BAT POPULATION MONITORING OF BIGHORN CANYON NATIONAL RECREATION AREA: 2015 PROGRESS REPORT

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INTRODUCTION

This report briefly summarizes activities conducted under a 2015 pilot project to implement an acoustic bat monitoring plan for Bighorn Canyon National Recreation Area (BICA). BICA supports a diverse and large bat population (Keinath 2005), but there is currently no way to monitor this population because there is currently no quantifiable data. One of the most common species in BICA, the little brown bat (*Myotis lucifugus*), is highly susceptible to White-Nose Syndrome (WNS) and has experienced large declines in areas where WNS has been documented, leading to an ESA listing petition (Kunz and Reichard 2011). The primary purpose of this project is to initiate monitoring of this species, which has been recommended by the U.S. Fish and Wildlife Service pertaining to WNS response (US Fish Wildlife Service and Pennsylvania Game Commission 2011).

METHODS

Study Area

Bighorn Canyon National Recreation Area (BICA) was established in 1966, following the construction of the Yellowtail Dam, which created Bighorn Lake, a 71 mile long reservoir, most of which is contained within Bighorn Canyon. The canyon is over 650 feet deep and carved from massive beds of limestone and dolomite that extend throughout the area and form numerous cliffs and caves. When not contained by steep canyon walls, the broad riparian corridors around the Bighorn and Shoshone Rivers contain expansive wetlands with many open water ponds. Habitat across BICA is diverse, and includes deciduous spring-fed riparian corridors, sagebrush and desert shrublands, badlands, low-elevation juniper woodlands, and mid-elevation conifer forests. The combination of geologic, hydrologic and vegetative features provides an abundant and diverse array of bat habitat resulting in a locally high diversity of bats (Keinath 2005).

Bat survey methods

We collected bat echolocation calls between July 7 and July 26, 2015 using Wildlife Acoustics Song Meter SM2BAT+ full-spectrum recording equipment (http://www.wildlifeacoustics.com/). Two bat detectors were placed 50 meters apart at each sample location to maximize the probability of recording bat calls while minimizing the probability of overlap of the detection zones between detectors (Duchamp et al. 2006, Yates and Muzika 2006). Detectors were allowed to run for 3-4 consecutive nights, with units operating from one half hour before civil sunset to one half hour after civil sunrise. Microphones were suspended approximately 2 m above the ground on poles with the detector secured in a weather tight container at the base (Figure 1).

Bats are generally attracted to waterbodies (Krusic et al. 1996), particularly species like *M. lucifugus*, which is known to forage over water. It is therefore likely that occupancy and detection rates could be impacted by proximity to water, so we stratified sampling into areas within acoustic range (i.e., about 40 m) of permanent or semi-permanent water and those in upland habitats (i.e., > 80 m from water). Ten sites were selected in each of these two categories via a spatially-balanced, random sample of public land within about 3 km of BICA. Sample locations were selected using the Equi-probable Design option and Balanced Acceptance

Sampling (BAS) algorithm (Robertson et al. 2013) within the SDraw Package in Program R (https://www.r-project.org/).

All calls were analyzed using the Sonobatch automated call analysis algorithm in the Wyoming Species Package of SonoBat3. We used an acceptable call quality threshold of 0.70 and a discriminant probability threshold of 0.90. To guard against false detections of species at sites, we visually assessed all recordings where the number of detections for a species at a site was less than three. For visually-assessed recordings, we evaluated the veracity of the species identification by assessing the quality of the recording and, if the recording was of sufficient quality, manually comparing bat calls to known reference calls. Recordings deemed unreliable as a result of this visual examination were excluded from the occupancy analysis.

Habitat data

We collected habitat data to at acoustic monitoring sites for use as covariates in our occupancy modeling analysis to explain variation in occupancy and detection probabilities related to habitat characteristics across our study area. We surveyed two 25 m radius plots at each acoustic survey location; one centered on each bat detector. Within each plot, we collected data on vegetative structure and topography within three 25 m by 2 m belt transects radiating from the plot center. The orientation of first transect was delineated using a table of randomly generated compass bearings, and the remaining transects were oriented 120° and 240° from the first.

At the plot center and at 12.5 m and 25 m along each belt transect, we recorded the slope, aspect, and slope position as ridgetop, shoulder, backslope, footslope, toeslope or valley bottom (Schoeneberger and Wysocki 2012). We tallied all trees whose stems intersected a belt transect and recorded their status as alive or dead, their height as overstory (> 3 m tall) or understory (< 3 m tall), their species, and their diameter at Breast Height (DBH) using a Biltmore stick. We recorded the decay class (Figure 2) of dead trees. Because trees were often very sparse on the BICA landscape, many belt transects intersected few trees. For those locations, we recorded data for all trees within the 25 m plot.

We measured canopy cover using a spherical densitometer at each cardinal direction at the plot center and at distances of 12.5 m and 25 m along each belt transect. We estimated ground cover composition along each of the 25 m belt transects by laying a 25 m tape measure down the center of the transect and recording the percent of the tape falling within each of eight ground cover categories: shrub, grass, form, coarse woody debris, vegetative litter, rock, trunk (including large roots), or bare ground. For each instance when the ground cover category was shrub, we recorded the species and height of the shrub.

Minimum daily temperature and daily precipitation data were obtained from the Lovell, Wyoming National Oceanic and Atmospheric Administration weather station (https://www.ncdc.noaa.gov/data-access/land-based-station-data). The moon phase, reported as fraction of the moon illuminated was calculated for each night based on data from the United States Naval Observatory (http://aa.usno.navy.mil/data/docs/MoonFraction.php).

Occupancy Analysis

Occupancy analyses were run in the "unmarked" package within Program R (Fiske and Chandler 2011) using the simple single-Season model for which we pooled acoustic detections recorded by the two detectors at each site. We treated each night of recording at our pooled site-scale plots as a survey event. We used a two stage process to model occupancy as a function of site and survey covariates (MacKenzie 2006, Yates and Muzika 2006). First, to optimally partition the variance due to imperfect detection, we used an information theoretic approach (Burnham and Anderson 2002) with Akaike's Information Criterion (AIC) to compare a set of models that included detection covariates for variables likely to influence the ability to detect bats at a site. Covariates investigated for the detection model included minimum temperature for each survey night, if any measureable precipitation fell on each survey night, the fraction of the moon illuminated for each survey night, the site type (Water or Upland), and the site habitat category (Woodland, Shurbland, or Xeric). Due to limited sample size, we selected a small set of covariates at each step and limited individual models to three covariates.

Second, with the optimal detection model identified, we explored the influence of habitat covariates on occupancy by holding the detection model constant and comparing models differing only in occupancy covariates using the same AIC approach. Occupancy covariates were drawn from habitat data we collected on site, but habitat data are still being compiled so the analyses in this report do not make use of the full dataset. Variables included here are: site type (Water or Upland), habitat category (Woodland, Shrubland, or Xeric), slope, and overstory canopy cover. The latter of these was discarded after preliminary models failed to converge, which likely results from the general dearth of canopy cover across the BICA landscape and a resulting prevalence of sites with no canopy cover.

When assessing the importance of particular variables in our AIC analysis, we identified a 'confidence set' of models. The confidence set of candidate models include all models with AIC weights that are within 5% of the best model and can be used as a general rule-of-thumb for evaluating strength of evidence (Royall 1997). All variables occurring in models within the confidence set can be deemed as having plausible support for influencing detectability or occupancy, while those falling outside the confidence set can be considered uninformative. AIC rankings mean little if the best model is still a poor fit to the data, so we additionally assessed goodness of fit for the top occupancy model using the MacKenzie and Bailey (2004) goodness-of-fit test.

RESULTS AND DISCUSSION

We detected 13 species of bats during acoustic surveys in 2015 (Table 1). The species list was the same as that complied during previous bat inventories of BICA (Keinath 2005), and preliminary assessment suggests that those species occurred at roughly the same prevalence in 2015 as in the 2005 inventories. Between one and twelve species were detected at individual sites, with those sites near water generally having more species than upland sites (Figure 3).

Myotis lucifugus occurred throughout the study area and was documented at all but two sampling locations (Figure 4). Occupancy analysis suggests that the detection rate for *M. lucifugus* was high (~ 98%), and most variability in detection was accounted for by moon phase (Table 2). Oddly, the impact of moon on detection was positive, with detections varying from 26% on moonless nights nearly 100% on nights with full moon. This relationship is opposite of that expected based on previous studies, which have suggested reduced bat activity on nights with a fuller moon (Anthony et al. 1981, Lang et al. 2006), though there might be exceptions to temperate zone bats (Karlsson et al. 2002).

With detection probability partitioned, occupancy of *M. lucifugus* in the BICA landscape was estimated at roughly 95% based on the top occupancy model (Table 3). Model fit was good, based on the MacKenzie and Bailey (2004) goodness-of-fit test (χ^2= 53.8, P = 0.68, c-hat = 0.39). There was some evidence that occupancy rate differed by site type and habitat category, with the occupancy rate being slightly lower in upland sites than water sites, and occupancy rate being slightly lower in shrubland habitats than woodland or xeric habitats. More formal quantification of these patterns would best we done by model averaging across the confidence set of models shown in Table 3, which we have not done here because our primary goal was to assess occupancy, not evaluate habitat use. None-the-less, evidence for these patterns was fairly weak, since the top model based on AIC ranking contained no occupancy covariates whatsoever. Based on this analysis, *M. lucifugus* should be considered nearly ubiquitous in the BICA landscape.

Optimal models varied across species (Table 4), but resulted in occupancy estimates generally in line with findings from earlier bat surveys in and near BICA (Table 1). Though methods differed from previous studies (making quantitative assessment of trends impossible), there do not appear to be any major shifts in abundance since inventories were conducted roughly a decade ago (Keinath 2005). *M. ciliolabrum*, *Eptesicus fuscus* and *M. lucifugus* are clearly the most prevalent bats on the BICA landscape, both in terms of abundance and occupancy. All three species are nearly ubiquitous, although this classification is slightly more questionable for *M. ciliolabrum*, because it is detected primarily via acoustic monitoring and physical conformation of detections is difficult due to low capture rates via mist netting. Similarly, occupancy rates of *L. noctivagans* should be viewed with caution, because it has never actually been captured in BICA, and its echolocation calls can be easily confused with those of the omnipresent *E. fuscus*.

The relatively high detectability and occupancy rates of *M. lucifugus* in our BICA surveys bode well for use of this method to monitor this species using occupancy analysis (MacKenzie and Royle 2005, Shannon et al. 2014). A more formal power analysis of the form demonstrated by Guillera-Arroita and Lahoz-Monfort (2012), suggests that if 20 sites are monitored for 4 nights each (as done here), we would be able to detect a decrease in occupancy of about 28% with power = 0.8. At this power, which is commonly used for planning monitoring efforts (Guillera-Arroita and Lahoz-Monfort 2012), there is a 20% chance of Type II error given an observed decline in occupancy (i.e., a 20% chance of failing to detect an actual decline). Based on similarly high detection and occupancy rates, methods outlined in this report would likely be suitable for monitoring both *M. ciliolabrum* and *Eptesicus fuscus*. Given generally lower detection and occupancy for other species, further investigation is necessary to make additional recommendations. Data from 2016 can be used to refine this power analysis and better inform long term implementation of these surveys to monitor populations of *M. lucifugus* and other species in the BICA landscape.

In 2016, WYNDD will repeat the same acoustic surveys outlined in this report. Additionally, we will continue to compile habitat data collected in 2015 and add additional variables to the occupancy analysis. These data will be used to further refine occupancy estimates. The final report, due in spring of 2017, will make recommendations for long-term implementation of these methods to monitor bat populations for bats in the landscape surrounding BICA.

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TABLES AND FIGURES

Table 1: Species detected during acoustic surveys in 2015 presented with the average number of acoustic detections across all sites in 2015, the occupancy rate across sites in 2015 estimated from the top occupancy model, and the qualitative estimate of abundance from the previous bat inventory (Keinath 2005). Species are ordered based on decreasing occupancy.

Species	Average Detections	2015 Occupancy Estimate	2005 Inventory Abundance
Small-footed myotis (*Myotis ciliolabrum*)	144.4 +- 207.6	1	Medium (few captures)
Big brown bat (*Eptesicus fuscus*)	31.2 +- 59.3	0.99	High (widespread)
Little brown bat (*Myotis lucifugus*)	165.5 +- 325.2	0.95	High (common and widespread)
Hoary bat (*Lasiurus cinereus*)	8.3 +- 14.3	0.93	Low (sparse but widespread)
Silver-haired bat (*Lasionycteris noctivagans*)	17.6 +- 20.8	0.87	Uncertain (questionable; no captures)
Spotted bat (*Euderma maculatum*)	4.5 +- 6.3	0.79	Medium (localized)
Long-eared myotis (*Myotis evotis*)	33.8 +- 50.4	0.78	Medium
Yuma myotis (*Myotis yumanensis*)	3.0 +- 7.4	0.63	Medium
Townsend's big-eared bat (*Corynorhinus townsendii*)	0.5 +- 1.1	0.52	Low-Medium (localized)
Long-legged myotis (*Myotis volans*)	0.5 +- 1.3	0.43	Medium
Pallid bat (*Antrozous pallidus*)	1.5 +- 2.6	0.32	Low (localized)
California myotis (*Myotis californicus*)	0.6 +- 1.9	0.24	Uncertain (questionable; no captures)
Fringe-tailed bat (*Myotis thysanodes*)	0.0 +- .2	0.12	Low (localized)

Table 2: Candidate models and associated AIC statistics investigating the detection probability of *Myotis lucifugus* from acoustic surveys on the landscape surrounding BICA. Detection (P) was modeled as a function of proportion of moon illuminated (Moon), site type (ST), habitat category (HC), precipitation (Precip), and minimum nightly temperature (Temp), while holding occupancy (Ψ) constant (Dot), as explained in the methods section.

Model	K	AIC	AICwt	Confidence Set
P~Moon, Ψ~Dot	3	83.26	0.999944	TRUE
P~ST+HC, Ψ~Dot	5	104.37	2.61E-05	FALSE
P~ST, Ψ~Dot	3	105.99	1.16E-05	FALSE
P~Precip, Ψ~Dot	3	106.68	8.21E-06	FALSE
P~HC, Ψ~Dot	4	107.85	4.56E-06	FALSE
P~Temp, Ψ~Dot	3	108.45	3.39E-06	FALSE
P~Dot, Ψ~Dot	2	108.98	2.60E-06	FALSE

Table 3: Candidate models and associated AIC statistics investigating the occupancy rate of *Myotis lucifugus* from acoustic surveys on the landscape surrounding BICA. Detection (P) was modeled only as a function of the proportion of moon illuminated (the top model of Table 2), as described above, while occupancy (Ψ) was either held constant (Dot), or modeled as a function of site type (ST), habitat category (HC), and/or slope of the survey site (SL).

Model	K	AIC	AICwt	Confidence Set
P~Moon, Ψ~Dot	3	83.25	0.382519971	TRUE
P~Moon, Ψ~ST	4	83.97	0.268370828	TRUE
P~Moon, Ψ~HC	5	84.67	0.188357707	TRUE
P~Moon, Ψ~ST+HC	6	85.09	0.153131474	TRUE
P~Moon, Ψ~SL	4	91.09	0.007619026	FALSE

Table 4: Top occupancy models for each species of bat detected during acoustic surveys in the landscape surrounding Bighorn Canyon National Recreation Area in 2015. Resulting occupancy estimates are shown in Table 1. Detection (P) and occupancy (Ψ) were either held constant (Dot) or modeled as functions of the proportion of moon illuminated (Moon), minimum nightly temperature (Temp), site type (ST), habitat category (HC), and/or slope of the survey site (SL), using methods described in the text for *M. lucifugus*.

Species	**Model**
Pallid bat (*Antrozous pallidus*)	P~Moon, Ψ~HC
Townsend's big-eared bat (*Corynorhinus townsendii*)	P~Dot, Ψ~Dot
Big brown bat (*Eptesicus fuscus*)	P~ST, Ψ~Dot
Spotted bat (*Euderma maculatum*)	PHC, Ψ~ST
Hoary bat (*Lasiurus cinereus*)	P~ST, Ψ~Dot
Silver-haired bat (*Lasionycteris noctivagans*)	P~Temp, Ψ~ST
California myotis (*Myotis californicus*)	P~ST, Ψ~Dot
Small-footed myotis (*Myotis ciliolabrum*)	P~HC, Ψ~Dot
Long-eared myotis (*Myotis evotis*)	P~STHC, Ψ~Dot
Little brown bat (*Myotis lucifugus*)	P~Moon, Ψ~Dot
Fringe-tailed bat (*Myotis thysanodes*)	P~Temp, Ψ~ST
Long-legged myotis (*Myotis volans*)	P~ST, Ψ~Dot
Yuma myotis (*Myotis yumanensis*)	P~ST, Ψ~Dot

Figure 1: Photograph of acoustic setup used during this study. The pole is 2 meters high and holds a microphone connected to an SM2+ bat detector in a weather-proof box.

Figure 2: Tree senescence stages used to classify snags adapted from Maser et al. (1979).

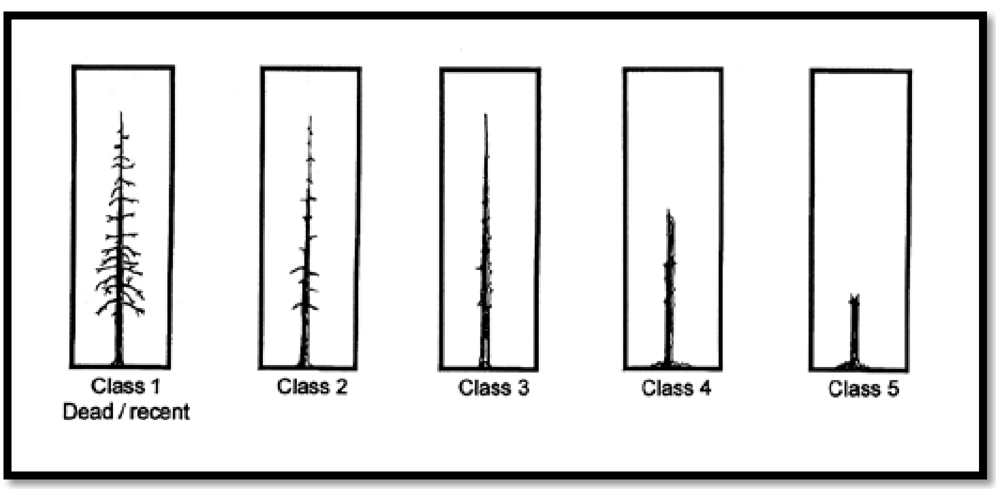

Figure 3: Species richness at acoustic sample locations within the study area during surveys in 2015. Color of symbol indicates whether the site was within 40 meters of water or was in upland habitat. Size of symbol is proportional to the number of species detected at each site, which is displayed next to each symbol.

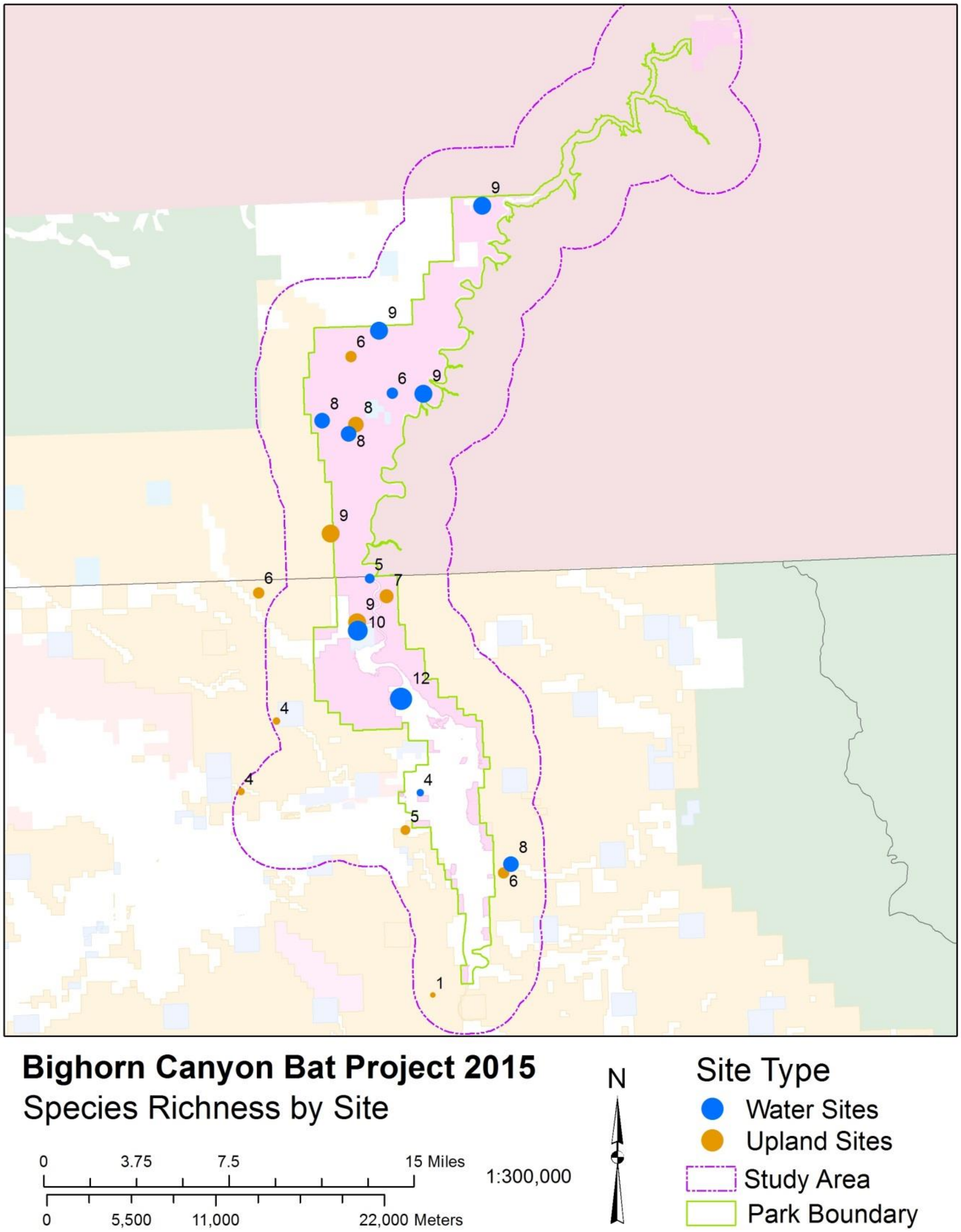

Figure 4: Detections of little brown bat (*Myotis lucifugus*) at acoustic sample locations within the study area during surveys in 2015. Color of symbol indicates whether the site was within 40 meters of water or was in upland habitat. Size of symbol is proportional to the number of positively identified passes of *M. lucifugus* at the site.