A survey of bat communities in Grand Teton National Park in relation to anthropogenic structures and light

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Abstract Bats (order Chiroptera) are increasingly recognized as critical in diverse ecosystems around the world. However, there have been relatively few studies of bats in Grand Teton National Park (GRTE), such that a great deal remains to be learned about bat communities in the region. We recorded bat echolocation calls with acoustic monitoring device and analyzed recordings with species identification software to characterize bat communities in GRTE. These data, along with data on human-made structures and lightscapes around the park will be used to analyze relationships between bat communities and anthropogenic infrastructure within the park.

Introduction

Relative to their ecological importance, bat species around the world have historically received very little attention from the scientific community. Recently, however, the ecosystem services of bats have been recognized to a much greater extent than in the past. From pollination (Stewart and Dudash, 2017) to seed dispersal (Kunz et al., 2011) to arthropod suppression (Ketzler et al., 2017), bats play important roles in shaping the ecosystems in which they occur, often to the economic benefit of local human populations. As a result of this knowledge, bats have been receiving more attention from researchers in recent years.

Grand Teton National Park (GRTE) has been the subject of multiple bat community inventories (Keinath, 2005; Genter and Metzgar, 1985), but there is still much to learn regarding the bats in the region. During the summer of 2016, I collected data regarding bat communities and bat activity levels throughout GRTE in an effort to gain new insight into localized bat communities within the park.

I also documented locations and condition of human-made structures, as well as detailed descriptions of lightscapes throughout GRTE. This information was collected in an effort to contribute to the growing wealth of knowledge regarding the effects of anthropogenic light and man-made structures on localized bat communities and bat activity levels (Border, Newson, White, and Gillings, 2017; Lewanzik and Voigt, 2017; Stone, Wakefield, Harris, and Jones, 2015*b*; Stone, Harris, and Jones, 2015*a*).

Methods

Active acoustic monitoring

To rapidly assess bat community profiles and relative activity levels, as well as identify flyways, I employed a handheld acoustic monitoring device. I placed a Wildlife Acoustics Echometer Touch attached to an iPhone 6S atop a camera tripod and recorded echolocation calls for 20-60 minutes. These preliminary data guided subsequent study site choice and detector placement.

Passive acoustic monitoring

Passive acoustic monitoring via bat detectors has proven to be a useful tool when constructing localized bat community profiles and assessing relative activity levels in the area immediately surrounding the detector (Britzke, 2004). I used Wildlife Acoustics SM2BAT bat detectors in conjunction with SMX-U1 and SMX-US microphones, as well as SM3BAT bat detectors in conjunction with SMM-U1 microphones to collect bat echolocation call data. The data collected from each recorded echolocation call included the time at which the call was recorded and a WAV file of the recording.

Bat detector placement was dictated by numerous factors including: the local lightscape, the presence of reflective surfaces, and identified flyways. Microphones were deployed as far away from reflective surfaces (leaves, trees, roofs, etc.) as possible to obtain high quality recordings without echoes. From the tree or pole that the bat detector was attached to, the microphone was extended away on a stick strapped to the tree or pole.

In an effort to construct a full bat community profile for study sites, bat detectors were initially deployed at a single site for up to twelve nights. However, detectors were eventually deployed for only six nights per site to collect data in as many locations as possible while still maintaining adequate sample nights for each site.

Beginning on July 22, 2016 sets of bat detectors were deployed within five days of each other to control for temporal changes in bat activity and community profiles. To control for habitat use discrepancies, sets of detectors were also deployed in areas with similar microhabitat characteristics (distance from riparian area, distance from forest, lightscape, human activity levels, man-made structure presence, etc.) with the exception of control sites. Control sites were areas with microhabitats similar to other sites in deployment sets, but without artificial lighting or man-made structures.

Structures

For each study site in which there were man-made structures, I inspected the nearby structures, photographed relevant structure characteristics, and documented structure characteristics including: the date and time that I inspected the structure, the code that I gave the building, the NPS specified building number if available, the structure's latitude and longitude, a brief description of the surrounding habitat within 100 meters, the primary external building materials, any major openings in the structure, any evidence of bat inhabitation, additional notes, and file names for associated images.

I attempted to collect data from every structure in the areas that I sampled in an effort to document all present structure characteristics that may affect the local bat community profile or relative bat activity levels. The Colter Bay Guest Cabin area was the only study area that could not be comprehensively sampled. In this case, 44 representative structures of the 100 structures in the area were sampled.

Lights

For each study site with anthropogenic light sources, I documented light sources and characteristics of those sources including: the name of the study site and the date and time that I began inspecting light sources, as well as the name, location, light projection description, latitude and longitude, brightness score, color, and approximate height of each light fixture.

Only lights that were on while I was sampling were recorded in an attempt to capture a representative nightly lightscape. To ensure that lights documented would likely be on all night, sampling started after 2300. Motion-sensing lights were not recorded, as they would almost certainly not be on for extended periods throughout the night.

Study sites

All data collection efforts occurred between June 1, 2016 and August 31, 2016 in Grand Teton National Park, Wyoming, USA. Bat detectors were deployed at 26 sites (Figure 1) with a total of 29 deployments (Supplementary Table 1). Structure data was collected at 18 sites, with data collected from a total of 428 structures (Supplementary Table 2). Light data

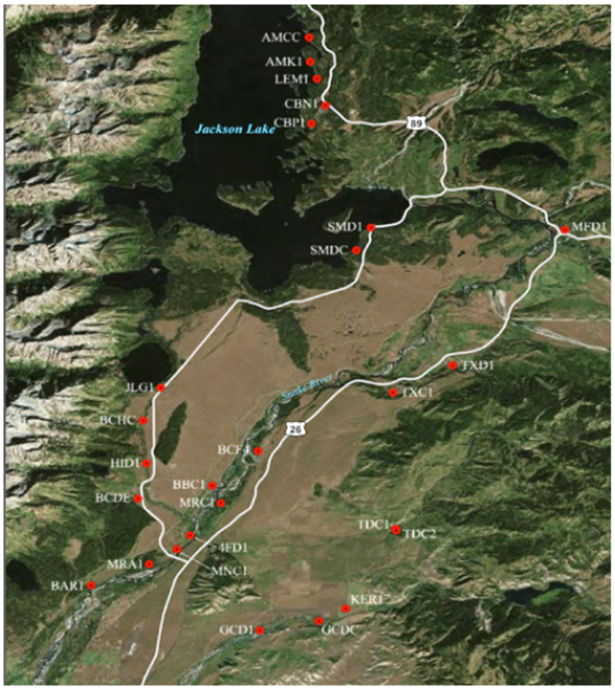

Figure 1. Map of passive acoustic monitoring sites in Grand Teton National Park.

was collected at 13 sites, with data collected from a total of 326 light fixtures (Supplementary Table 3). Study sites were chosen based on man-made structure presence, artificial light presence, and bat presence. The array of sites chosen provided a combination of varying magnitudes of each variable listed above. Control sites were chosen based on similarities to study sites with respect to habitat type, elevation, distance from the nearest riparian area, and distance from the nearest road.

Preliminary Results

GRTE community profile

Throughout the summer of 2016, over 82,000 bat echolocation calls were recorded using passive acoustic monitors. Approximately 38% of these calls were attributed to a species (12 total species recorded) when analyzed by the SonoBat 4 software. The total number of calls attributed to each species is detailed in Figure 2. The majority of recorded calls that SonoBat 4 was able to attribute to a species (51.7%) were attributed to *Myotis lucifugus* (Little brown bat). Other species that were prominent throughout GRTE as indicated by SonoBat 4 call attributions were *Lasiurus cinereus* (Hoary bat; 14.3% of call attributions), *Lasionycteris noctivagans* (Silver-haired bat; 10.8% of call attributions), *Eptesicus fuscus* (Big brown bat; 9.7% of call attributions), *Macrophyllum macrophyllum* (Long-legged bat; 8.3% of call attributions), and *Myotis septentrionalis* (Northern long-eared myotis; 3.7% of call attributions).

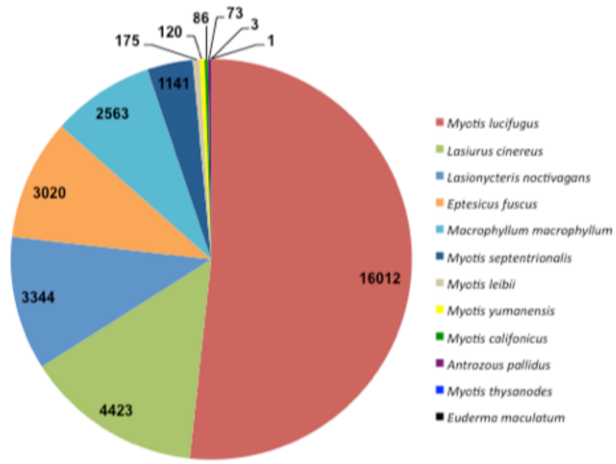

Figure 2. Number of echolocation calls identified by species. Calls were attributed to species by analyzing each echolocation call recorded in SonoBat 4.

Other species that SonoBat attributed calls to included: *Myotis leibii* (Eastern small-footed myotis), *Myotis yumanensis* (Yuma myotis), *Myotis californicus* (California myotis), *Antrozous pallidus* (Pallid bat), *Myotis thysanodes* (Fringed myotis), and *Euderma maculatum* (Spotted bat). Some of these species that constituted a very low portion of all calls identified by SonoBat 4, such as *Antrozous pallidus* and *Euderma maculatum* are likely not a part of the Grand Teton bat community, as their ranges are not thought to include GRTE.

Further analysis

These preliminary analyses suggest a diverse and abundant GRTE bat community. Further analyses will be completed by the Barber Lab at Boise State University. Some aspects of the analysis to be completed include: nightly temporal distribution of detections, the temporal distribution of nightly detections throughout the summer, the effects of man-made structure characteristics on local bat community profiles and relative bat activity levels, spatial distributions of bat species throughout GRTE, and the effects of various light colors and intensities on relative bat activity levels.

Conclusions

The bat species inventory generated from data collection efforts in 2016 is almost entirely in congruence with past species inventories for GRTE. Of the more than 82,000 echolocation calls I recorded throughout the summer of 2016, one was attributed to *Euderma maculatum*, which was not included in past bat species inventories of GRTE. This call was likely misattributed to this species, and is likely not present in the region as mentioned previously. 73 calls were attributed to *Antrozous pallidus*, which has a range that does not encompass GRTE. It is likely that the call profile for this species is similar to another, and SonoBat frequently misattributes calls to *Antrozous pallidus*. Further data collection efforts will allow for a more definitive statement regarding the presence of this species in GRTE.

Corynorhinus townsendii has been detected in GRTE during previous data collection efforts, but I did not record any echolocations that were attributed to this species. Past detections of *Corynorhinus townsendii* were at the White Grass Ranch, which was not a study site during 2016. It is possible that *Corynorhinus townsendii* is still present in the park, and further data collection efforts will allow for a more definitive statement regarding the presence of this species in the park.

Future Work

Intended data collection efforts for 2016 were postponed due to delayed grant approval and distribution. These intended data collection efforts included mistnetting, individual bat tracking through radio telemetry, and more extensive passive acoustic monitoring. Adequate funding has been received for these data collection efforts to occur in 2017.

Data collection occurring throughout the summer of 2017 will allow for a more thorough examination of the bat communities of GRTE. Not all bat species can be positively identified through passive acoustic monitoring and automated bat echolocation identification software. Mistnetting in conjunction with extensive acoustic monitoring efforts may lead to a more comprehensive understanding of local and regional bat community profiles (O'Farrell and Gannon, 1999; Russo and Voigt, 2016). Tracking of individual bats through radio telemetry techniques will allow data to be collected that cannot be collected through acoustic monitoring alone, such as foraging ranges, roost locations, and habitat selection. Radio telemetry data may also help inform acoustic monitor placement by identifying areas of high bat foraging activity and flyways.

As of yet, there are no plans for 2017 to continue the collection of anthropogenic structure and light data. The collection of lightscape data may reveal detrimental effects of current lighting schemes throughout the park, informing future lighting renovations and creating a lightscape that has a decreased impact on the distribution and behavior of bats, as well as other fauna inhabiting the park.

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Site	Location	Date Deployed	Date Retrieved
AMK1	N 43.93943° W 110.64286°	6/10/16	6/22/16
MNC1	N 43.65862° W 110.71342°	6/12/16	6/22/16
CBP1	N 43.90378° W 110.64228°	6/13/16	6/22/16
KER1	N 43.62432° W 110.62407°	6/13/16	6/22/16
JLG1	N 43.75166° W 110.72208°	6/23/16	6/30/16
BAR1	N 43.63780° W 110.75896°	7/11/16	7/18/16
TXD1	N 43.76460° W 110.56729°	7/12/16	7/20/16
MFD1	N 43.84260° W 110.50792°	7/13/16	7/20/16
TDC1	N 43.67043° W 110.59766°	7/14/16	7/15/16
TDC2	N 43.66943° W 110.59731°	7/15/16	7/21/16
CBN1	N 43.91422° W 110.63477°	7/18/16	7/25/16
LEM1	N 43.92962° W 110.63933°	7/20/16	7/27/16
MRA1	N 43.64998° W 110.72827°	7/21/16	7/27/16
TXD1	N 43.76460° W 110.56729°	7/22/16	7/28/16
BBC1	N 43.69530° W 110.69482°	7/27/16	8/2/16
TXC1	N 43.74881° W 110.59898°	7/28/16	8/3/16
4FD1	N 43.66676° W 110.70655°	7/30/16	8/5/16
BCF4	N 43.71526° W 110.67044°	7/31/16	8/6/16
GCD1	N 43.61196° W 110.66952°	8/3/16	8/9/16
HID1	N 43.70801° W 110.72964°	8/5/16	8/11/16
BCDE	N 43.68774° W 110.73414°	8/5/16	8/11/16
SMD1	N 43.84385° W 110.61071°	8/9/16	8/15/16
GCDC	N 43.61725° W 110.63822°	8/9/16	8/15/16
CBP1	N 43.90378° W 110.64228°	8/10/16	8/17/16
AMK1	N 43.93943° W 110.64286°	8/12/16	8/18/16
BCHC	N 43.73271° W 110.73144°	8/12/16	8/18/16
SMDC	N 43.83083° W 110.61836°	8/15/16	8/21/16
AMCC	N 43.95345° W 110.64344°	8/16/16	8/22/16

Supplementary Table 1. List of passive acoustic monitor deployments including: site code, latitude and longitude of site, date monitor was deployed, and date monitor was retrieved.

Site	Approximate Location	Number of Structures Inspected	Description of Structures
4 Lazy F Ranch	N 43.667354° W 110.703113°	16	Primarily unmaintained and uninhabited historic log structures, with the exception of one maintained structure used for seasonal housing. Structures are generally porous with many points of entry for bats.
AMK Ranch	N 43.939776° W 110.640263°	16	Relatively well maintained historic log structures that are used for seasonal housing. Most structures have multiple points of entry for bats.
Bar BC Ranch	N 43.695491° W 110.694018°	29	Uninhabited historic log structures that are in disrepair. Most structures are very porous, with large openings in walls and roofs.
Barker-Davis Residence	N 43.638745° W 110.756843°	5	Uninhabited log and board structures that are in disrepair. Most structures have multiple points of entry for bats.
Beaver Creek Employee Housing	N 43.687578° W 110.734166°	39	Log structures that serve as employee housing as well as multiple storage buildings. Most inhabited structures are well maintained with no major openings. The storage buildings are very porous.
Colter Bay Employee Housing	N 43.912761° W 110.634170°	37	Structures with synthetic siding materials used for employee housing. Most structures are well maintained, with few or no major openings to the interior of the structure.
Colter Bay Guest Area	N 43.904314° W 110.637391°	50	Log structures that are used as seasonal guest housing. Structures are generally well maintained with few openings leading to the interior. Adjoined cabins often create a sheltered area between them that is easily accessible to bats.
Colter Bay Ranger Station	N 43.913241° W 110.633566°	10	Structures with synthetic or metal exteriors that are used as storage and office buildings. Most structures are well maintained with few openings leading to the interior.
Highlands	N 43.708984° W 110.728611°	23	Log cabins used as employee housing. Structures often have openings leading to interior that are covered by mesh netting or partially sealed with caulk.

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Site	Approximate Location	Number of Structures Inspected	Description of Structures
Jenny Lake South Entrance	N 43.751955° W 110.721332°	6	A mixture of log and wood board structures used as retail areas and visitor facilities. Structures are generally well maintained, with some small openings that may lead to the interior. Large covered porch areas.
McCollister Ranch	N 43.682798° W 110.630798°	6	Historic log structures that are uninhabited and in disrepair. Buildings have large openings leading to the interior.
Moose NPS HQ	N 43.657308° W 110.712413°	29	A mixture of log and metal sided structures. Metal sided structures are generally used as office buildings or storage facilities, and are well maintained with few or no openings leading to the interior. Most log structures are uninhabited and very porous, with multiple openings leading to the interior.
Moran Complex	N 43.842428° W 110.505301°	13	A mixture of log and wood board structures that are used as employee housing or storage facilities. Structures are generally well maintained, with some or no openings leading to the interior.
Mormon Row	N 43.665510° W 110.663145°	16	Primarily historic log structures that are uninhabited and in disrepair. Most structures have large openings that lead to the interior.
Murie Ranch	N 43.650985° W 110.723679°	18	Historic log structures that are generally uninhabited, with the exception of some buildings that are used to house employees. Structures generally have openings that lead to the interior, many of which are patched.
Signal Mountain Lodge	N 43.843383° W 110.609084°	42	Seasonal guest housing and visitor facilities that are primarily log structures. Generally well maintained with few or no openings in structures leading to the interior.
Teton Science School	N 43.670980° W 110.594296°	31	Seasonally used as housing for students and employees. Log structures that often have openings leading to interior.

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Site	Approximate Location	Number of Structures Inspected	Description of Structures
Triangle X Ranch	N 43.764995° W 110.564715°	42	Seasonally used as guest housing and storage facilities, with some buildings inhabited year round by employees. Structures often have openings leading to interior that are patched with foam or screen material.

Supplementary Table 2. List of sites at which anthropogenic structure data was collected, including site name, latitude and longitude of site, number of structures inspected at each site, and a general description of structures at each site.

Site	Approximate Location	Lights Surveyed	Lightscape Description
AMK Ranch	N 43.939776° W 110.640263°	5	Blue-white and yellow-white lights. Average brightness score of 2.
Beaver Creek Employee Housing	N 43.687578° W 110.734166°	2	Only yellow-white lights. Average brightness score of 3.
Colter Bay Employee Housing	N 43.912761° W 110.634170°	14	Primarily yellow-white lights, with one blue-white light and two white lights. Average brightness score of 2.29.
Colter Bay Guest Area	N 43.904314° W 110.637391°	118	Ranging in color (blue-white, yellow-white, white). Average brightness score of 2.56. Some lights have shields that direct light down, reducing their impact on the lightscape.
Colter Bay Ranger Station	N 43.913241° W 110.633566°	16	Primarily blue-white lights, with two yellow-white lights and two orange lights. Average brightness score of 3.13.
Jenny Lake South Entrance	N 43.751955° W 110.721332°	6	Yellow-white lights. All lights had a brightness scores of 3.
Moose NPS HQ	N 43.657308° W 110.712413°	11	Ranging in color (blue-white, green-white, white, and orange). Average brightness score of 3.45. Many lights have shields that direct light down, reducing their impact on the lightscape.
Moran Complex	N 43.842428° W 110.505301°	4	Blue-white and orange lights. Average brightness score of 2.
Triangle X Ranch	N 43.764995° W 110.564715°	7	Primarily yellow-white lights, with two white lights. Average brightness score of 3.29.
Highlands	N 43.708984° W 110.728611°	1	Yellow-white lights. Brightness score of 3.
Signal Mountain Lodge	N 43.843383° W 110.609084°	129	Ranging in color (blue-white, yellow-white, orange, white, yellow). Average brightness score of 2.49.
Teton Science School	N 43.670980° W 110.594296°	2	Yellow-white lights. All lights had brightness scores of 3.

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Site	Approximate Location	Lights Surveyed	Lightscape Description
Leek's Marina	N 43.929785° W 110.639330°	11	Primarily orange lights, with three blue-white lights and two yellow-white lights. Average brightness score of 2.27.

Supplementary Table 3. List of sites at which lightscape data was recorded including site name, latitude and longitude of each site, number of lights surveyed at each site, and general lightscape description for each site.