New York City
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Understanding bat use of human-altered habitat is critical for developing effective conservation plans for this ecologically important group. Green roofs, building rooftops covered in growing medium and vegetation, have become increasingly important conservation tools that make use of available space to provide breeding and foraging grounds for urban wildlife. They are especially important in highly urbanized areas such as New York City (NYC), which has more rooftop (34%) than green space (13%). To date, no studies have examined the extent to which North American bats utilize these microhabitats. To investigate the role of green roofs in supporting urban bat populations, I monitored bat activity using ultrasonic recorders on four green and four traditional roofs located highly developed areas of NYC, which were paired to control for location, height, and local variability in surrounding habitat and species diversity. I then analyzed and identified calls to the species level. Results indicate the presence of five of the nine bat species found in New York State, significantly higher levels of forging activity over green roofs than over traditional roofs, and higher species richness on green roofs. This study provides evidence that, in addition to many other ecosystem benefits, urban green roofs provide important patches of habitat that support a variety of bat species.

Evaluating Species Boundaries of a Monophyletic Group, *Dermanura*
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Morphological studies have failed to resolve the number of, and relationships among, species within the genus *Dermanura* (Chiroptera: Phyllostomidae), with morphologically based species delimitations ranging from one to ten. It is unclear to what extent complex evolutionary histories and ancient or ongoing patterns of gene flow contribute to this uncertainty. Recent evaluation of the Cytochrome-*b* gene has recovered eleven statistically supported monophyletic species-level groups which were generally correlated with morphology. Because of a common lack of congruence among previous morphological methods for many taxa, we used the genetically defined monophyletic bat genus *Dermanura* to assess congruence among previous morphological data with mitochondrial and nuclear datasets (amplified fragment length polymorphisms (AFLPs) and microsatellites). Morphological and mitochondrial DNA datasets were found to be incongruent with both nuclear datasets. Notably, a previous allozyme study (Koop and Baker 1983) found very few fixed differences, but considerable shared polymorphisms, among species of *Dermanura*. Contrasting results among datasets may reflect incomplete lineage sorting at the nuclear level (i.e., microsatellites) or reticulated evolution of sympatric populations (i.e., AFLPs). In an effort to further diagnose the lack of congruence among these datasets, and to qualify the potential role of gender-biased life history characteristics in shaping these patterns, future work will incorporate sequence data from paternally transmitted Y-chromosome.

The Cultural Potential of Bats
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Culture, defined here as group differences in socially-learned behaviors, can range along a continuum from group differences to normative and symbolic culture, traditions, and cumulative culture Theoretical and empirical studies across a range of taxa have revealed that these different forms of culture are shaped by relationships among

biology, ecology, social learning, and social structure. Specifically, culture is more likely when individuals 1) are long-lived, 2) live in moderately variable environments, 3) are capable of tracking relationships and changes in the environment, 4) learn from others, and 5) live in moderately stable groups. Many bats demonstrate these features, which they share in common with elephants, cetaceans, and primates that are commonly cited as exhibiting culture. Yet bats have been noticeably absent from the discussion of animal culture. We therefore reviewed existing literature using Greggor's framework for examining the cultural potential of a species for evidence of culture in bats. Indeed several species show group differences in socially-learned vocalizations that appear to be normative and symbolic of group identity. Evidence of group-specific foraging grounds and roost-use are also suggestive of the potential for culture in several bat species that warrants more detailed examination. In fact, with roughly 1,200 species distributed globally, bats vary in diet, roost-use, and social structure, thus offering an opportunity to explicitly test hypotheses about the roles of biology, ecology, social learning, and social systems in the evolution of culture. In turn, examining culture in bats may have implications for understanding group dynamics and speciation.

Bat Activity Survey of Wrangell-St. Elias National Park and Preserve, Alaska

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Little is known about bat activity in high latitude areas, especially Alaska. While presence may not be known, these areas may benefit from the many important services bats have to offer such as natural insect pest control and pollination. In the summers of 2012 and 2013, Gary McCracken and Justin Boyles acoustically surveyed the area of Wrangell-St. Elias National Park and Preserve in Alaska. We hypothesized that bats, if any, in this area of Alaska were more likely to move along the Copper River Valley. Through my analysis of thousands of bat call recordings as well as Sonobat identification, our results show that bats of multiple species are more present along this valley than in other areas outside this valley. This being said, our results are not sufficient to actually conclude movement patterns of bats in Alaska. Furthermore, it is necessary to trap bats to properly confirm our species results. Our results suggest that more bat species of higher numbers are present in areas of Alaska. The preliminary findings set the groundwork for future studies as well as implementing conservation strategies.

Species Delimitation in the Genus *Pteronotus* (Chiroptera: Mormoopidae) through an Integrative Approach

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A phylogenetic systematics perspective is instrumental in recovering new species and its evolutionary relationships. The advent of new technologies in the last two decades revealed a hidden diversity for many groups, bringing taxonomic issues back to a fundamental position in evolutionary studies. Consequently, a new trend is observed in systematic researches, which are incorporating concepts from areas such as ecology, population and quantitative genetics for delimiting species through different sources of evidence. The genus *Pteronotus* (Chiroptera: Mormoopidae) are a good model for the application of this integrative approach. According to the last systematic review it has six species with 17 subspecies. Posterior studies using discrete morphological characters support the same arrangement. However, recent papers reported high levels of genetic divergence among conspecific taxa followed by bioacoustic and geographic agreement, suggesting an underestimated diversity for the genus. To date, no work merging genetic evidences and morphometric variation along the entire geographic range of this group was realized. Based on a comprehensive sampling and an integrative approach including multi-locus inference and skull morphometrics, we investigated the variation in all the current species of *Pteronotus*. The phylogenetic analysis reveals a greater diversity than previously reported, with a high correspondence among the genetic lineages and the currently recognized subspecies. Discriminant analysis of 41 variables describing size and shape of cranial bones support the rising of these groups to the specific status. Therefore, we present an updated taxonomic arrangement composed by 17 species and the phylogenetic relationships within the genus *Pteronotus*.

Comparing Indiana Bat Roosts at Two Sites Using Dendrochronology
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Indiana bats often use snags as roosts but we are limited in our knowledge of snag ages and time between death and use as a roost. Height and girth are typical measures of roost trees, but these measures do not yield data on the tree's age or decay time. Our objective was to determine age at death of Indiana bat roost trees and the time a snag is dead before housing bats. We used dendrochronological methods to sample Indiana bat roosts, 32 in central Indiana and 31 from the southern Appalachian Mountains in Tennessee and North Carolina. We found that before being documented as roosts, snags stood dead 4.5±0.99 years (n=13) and 9.3±0.95 years (n=6) in Indiana and TN/NC respectively. The median age of roosts is 102 years in Indiana and 90 years in TN/NC. Across both study areas, primary roosts ranged in age from 58–283 years. Relatively young trees served as primary roosts; for example, in Indiana, four of seven primary roosts were early successional species (e.g., cottonwood) and early successional species were also used regularly in TN/NC (e.g., white pine). Early successional species may be a short-term surrogate for suitable Indiana bat habitat in the absence of mature late successional trees, such as oaks and shortleaf pines, which are known to be excellent roost habitat. Tree ring data may also help us to understand gap dynamics, gap infilling and their relation to the influx of nutrient inputs from bat guano.

Prioritizing Caves for Bat Conservation: Identifying Factors that Shape Cave Bat Diversity in the Philippines
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Caves are critical roosting sites for many bat species, housing some of the largest and most diverse aggregations of bat species in the world. However, cave-dependent bat populations are declining globally, with cave disturbance identified as the leading cause of these declines. In the Philippines, caves are protected under the National Cave Act, yet implementation of the Act is hindered by a lack of information to identify caves to protect. Thus, to prioritize caves to conserve cave bat assemblages, it is vital to identify factors that influence bat diversity in caves. No studies to date have explicitly quantified factors, both anthropogenic and environmental, that may shape assemblages of cave-dependent bats in the Philippines. Anthropogenic (visitation rate, hunting intensity, mining, etc.) and environmental (cave dimensions, microclimate, roost area) factors were assessed at 60 caves on Bohol Island in the central Philippines, and compared with species diversity and composition of bat assemblages documented over two consecutive nights at each cave. Between July 2011 and June 2013, we captured 7,419 individuals comprising 24 bat species. Using non-metric multidimensional scaling we elucidated the primary drivers that shape cave bat diversity and composition. Results are used to evaluate the significance of individual caves for maintaining viable populations of cave-dependent bats, a priority under the National Cave Act.

Wound Healing in the Flight Membranes of Wild Big Brown Bats
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The flight membranes of bats are susceptible to damage from impacts with natural and man-made objects, fighting with conspecifics, and attacks by predators. Extensive flight membrane damage can also occur in bats that survive an infection with *Pseudogymnoascus destructans,* the fungus that causes white-nose syndrome. Membrane biopsy is a common procedure used by bat researchers to collect tissue samples and/or to temporarily mark animals in the field. A previous study by Faure et al. (2009; *J. Mammalogy* 90:1148) demonstrated that flight membrane wounds rapidly healed in captive big brown bats (*Eptesicus fuscus*), with the tail membrane (uropatagium) healing faster than the wing membrane (chiropatagium) for wounds of the same size likely because of the increased thickness and vasculature of the uropatagium. Given that biologists routinely biopsy bat flight membranes in the field, we sought to determine whether the relative healing times of the wing and tail membrane measured for *E. fuscus* in captivity were valid in the wild. We used a 4 mm diameter biopsy punch to inflict circular wounds in the wing and tail membrane of 50 non-reproductive adult female *E. fuscus* from a colony in Cuba. Following recapture, we found that the uropatagium healed significantly faster than the chiropatagium. Thus, the relative healing times we measured from free-ranging *E. fuscus* were concordant with wound healing times measured from bats in captivity. Our data also confirm that tissue excision from the chiropatagium is better for long-term identification of bats in the field because the wound and scar persist longer.

Does Parturition Date Impact Adult Female Survival in *Myotis lucifugus*?
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Previous studies of temperate zone bats have indicated that juvenile survival is lower for pups born later in the season, presumably because they have less time to store fat prior to winter hibernation. If this presumption is correct, mothers that give birth later may also have lower survival in years when they give birth late. We conducted a four-year field study at a *Myotis lucifugus* maternal colony in western Illinois. We palpated gravid females and placed them into two categories based on fetal size: "early" (before June 21st) and "late" (on or after June 21st). We banded females and recaptured females from 2011 through 2014, then used program MARK to estimate apparent survival. We then constructed generalized linear models of apparent survival using parturition date, year, and an interaction between parturition date and year as predictor variables, and chose the best model using Akaike Information Criterion. Our data support the hypothesis that adult female survival is lower for females that give birth late in the reproductive season. Adult female survival is typically the predominant factor that determines population growth in long-lived species like bats, so these results suggest that variation in reproductive phenology could have a large impact on *M. lucifugus* population dynamics.

A Phylogenetic Approach to Bat Intramembranous Muscle Diversity and Evolution
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The plagiopatagiales proprii are a group of muscles embedded within the bat wing membrane. They activate in synchrony during the flight downstroke, likely to maximize force production. We examined plagiopatagiales proprii number and cross-sectional area in a phylogenetic context to gain insight into the diversity and evolution of this major component of bat wings. Using published mitochondrial and nuclear sequences, we inferred the phylogeny for 73 bat species representing 16 of the 17 bat families and five outgroups by applying maximum likelihood and Bayesian algorithms. The best phylogeny was then scaled to time using previously published fossil constraints. Using a newly compiled database of plagiopatagialis proprius thickness and width from high-resolution polarized lighes from museum collections, we calculated muscle cross-sectional area. We then applied a series of comparative methods to test the hypothesis that selection increases total muscle cross-sectional area to control the wing. Increases in cross-sectional muscle areas were strongly related to changes in both the number and mean cross-section of muscles. Total plagiopatagiales proprii cross-sectional area scales isometrically to body mass, suggesting geometric constraints. Relative to the reconstructed ancestral condition, and contrary to our hypothesis, plagiopatagiales are reduced in vespertilionids and in *Macrotis waterhousii*, a phyllostomid. In several other parts of bat phylogeny, average muscle cross-sectional area and muscle number increase. Our analyses show multiple mechanisms, including selection, operate on the plagiopatagiales proprii of different bat lineages and suggest a rich field for future studies of the functional and evolutionary significance of the patterns of intramembranous muscle evolution.

The Epidermal Fatty Acids of *Myotis lucifugus* Influences the Growth of *Pseudogymnoascus destructans*
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White-nose syndrome (WNS) increases over-winter mortality for several species of bats in North America; little brown (*Myotis lucifugus*), Indiana (*Myotis sodalis*) northern (*Myotis septentrionalis*) and tricolored (*Perimyotis subflavus*) bats. The fungus *Pseudogymnoascus destructans* (*Pd*) produces a cutaneous infection resulting in the disruption of torpor patterns, leading to the exhaustion of depot fat and eventual death. Despite increases in mortality of certain species, such as *M. lucifugus*, other bat species do not exhibit increased mortality such as the big brown (*Eptesicus fuscus,* North America) and the greater mouse-eared bat (*Myotis myotis,* Europe). The epidermis acts as a physical barrier to infection and the stratum corneum of mammals contains free fatty acids, some which are known to exhibit antimicrobial/antifungal properties. Wing epidermis from *M. lucifugus* was analyzed prior to and during hibernation. Seven fatty acid types were found: myristic, pentadecanoic, palmitic, palmitoleic, stearic, oleic, and linoleic acids. Pentadecanoic and oleic acid levels increased during hibernation while the level of linoleic acid decreased. Laboratory culture experiments were performed to determine the influence each fatty acid had on *Pd* growth. Pentadecanoic acid had a minimally negative effect on *Pd* growth. Oleic and linoleic acid both greatly inhibited *Pd* growth, with linoleic acid having a much larger effect. These findings suggest that the fatty acid profile of wing epidermis can influence the severity of *Pd* infection, and the ability to resist *Pd* infection may decrease throughout hibernation in *M. lucifugus* leading to increased WNS mortality.

Monitoring Bat Populations Impacted by White-nose Syndrome through Winter Colony Surveys

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Since 2007, white-nose syndrome (WNS) in North America has spread in all directions from 5 hibernacula in 2 counties in upstate New York to hundreds of hibernacula in 25 states and 5 provinces up to ~1800 km away. Quantifying the impacts to bat populations is challenging due to the limitations in existing data, and these challenges are compounded by behavioral changes resulting from the disease and the open nature of hibernating colonies between years. Of the seven bat species diagnosed with WNS in North America, six have exhibited losses that can be attributed to the disease. We report results from over 1800 winter surveys conducted at over 270 caves, mines, and tunnels in 16 WNS-affected states and provinces over the past 35 years. We assessed changes in colony sizes for 12 species by site, region, and species. Responses to WNS varied among species and location and some species have increased in number at a few sites, although most such increases have been small or temporary. Overall, *Myotis lucifugus* has experienced the greatest total observed losses. No WNS-associated mortality or population declines have been documented for *M. grisescens*, despite this species having been documented with the disease. Although assessing population- or species-level changes from winter hibernacula surveys has environmental, biological, and logistical limitations, the data from these efforts are still the best available for most hibernating bats in eastern North America, and are critical for monitoring how WNS or other threats are impacting species.

Seed Dispersal by Tent-roosting Bats in the Lacandona Rain Forest, Chiapas, México

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In the Neotropics, more than 80% of the plant species are dispersed by vertebrates that feed on their fruits, contributing to generate and maintain plant diversity in the tropical forests. However, current defaunation caused by human factors, such as hunting and habitat loss, is turning large-body vertebrates scarce, which threatens the demographic recruitment of many of the tropical tree species. Therefore, it would be expected that the remaining fauna, composed mainly of small vertebrates, and especially fruit-eating bats, play a key role in the dispersal of large-seeded plants. To assess the relationship between tent making bats and seed dispersal, we surveyed approximately 27km of trails in two sites in the Lacandona forest for the presence of tents. We found over 200 tents in 148 palm plants from four different architectures. Tent density was 9.14 tents / ha. On the other hand, we collected 2864 seeds deposited beneath the tents during 9 months and we found that tent-roosting bats can disperse at least 50 species of larger seeds. Our findings indicate that the tent roosting bats play an important role in the maintenance and regeneration of the tropical forest. Their large-scale effects are likely essential for forest regeneration.

Sexual Dimorphism in Ears and Leaf-nose Coloration of Tent-roosting Bats

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Sexual selection by color is usually given in visual vertebrates such as birds and primates but little is known about bats. Ears and leaf-nose coloration of Neotropical tent-roosting bats were studied using photography and pixel color intensity analysis in Costa Rica. Bats of the species *Uroderma bilobatum* and *Ectophylla alba* were captured and photographed. Photos were viewed in Photoshop® and red, green, and blue color intensities were recorded for several pixels at multiple locations on bats' faces. Color intensities were analyzed comparing sex, reproductive state, and length of time bats were in captivity before photos were taken. Differences in color intensity were found between males and females and between reproducing and non-reproducing males of both species. Additionally we found a relation between color intensity and time bats' were in captivity for both species. Ear locations exhibited more difference than leaf-nose locations in color intensity between males and females and between reproducing and non-reproducing males. Results suggest ear and leaf-nose coloration as a factor in sexual selection, including significantly greater intensity of all colors in males than in females at the tragus tips of *E. alba*, and a stronger relation between a color intensity decreasing and the time in captivity for males than for females in *U. bilobatum*. Possibly the type of roost influences the coloration of ears and leaf-nose of bats, as the species in caves are much more inconspicuous than those living in vegetation, which may indicate that the color may itself be subject to sexual selection.

Validating and Refining a *Myotis sodalis* Presence Probability Model

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Endangered Indiana bat (*Myotis sodalis*) populations face many threats, including white-nose syndrome (WNS). Understanding the species' distribution will allow us to protect its summer habitat effectively. Our research site was the North Cherokee National Forest (CNF) in northeast Tennessee, where WNS was first detected in 2009–10. The distribution of *M. sodalis* encompasses the CNF, however there are no capture records in the North CNF. Our objective was to validate and refine a MaxEnt roost habitat probability model created for bordering regions south of our focus area. We adapted the model to include the North CNF and used it to predict areas of low, fair, and high probability of presence. We surveyed 36 sites during May–July 2013–2014, with mistnet and acoustic methods. We used Anabat SD2s at road corridors that we mist netted. Acoustic data were analyzed using Bat Call ID v2.6a. Preliminary analyses show we recorded *M. sodalis* at 21 sites (63.6 % of low sites, 50% of fair, 72.7% of high) although we did not capture this species at any site. Because we recorded *M. sodalis* at most sites and across all probability classes, we plan to refine the existing model for the North CNF. We will use MaxLike to create the probability model, with site and landscape measurements (e.g., elevation and distance to open grassland or agriculture) and 2013–2014 acoustic results as predictors of *M. sodalis* presence. With decreasing populations and likelihood of captures, probabilistic models may serve as alternative resources for informing decisions about future management actions.

Rock Climbing vs. Rocky Mountain Bats

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The Front Range of Colorado is located along the southeastern region of the Rocky Mountains, and is home to nine species of bat. Of these, no fewer than six species (*Corynorhinus townsendii, Eptesicus fuscus, Myotis ciliolabrum, M. evotis, M. lucifugus*, and *M. thysanodes*) have been observed using the crevices of the Rocky Mountain Foothills as roosts. Presumably, these microhabitats may be critical for the establishment of maternity colonies for at least some of these species. We investigated the impacts of rock climbing on roost selection by bats, and hypothesized that increased rock-climbing would decrease the quantity of roosts, and the number of roosting individuals in the crevices. We sampled nine sites throughout the City of Boulder Open Spaces and Mountain Parks, based on the degree of rock-climbing use (low, medium, or high) of the eastern cliff-faces. For species identification of roosting bats, we recorded calls using SM2Bat+ devices (with directional acoustic horns), which were placed near

the cliff's base, and with the microphones angled equally to the cliff-face. Kruskal-Wallis tests based on visual counts showed no difference in the quantity of roosts among use-levels ($H = 2.42$; $p = 0.29$); however, the cliffs with the greatest number of roosting bats were those of medium-use by rock climbers ($H = 7.16$; $p = 0.027$). In addition, no differences were found in the number of foraging bats observed among use-levels ($H = 1.28$; $p = 0.52$), suggesting a preference for certain cliffs over others for the purpose of roosting, but not foraging.

Estimating the Effective Population Size of the Common Vampire Bat at the Edge of Their Range
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Understanding the demography and evolutionary history of a species at the edge of its range can provide insight into factors influencing the distribution of a species. In a long term study from 2003–2010 we sampled common vampire bats (*Desmodus rotundus*) across the northeastern-most portion of their range in the states of San Luis Potosí and Tamaulipas, Mexico. From over 600 samples, we obtained mitochondrial DNA sequences and nuclear DNA genotypes from 12 microsatellite loci. Our ultimate goal for this project is to estimate the magnitude and timing of population expansion in this portion of the species' range, as field work suggests vampire bats from this region are being found farther north and at higher elevations than expected. As preliminary analyses for this goal, we present here analyses of geographic and sex-biased population structure, as well as statistically rigorous estimates of effective population size.

Roost Specialization: a Critical Factor in Extinction Risk
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Understanding causes and consequences of ecological specialization is of major concern in conservation. Specialist species are particularly vulnerable to human activities; if their food or habitats are depleted or lost, they may not be able to exploit alternative resources, suffering population losses. Here we provide evidence that roost specialization is an important correlate of extinction risk in bats. We test the hypothesis that species that use fewer roost types are at greater risk of extinction. This is the first study that investigates the relationship between roost specialization and extinction risk in bats worldwide, accounting for phylogenetic nonindependence. We found a significant correlation between the IUCN Red List category and the number of roost types used. In general, species using fewer roost types had a higher risk of extinction. Caves and similar structures are the most widely used roost types, particularly by species that are under some level of risk of extinction. In addition, many critically endangered, endangered or vulnerable species use natural roosts exclusively; whereas less threatened species use natural and human-made roosts. Our study suggests that roost loss, particularly in species that rely on a single roost type, may be in fact a major cause of extinction risk.

Bat Anatomy *in silico*: Using High Contrast Micro-CT Imaging to Understand Morphological Evolution
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Modern computational and imaging methods have tremendously enhanced our ability to document and measure complex morphological structures and investigate their macroevolution. The use of X-ray Computed Tomography (CT) and micro-CT has become increasingly accessible, allowing functional morphologists to describe, quantify and compare the internal and external anatomy of bone tissue in bats and other vertebrates with unprecedented detail and in three dimensions. However, because non-mineralized tissues have low X-ray absorption, similar advancements have not been attained for soft tissues, and many aspects of the internal morphological diversity of bats remain unknown. Here I describe how the soft-tissue anatomy of bat heads can, for the first time, be fully visualized in adult individuals using iodine-enhanced micro-CT protocols. These methods have proven successful in the study of soft-tissue morphology in invertebrates, vertebrate embryos, archosaurs, rodents, lagomorphs and carnivorans. This research capitalizes on these previous studies and compares tissue contrast levels resulting from treatments of Lugol's iodine on intact bat heads. Using a varied sample of bat species, I further demonstrate the value of these methods for generating realistic computer renditions of the three-dimensional anatomy of structures including the brain and cranial musculature, which allow for accurate documentation, quantification and modeling of their function.

Bat Assemblage and Selection of Maternity Roosts in a Post-wildfire Forested Landscape
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Ponderosa pine (*Pinus ponderosa*) forests in the southwestern U.S. have increased in density over the last 100 years following EuroAmerican settlement and subsequent changes in fire suppression, logging, and livestock grazing. These changes dramatically increased the size and severity of wildfires. Although wildfires rarely kill animals, they have immediate consequences to bat populations by drastically altering vegetation which affects roosting and foraging. We documented effects of the 2011 Wallow Fire (217,721 ha) on bats 2- and 3-years post-wildfire. We assessed how low (~25% basal area removed) or high (~75% basal area removed) fire severity affected the bat assemblage and roost selection by reproductive female bats. We captured bats at water sources to identify the bat assemblages, radio tagged bats, and located maternity roosts for 4 species. We measured characteristics of roost snags for comparison to randomly-selected snags. Species richness at ponds surrounded by low- or high-severity burn was similar 2 years post-fire but greater at low- (13 species) compared to high-severity (10 species) sites 3 years post-fire. Preliminary results show that 24% of snags were completely burned and Arizona myotis (*Myotis occultus*) selected unburned over burned snags. However, since some roosts occurred in charred conifer snags ≥26.5 cm diameter at breast height, even small fire-killed snags offer habitat for reproductive female bats. Lower species richness at the high severity sites could indicate a decline in bat species in areas impacted by high severity fire.

The Effect of Aspect Ratio on the Generation of Lift and Drag of Bat-like Flapping Wings
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Aspect ratio is frequently used to describe bat wing shape variation. Bats with high aspect ratio wings are expected to fly with high efficiency and to have superior lift-to-drag ratios. In contrast, bats with lower aspect ratio wings are thought to exhibit higher maneuverability. However, those assumptions derive from theoretical models based on fixed wing aerodynamics. We tested flight performance of a flapping bat-like mechanical model with highly compliant wings, in which it was possible to vary aspect ratio while keeping constant other basic parameters, such as flapping frequency and amplitude. We built wings with different aspect ratios that, while simplified, preserve many important features of bats such as a sharp leading edge of the propatagium, skeletal reinforcement of a compliant membrane and bat-relevant ratios of plagiopatagium to dactylopatagium. A two-degree-of-freedom shoulder joint allows for independent control of flapping amplitude and wing sweep to mimic the flapping motion of bats. We measured the lift and drag forces generated by these bio-inspired mechanical wings flapping at frequencies that range from 2 to 10 Hz. Even with our very simplified model, the results do not show a clear dependency of aspect ratio and lift-to-drag ratio. This suggests that in bats, in which many parameters vary constantly, aspect ratio alone might not effectively quantify flight performance.

Timing the Developmental Origins of the Bat Wing
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A major goal of evolutionary biology is to understand the mechanisms that generate the divergent morphologies that characterize the history of life. The bat forelimb, or wing, has arguably among the most divergent adult morphology of mammals. Bat wings are supported by greatly elongated long bones, especially those of the third, fourth and fifth digits that support an interdigital webbing. To investigate the developmental processes that produce the unique morphology of the bat wing, we took a two-pronged approach. First, we used low- (i.e., ISH) and high- (i.e., RNASeq) throughput methods to assay gene expression in developing bat limbs, and the limbs of mice, pigs and opossums from comparable developmental stages (limb ridge, bud, paddle). Second, we quantified limb morphology at these stages for all species, and compared the results. Our results suggest that the gene expression profile and morphological shape of the bat forelimb closely resemble that of other mammals during its earliest outgrowth (limb ridge), but diverge from other mammals shortly thereafter at the bud stage (when the limb is as wide as tall). We also identified several genes that are differentially expressed in bat fore- and hind limbs, and between the forelimbs of bats and other mammals at these later stages consistent with a role in the generation of the unique structures of the bat forelimb. Taken together, our findings suggest that the earliest development of the bat forelimb is conserved, and that the changes that led to the unique bat wing occurred at subsequent developmental stages.

Using Carbon and Nitrogen Stable Isotope Signatures in Bat Fur to Make Inferences on Regional Migration

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Migratory patterns of bats are not well understood and traditional methods to study these, like mark-recapture, often do not provide enough detail. Stable isotope profiles of many animal species have been studied to make inferences on migration. *Myotis lucifugus* and *M. septentrionalis* migrate every year from summering roosts to swarming sites in the fall, but how bats move between these sites is not well understood. In this study, carbon ($\delta^{13}C$) and nitrogen ($\delta^{15}N$) isotopes of 305 *M. lucifugus* and 200 *M. septentrionalis* fur samples were analyzed to make inferences on migration patterns between summering and swarming sites in Nova Scotia, Canada. We expected that there would be greater variability in $\delta^{13}C$ and $\delta^{15}N$ among individuals at swarming sites because it was believed that these sites are used by individuals originating from many summering sites. There was extensive overlap in the standard ellipse area (SEA_c) of bats at swarming sites, whereas there was much less overlap in SEA_c among summering sites. For *M. lucifugus*, swarming sites had larger SEA_c than summering sites and discriminant analysis assigned swarming bats to several summering sites. *Myotis septentrionalis'* SEA_c was much smaller than *M. lucifugus* indicating a more narrow dietary niche breadth. Isotopic profiles of *M. lucifugus* varied among summering sites and the data support the contention that swarming sites are catchment areas for bats from multiple summering sites. These data suggest that $\delta^{13}C$ and $\delta^{15}N$ profiling of bat fur offer potential to make inference on regional migration in bats.

Collision-Avoidance in Cluttered Environments: Do the Responses to Obstacles Align with Wing Morphology in Insectivorous Bats of Malaysia?

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It is predicted that differences in wing morphology will reflect differences in foraging strategies of bats. Several studies have experimentally tested this prediction, providing a better understanding of the relationship between morphology and maneuverability. However, studies have lacked measures of flight performance ("ability" scores) and, as a consequence, the unidimensionality of flight performance has never been validated. To determine the relationship between flight performance, wing morphology and foraging strategy in an insectivorous bat assemblage we conducted a collision-avoidance experiment using 15 species of Paleotropical insectivorous bats from three families. Flight performance scores were quantified based on individual responses to 11 different obstacle arrangements (four banks of vertical strings 10–60 cm apart). Flight performance was scaled using Rasch analysis—an approach widely used in human sciences. Both bat ability and obstacle difficulty appear along the same scale and all inter-string distances fit to define a unidimensional variable of flight maneuverability. Spearman's rank correlation coefficients indicated that there were significant negative correlations between flight performance and wing area, body mass and wing span. There was also a significant negative correlation between flight performance and wing loading but not with aspect ratio or wingtip index. These findings suggest that species' responses to obstacles were largely determined by size, bats with smaller wing area, body mass and wing span having greater maneuverability. They also indicate that species with relatively lower wing loading will perform better in a collision-avoidance experiment.

***Speciation and Skull Morphological Evolution Are Decoupled across Extant Bats**
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* **Jeff Shi** received the **Karl F. Koopman Award**.

Diversity—whether it be taxonomic, morphological, or ecological—is not evenly distributed across the tree of life. For every clade that has explosively radiated into a variety of forms and functions, there are clades that have remained constrained and species-depauperate. Though classical models of adaptive radiations predict that morphological evolution and speciation are closely linked in many species-rich groups, it is unclear how prevalent this pattern is across modern organisms. Using a species-level, multilocus molecular phylogeny, we assess the macroevolutionary dynamics that have structured both diversification and trait evolution across extant bats. Our phylogenetic data are paired with trait data from skulls from all non-monotypic extant families. We use the program Bayesian Mixture of Macroevolutionary Mixtures (BAMM) to infer macroevolutionary rates and regime shifts across bats, for both diversification and trait evolution. We establish that, while distinct, clade-specific regimes govern both diversification and trait evolution dynamics across extant bats, they are decoupled from one another. Diversification dynamics are relatively homogeneous, save for an accelerated burst at the base of the subfamily Stenodermatinae. By contrast, morphological evolution is dominated by bursts of accelerated phenotypic evolution in the family Pteropodidae and across the superfamily Noctilionoidea. These patterns lead to overall rates of diversification and rates of morphological evolution that are entirely uncorrelated from one another. Our BAMM results suggest that, while bats as a whole may be a classical example of an adaptive radiation, the relationship between morphological evolution and diversification within the clade is considerably more complex.

Scrotal Pigmentation in Bats: a Mysterious Trait Revisited
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Animal pigmentation is incredibly diverse serving a variety of functions including heat balance, social signaling, and crypsis. A particularly unusual type of pigmentation is that surrounding the reproductive organs of some male vertebrates. Indeed, some species of fishes, mammals and amphibians have coloration associated with their reproductive organs. However, the function of this melanization remains poorly understood. Bats show extensive diversity both in ecologies and the presence of a darkly pigmented tunica vaginalis surrounding the testes. Why might this structure be melanized in some bat species but not others? We explore several hypotheses regarding the selective benefits of scrotal melanization in bats. For example; melanin may protect testes from UV radiation or play a role in male sperm storage. Alternatively, coloration may be a byproduct diet, enable testis thermoregulation, crypsis, indicate male quality; or reflect phylogenetic relationships. We examine the roles of: roosting habitat and UV radiation, diet, mating systems, sperm storage and phylogeny in 138 species of bats. Although melanin is predicted by exposure to UV radiation, additional complexities were noted. Sperm storage, diet, sun exposure, and roost behavior all predict if a bat species has scrotal pigment (i.e., insectivorous, arboreal bats exposed to the sun are more likely to have pigment). Surprisingly, we did not find strong phylogenetic relationships in the presence of scrotal pigmentation. We conclude with several suggestions for future studies on reproductive pigments.

Roost Tree Selection by Bats — What Do Random Trees and One Year of Data Really Tell Us?
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Day-roost characteristics often are compared to those of randomly paired trees to describe bat day-roost selection. Few studies, however, have looked at patterns of multi-year selection or compared roosts used in different years, despite the fact that roost selection is widely considered to be related to climatological factors that may vary from year to year. We explored the process of determining roost selection using two years of roost selection data for northern long-eared bat maternity colonies on the Fort Knox Military Reservation, Kentucky, USA. We compared characteristics of random trees and roosts used in two different years using a multinomial logistic model and day-roost species selection using Chi-square tests. We found that the factors differentiating day-roosts from random trees and roosts between years varied substantially. Day-roosts differed from random trees in the first year of data in all

measured factors, but only in diameter at breast height and decay stage in the second year. Between years, day-roosts differed in roost size and canopy position, but not decay stage. Day-roost species selection was non-random and did not differ significantly between years. While bats use multiple trees within a colony, our results suggest that there are unused trees that are suitable for roosts at any time. Day-roost selection patterns are inadequately described with only a single year of data, and comparisons with random trees may be less informative in some instances than comparisons of roost trees used in different years.

How Many Different Kinds of Bat Sonar Are There?
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Across different bats, there are FM signals, FM/QCF signals, QCF signals alone, short-CF/FM signals, long-CF/FM signals, and clicks, with various combinations of one or more harmonics. What do these sounds mean in terms of behavior and perception? Wider signal bandwidth means better perception of target location, and more continuous coverage of frequencies means better image quality for object shape and flutter. While flying and hunting in the open probably can be supported by even modest signal bandwidth, the presence of continuous FM sweeps and multiple harmonics appear to be important to operate in clutter. Short-CF and QCF signals are used for enhanced longer-range detection because energy is concentrated in a narrow band and auditory sensitivity is correspondingly concentrated. Long-CF signals have conferred special sensitivity to insect flutter, which has moved bats into a different acoustic class, with Doppler-shift compensation to zero out flight velocity. Nevertheless, long-CF bats always emit FM components that they emphasize when flying in clutter and in each other's company. FM bats adapt their signals to clutter and to each other, especially with respect to segregating echoes according to broadcasts. Not surprisingly, convergence on similar signals has occurred across several taxa (e.g., *Rhinolophus* sp. and *Pteronotous parnellii* group; Hipposideridae and most Mormoopidae; Phyllostomidae, Megadermatidae, and Nycteridae; Molossidae and Vespertilionidae). Auditory perception involves the dimensions of pitch, timbre, and location. Can the same auditory receiver match different types of sonar sounds, perhaps only with local alterations in the inner-ear frequency scale (e.g., smoothly exponential vs. acoustic fovea)?

A New Family of Large Omnivorous Bats from the Late Eocene of Egypt
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The Eocene was a time of explosive diversification for Chiroptera. The oldest known bats are early Eocene in age (~55–52MY BP). Thirty families of bats are currently recognized, including ten known only from fossils, and virtually all of these lineages were distinct by the end of the Eocene (~34 MY BP). A new fossil from the BQ-2 locality in the Fayum Depression of northern Egypt (dated to ~37MY BP) does not fit within the diagnosis of any previously described family of bats. Known from a partial maxilla, this taxon has molars with a well-developed W-shaped ectoloph lacking a distinct mesotyle but with a strong parastyle and shallow U-shaped ectoflexus—all traits that are found in most archaic bat families and which are probably plesiomorphic for bats. However, this taxon also has an M2 with a large metaconule cusp and a large, bulbous hypocone set low on the posterolingual corner of the tooth, neither of which occur in any other known bat family, living or extinct. Also notable is the size of the new BQ-2 bat, which appears to have been only slightly smaller than the largest extant bats with tribosphenic dentitions. The molars of the new bat lack the high, sharp crests and elongated preparacrista and postmetacrista common in large tribosphenic bats, features that are associated with an insectivorous/carnivorous diet. The combination of traits suggests that the BQ-2 bat may have been more omnivorous than other known Eocene bats, perhaps including plant material in its diet.

Chromosome Painting Reveals Unique Karyotypic Reorganization in the Phyllostomid Bat, *Tonatia saurophila

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The term karyotypic megaevolution was coined in the early 1980's to describe major repatterning of the synteny of genomic segments presented by some species. The phyllostomid bat *Tonatia saurophila* was used as an example of extreme chromosomal reorganization. Because no homology could be found among its chromosomes and those of closely related species, *T. saurophila* is considered one of the bats with the most rearranged karyotype described so far. Changes on the Phyllostomidae classification have redefined the taxonomy of *Tonatia* and the intergeneric relationships of Phyllostominae. Additionally, the development of molecular cytogenetic techniques that can identify chromosome homologies based on DNA sequence provides a new landscape to study the magnitude of chromosomal change of species with highly rearranged karyotypes. In this context, we used chromosome painting to access the chromosome homologies between *T. saurophila* and six phyllostomid species and integrated the results with recent molecular phylogeny findings. We proposed the ancestral karyotype for the subfamily Phyllostominae and found, for the first time, correspondence among *Tonatia* and other phyllostomid chromosomes. We calculated the minimal number of rearrangements required to derive the extant karyotype of *T. saurophila* from the ancestral Phyllostominae condition and concluded that this species has one of the highest rates of chromosomal change among the New World leaf-nosed bats.

The Chronology of Extinction of a Late-Holocene Bat Community from Hispaniola

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The latest summary of Hispaniolan bats includes 18 extant and four extinct species on this island. Documenting fossil faunas is important to assess biogeographic, species assemblage, and recent evolutionary patterns in Caribbean bats. Nonetheless, refined chronologies of recent bat species assemblages are rarely available. Here, we report on a late-Holocene fossil bat community of over 1900 specimens from Trouing Jean Paul, a high elevation sinkhole in Massif de la Selle, Haiti. These bat fossils represent the prey remains of two extant owls, the widespread *Tyto alba* and the Hispaniolan endemic *T. glaucops*. We found 13 species of bat including representatives of five families. One species of bat is extinct from Hispaniola (*Lasiurus* cf. *cinereus*) and another species is considered rare today (minor red bat, *Lasiurus minor*). Ages of the bat fossil deposit from Trouing Jean Paul were determined based on six radiocarbon dates from associated individual bird fossils collected adjacent to the bats. Our chronology represents recent changes over ca. 1600–600 cal. BP. Change in the fossil bat community of Trouing Jean Paul provides further evidence supporting the late-Holocene extinction of bats in the Caribbean and emphasizes the importance of detailed chronologies for assessing recent evolutionary patterns in insular bat communities.

***Resource Partitioning among Old World Pollinating Bats**

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* **Alyssa Stewart** received the **Bat Conservation International Award**.

The vast majority of tropical plant species depend on animals for pollination. While the immense biodiversity and complexity of the Old World tropics makes this region challenging to study, these traits also make it ideal for exploring how multiple pollinator species share or partition plant resources. First, we compared the diets of nectarivorous bats in southern Thailand since these species are typically assumed to be generalist foragers, but have not been closely examined. Second, we determined the major pollinators of focal night-blooming plant species. We hypothesized that nectarivorous bats would exhibit preferences for different food resources, resulting in variation in the important pollinators among plant species. To address our objectives, we compared bat visitations by mist-netting at different plant species. We also collected and identified pollen from the fur of netted bats. Our results show that Old World nectarivorous bat species appear to partition resources, as they exhibit significant preferences for distinct plant species. Furthermore, we found that *Eonycteris spelaea* was the most common visitor to nearly all of the flower species, but in some instances other bat species carried significantly larger pollen loads. Resource partitioning in this system may be a way of promoting the coexistence of multiple pollinators occupying similar ecological niches, as well as facilitating conspecific pollen transfer in a highly diverse plant community. Understanding these plant-pollinator interactions is important to assessing the vulnerability of different species to disturbance, and to guiding the conservation efforts of both plants and pollinators in this biodiversity hotspot.

The Influence of Winter Weather Conditions and Habitat on Bat Activity in the Piedmont of South Carolina, USA
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The decline of bat populations due to white-nose syndrome has resulted in many studies centered on winter behavior of cave dwelling bats, but few studies have focused on bats that winter in trees and leaf litter. The objectives of this study were to determine how weather conditions influence bat activity in winter and if bats were more active at sites with water as opposed to no water. We conducted a 10-week (20 Jan–7 Apr 2014) acoustic monitoring study of bats in the Clemson Experimental Forest in the upstate of South Carolina. We placed AnabatII bat detectors connected to CF-ZCAIMS in 3 open field sites and 3 sites adjacent to small ponds or wetlands. Detectors ran from 30 minutes before sunset to 30 minutes after sunset. Bats were more active at higher temperatures but were rarely active when average nightly temperatures were below 2°C. However, bats were often active when average nightly temperatures were 3–10°C. There was no relationship between activity and precipitation or wind speed. The sites with water had two times as many bat calls as the field sites. Our data suggest water sites may be more important than other sites for bats in winter. Better understanding of bat winter activity will help predict effects of future climate change.

Genetic Attributes of Host Associations in an Ectoparasite of Bats and Humans
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Cimicid insects (Hemiptera) are ectoparasites of warm-blooded animals, such as bats, birds and humans. There is evidence of host switching in many species of cimicids, and, in the case of *Cimex* spp., between bats and humans. My goal is to determine if phylogenetic techniques can distinguish between two ecotypes, the ones found feeding on bats and the ones found feeding on humans, of *Cimex lectularius* and *C. adjunctus* found in North America. To do this, we participated in the collection of samples from human homes (in collaboration with Abell Pest Control) and bat colonies (in collaboration with several bat researchers) throughout Canada and the United States. We then extracted DNA of all the samples collected (146 human parasites and 165 bat parasites), and sequenced their Cytochrome Oxydase 1 (CO1) gene. We used haplotype networking analyses on obtained sequences to verify if there is overlap in the two ecotypes. In at least *Cimex lectularius*, it seems as though sequences overlap for only one haplotype over 16. It thus seems unlikely that individuals of *C. lectularius* found on one host, a bat or a human, will be found feeding on the other, otherwise gene flow would have homogenized sequences between the two ecotypes. So, even if they are of the same species, cimicid insects found on different hosts, bats or humans, may require to be considered different in management procedures.

A Recent Survey of Bats from Southern Nigeria with Two New Country Records and Revised Species Checklist
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Bat species composition, richness and diversity within three vegetation types in southern Nigeria were investigated. Empirical comparisons of bat species richness and diversity between sites in relation to vegetation type is lacking in Nigeria. Localities sampled during this study include Emu (derived savanna), Okomu National Park (lowland forest) and Ososo (Guinea savanna). Bats were captured bimonthly using mist nets in canopy and ground installations in two plots per sampling locality. A total of 239 bats were captured in 28 net nights between February and September 2011. Species richness was lowest in derived savanna (Eight species of four families, n = 130), next to Guinea savanna (11 species of six families, n = 45) and highest in lowland forest (13 species of seven families, n=

64). From rarefaction curves, Guinea savanna (n = 11) recorded higher observed species richness than derived savanna (n = 5) and lowland forest (n = 10). Shannon diversity and evenness were higher in Guinea savanna than other two vegetation types. Two species were recorded for the first time in Nigeria; *Casinycteris campomaanensis* and *Chaerephon aloysiisabaudiae* bringing the species richness of Nigerian bats to 87 species with three additional but unconfirmed species that potentially occur. The high diversity of the Guinea savanna bat assemblage in comparison to other vegetation types supports the notion that the Guinea savanna zone supports peak diversity in relation to forest areas. The data provides a baseline for the study of the community ecology of bat assemblages in southern Nigeria.

The Sensory Ecology of a Predator-Prey Community: Neural Representation of Bat Predation Risk in Moths
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The ears of noctuid moths contain only two auditory receptor cells (A1 and A2) that are tuned to the ultrasonic sound frequencies used by predatory bats for echolocation. We tested the hypothesis that the frequency-dependent A-cell thresholds allow moths to detect bat species calling at different frequencies at distances at which they pose a similar threat. First, we show that bat call frequencies are tightly correlated with four bat characteristics related to the danger posed to moths by bats. Second, we measured auditory receptor thresholds in 12 moth species for the echolocation calls of 13 sympatric bat species in the lab and compared them with data collected for several species in the field. Third, we modeled temporal and spatial safety margins before detection by the bat for moths initiating directional flight at A1 threshold. In general, moths detect bats long before bats can detect the moth. For moths almost directly in front of an approaching bat, A1 activity translated into similar temporal safety margins across all bat species. At greater angles away from the bat, the safety margins varied greatly, often resulting in unnecessary directional flight. This suggests that the A1 cell has adapted to the worst-case scenario for the moth. In contrast, the less sensitive A2-cell starts to fire at approximately the same time as the bat detects the moth for bat species calling at 30 kHz and greater, suggesting that A2 activity informs moths that they have been detected by a bat.

The Use of Great Lakes Islands by Migrating Bats
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Many North American bats migrate in response to seasonal temperature changes, moving south to avoid the winter cold or traveling from summer ranges to hibernation sites. We used bats' echolocation calls to monitor migration activity and quantify the value of two Great Lakes islands – Amherst and Pelee. In June–October 2013 we recorded bat calls with eight Batcorders on Amherst Island and four Song Meters on Pelee Island. In April–September 2014 we deployed two Batcorders and two Song Meters per site on Amherst and Pelee Islands, at Pinery Provincial Park and near to Kingston, giving a total of sixteen detectors. We used automated analyses to analyze ~4-million recorded calls and averaged the numbers of calls across detectors at each site to control for spatial variation. We identified the echolocation calls of six species and compared activity at different times across the season, between islands, between mainland sites and among mainland and island sites. We recorded increases of activity of several species (*Lasionycteris noctivangans*, *Lasiurus borealis*, *L. cinereus* and *Myotis* species) on the islands during August, the putative migration peak for these bats. For example, *Lasiurus borealis* was more than twice as active in August and September (159 calls/detector/night) than during June and July (71.48 calls/detector/night). This difference was not observed at mainland sites. We have shown high activity of species during times that migratory behavior occurs in bats, from which we suggest that island sites are valuable to migratory bats crossing the lakes.

What's New? An Update on the Conservation State of the Mexican Long-nosed Bat
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Because of its degree of rarity, its migratory biology and threats affecting it, the Mexican Long-Nosed Bat (*Leptonycteris nivalis*) was listed as an endangered species by the US Fish and Wildlife Service in 1988 and as threatened by the Mexican law in 1991. The Recovery Plan was written in 1994 with the aim of highlighting the urgent needs for the conservation of this species, and the recovery actions to attend these needs. These actions include the identification, protection and monitoring of roosting sites as well as its foraging needs and protection of

the habitat. Detection and control of other threats and demographic and genetic population analysis are contemplated too. We conducted an assessment of the recovery actions and implemented some. Although not all proposed actions have been achieved, most have been at least partially addressed by different research groups over the species range (except for the demographic and genetic section). An update was conducted a few years ago by the Fish and Wildlife Service but there has been no follow-up. In order to recover the species, we propose new priorities. After our analysis some recovery actions emerge as critical, such as the identification of the transitory roosts that this species use during migration movements as well as the associated roosting habitats and a population viability analysis based on demographic and genetic data.

***Divergence Times of Phyllostomidae: Origin of Nectarivory**

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*** Roberto Emiliano Trejo Salazar** received the **Bernardo Villa Award**.

There are relatively few works that deepen into the study of the evolution of nectar consumption and some aim to contribute to the study of the evolution of bats, particularly the subfamily Glossophaginae in Mexico (through ancestry-offspring relationships). This study aims to solve the phylogeny and the emergence of the nectar-feeding strategy in the family Phyllostomidae. This family includes species that feed on blood, fruit, nectar, insects and meat. Based on a data matrix of 120 species with the two mentioned genes, a total of 2503 characters, a phylogeny was obtained and divergence times were calculated with Bayesian methods for species of the family Phyllostomidae. The time of origin (origin date) of the family was 27.67 million years ago, and for the subfamily Glossophaginae (nectar bats) the age was 21.11 million years ago. These times are similar to those previously calculated by other methods and also coincide with geological and ecological events that occurred mainly during the Miocene. Also worth noting, is that these results are consistent with results of previous works in which it was intended to determine the coevolutionary relationship between nectar bats and members of the genus *Agave* and the family Cactaceae. In these studies it is suggested that the ancestral condition in Phyllostomidae feeding strategy is insectivorous. From the results, it is thought that phyllostomid bats and particularly those ecologically related to species of plants they pollinate have diversified as part of a process of diffuse coevolution with these groups of plants.

***Molecular Phylogeny of the Genus Pteropus and Its Biogeographic Implications**

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The genus *Pteropus* consists of the largest bats in the world and is widely distributed on islands off the coast of East Africa, throughout Southeast Asia, and into the South Pacific. Single islands or biogeographic areas can host multiple sympatric *Pteropus* species, either due to repeated colonization or *in situ* speciation. *Pteropus* are of increasing interest to conservation biologists and disease ecologists alike, but are poorly resolved taxonomically due to high levels of morphological convergence. Despite the advent of genetic tools, wide biogeographic inferences for *Pteropus* may be inaccurate or lack resolution because previous studies had limited molecular coverage and included relatively few species. We chose a multilocus species tree approach to overcome problems associated with concatenated genetic data and incomplete lineage sorting. We obtained representative specimens from geographically distinct populations of widespread *Pteropus* species, with special attention to sampling from Indonesia. We sequenced 9 loci (7 nuclear, 2 mitochondrial) and inferred a species tree using BEAST. Biogeographic reconstructions were conducted using both a Bayesian approach to dispersal-vicariance analysis (as implemented in RASP) and the dispersal-extinction-cladogenesis model (as implemented in Lagrange). We found that *Pteropus* species richness is due to both repeated colonization of biogeographic areas by non-sympatric lineages and radiation by a single lineage in a biogeographic area. We further discuss what this may mean for the species status and taxonomic position of several poorly known taxa.

A Comparison of Pre- and Post White-nose Syndrome Fungal Associations on Hibernating Bats in Eastern Canada

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White-nose syndrome (WNS) is a disease caused by the fungus *Pseudogymnoascus destructans* (Pd). WNS has killed millions of bats in North America since first observed in 2006. Data documenting fungi naturally present on hibernating bats are still exceedingly rare, making it difficult to predict what, if any, impact the introduction of Pd might have on these assemblages. It has been suggested in a previous study that fungal diversity on hibernating bats may be suppressed by the presence of Pd. However we hypothesize that the natural fungal diversity on hibernating bats was not influenced by the introduction of Pd, in large part because fungi, other than Pd, are not known to actively grow on live bats. Based on a unique dataset collected immediately pre- and post-WNS infection in eastern Canada, we compare and contrast fungal assemblages cultured from hibernating *Myotis* spp. We also sought to identify any fungi that may interact with Pd in culture. Preliminary data indicate that over-all fungal diversity on hibernating bats did not change with the introduction of Pd. Several fungal isolates examined post-WNS appear to be antagonistic to Pd *in vitro*, although the nature of these interactions is still under study.

Trypanosomiasis and Leishmaniasis in Bats: Evaluating the Environmental Disturbance Influence in the Greater Lacandona Ecosystem

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Habitat loss and forest fragmentation have proven to be two major threats to bats in the tropics, as fragmentation increases, the diversity decreases. The dilution hypothesis states that as the species richness decreases due to habitat loss or disturbance, the incidence of parasites becomes higher. Since bats are known reservoirs of *Trypanosoma* and *Leishmania*, two pervasive zoonotic parasites, the primary objective of our study was to determine the prevalence of *Trypanosoma* sp. and *Leishmania* sp. in bats on conserved and disturbed conditions in the Lacandona forest in southern México. The disturbed area is dotted by human communities extracting forest resources and causing fragmentation and deforestation. Our hypothesis is that in conserved ecosystems bats will have a lower prevalence of the parasites due to the dilution effect. We worked with 2 common tropical rain forest species (*Carollia sowelli* and *Sturnira lilium*). Bats were captured using mist nets in 6 sites (3 under conserved conditions and 3 within the agricultural matrix of the surrounding areas) and tissue samples (heart and spleen) were taken. We obtained the prevalence of both pathogens through direct detection by PCR. We found several positive individuals for both *Trypanosoma* and *Leishmania.* Results of this study are crucial to secure conservation efforts and keep low incidences of pathogens through forest conservation for the benefit of neighboring human communities.

Spotted Bat Population Genetics across Time and Space

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Spotted bats (*Euderma maculatum*) are cryptic (nocturnal, volant, and roost solitarily) and thus their biology remains largely undescribed. Only 35 specimens were known to science before the mid-1960s. Hence, they are excellent candidates for elucidation of aspects of population biology and natural history via genetic tools. We sought to determine the degree of historical and contemporary regional movement. To this end, we applied microsatellite (N = 17) and mitochondrial markers (control region) to 50 museum specimens dating from 1904 and 60 recently-collected samples across the species range (western North America, Canada to Mexico). We found isolation by distance over their range, but little genetic structure on a regional scale and no difference between age of samples. These results likely reflect long-distance flight capability and long lifespan. The individuals from Mexico were genetically differentiated from individuals to the north, and exhibited genetic signatures of population isolation. This study demonstrates the utility of genetic approaches for species that are otherwise scientifically intractable and will lead to a greater understanding of the conservation challenges faced by this species.

Phenotypic Plasticity Explains Advancing Parturition Dates in Wild Greater Horseshoe Bats

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Birth timing can have important consequences for offspring growth and survival. Consequently the extent to which females are flexible in the timing of their reproductive efforts has become increasingly pertinent in the face of climate change. Here we studied the determinants of parturition timing in a wild population of greater horseshoe bats, living at the edge of their geographical range. Mean parturition date has been getting earlier in this population since 1984, while over the same timeframe annual local temperatures have increased. To determine to what extent observed annual changes in parturition date reflect genetic adaptation or phenotypic plasticity, we estimated the heritability and repeatability of this trait using long-term pedigree data. We found that parturition date had low heritability and that annual variation was almost all explained by April maximum temperature. While population level plasticity was evident, we found no evidence that individual bats differed in their degree of plasticity, or that plasticity itself was heritable. We conclude that female greater horseshoe bats appear to have responded to rapidly changing climate conditions by altering their breeding time appropriately without any selection having taken place.

Social Network Characteristics and Pathogen Transmission in Forest-roosting *Eptesicus fuscus*

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Host behavior can affect host-pathogen dynamics and colonial behavior is predicted to increase risk of pathogen exposure. Social network analysis can quantify complex interactions among conspecifics and network metrics can be used to model pathogen transmission. We quantified interactions of big brown bats (*Eptesicus fuscus*) using social network analysis and simulated transmission of a contagious pathogen throughout a forest-roosting colony. We tested the hypotheses that: 1) network metrics would change between pregnancy and lactation; and 2) changing network dynamics between reproductive stages would influence pathogen transmission. We predicted that network connections between bats would be stronger during pregnancy than lactation because of a greater need by pregnant bats for social thermoregulation in large roosting groups when ambient temperature is colder, and because the combination of passive aggregation and active associations at relatively few warm roost trees during lactation would reduce novel roosting associations. We also predicted that, in the event of a pathogen introduction, these network dynamics would lead to faster transmission during pregnancy compared to lactation. We used a previously published dataset on *E. fuscus* associations and quantified social network metrics that could affect pathogen transmission. As we predicted, network connectivity was stronger during pregnancy compared to lactation and our model predicted that colony-wide infection would occur more quickly during pregnancy compared to lactation. In light of growing appreciation of the importance of understanding host-pathogen dynamics of bats, our results have conservation and public health implications for understanding the role of host social behavior in pathogen transmission.

Spring Time Roosting Ecology of Virginia Big-eared Bats in North Carolina

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The southernmost population of the endangered Virginia big-eared bat (*Corynorhinus townsendii virginianus*) occurs in North Carolina and Tennessee, 2 of 5 states where the subspecies exists. The state of NC first identified winter hibernacula for the species in the 1980s; however, prior to 2013, we had no information on locations and characteristics of maternity sites used by this population. Our goal was to locate maternity roosts and to identify factors important in roost habitat selection. From March–May 2013 and 2014, we tracked 42 female Virginia big-eared bats to 27 roosts in NC and 6 roosts in TN. We recorded elevation, aspect, dimensions, number of entrances, outside clutter, and distances to water and roads for each roost. In April 2013, we discovered the primary maternity roost used by this population; this cave is 14 km NNW of the primary hibernaculum and is used by ≥350 adult bats. Roosts included spacious caves (n=13), relatively open rock structures (n=9), and buildings (n=11). Spring time roosts were at lower elevations (1054 ± 41, range 658–1422 m) than the hibernaculum (1440 m) and most (n=27) had multiple entrances. Identifying roost locations and characteristics will enable managers to protect critical maternity habitat for Virginia big-eared bats. Because bats roosted in buildings, it will be important to reach out to

homeowners and developers in the area. We found the NC population has a larger range than previously assumed; data on roost characteristics can be used to predict the distribution of the species in this region.

The Bat Acoustic Monitoring Portal (BatAMP): Archiving Echolocation Monitoring Results to Address Continental Conservation Concerns

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Over the past decade, wind energy development and white-nose syndrome have emerged as critical conservation concerns for North American bats. In both cases, a lack of basic information on the seasonal whereabouts and timing of activity across the continent has impeded response efforts. Concomitantly, the use of long-term, remotely-deployed, echolocation monitoring stations to ascertain seasonal species presence at local scales has grown explosively to bridge some of these information gaps. This has been coupled with a proliferation of new hardware and software applications for conducting this work. Nevertheless a central clearinghouse for the resulting records, which could help elucidate seasonal patterns of species presence at the largest spatial scales, did not exist. We developed the Bat Acoustic Monitoring Portal (BatAMP) to federate results of local monitoring efforts. Users simply upload files of species detected by night along with metadata on location, detector type, and species identification procedures. Data from all detector types and species identification processes are accepted. Utilities within the portal allow users to dynamically visualize species locations within interactive maps and explore charts of time-series records across one or more locations. Most importantly, the portal provides an archive for results from the multitude of echolocation detectors in operation across the continent. The assembled data will afford opportunities to explore questions such as continental movement patterns of migratory species, the timing and use of habitat features (e.g., rivers, ridgelines) during migration, and the location and changes in timing of winter activity for individual species.

Evaluating the Effectiveness of Three Acoustic Monitoring Techniques for Bat Population Monitoring

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Understanding population trends of any species is essential for conservation and management. However, population status of many bat species at a landscape level is poorly understood due to the difficulty sampling these species. In an effort to resolve this issue, especially with emerging threats (e.g., white-nose syndrome and wind energy) a national mobile acoustic monitoring protocol was developed to survey summer bat populations. We compared species richness and abundance along car and boat mobile acoustic transects to identify the most efficient method. We further compared species richness to stationary acoustic detectors placed along the route to better understand the capabilities of mobile acoustic transects compared to traditional survey methods. Using sample-based rarefaction, there was no difference at the 95% confidence level in species richness (species/individual), density (species/sample), or diversity (Shannon-Weaver and Simpson's indices) between transect methods. However, car transects tended to show slightly higher measures. While over 1.5 as many calls were recorded and identified along boat transects, there were no clear advantages to boat transects (except for sampling *Myotis grisescens*). Additionally, car transects were less variable and least time consuming, leading us to conclude that car transects are the most efficient mobile acoustic method to monitor species. However, only two species (*Perimyotis subflavus* and *Lasiurus borealis*) were likely in sufficiently high abundance using either method to allow detection of small trends. Nonetheless, mobile acoustic transects offer the only measure of summer abundance and car transects likely provide opportunity to monitor 2–4 species in the eastern United States.

Diversity, Discovery and Conservation in Indonesian Karsts

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Indonesia is a hotspot for chiropteran diversity, with 224 species comprising 9 families, or almost 20% of all bat species. The total species diversity for Indonesia is likely even higher than predicted due to a combination of lack of taxonomic study and many areas remaining unexplored. This is especially true for Indonesian karst ecosystems, which is the largest in Southeast Asia, and provides ample new opportunities for species discovery. Bat research has only been a part of the Indonesian karst survey project since 2001. In total, 81 species were found in karsts, of which 6 were suspected to be new species. Cave maps were also produced to learn about bat roosting ecology, to monitor species activities, and to make well-informed management and conservation programs. Caves and karsts are of special conservation concern because they have all the usual problems associated with human disturbance and development, but must additionally contend with mining, guano harvest, cave tourism and bat harvesting for food. Outreach activities such as communicating project results, training students, and working in concert with speleological clubs and local government entities have been conducted to educate stakeholders and the public about the importance of bat populations to the karst ecosystem. Furthermore, the karst project has pushed for formal regulation from the government to protect karsts. However, much work remains to be done to truly uncover the mysteries within Indonesian karsts. The use of the modern tools, such as genetic analyses and bat detectors, is needed to solve taxonomic issues and complement currently available bat diversity information. Additionally, increasing research interest in these areas will benefit bat conservation, as more people understand the importance of bats to the environmental issues that Southeast Asia will uniquely face in the coming decades.

Phylogeography of Little Brown Myotis Using RAD-Seq: Genome-wide Patterns of Genetic Diversity and Divergence

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The little brown myotis (*Myotis lucifugus*) is among the most widespread and well-studied bat species in North America, but information on population boundaries, history, gene flow and regional adaptive genetic variation is lacking. Such information is particularly relevant to the implementation of conservation strategies given precipitous declines from white-nose syndrome (WNS). We used restriction-site associated DNA sequencing (RAD-seq) to generate ~440 kb of sequence data per sample for more than 300 samples, and compared population genetic structure at autosomal RAD loci, Y chromosome loci, and the mitochondrial cytochrome *b* gene. Analysis of genome-wide markers suggests historical divergence of eastern and western populations across the Rocky Mountains, followed by contact and gene flow, resulting in a clinal pattern of allele frequencies between the two populations in the Midwest. Demographic models fit to the joint allele frequency spectrum suggest that the populations diverged early in the Pleistocene, with the eastern population growing to several times the size of the western. Geographic structure east of North Dakota and Manitoba is minimal; by contrast, west of the Rockies, differentiation of bats sampled <300 km apart indicates that seasonal dispersal is more limited in the West than the East. Contrasting geographic structure of nuclear, mitochondrial, and Y chromosomal genetic variation is consistent with male-biased gene flow. Outlier analyses reveal an excess of loci with divergent allele frequencies between the two populations relative to neutral expectations, indicating divergent natural selection between populations and the possibility that adaptive genetic variation may be threatened by declines from WNS.

Bat Response to Oak Savanna Restoration Treatments in Hardwood Forests of the Mid-South

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In the Southeastern United States, prescribed fire, in combination with canopy reduction, is being used to restore areas of hardwood forest to woodland and savanna. These treatments have the potential to dramatically alter habitat conditions for bats. Many bat species are forest dwelling, utilizing hardwood forests for foraging during critical pre/post-hibernation and maternity periods. Therefore, managing hardwood forests to provide high-quality foraging areas may be critical to the persistence of some bat populations, particularly in regions where they are threatened by white-nose syndrome. We used acoustic sampling to examine the effect of four prescribed fire and canopy reduction treatments on bat activity and species richness. We also examined the effect of treatments on stand structure and abundance and biomass of nocturnal insects. Initial data analysis found treatments had no effect on total bat activity or species richness, or bat activity within high and low frequency phonic groups. However, eastern red bat (*Lasiurus borealis*) exhibited higher activity in stands subject to growing and dormant season burning in combination with high levels of canopy reduction compared to controls ($P = 0.001$). In contrast, northern long-eared bat (*Myotis septentrionalis*), a species currently proposed for federal listing as endangered as a result of WNS, exhibited lower activity in all treatment stands compared to controls ($P = 0.002$), suggesting these treatments may not be beneficial to this species. We will present final study results, which incorporate vegetation, insect, and additional acoustic data, and provide management recommendations for multiple bat species.

Range-dependent Flexibility in the Acoustic Field of View of Echolocating Whales

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Toothed whales and bats are the only animals to use sonar to detect, locate, and track prey and the demands of preycapture are positively related to biosonar sophistication. Both groups adjust emitted sound intensity, auditory sensitivity and signal emission rate in response to changing spatial relationships with targets. Here we show that porpoises (Phocoena phocoena) broaden their biosonar beam by >50% in the terminal phase of attack, but unlike echolocating bats, that they also are able to change beamwidth within this phase. Until now, toothed whale biosonar beamwidth was thought to be stable throughout target approach. Our results, in contrast, demonstrate that porpoises' acoustic field of view (FOV) is responsively flexible. Based on high-speed video and magnetic resonance imaging we propose that this flexibility is effected by the melon and used to accommodate changing spatial relationships with prey and the acoustic complexity of the surroundings. Despite the independent evolution of echolocation in whales and bats, and vastly different means of sound generation and transmission, both groups have evolved mechanisms to change their acoustic FOV over the course of attack. This convergence suggests that beam flexibility has been an important driver in the evolution of echolocation for prey tracking. The much longer terminal attack phases typical of whales suggests that in these predators, prey-tracking demands may be more extreme than in bats. We propose that a flexible FOV during the terminal phase in whales suggests they may be more exquisitely equipped for hunting than are the bats.

Characterizing Pathogen Diversity, Feeding Behavior, and Spillover Risk in *Desmodus rotundus* in Guatemala

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Bats represent approximately 20% of all mammals with over 1,200 different species distributed worldwide. Certain bat species serve as the reservoirs for viral diseases including Henipa-, Lyssa-, Corona-, and Filoviruses, which may pose serious threats to human health. The common vampire bat (*Desmodus rotundus)* has historically been a species of interest due to its sanguivorous feeding habit and highly social behavioral ecology. Due to these factors, in addition to the abundance of this species and its frequent contact with humans and livestock, *D. rotundus* may have an unusually high potential for interspecies disease transmission. While previous studies have investigated rabies dynamics in *D. rotundus*, the diversity of other pathogens that these bats may carry remains largely unknown. We screened 396 blood, urine, saliva, and fecal samples for viral diversity using PCR with degenerate primers, focusing on several viral families and genera including coronaviruses, paramyxoviruses, rhabdoviruses, hantaviruses, adenoviruses and influenza A viruses. Positive results were found for rhabdovirus and adenovirus assays. Additional screening for potentially pathogenic bacteria also detected *Bartonella* in 39 out of 103 individuals. To characterize spillover risk associated with feeding behavior, we analyzed cytochrome B sequences from fecal samples. Sequences from domestic cattle (*Bos taurus*) were found in 47 out of 103 individuals, with horse (*Equus* sp.) and zebu (*Bos indicus*) also detected. The results of this study suggest that the risk of pathogen spillover from *D. rotundus* warrants further investigation of pathogen diversity and foraging ecology in *D. rotundus* populations in Central America.

Evidence of Vomeronasal Function in Noctilionoids from *Trpc2*

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The mammalian vomeronasal system (VNS) is a chemosensory system that detects pheromones and cues in conspecific social interactions. Similar to the olfactory system, the VNS has been shown to detect odorant molecules. Bats and primates are the only mammals to show variation in vomeronasal function, as all other mammals have a functioning vomeronasal organ (VNO). Most bats have lost vomeronasal function completely, but within the family Phyllostomidae many species still possess a well-developed VNO. The *transient receptor potential ion channel* (*Trpc2)* is necessary for VNO function, as it maintains the signal transduction from the VNO to the brain. A functional *Trpc2* gene is indispensable for VNS function, although it does not always indicate the VNO is present. According to previous studies, the *Trpc2* gene is disrupted in Old World bats. Here, we investigate *Trpc2* function among a large sample of New World bats, including >30 phyllostomid species. We sequenced a 450-bp exon from the *Trpc2* gene and identified whether a premature stop codon was present. We find that the *Trpc2* exon 2 is functional in all phyllostomid lineages, and in several additional noctilionoid species. This suggests that phyllostomids are under negative selection to retain a functioning channel for vomeronasal signal transduction, and suggest the potential for sister taxa to possess a functioning ion channel as well. If phyllostomids have regained or retained the VNO, the organ may have served as a key adaptation enabling New World Leaf-nosed bats to diversify into novel dietary niches.

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ANNOUNCEMENTS

Reminder—Renewal Time!

Just a reminder that this is the last issue of the 2014 series of *Bat Research News*. That means some of you will be receiving renewal information in the inbox of your e-mail fairly soon. I hope you will continue to support BRN for the 2015 volume-year. Regardless, all of us at *Bat Research News* wish you a safe and happy 2015!

Request for Manuscripts — *Bat Research News*

Original research/speculative review articles, short to moderate length, on a bat-related topic would be most welcomed. Please submit manuscripts as .rtf documents to Allen Kurta, Editor for Feature Articles (akurta@emich.edu). If you have questions, please contact Al. Thank you for considering submitting your work to *BRN*.

Change of Address Requested

Will you be moving in the near future? If so, please **send your new postal and e-mail addresses** to Margaret Griffiths (margaret.griffiths01@gmail.com), and include the date on which the change will become effective. Thank you in advance for helping us out!

FUTURE MEETINGS and EVENTS

2015

The North American Bat Working Group Meeting will be held March 3–6, 2015, at the Crowne Plaza in downtown St. Louis, Missouri. This will be a joint meeting of the Western and Midwestern Bat Working Groups, and the Southeast Bat Diversity Network.

The 45th Annual NASBR will be held October 28–November 1, 2015, in Monterey, California. See the NASBR website for more in formation — http://www.nasbr.org/.

2016

The 46th Annual NASBR will be held October 12–15, 2016, in San Antonio, Texas. See the NASBR website for future updates — http://www.nasbr.org/.

2017

The 47th Annual NASBR will be held in Knoxville, Tennessee, dates to be determined. Check the NASBR website for future updates — http://www.nasbr.org/.