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BAT ACTIVITY AND USE OF HIBERNACULA IN WOOD BUFFALO NATIONAL PARK, ALBERTA

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ABSTRACT—Relatively little is known about bats or bat hibernacula in northern Canada. We were interested in documenting species diversity and seasonal activity of bats in Wood Buffalo National Park, including use of a cave hibernaculum by Little Brown Myotis (*Myotis lucifugus*), Northern Myotis (*Myotis septentrionalis*), and Big Brown Bats (*Eptesicus fuscus*). We used acoustic monitoring and mist netting over 3 y to assess species diversity and seasonal activity. We also recorded cave temperature during hibernation. During the summers of 2010 to 2012, we captured 470 bats including *M. lucifugus, M. septentrionalis*, and *E. fuscus*. We identified 2 migratory species via echolocation recordings in 2011: *Lasiurus cinereus* (Hoary Bat) was recorded in the area from mid-May to early October, and *Lasiurus borealis* (Eastern Red Bat) from mid-June to early August. Resident bat activity at the hibernaculum was greatest from mid-June to early September. Our findings provide a first approximation of species diversity and describe seasonal activity patterns of bats in Wood Buffalo National Park.

Key words: Alberta, Big Brown Bat, Eastern Red Bat, *Eptesicus fuscus*, hibernaculum, Hoary Bat, *Lasiurus borealis*, *Lasiurus cinereus*, Little Brown Myotis, *Myotis lucifugus*, *Myotis septentrionalis*, Northern Myotis, seasonal bat activity, Wood Buffalo National Park

Species diversity and seasonal activity of bats have been well documented throughout much of North America. While initial studies on bats in northern Canada have been focused in southern Yukon (Jung and others 2006; Slough and Jung 2008; Talerico 2008), southwestern Northwest Territories (Lausen and others 2014), and the Fort MacMurray area of northeastern Alberta (Grindal and others 2011), there remains a large portion of northern Canada where we know relatively little about bats, including large, undeveloped areas such as Wood Buffalo National Park (WBNP). Investigating the presence and seasonal activity of bat species in these remote areas helps us better understand the complexity of local ecosystems, provides baseline data in an area already impacted by climate change (for example, Payette and others 2004), and provides insight into how species behave at the northern limit of their ranges. In addition, with the spread of white-nose syndrome (WNS; a fungal disease killing millions of bats in North America; Blehert and others 2009), investigating conditions in bat hibernacula at northern latitudes may provide insight into the survivability of *Pseudogymnoascus destructans* (fungus that causes WNS; Minnis and Lindner 2013) in these potentially colder environments. Therefore, the goals of this study were to survey bat species diversity in a portion of the park, describe seasonal activity of resident and migratory bats, and investigate microclimatic conditions at one of the most northern bat hibernacula currently known (Walk-in Cave), located in northeastern Alberta, Canada.

Based on previous bat surveys in northern Alberta and the Northwest Territories (van Zyll de Jong 1985; Caceres and Pybus 1997; Grindal and others 2011; Reimer 2013; Wilson and others 2014), we expected Little Brown Myotis (*Myotis lucifugus*), Northern Myotis (*M. septentrionalis*), and Big Brown Bats (*Eptesicus fuscus*) to be present in Wood Buffalo National Park. Given recent observations south (Grindal and others 2011) and west (Nagorsen and Paterson 2012; Lausen and others 2014) of our study area, we also expected migratory species including Hoary Bats (*Lasiurus cinereus*), Eastern Red Bats (*L. borealis*), and Silver-haired Bats (*Lasionycteris noctivagans*) to be present.

Based on studies at more southern latitudes (Twente 1955; Beer and Richards 1956; Henshaw and Folk 1966; Brack and Twente 1985; Davis and others 1999), hibernating bats prefer cave temperatures of 2.6 to 8°C. We predicted that Walk-in Cave would provide similar temperature profiles as those for hibernacula selected by bats at more southern locations. We also investigated another, nearby cave (Peace Point Cave) as a potential hibernaculum in the southern region of WBNP.

METHODS

Study Site

We studied bats in the Alberta portion of WBNP, mainly in the vicinity of Walk-in Cave, the largest cave currently known in the park (Figure 1). WBNP is within the Boreal Plains Ecozone (Ecological Stratification Working Group 1996), and the area is primarily boreal forest dominated by Trembling Aspen (*Populus tremuloides*) and Jack Pine (*Pinus banksiana*), interspersed with wetlands, meandering streams, and a large number of karst landforms. Walk-in Cave is a limestone cave formed as an underground drainage system. It has 2 entrances each located at the bottom of large sinkholes (approximately 7-m deep). The main entrance is approximately 12-m wide by 4-m high; the secondary entrance is slightly narrower and lined with ice year round. Lewis (1974–1975) referred to this secondary entrance as the 'ice chute'. Surrounding trees shade both entrances and standing water in the sinkholes remains frozen for 9 months of the year. The cave is approximately 1 km long and has 4 main sections: (1) the entrance hall (approximately 2–5-m high, 6-m wide, and 90–100-m long); (2) the middle chamber (approximately 6-m high, 30–45-m wide, and 90-m long); (3) the main chamber (15-m high, 20-m wide, 120–180-m long); and (4) the ice chute chamber near the secondary entrance of the cave. An additional small back chamber (approximately 10-m deep, 1.5-m high, and 2-m wide) holds the majority of the hibernating bats (Lewis 1974–1975; hereafter, the ''Bat Chamber''). Two additional side chambers have recently been described as: (1) the rafting lake and aven (a side chamber and stream loop off of the ice chute chamber); and (2) the Lewis Rink (a large side-loop passage off of the entrance hall; Greg Horne, pers. comm.).

Acoustic Monitoring

To assess species diversity and seasonal bat activity, we recorded echolocation calls using AnaBat II ultrasonic detectors with CF-ZCAIMs set to a division ratio of 16 (Titley Electronics, Ballina, Australia) outside Walk-in Cave during 21 April 2011 to 7 October 2011 and 20 April 2012 to 26 October 2012; and at a pond 3 km to the west of the cave (hereafter, WB Pond), for the period of 11 May 2011 to 8 October 2011. At Walk-in Cave, we placed a detector in a weatherproof box 3 m from the entrance and pointed the microphone away from the entrance to prevent recording bats flying within the cave. At WB Pond, we mounted a detector on a tree trunk 2.5 m off the ground and 1 m away from the water's edge. Each detector remained in a fixed location for the duration of the survey.

We reviewed all AnaBat recordings using AnalookW version 3.8v. We identified species as *Eptesicus fuscus, Lasiurus borealis, L. cinereus, Lasionycteris noctivagans,* and *Myotis* spp., based on minimum frequency, call duration, and slope as outlined in Lausen and others (2014). Call characteristics of *M. lucifugus* and *M. septentrionalis* overlap (Fenton and Bell 1981), often making them indistinguishable with AnaBat II detectors; therefore, we grouped *Myotis* spp. in the analysis.

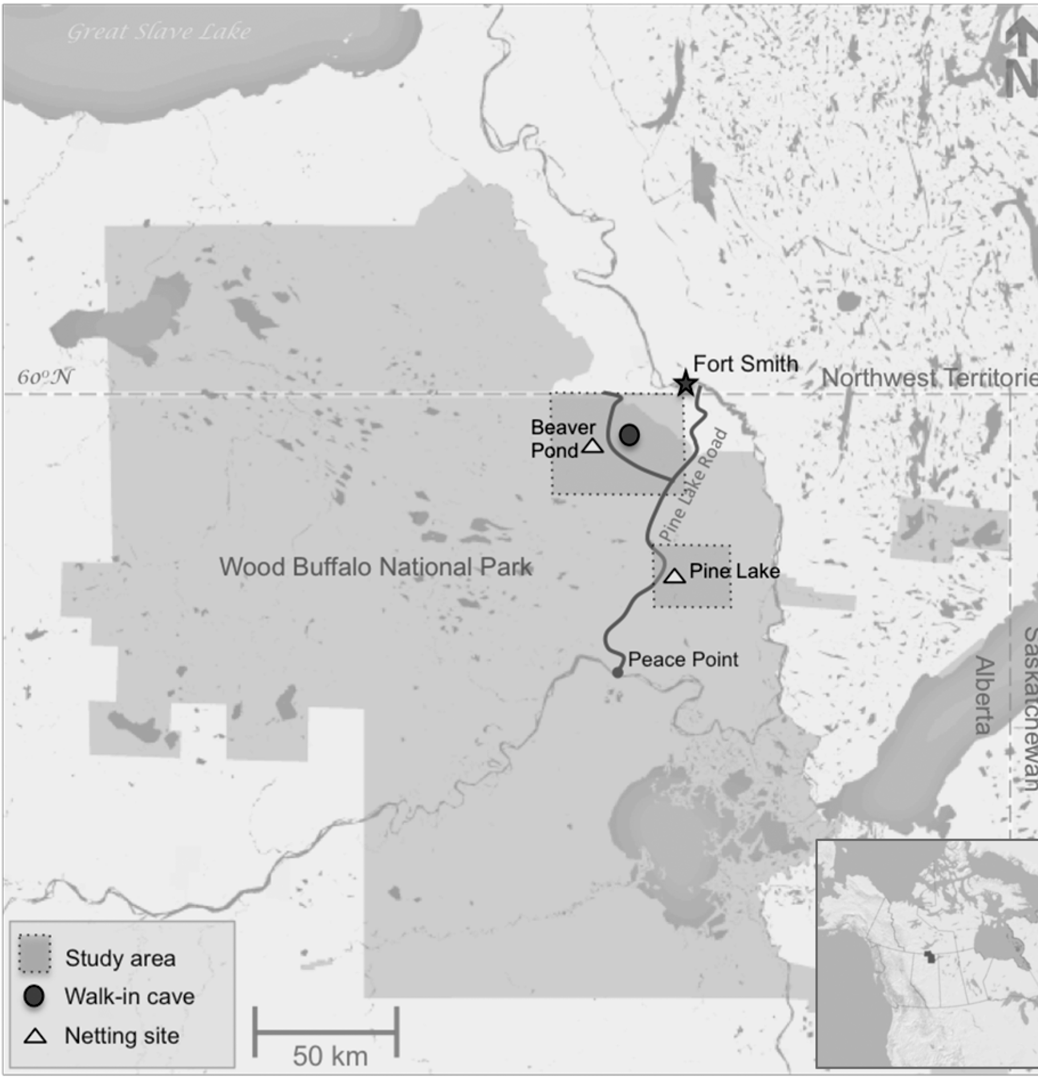

FIGURE 1. Location of the study area in Wood Buffalo National Park, Alberta, Canada. Inset map is of the location of Wood Buffalo National Park within western Canada.

Bat Captures and Handling

To complement our acoustic survey, we used mist nets (Avinet Inc., Dryden, NY, USA) to capture bats in 2010–2012. Capture sites included: (1) the mouth of Walk-in Cave (n = 7 nights); (2) WB Pond (n = 9); and (3) at Pine Lake, 25 km to the southeast of the cave (n = 1). We also investigated another known cave in WBNP (Peace Point Cave; near Peace Point, Fig. 1). Net size and location remained consistent at sites among nights. At Walk-in Cave, we set a 10-m long × 2.6-m high net across the mouth of the cave, approximately 1 m in front of the entrance. At WB Pond we set 2 nets (6 m × 2.6 m); 1 strung across a road and the other across an opening in the forest leading to the pond. Nets were open from 1 to 3 h depending on the capture rate and night length. Upon capture, we held bats in a cloth bag for 1 h to allow defecation prior to weighing. We identified individuals to species based on morphological features and measurements, using the key provided by Nagorsen (2002); determined sex, age (adult or juvenile), and reproductive condition, weighed them with a portable balance, measured forearm and ear lengths with calipers, fitted them with a uniquely labeled band (Porzana Ltd., East Sussex, UK) for future identification, and released them at their point of capture. We distinguished *M. lucifugus* from *M. septentrionalis* based on ear and tragus length (Nagorsen 2002). We identified volant juveniles by their evenly tapered phalangeal-metacarpal joints and unfused epiphyseal plates observed by back-illuminating the wing membrane (Kunz and Parsons 2009).

In September 2010 and November 2011, we surveyed bats in easily accessible chambers of Walk-in Cave, including the front, middle, main, and Bat Chambers, to estimate the number of individuals. We also handled a subsample to determine species, sex, and age. In September 2010, we surveyed bats in Peace Point Cave.

Cave Microclimate

To describe the temperature at Walk-in Cave, we recorded cave chamber temperature and ambient temperature at WB Pond, using temperature loggers (Hobo model UA-002-08; Onset, Bourne, MA) with an accuracy of ±0.47°C. We placed a temperature logger in both the middle chamber and Bat chamber of Walk-in Cave. We tested the effect of ambient temperature on bat activity at Walk-in Cave and WB Pond with linear regression, including bat activity (number of recorded AnaBat files) and ambient temperature as dependent and independent variables, respectively. Due to gaps in outside air temperature recordings at WB Pond, ambient temperatures for statistical analysis were obtained from the Environment Canada website (http://climate.weather.gc.ca) for the Fort Smith airport weather station, approximately 30-km north of the study area. All statistical analyses were performed with Stata/SE 12.1 (StataCorp, Texas).

RESULTS

Bat Activity at Walk-in-Cave

We recorded echolocation calls at the mouth of Walk-in Cave from 21 April to 22 September 2011 and 20 April to 21 October 2012 (Figure 2). The highest activity for both years was recorded during early September and there was a significant positive effect of ambient temperature at sunset on echolocation activity (linear regression, $F_{1,\ 280} = 50.3$, $P < 0.001$, $R^2 = 0.15$), with greater activity occurring during warmer nights.

We captured *M. lucifugus, M. septentrionalis*, and *E. fuscus* emerging from Walk-in-Cave during spring (May to early June; Figure 3). We captured no *M. septentrionalis* at the cave after 16 May. Fifty *Myotis* spp. were captured at the entrance to Walk-in Cave, of which only 2 were juvenile *M. lucifugus*. Of the 3 *E. fuscus* captured in a mist net at the entrance to Walk-in Cave on 11 September 2010, 2 were exiting within 2 h of dusk. All *E. fuscus* captured in mid- to late August, including juveniles (n = 24), were entering the cave 1 to 2 h after the 1st *Myotis* spp. was observed exiting the cave. The majority of *Myotis* spp. captured exiting the cave had mud on their bodies or wings; no mud was observed on *E. fuscus* captured entering the cave.

Internal Cave Inspections

On 10 and 11 September 2010, we surveyed Walk-in Cave and observed approximately 35 *Myotis* spp. roosting on the walls, mainly in the Bat Chamber. We handled 27 bats, all of which were *M. lucifugus*; 21 were reproductive adult males (swollen epidiymis clearly visible), 1 was a non-reproductive adult male, 2 were young-of-the-year males, and 3 were post-lactating adult females. On 10 November 2011, we observed 73 *Myotis* spp. in all chambers of Walk-in Cave except the entrance hall, middle chamber, and ice chute chamber (the outermost sections of the cave), including 22 bats in the main chamber, 41 bats in the Bat Chamber, and 10 distributed in various other locations. It is likely that more bats were present, but in locations where they were not visible. We handled 5 *M. lucifugus* randomly sampled from the cave wall, and all were adult males.

We observed *M. lucifugus* using the cave as a summer day roost (roosting in the front 3 chambers during the day and captured in mist nets as they emerged from the cave at dusk) on all summer visits to the cave (15 visits from 12 May to 6 September 2011 and 4 June to 13 August 2012). Specifically, we counted 30 and 47 *Myotis* spp. day-roosting in the front 3 chambers (entrance hall, middle chamber, main

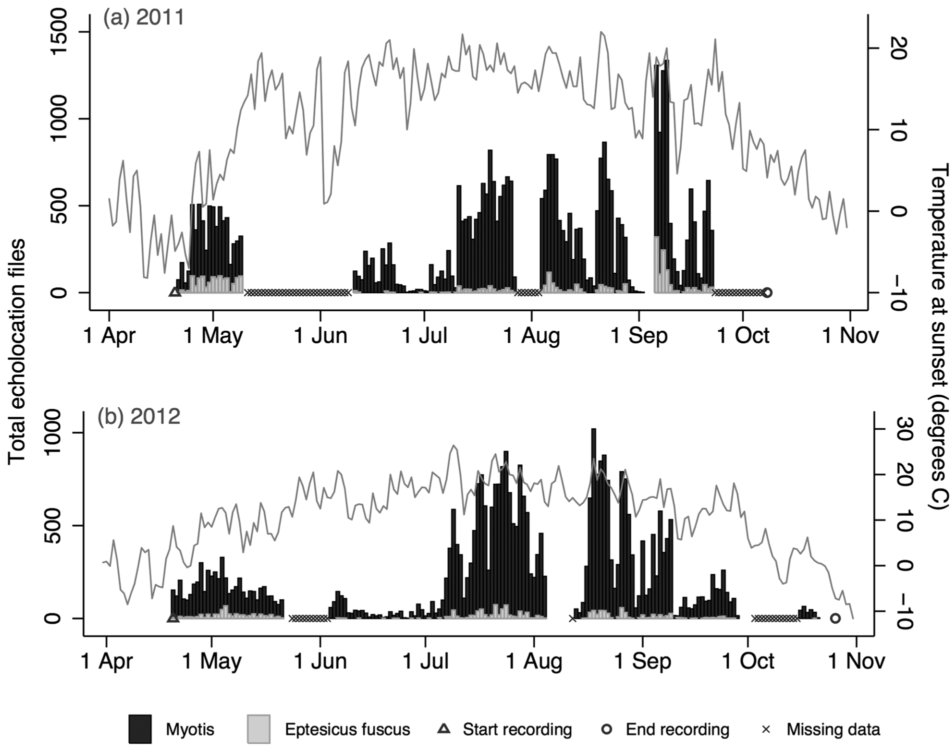

FIGURE 2. Bat echolocation activity recorded from sunset to sunrise at Walk-in Cave, Wood Buffalo National Park, Alberta, Canada, from mid-April to mid-October, during (a) 2011 and (b) 2012. Ambient temperature at sunset was obtained from Environment Canada for the Fort Smith Airport weather station. Nights with missing data (due to detector malfunction) are denoted with an ''x''. Note the y-axis scales differ between panels.

chamber) on 10 June 2011 and 11 June 2012, respectively.

Each time we entered the cave over the course of the 3 y (6 visits: 10 and 11 September 2010; 16 May, 11 June, and 10 November 2011; and 10 June 2012), we observed bat carcasses on the cave floor. On 10 November 2012 we observed a group of 6 *M. lucifugus* carcasses under a rock fall in the Bat Chamber, 3 separate *M. lucifugus* carcasses throughout the entrance hall and middle chamber, and 2 *E. fuscus* carcasses in the middle chamber, including 1 recently deceased, face down in a shallow puddle of water. On 10 September 2010, a similar observation was made of a recently dead adult female *E. fuscus* floating in the shallow cave water. There were no clinical signs of white-nose syndrome (see Gargas and others 2009) on bats in the cave.

On 12 September 2010 we entered Peace Point Cave to investigate bat presence and general habitat suitability for hibernating bats. The entrance is a large opening located mid-way along a chamber, creating a T-shape with each arm extending <25-m deep with a high ceiling. We observed only 2 *M. lucifugus*, one of which was covered in ice droplets.

Hibernaculum Conditions

Temperature in Walk-in Cave was relatively stable throughout 2011 and 2012 (Fig. 4). The entrance chamber ranged between 1 and 2°C from June through October 2011, dropped below 0°C in mid-November 2011 (minimum −4.1°C), and returned to above 0°C in mid-April 2012. The bat chamber, where the majority of *Myotis* spp. were observed hibernating, fluctuated between −1.1 and 0.8°C from 11 November 2011 to 10 June 2012.

Bat Activity at WB Pond and Surrounding Areas

We recorded echolocation activity of both resident and migratory species at WB Pond

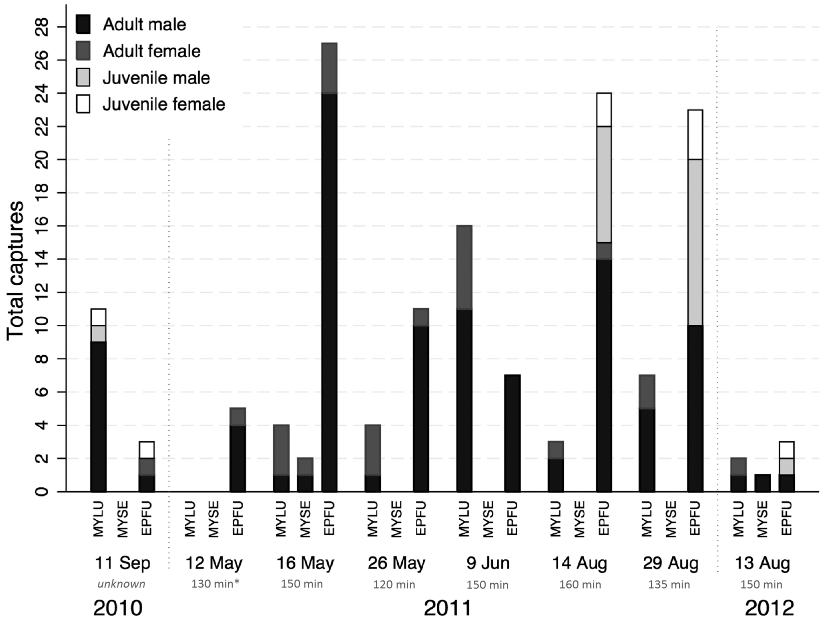

FIGURE 3. Mist net captures at the northern entrance of Walk-in Cave, Wood Buffalo National Park, Alberta, Canada, during 2011 (with the exception of captures on 12 May 2010, which occurred at the southern entrance of the sinkhole). Bars are stacked to represent total capture numbers; capture effort (netting minutes) is listed below each date (based on one 10- × 2.6-m net). MYLU = *Myotis lucifugus*, MYSE = *Myotis septentrionalis*, EPFU = *Eptesicus fuscus*.

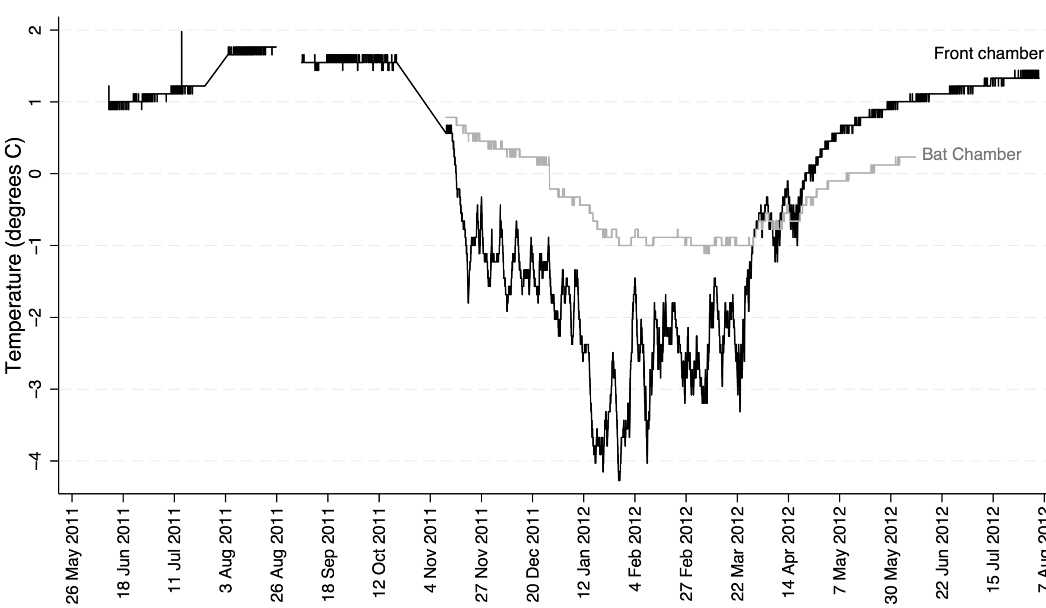

FIGURE 4. Hourly recordings of ambient temperature inside Walk-in Cave, Wood Buffalo National Park, Alberta, Canada. The highest concentration of hibernating bats was observed in the Bat Chamber.

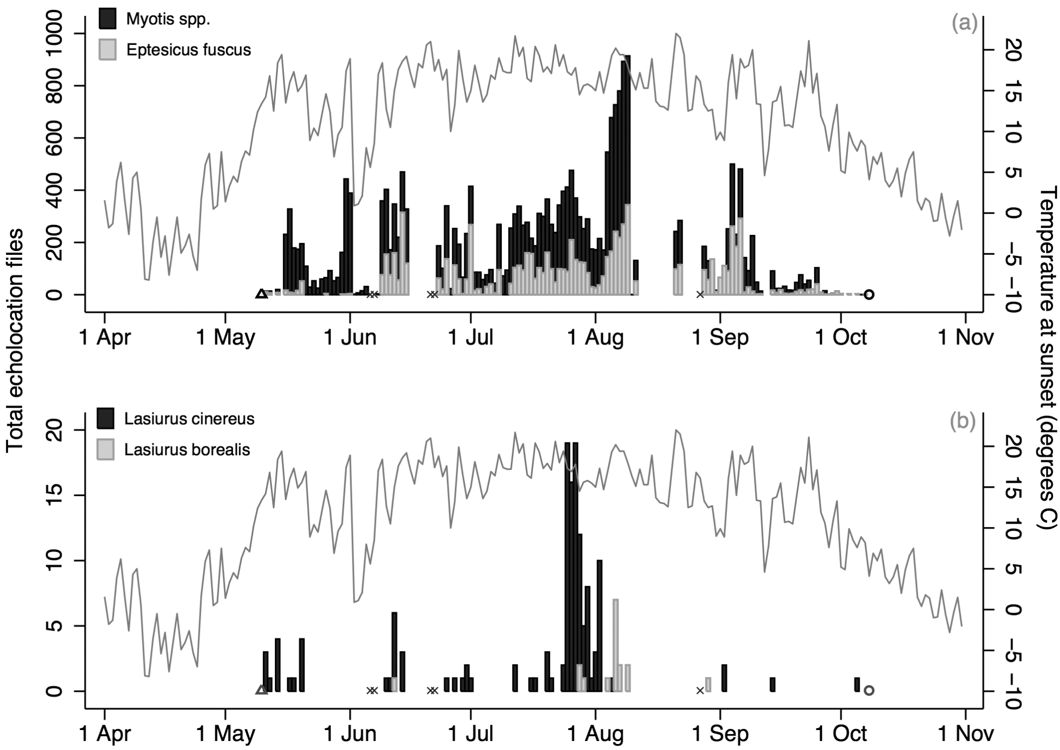

FIGURE 5. (a) Resident and (b) migratory bat activity recorded during 2011 at WB pond, Wood Buffalo National Park, AB. Ambient temperature at sunset was obtained from Environment Canada at the Fort Smith Airport weather station. Nights with missing data (due to detector malfunction) are denoted with an "x". Note the y-axis scales differ between panels to best illustrate the data.

during 11 May to 7 October 2011 (n = 166 nights). The greatest bat activity was recorded during early August (Figure 5). We identified echolocation files as *Myotis* spp. (n = 23,002 files recorded on 119 nights), *E. fuscus* (n = 7624 files recorded on 103 nights), *L. cinereus* (n = 140 files recorded on 35 nights), and *L. borealis* (n = 17 files recorded on 8 nights). Ambient temperature at sunset ranged from −1.7 to 36.7°C between 11 June and 8 September 2011, and had a significant effect on echolocation activity (linear regression, $F_{1,\ 119} = 47.5$, $P < 0.001$, $R^2 = 0.29$), with more activity on warmer nights. We captured adult male and female *M. lucifugus* (n = 188) and *M. septentrionalis* (n = 58) throughout the summer, with the highest capture numbers from early August through early September when we began catching juveniles in addition to adults (Figure 6). We captured *E. fuscus* of both sexes and age classes (adult, juvenile), although far fewer (n = 6) than *Myotis* spp.

DISCUSSION

Species Diversity

We identified 5 bat species in WBNP: *M. lucifugus*, *M. septentrionalis*, *E. fuscus*, *L. cinereus*, and *L. borealis*. As predicted, *M. lucifugus*, *M. septentrionalis*, and *E. fuscus* were the most commonly detected bats, as illustrated by captures and echolocation recordings. This is consistent with the wide distribution of *M. lucifugus* (Fenton and Barclay 1980) and the presence of *M. lucifugus* and *M. septentrionalis* directly north (Reimer 2013; Wilson and others 2014) and south (Caceres and Pybus 1997; Vonhof and Hobson 2001; Grindal and others 2011) of our study area. Despite the lack of records of *E. fuscus* in northeastern Alberta (300-km south of WBNP; Grindal and others 2011), captures of *E. fuscus* at Walk-in Cave, and echolocation recordings at WB Pond were relatively common.

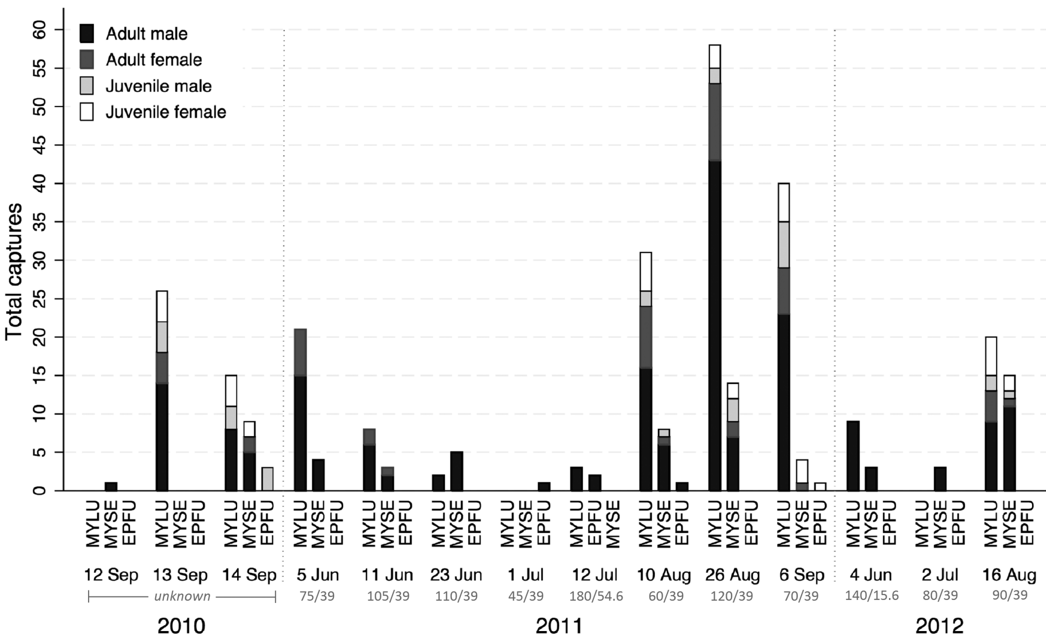

FIGURE 6. Mist-net captures of bats in Wood Buffalo National Park at Pine Lake (14 September 2010), and sites within 3 km of Walk-in Cave (all other dates). Bars are stacked to represent total capture numbers; netting effort is listed below dates as min/m^2. MYLU = *Myotis lucifugus*, MYSE = *Myotis septentrionalis*, EPFU = *Eptesicus fuscus*.

Two migratory species were detected in the study area: *L. cinereus* and *L. borealis*. Echolocation calls and captures of these migratory species have been recorded directly south in northern Alberta (Patriquin 2004; Grindal and others 2011), and echolocation calls of *L. cinereus* have been recorded as far north as Yellowknife, Northwest Territories (Wilson and others 2014) and southeastern Yukon (Slough and others 2014). However, captures of either species have yet to be reported in the Northwest Territories or Yukon. As these species roost solitarily and often fly above the forest canopy (Kalcounis and others 1999; Menzel and others 2005), the lack of captures may be due to an emphasis on netting at ground level. Future studies should consider using stacked nets to gain height, and acoustic lures (Reyes and Szewczak 2010) to bring the bats lower during flight. There are only 2 records of *L. noctivagans* farther north than our study area: an acoustic recording and a photograph of a live animal (Wilson and others 2014). The absence of this species in southwestern Northwest Territories was also noted by Lausen and others (2014). In northern Alberta, south of the Peace River, *L. noctivagans* is reportedly relatively common (Grindal and others 2011). The absence of captures or echolocation recordings in our study area suggests that this species is either not present or uncommon; however, due to similarities in echolocation calls between *E. fuscus* and *L. noctivagans* (Betts 1998), it is possible that some *L. noctivagans* calls were misidentified as *E. fuscus*. In addition, our sampling was restricted geographically, and a survey covering a larger area and different habitats may yet reveal the presence of *L. noctivagans*.

Seasonal Activity

Echolocation activity at the mouth of Walk-in Cave indicated that *Myotis* spp. and *E. fuscus* were active on or before 21 April 2011 and 2012, as activity was recorded immediately after deploying the bat detectors. Activity continued through the end of September for both years and ceased in mid-October in 2012. These timings are consistent with the onset and decline of activity at the nearby WB Pond, as well as seasonal activity observed in other northern (Slough and Jung 2008; Talerico 2008; Reimer 2013) and more southerly locations (Davis and Hitchcock 1965; Anthony and others 1981). In addition, an increase in *Myotis* spp. activity from early July to early September corresponds with the addition of flying young-of-the-year, followed by the return of males and then females to hibernacula for autumn swarming (Hall and Brenner 1969; Thomas and others 1979; Schowalter 1980). These timings suggest that despite living at higher latitudes, *Myotis* spp. in WBNP may have a hibernation schedule similar to those of species of *Myotis* occurring farther south (Davis and Hitchcock 1965; Hall and Brenner 1968).

We performed extensive acoustic monitoring at the WB Pond during 2011 to record the presence and seasonal distribution of species. *L. cinereus* was active in the area from mid-May to early October, and *L. borealis* was active to a lesser extent from mid-June to late August. The peak in activity of migratory species during late July and early August corresponds with autumn migration observed in more southern locations (Dalquest 1943; Findley and Jones 1964; Timm 1989; Cryan 2003; Baerwald and Barclay 2011). Resident bat species (*Myotis* spp. and *E. fuscus*) were more active in the area than migratory species, and remained in the area throughout the entire non-hibernating season. This is not surprising given the close proximity to hibernacula, and apparently suitable foraging habitat. Resident bats also displayed an increase in activity with warmer ambient temperatures, which has also been observed in several studies farther south (for example, Menaker 1962; Anthony and others 1981; Negraeff and Brigham 1995; Erickson and West 2002; Dzal and Kunz 2012).

Myotis lucifugus, *M. septentrionalis*, and *E. fuscus* were all captured emerging from Walk-in Cave during spring, and were captured frequently at the nearby WB Pond throughout the summer. *Myotis lucifugus* was the only species observed using Walk-in Cave as a summer day roost. Other studies occasionally report a small number of *M. lucifugus*, typically males, day-roosting at winter hibernacula during the summer months (Davis and Hitchcock 1965; Hall and Brenner 1968). Roosting in cooler temperatures, such as in Walk-in Cave, and using torpor would provide energy savings for male *M. lucifugus* who do not bear the burden of fetal development and lactation; however, warmer temperatures are thought to be necessary for spermatogenesis (Kurta and Kunz 1988). Perhaps, rather than a few males repeatedly using the cave as a summer day-roost, many individuals use it sporadically throughout the summer.

Juveniles of each resident species were captured in our study area, indicating that females reproduce in the area. This is not surprising given the close proximity of *M. lucifugus* and *M. septentrionalis* maternity colonies farther north in the South Slave region (Reimer 2013; Reimer and Kaupas 2013), the presence of cabins used as roosts along Pine Lake, and tree roosting opportunities across the study area.

Hibernaculum Conditions

A majority of the *Myotis* spp. in Walk-in Cave during September and November were observed roosting in the Bat Chamber. This is consistent with where Lewis (1974–1975) reported bats (he speculated that they were *M. lucifugus* or *E. fuscus*) during the only winter census performed prior to our work. He reported estimated populations of approximately 150 bats residing in the Bat Chamber while our counts were lower (35–75 *Myotis* spp.). Although *E. fuscus* was not observed in the cave during our 2011 winter count, the capture of individuals emerging from the cave during spring, the presence of carcasses throughout the cave, and previous winter records of *E. fuscus* in the cave (Lewis 1974–1975) suggest that some individuals hibernate in Walk-in Cave. We hypothesize that this species readily roosts in crevices created by rock slabs in the cave. These rock slabs were common throughout the cave and were heard falling from the ceiling into the water at the bottom of the cave. This may explain the Big Brown Bats that appeared to have drowned. Torpid bats that fall into the water when a rock slab used for roosting falls would most likely drown before they could warm enough to swim.

Cave temperatures during the hibernation period (October to April) in the Bat Chamber were warmer and more stable than the entrance chamber. These temperatures (-1.1 to $0.8°C$) were colder than hibernacula temperatures at lower latitudes (2.4 to 5.6°C; Twente 1955; Beer and Richards 1956; Henshaw and Folk 1966; Brack and Twente 1985; Davis and others 1999). Because the thermal neutral zone of bats varies with latitude (Dunbar and Brigham 2010), bats hibernating in WBNP may have similar overall energy savings and expenditures during hibernation compared to southern conspecifics. As the Bat Chamber falls below freezing during the winter months, further studies are needed to assess basal temperature and torpor use of bats in Walk-in Cave to investigate what additional energetic expense the bats incur to remain above ambient temperature during periods below freezing, or what benefit they may have as a result of a lower basal temperature (slower metabolic rate) than bats farther south.

Evidence of infection by *P. destructans*, the fungus that causes WNS (Minnis and Lindner 2013), or clinical signs of disease (Gargas and others 2009) were not observed in Walk-in Cave. The hibernaculum temperatures were below the optimal growth conditions for the fungus (5 to 10°C; Blehert and others 2009), although the fungus is able to grow at temperatures near freezing. Further studies are required to determine the probability of WNS establishing under the conditions at this site.

After investigating the Peace Point Cave, we suggest that it may be unsuitable for bat hibernation. Given its shallowness and shape, we suspect temperature and humidity fluctuation would make this cave unsuitable for hibernating bats, and that the 2 observed bats in the cave would have moved to a deeper cave prior to the onset of winter.

In conclusion, we found that WBNP is home to 2 migratory species (*L. cinereus* and *L. borealis*) and 3 resident species of bats (*M. lucifugus*, *M. septentrionalis*, and *E. fuscus*). With extensive industrial development occurring in northeastern Alberta, WBNP may provide important intact habitat for bats, especially given the presence of karst for hibernation, and wetlands, riparian, and intact mixed-wood forests for foraging and roosting. Given the vast region of karst topography and undeveloped habitat in WBNP, other hibernacula likely exist in the park. Further exploratory studies and efforts to radio-track bats late in the summer may reveal important hibernacula in this region, which currently represents one of the most northern areas of bat hibernation in North America. More extensive mist-netting surveys in late July or early August that target higher flying species are likely to confirm the presence of migratory species that we could only identify from echolocation recordings. In addition, thermoregulation studies investigating winter basal temperature of bats hibernating in Walk-in Cave would provide insight into both the effect of colder cave temperatures on energy expenditure and the likelihood of establishment of *P. destructans* in the area.

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