OBSERVATIONS OF LITTLE BROWN MYOTIS (*MYOTIS LUCIFUGUS*) HABITAT ASSOCIATIONS AND ACTIVITY IN THE CHUGACH NATIONAL FOREST, ALASKA

SUSAN C LOEB, ERIC A WINTERS
US Forest Service, Southern Research Station, Clemson, SC 29634 USA

MARION E GLASER
Chugach National Forest, Moose Pass, AK 99664 USA

MARIAN L SNIVELY
Alaska Department of Fish and Game, Anchorage, AK 99518 USA

KEVIN S LAVES
Chugach National Forest, Moose Pass, AK 99664 USA

JESSICA K ILSE
Chugach National Forest, Girdwood, AK 99587 USA

ABSTRACT—Little is known about the ecological relationships of bats of Southcentral Alaska. We used AnaBat II bat detectors, mist-netting, and radio-telemetry to collect preliminary data on the distribution and status of bats on the Chugach National Forest (CNF), their activity patterns, and their roosting and foraging habitats. *Myotis* spp. were detected at 20 of 25 acoustic sampling sites. Bat activity tended to be higher at water sites than at road or trail sites, and higher in hardwood stands than in conifer stands, although these differences were not statistically significant. Based on data recorded at a maternity roost, the total activity period for bats during July was approximately 5 h per night; no bat activity was observed prior to sunset or after sunrise at any of the sites. Hourly activity was not related to temperature, but activity ended earlier on cooler nights. An adult male Little Brown Myotis (*Myotis lucifugus*) was tracked to a day-roost in a large Sitka Spruce (*Picea sitchensis*) snag with sloughing bark. Most female Little Brown Myotis captured at a maternity roost were either lactating or post-lactating. These preliminary findings suggest that bats are common on the CNF, but more research is needed to determine their habitat associations and their responses to disturbances including forest management practices, fire, insect outbreaks, climate change, and disease.

Key words: activity patterns, Alaska, Chugach National Forest, foraging habitat, habitat associations, Little Brown Myotis, maternity roost, *Myotis lucifugus*, snag roost

Bats that live at northern latitudes face many challenges during the summer active period. Because of the short nights and lack of complete darkness in some areas, the amount of time available to obtain sufficient energy for reproduction, growth of young, and preparation for hibernation is limited (Michaelsen and others 2011). Further, greater light levels may increase the risk of predation (Speakman 1991; Rydell and others 1996). Yet, in Scandinavia, bats are known to live as far north as 69°N latitude where there is continuous daylight during parts of the summer (Speakman and others 2000). Recent studies suggest that many bat species have moved or will move farther north in response to global climate change (Humphries and others 2002; Sachanowicz and others 2006; Rebelo and others 2010). Understanding how bats respond to environmental conditions encountered at northern latitudes may be critical for future conservation and management.

Despite the considerable increase in research on forest bats in the USA and other parts of the world over the past 2 decades (Brigham 2007), very little is known about the bats of Alaska. Further, most studies on Alaskan bats have taken place in southeast Alaska (Parker and Cook 1996; Parker and others 1996, 1997; West and Swain 1999; MacDonald and Cook 2007; Boland and others 2009a, 2009b). Only 2 studies have been published on the bats of Southcentral or Interior Alaska (Whitaker and Lawhead 1992; Rydell and others 2002), although other papers have reported on the occurrence of bats in this part of the state (Haas and others 1982; Parker and others 1997).

The Little Brown Myotis (*Myotis lucifugus*) is the only species known to inhabit Southcentral and Interior Alaska, but it has been found as far north as Fort Yukon (65.6°N) and Nulato (64.7°N; Parker and others 1997). There is 1 record of a Big Brown Bat (*Eptesicus fuscus*) in Interior Alaska, but this bat is thought to have been transported by a vehicle (Parker and others 1997). However, Big Brown Bats have likely been recorded in the Yukon (approximately 60°N; Slough and Jung 2008). Although Little Brown Myotis are thought to occur throughout the forested regions of Alaska (Parker and others 1997), most records of bats in Southcentral and Interior Alaska are associated with buildings (Haas and others 1982; Whitaker and Lawhead 1992; Rydell and others 2002). Little is known about the forest habitat associations of Little Brown Myotis in Alaska or the factors that affect their distribution.

Many bat species in North America prefer to forage in open areas, along edges, or in mature forests with open understories due to reduced physical and acoustical obstructions or clutter in these types of habitats (Loeb and O'Keefe 2011). Use of less cluttered habitats allows bats to more efficiently locate and capture prey (Brigham and others 1997). However, when light levels are high, as they are at northern latitudes in late spring and summer, foraging in more open areas may increase the risk of predation. Therefore, unlike bats in more temperate regions, bats at northern latitudes may prefer more cluttered habitats or forests with denser canopies, particularly on nights close to the summer solstice (Rydell and others 1996; Speakman and others 2000; Talerico 2008; Randall 2009). Smaller, more maneuverable bats that use high-frequency broadband echolocation calls, such as Northern Long-eared Myotis (*M. septentrionalis*), are better adapted for foraging in cluttered habitats than larger species such as Big Brown Bats or Hoary Bats (*Lasiurus cinereus*; Aldridge and Rautenbach 1987; Fenton 1990). Little Brown Myotis have morphological features that are intermediate between large and small bats (Duchamp and Swihart 2008) and use open, edge, and cluttered habitats throughout their range (Kalcounis and Brigham 1995; Patriquin and Barclay 2003; Ford and others 2005; Brooks 2009). The ability to use a wide range of habitat types may allow them to adapt to changing conditions across a season. Understanding how Little Brown Myotis in northern latitudes use different forest types may be important for managing forest landscapes in the future.

Throughout their range, maternity roosts of Little Brown Myotis are usually in buildings or other anthropogenic structures such as bat houses and bridges (Fenton and Barclay 1980; Harvey and others 2011). However, a Little Brown Myotis maternity roost was found in a hydrothermally-heated roost on the outer coast of Chichagof Island, southeast Alaska (West and Swain 1999) and males have been found roosting in a variety of structures including trees, rock crevices, wood piles, caves, and mines (Fenton and Barclay 1980; Broders and Forbes 2004; Olson and Barclay 2013; Randall and others 2014). Most of the known Little Brown Myotis roosts in Southcentral and Interior Alaska are associated with anthropogenic structures and little is known about their use of natural roosts (Tessler and others 2014). Additional information on natural roosts will aid in conservation and management of these bats in natural habitats.

The Chugach National Forest (CNF) is the most northern national forest, extending from Prince William Sound to the Kenai Peninsula. Little is known about the bats of the CNF, although roosts have been found near the forest in the past (Haas and others 1982; Parker and others 1997). Our objectives were to collect preliminary data on reproductive status and distribution of bats on the CNF, their activity patterns, and their roosting and foraging habitats, using acoustic surveys, mist-netting, and radio-telemetry.

METHODS

Study Area

The study was conducted on the Seward and Glacier Ranger Districts of the CNF. The Seward

District ranges from 0 to 1950 m above sea level (asl) and comprises coastal rainforest and boreal forest. The Glacier District ranges from 0 to 3740 m asl in coastal rainforest. Conifers including Sitka Spruce (*Picea sitchensis*) and Mountain Hemlock (*Tsuga mertensiana*) dominate the mountainsides, whereas mixed forests including Black Spruce (*Picea mariana*), Paper Birch (*Betuala papyrifera*), Balsam Polar (*Populus balsamifera*), Aspen (*Populus tremuloides*), and willow (*Salix* spp.) occur on disturbed sites and in recently deglaciated valleys. Most of the forest is managed for fish and wildlife habitat (USDA Forest Service 2002). The climate is subarctic-boreal. Average high and low temperatures (1952–2004) in July were 19.2 and 5.2°C, respectively, in the Seward Ranger District (Moose Pass, 60.500°N, 149.4333°W) and 18.6 and 8.3°C, respectively, in the Glacier District (Girdwood, 60.9333°N, 140.1667°W). Precipitation patterns vary considerably across the area, with coastal areas receiving an average of 46.0 cm between May and September and interior areas receiving far less (mean May–September rainfall = 24.5 to 29.3 cm).

Acoustic Surveys

Acoustic surveys were conducted using AnaBat$^{\text{TM}}$ II acoustic detectors connected to CF-ZCAIMs (Titely Electronics, Ballina, New South Wales, Australia; hereafter, AnaBats), from 11 to 22 July 2011, with an additional sampling session in mid-August 2011. Each AnaBat was placed in a weatherproof container with the microphone at the base of a 45° PVC tube and set on a tripod at approximately 1.4 m above ground. AnaBats were programmed to begin recording at 22:00 AKDT and stop recording at 06:00 AKDT, which was ≥55 min before sunset and ≥44 min after sunrise in July, but 15 min after sunset and 20 min before sunrise in August. Acoustic sampling sites were not selected randomly. Instead, we placed detectors at 26 sites that were selected *a priori* as potentially good foraging sites for bats (for example, near slow-moving water, lakes or ponds, along flyways such as forest roads and trails, and in mature forest stands, Appendix 1). We also selected sites that might be good mist-netting sites. In addition, we placed 1 detector outside a maternity roost in a residence and 1 detector at a mine opening at which a bat gate had been placed during the previous fall. All sites were sampled for 2 consecutive nights, although we obtained 3 nights of data from 1 site. A substantial amount of rain fell during 1 night and this night was not included in the analysis. Acoustic data were uploaded to a computer after each point was sampled. We used a filter to remove insect and other noise (Britzke 2003) using the software Analook (version 4.9j) and removed all files without bat calls. Calls were then examined qualitatively to determine the minimum frequency and slope and identify species (O'Farrell and others 1999). We used 2 metrics of bat activity: the number of bat passes, and the number of bat calls or pulses (Britzke and others 2013). A bat pass was defined as a series of ≥1 echolocation calls without interruption for >5 s. To examine activity patterns at 3 sites with very high activity, we summed the number of bat passes per 5 min using the CountLabels function in AnalookW.

Mist-netting and Radio-telemetry

We attempted to capture bats at 4 sites. We placed 38 mm polyester mesh mist nets (Avinet Inc., Dryden, NY) across forest streams or roads at the 3 sites. The other mist net site was at a private residence that was used as a roost site by a Little Brown Myotis maternity colony. Nets were opened at or near civil twilight (when artificial light is usually not required for human activities) and checked every 10 to 15 min at the forest sites and remained open for ≥3 h. Nets were monitored continuously at the maternity roost and were closed after 2 h. We recorded species, sex, age, reproductive condition, body mass, forearm length, and wing damage index of each bat captured. Age was determined by assessing the degree of epiphyses fusion in the 3rd and 4th fingers (Anthony 1988), and wing damage was scored using criteria developed by Reichard and Kunz (2009) to determine whether bats showed signs of white-nose syndrome. We placed a numbered aluminum-lipped band on the forearm of each bat. Two 3 mm biopsy punches were taken from each bat for genetic verification of species and subspecies.

We placed a 0.42 g radio transmitter (Holohil Systems, Ltd., ON) on an adult male Little Brown Myotis captured on 14 July 2011, and tracked him to his roost the next day using a 3-

element Yagi antenna. The male weighed 7.8 g, and thus the transmitter represented 5.4% of the bat's body mass, just slightly higher than the recommended 5% (Aldridge and Brigham 1988). We also attempted to locate him on 21 July 2011. All handling and telemetry procedures followed guidelines established by the American Society of Mammalogists (Sikes and others 2011) and were approved by Clemson University Animal Use and Care Committee (AUP # 2011-030).

Analysis

Each site was classified as either a road/trail or water site (set adjacent to a stream, pond, lake, or wetland). The maternity roost and the mine adit were the only sites not on a road/trail or next to a water body. Due to the unique nature of the maternity site we excluded it from most analyses except for nightly activity patterns, and we excluded the mine adit site from the analysis of road versus water sites. Using orthophotographs, we also measured the distance from the sampling point to the nearest water body (stream, lake, or pond), road or trail, and building. To examine activity patterns in relation to temperature, we used the hourly activity levels at each site each night. We obtained hourly temperature data from the Remote Automatic Weather Stations (RAWS) data set (NWCG Fire Weather Working Team 2005) at the Broadview, Kenai Lake, Granite, and Girdwood stations.

We examined bat use of forest types by overlaying forest type data on acoustic sampling point locations in ArcGIS 10.1 (ESRI, Redlands, CA, USA). We used 3 forest types in our analysis: (1) Conifer, which included Sitka Spruce, White Spruce, Mountain Hemlock, and Hemlock-Spruce forest types ($n = 12$); (2) Hardwood, which included Aspen, Paper Birch, Balsam Poplar, and willow forest types ($n = 6$); and (3) Mixed Hardwood-Softwood (Mixed; $n = 3$).

Because sites were not randomly selected, we were primarily interested in conducting exploratory data analysis to provide a preliminary assessment of habitat use in relation to forest habitat type. To examine activity levels in relation to habitat types and landscape features, we averaged the number of bat passes, number of calls, number of min after sunset when activity began, and number of min before sunrise when activity ceased across recording nights at each site to get an activity index for each site. The activity index data were not normally distributed, so we used a Wilcoxon Rank Sum Test to test whether the number of passes per site, number of calls per site, activity initiation (number of minutes after sunset), activity cessation (number of minutes before sunrise), and total activity period (number of minutes from onset to cessation of activity) differed between road-trail and water sites; and used the Kruskal-Wallis procedure to test whether these variables varied among forest types. We used Spearman rank correlations (r_s) to test whether these variables were related to distance to roads, water, or buildings, and to test whether hourly activity levels (number of passes/h) were correlated with ambient temperature during that hour; and the duration of the activity period, activity onset, and activity end were related to the temperature at sunset, temperature at sunrise, and average nightly temperature. All analyses were conducted in SAS 9.1. Either means ± 1 SE or medians and 90% confidence limits are presented for results.

RESULTS

Bat Activity and Habitat Use

Due to equipment failure at 1 site, data from only 25 of the 26 sites were used in the analyses. Bats were detected at 20 of the 25 sampling sites, and all bat calls were characteristic of those made by *Myotis* spp. (short-duration broadband echolocation calls with minimum frequencies of approximately 40 kHz and maximum frequencies of approximately 60–65 kHz). High levels of bat activity were recorded at the maternity roost (mean number of passes per night = 451) and 2 stream sites (mean number of passes per night = 188.5 and 770.5), compared to other sites. No echolocation calls were recorded at the mine adit, 1 road site, and 3 water sites.

Although the median number of passes and calls per site tended to be higher at water sites than at road or trail sites (Table 1), these differences were not statistically significant ($z = -1.24$, $n = 23$, $P = 0.21$ and $z = -0.87$, $n = 23$, $P = 0.38$, respectively). The number of passes per site was not correlated with distance to water ($r_s = -0.27$, $n = 22$, $P = 0.23$), distance to roads ($r_s = 0.09$, $n = 22$, $P = 0.69$), distance to a

TABLE 1. Median and 90% confidence limits (in parentheses) of number of bat passes and bat calls per site, and the number of minutes post sunset when activity began, number of minutes prior to sunset when activity ended, and the total activity period.

Habitat type	Passes	Calls	Minutes post- sunset	Minutes pre- sunrise	Total activity period
Road	3 (0, 26)	22 (0, 186)	81 (26, 140)	92 (60, 200)	166 (52, 393)
Water	6 (0, 188)	50 (0, 5678)	60 (45, 98)	88 (39, 157)	233 (114, 260)
Conifer	3 (0,54)	19 (0,454)	84 (27, 140)	111 (33, 200)	124 (52, 260)
Mixed	26 (0, 770)	186 (0, 38972)	53 (45, 62)	74 (60, 88)	313 (233,392)
Hardwood	35 (0, 188)	252 (0,5678)	59 (14, 88)	45 (39,122)	240 (160,290)

building (r_s = 0.23, n = 22, P = 0.31), or elevation (r_s = 0.33, n = 22, P = 0.14). Similarly, the number of calls per site was not correlated with distance to water (r_s = −0.22, n = 22, P = 0.34), distance to roads (r_s = −0.02, n = 22, P = 0.92), distance to a building (r_s = 0.35, n = 22, P = 0.11), or elevation (r_s = 0.39, n = 22, P = 0.07). The number of passes and the number of calls did not vary significantly among forest types (all $P > 0.30$), although there was a trend for higher activity in hardwood stands than in conifer stands, with mixed hardwood-conifer stands being intermediate (Table 1). However, sample sizes were low in each category.

Based on activity recorded at the maternity roost, the total activity period for bats during July was approximately 5 h/night (Fig. 1a and 1b). No bat activity was observed prior to sunset or after sunrise at any site, although considerable activity occurred prior to evening civil twilight and after morning civil twilight. Total activity periods at sites other than the maternity roost in July ranged from 51.5 ± 9.5 min to 290.5 ± 20.5 min per night and averaged 198.9 ± 23.6 min. Activity at these sites began a mean of 69.3 ± 8.4 min after sunset and ceased a mean of 96.4 ± 13.1 min before sunrise. Activity patterns within sites were relatively similar from night to night, but even for those sites with the greatest activity, the patterns varied among sites (Fig. 1).

Hourly activity (number of passes per h) and the onset of activity were not related to any temperature variable (all $P > 0.08$). However, the end of activity (min before sunrise) was negatively related to temperature at sunset (r = −0.40, n = 37, P = 0.014), temperature at sunrise (r = −0.48, n = 37, P = 0.003), and average nightly temperature (r = −0.41, n = 37, P = 0.01), and the total activity period was positively related to temperature at sunrise (r = 0.34, n = 34, P = 0.05; Fig. 2). Thus, activity ended earlier on nights when the temperature was cooler, resulting in shorter activity periods. Although there was no clear-cut threshold temperature that governed activity, once temperatures dropped below 10°C activity began to decline (Fig. 2).

The onset, cessation, and total length of activity did not differ significantly between road and water sites (z = 0.72, n = 15, P = 0.47; z = 0.45, n = 15, P = 0.65; and z = −0.45, n = 15, P = 0.65, respectively; Table 1). Sample sites were 0 to 1025 m from the road. The onset of activity (minutes after sunset) was negatively correlated with distance to the nearest road (r = −0.65, n = 15, P = 0.0089), and the total activity period was positively correlated with the distance to the road (r = 0.51, n = 15, P = 0.05). Thus, activity began earlier and lasted longer as distance from roads increased.

Demographic and Roost Data

Eighteen bats were captured during mist-netting, 2 at one of the stream sites (Moose Creek) and 16 at the maternity roost in the residence. All bats were *Myotis lucifugus alaskensis* (M Vonhof, Western Michigan University, pers. comm.). The 2 bats captured at Moose Creek were adult males and 15 of the 16 bats captured at the maternity roost were adult females. The other bat captured at the maternity roost was a newly volant juvenile male (mass = 7.8 g). Five of the adult females were lactating, 9 were post-lactating, and 1 showed no signs of reproductive activity. None of the bats had wing damage indicative of white-nose syndrome and all appeared healthy. Mean body mass of adult females captured at the maternity roost was 8.0 ± 0.1 g and mean forearm length was 38.0 ± 0.2 mm. Masses of the adult males were 7.5 and 7.8 g.

The radio-tagged adult male bat was tracked on the day following tagging to a roost 222 m

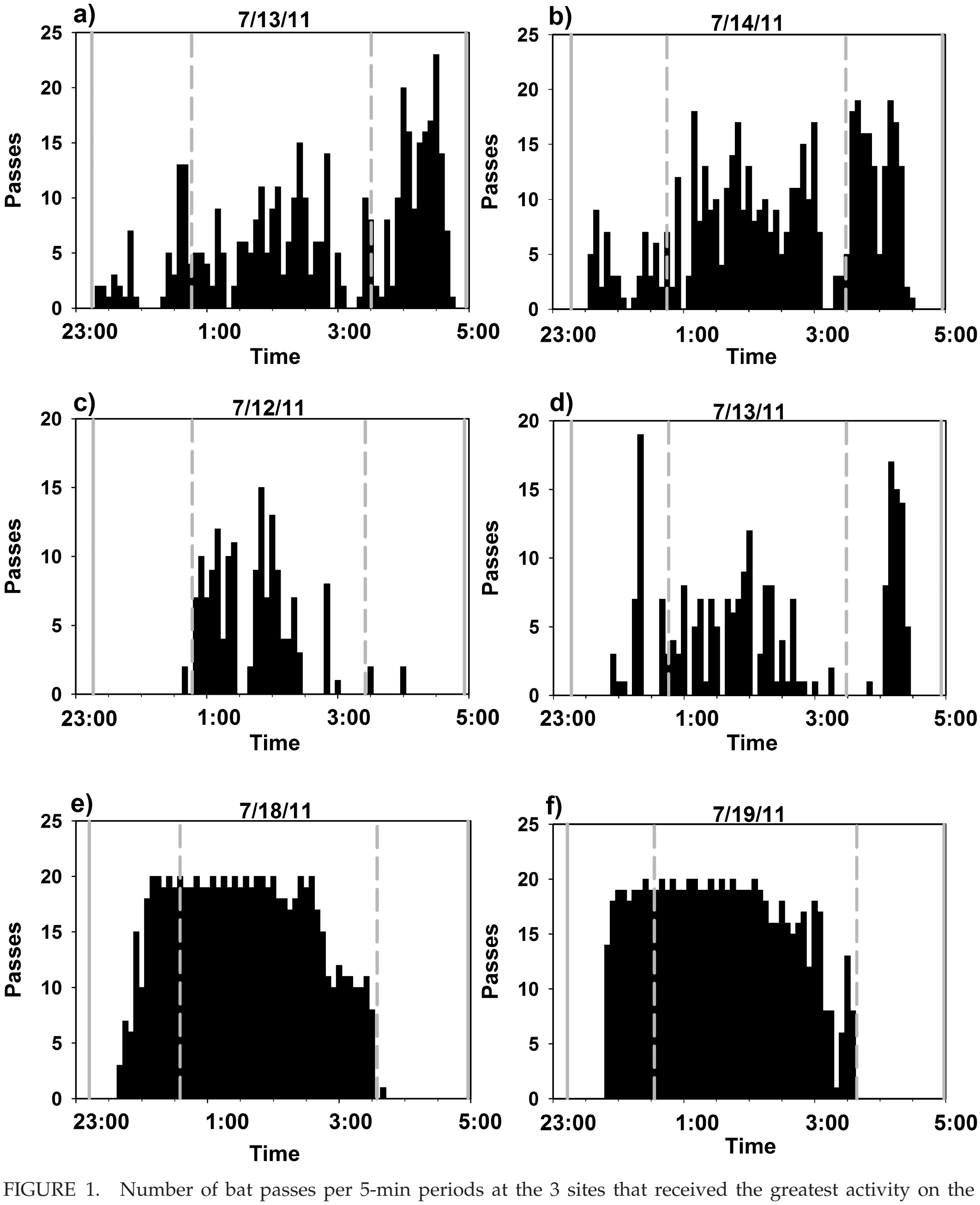

FIGURE 1. Number of bat passes per 5-min periods at the 3 sites that received the greatest activity on the Chugach National Forest, July–August 2011. a) and b) activity at the entrance to a maternity roost in a residence; c) and d) activity at Dave's Creek; e) and f) activity at North Willawaw Creek. Solid gray lines represent sunset and sunrise and dashed gray lines represent civil twilight.

from the capture point. The roost tree was 182 m asl on an ENE facing slope. The roost was a large (35.0 cm dbh, 15.8 m tall) Sitka Spruce snag with approximately 40% of its bark remaining. The tree was not in dense canopy and most likely received a large amount of solar exposure during the early part of the day. The bat flushed as we approached the tree and

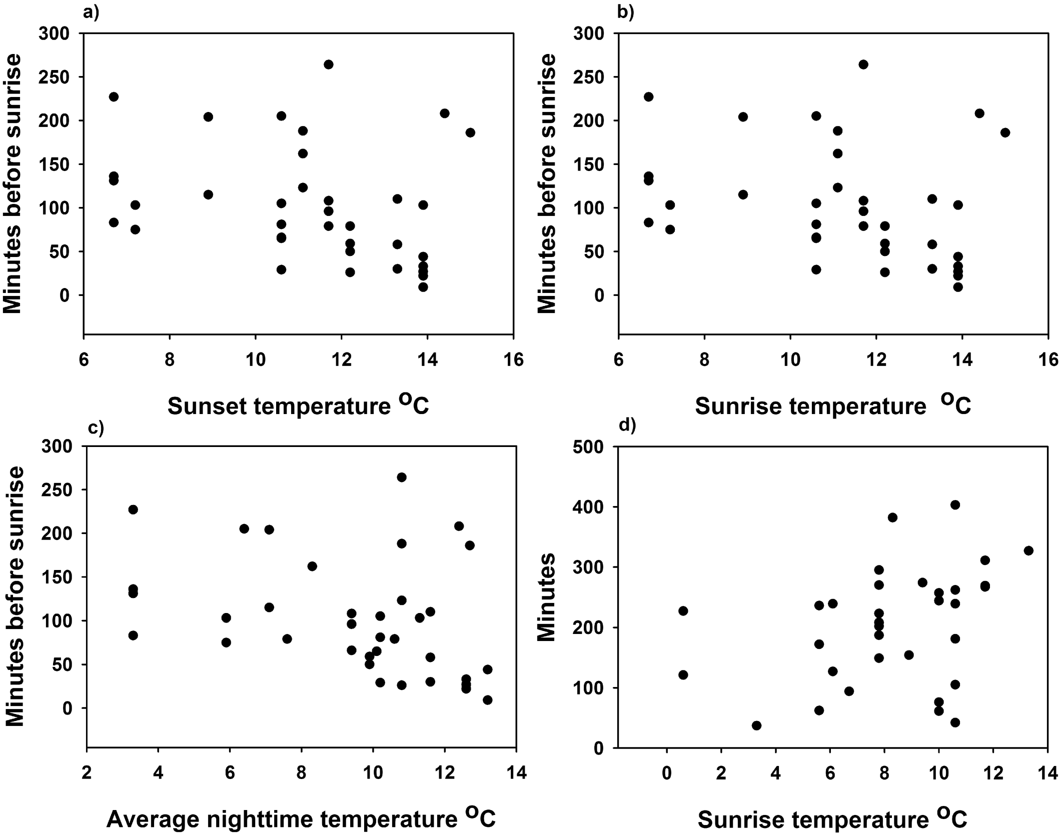

FIGURE 2. Relationship between a) the cessation of activity and the temperature at sunset; b) the cessation of activity and temperature at sunrise; c) cessation of activity and average nighttime temperature; and d) the total active period and temperature at sunrise.

appeared to fly from behind a piece of loose bark approximately halfway up the tree. We were not able to track the bat again until the following week. The bat had moved from this tree, but we were not able to locate its new roost because the area from which the signal was heard was inaccessible.

DISCUSSION

Bats were found in all areas of the Chugach National Forest that we sampled during July and August 2011. Only Little Brown Myotis were captured, and there was no evidence that other species, particularly non-myotids, were present on the forest. This is consistent with other studies in Southcentral Alaska (Parker and others 1997) and the Yukon (Talerico 2008; Randall 2009). However, identification of bats, particularly *Myotis* spp., using acoustic means is controversial (Barclay 1999), and Northern Long-eared Myotis, Long-legged Myotis (*Myotis volans*), Hoary Bats, and either Silver-haired Bats (*Lasionycteris noctivagans*) or Big Brown Bats have recently been recorded in the Yukon (Jung and others 2006; Slough and Jung 2008; Slough and others 2014).

Although there was not a statistical difference between activity at road and water sites, 7 of the 8 sites with the highest activity other than the maternity roost were at streams, ponds, or lakes, suggesting that sites with water may provide more suitable habitat for Little Brown Myotis than other sites on the forest. Little Brown Myotis usually forage over water and feed primarily on aquatic insects (Fenton and Barclay 1980; Lunde and Harestad 1986; Barclay 1991). Therefore, it is not surprising that water sites received greater use than other sites. Bat activity also appeared to be somewhat higher in hardwood stands than in conifer stands. However, 5 of the 6 hardwood stands we sampled were associated with water sites, and the association with hardwoods may be a by-product of the preference of Little Brown Myotis for foraging in riparian areas. Future studies should try to tease apart the effects of forest type and water presence through the use of stratified random sampling procedures that will control for the presence of water and forest type.

No activity was detected at the gated mine adit. The adit was surveyed in 2007 and the presence of scattered moth wings in the mine suggested use by bats during the active season. However, the mine was not monitored for bat activity prior to or after gate installation (except for our sampling), and thus it is not possible to determine whether the lack of activity at the mine was due to general variability of use or negative effects of the gate itself.

Activity levels were not related to landscape features such as distance to water, distance to the nearest road, distance to the nearest building, or elevation. Because Little Brown Myotis are often associated with buildings, we expected greater activity closer to anthropogenic structures such as buildings or roads. At a similar latitude in the Yukon (60.8°N), Little Brown Myotis activity was greatest in forest stands closest to town or the nearest lake (Randall and others 2011). Female bats in the Yukon study were tracked to a maternity colony in a building in town, which may explain the high activity close to town (Randall and others 2014). Due to time constraints, we were not able to sample sites >1 km from the road. Because activity may decline or completely drop off in more remote areas, it will be important to sample these areas in future studies to determine their importance to bats.

No activity was observed prior to sunset or after sunrise at any of the sites, although there was considerable activity prior to evening civil twilight and after morning civil twilight. Talerico (2008) also did not observe activity by Little Brown Myotis prior to sunset or after sunrise in the Yukon, even when nights were only 3.5 h long at the summer solstice. Thus, it appears that Little Brown Myotis avoid full sunlight even when the hours of relative darkness are brief. The avoidance of high light levels by bats at northern latitudes suggests that there may be a northern limit to their distributions even if warming temperatures make northern areas more climatically suitable in the future.

The colony of Little Brown Myotis in the CNF in July was active for approximately 5 h/night. Activity started soon after sunset and continued until just before sunrise. During July, female bats have high water and energy demands related to lactation (Kurta and others 1989a, 1989b) and it is likely that they must forage continuously during the darkest period of the night. Activity at the roost was continuous throughout the night, and it is likely that females returned to the roost several times to nurse young, as has been observed for Little Brown Myotis in Quebec (Henry and others 2002) and Indiana Myotis (*M. sodalis*) in Michigan (Murray and Kurta 2004).

Hourly bat activity was not related to temperature. This is in contrast to several other studies that have found positive associations between bat activity and temperature (Hayes 1997; Erickson and West 2002; Milne and others 2005; Scanlon and Petit 2008; Wolcott and Vulinec 2012; but see Lučan and Radil 2010). However, we found that the duration of activity was related to temperature. Although the onset of activity was not related temperature, activity stopped earlier on nights when the average nightly temperature and temperature at sunrise and sunset were lower. This suggests that bats begin to forage at approximately the same time each night despite ambient conditions, but stop feeding if temperatures decline. Once temperatures dropped below approximately 10°C, activity began to decline. In the Yukon, bats did not forage when temperatures dropped below 6°C (Talerico 2008). Insect availability during the night is often correlated with temperature, and activity levels of bats are commonly greatest during the first hours of the night (Speakman and others 2000; Milne and others 2005). Bats may cease foraging as temperatures drop because foraging costs and the costs associated with maintaining body temperature may not be balanced by energy intake. Maintaining water balance is also important, particularly for pregnant and lactating females (Kurta and others 1989b). On colder nights bats may emerge simply to drink and then return to their roosts if insect availability is depressed due to low temperatures.

The total length of the activity period and its onset and cessation did not differ between water and road-trail sites. However, activity began earlier at sites farther from the road and lasted longer as distance from the road increased. Light levels on and near roads may be greater than in more sheltered areas, and bats may prefer to commute and forage in areas with greater cover early in the evening (Rydell and others 1996; Speakman and others 2000; Talerico 2008; Randall 2009). Thus, providing forest cover near roost sites may be an important management strategy for bats in northern latitudes.

Body mass of adult females was about 1 g lighter than that of adult female Little Brown Myotis captured at 2 sites in the Yukon (Randall 2009; Jung and Slough 2011), but forearm lengths were similar (Talerico 2008; Randall 2009). We captured females as they were exiting the roost at the beginning of their activity period when they may have been at their lowest body mass due to their 19-h fast. The adult males that we captured were also about 1 g lighter than adult males captured in the Yukon (Randall 2009), but bats were also captured early in the evening. We observed high levels of reproductive activity among bats at the maternity roost, including the capture of a juvenile bat on 21 July. This is similar to the chronology of reproductive activity observed by Randall (2009) for Little Brown Myotis at a latitude similar to our study site. However, the reproductive rate that we observed (14 of 15 adult females were either lactating or post-lactating) was much higher than was observed at a different site in the Yukon (32 to 74%; Talerico 2008). Mean temperatures in Moose Pass in July 2011 were either similar or lower than those observed during the study in the Yukon. Thus, differences in reproductive rates between the bat colonies in Moose Pass and the Yukon may have been due to the quality of roosts. For example, Big Brown Bats that roost in buildings have higher reproductive success than those that roost in rocks, due to warmer conditions and better predator protection (Lausen and Barclay 2006).

The roost tree used by the male bat on the CNF was very similar to tree roosts used by a number of other *Myotis* species (Barclay and Kurta 2007), a large snag with sloughing bark that is not obscured by other trees and received some solar radiation, at least in the morning. Male Big Brown Bats use daily torpor to reduce their energy costs more frequently than reproductive females, and are more likely to use torpor in the afternoon than females (Hamilton and Barclay 1994). The ENE location of the roost use by the adult male on the CNF is consistent with the use of daily torpor, particularly in the afternoon. In the Yukon, male and female bats have also been reported to roost in rock crevices (Slough 2009; Randall and others 2014). Several people we spoke to while working at the CNF thought that bats in their neighborhoods might be using rock crevices. As this type of roost has been documented in other parts of the far north, these anecdotal observations or conjectures warrant follow-up.

In summary, our study demonstrated that Little Brown Myotis are common in many parts of the CNF. However, much more information is needed before predictions can be made on how forest management and other disturbances may affect bats on the CNF. In particular, a well-designed, statistically robust study is needed to determine the factors associated with habitat use across the forest. Forest management practices may have negative, neutral, or beneficial effects on bats (Hayes and Loeb 2007). In many areas, bats are more active in openings and clearings than in forests with dense canopy cover (Loeb and O'Keefe 2011). However, in the Yukon, bats forage in more protected areas such as interior forest near the solstice and in more open areas such as forest edges on darker nights (Talerico 2008). Further, bat activity in the Yukon is lower in salvaged logged areas than those with dense canopy cover, particularly near the solstice when light levels are highest (Randall 2009). In Southeast Alaska, bat activity is lower in clearcut and second-growth forest than in old-growth forest and riparian areas (Parker and others 1996). Because bats in northern latitudes may respond differently to forest management activities than bats in more temperate regions due to light levels (Randall and others 2011), further research is needed to test the effects of forest management practices and other disturbances on bats in Alaska.

Much research remains to be done on northern bats. Bat populations are currently facing many threats, including global climate change, disease, and increased human development (Jones and other 2009). As white-nose syndrome moves west across the United States and Canada (Turner and others 2011), it will be crucial to determine whether Alaskan bats are at risk, and to establish baseline population estimates that can be compared across time and space. It will also be important to determine the hibernation patterns and migratory routes of bats that summer in the CNF. It is not currently known whether bats in Southcentral Alaska hibernate locally or whether they migrate to hibernacula in other locales, and whether bats are widely dispersed or densely congregated in these over-wintering sites. Effective conservation and management of bats on the CNF will require knowledge and understanding of their winter and summer habits and ecology.

ACKNOWLEDGMENTS

M Vonhof (Western Michigan University) conducted the genetic analyses. We thank CA Carrothers, G Hayward, CJ Jorgensen, LA Randall, SJ Zarnoch and 2 anonymous reviewers for providing helpful comments on earlier drafts of the manuscript.

LITERATURE CITED

ALDRIDGE HDJN, BRIGHAM RM. 1988. Load carrying and maneuverability in an insectivorous bat: A test of the 5% ''rule'' of radio-telemetry. Journal of Mammalogy 69:379–382.

ALDRIDGE HDJN, RAUTENBACH IL. 1987. Morphology, echolocation and resource partitioning in insectivorous bats. Journal of Animal Ecology 56:763–778.

ANTHONY ELP. 1988. Age determination in bats. In: Kunz TH, editor. Ecological and behavioral methods for the study of bats. Washington, DC: Smithsonian Institution Press. p 47–58.

BARCLAY RMR. 1991. Population structure of temperate zone insectivorous bats in relation to foraging behavior and energy demand. Journal of Animal Ecology 60:165–178.

BARCLAY RMR. 1999. Bats are not birds – a cautionary note on using echolocation calls to identify bats: A comment. Journal of Mammalogy 80:290–296.

BARCLAY RMR, KURTA A. 2007. Ecology and behavior of bats roosting in tree cavities and under bark. In: Lacki MJ, Hayes JP, Kurta A, editors. Bats in forests: Conservation and management. Baltimore, MD: Johns Hopkins University Press. p 17–59.

BOLAND JL, HAYES JP, SMITH WP, HUSO MM. 2009a. Selection of day-roosts by Keen's Myotis (*Myotis keenii*) at multiple spatial scales. Journal of Mammalogy 90:222–234.

BOLAND JL, SMITH WP, HAYES JP. 2009b. Survey of bats in Southeast Alaska with emphasis on Keen's Myotis (*Myotis keenii*). Northwest Science 83:169–179.

BRIGHAM RM. 2007. Bats in forests: What we know and what we need to learn. In: Lacki MJ, Hayes JP, Kurta A, editors. Bats in forests: Conservation and management. Baltimore, MD: Johns Hopkins University Press. p 1–15.

BRIGHAM RM, GRINDAL SD, FIRMAN MC, MORISSETTE JL. 1997. The influence of structural clutter on activity patterns of insectivorous bats. Canadian Journal of Zoology 75:131–136.

BRITZKE ER. 2003. Use of ultrasonic detectors for acoustic identification and study of bat ecology in the eastern United States [dissertation]. Cookville, TN: Tennessee Technological University. 64 p.

BRITZKE ER, GILLAM EH, MURRAY KL. 2013. Current state of understanding of ultrasonic detectors for the study of bat ecology. Acta Theriologica 58:109–117.

BRODERS HG, FORBES GJ. 2004. Interspecific and intersexual variation in roost-site selection of Northern Long-eared and Little Brown Bats in the Greater Fundy National Park Ecosystem. Journal of Wildlife Management 68:602–610.

BROOKS RT. 2009. Habitat-associated and temporal patterns of bat activity in a diverse forest landscape of southern New England, USA. Biodiversity and Conservation 18:529–545.

DUCHAMP JE, SWIHART RK. 2008. Shifts in bat community structure related to evolved traits and features of human-altered landscapes. Landscape Ecology 23:849–860.

ERICKSON JL, WEST SD. 2002. The influence of regional climate and nightly weather conditions on activity patterns of insectivorous bats. Acta Chiropterologica 4:17–24.

FENTON MB. 1990. The foraging behaviour and ecology of animal-eating bats. Canadian Journal of Zoology 68:411–422.

FENTON MB, BARCLAY RMR. 1980. Myotis lucifugus. Mammalian Species 142:1–8.

FORD WM, MENZEL MA, RODRIGUE JL, MENZEL JM, JOHNSON JB. 2005. Relating bat species presence to simple habitat measures in a central Appalachian forest. Biological Conservation 126:528–539.

HAAS GE, WILSON N, ZARNKE RL, BARRETT RE, RUMFELT T. 1982. Siphonaptera from mammals in Alaska. Supplement III. Western Alaska. Canadian Journal of Zoology 60:729–732.

HAMILTON IM, BARCLAY RMR. 1994. Patterns of daily torpor and day-roost selection by male and female Big Brown Bats (*Eptesicus fuscus*). Canadian Journal of Zoology 72:744–749.

HARVEY MJ, ALTENBACH JS, BEST TL. 2011. Bats of the United States and Canada. Baltimore, MD: Johns Hopkins University Press. 202 p.

HAYES JP. 1997. Temporal variation in activity of bats and the design of echolocation-monitoring studies. Journal of Mammalogy 78:514–524.

HAYES JP, LOEB SC. 2007. The Influences of forest management on bats in North America. In: Lacki MJ, Hayes JP, Kurta A, editors. Bats in forests: Conservation and management. Baltimore, MD: Johns Hopkins University Press. p 207–235.

HENRY M, THOMAS DW, VAUDRY R, CARRIER M. 2002. Foraging distances and home range of pregnant and lactating Little Brown Bats (*Myotis lucifugus*). Journal of Mammalogy 83:767–774.

HUMPHRIES MM, THOMAS DW, SPEAKMAN JR. 2002. Climate-mediated energetic constraints on the distribution of hibernating mammals. Nature 418: 313–316.

JONES G, JACOBS DS, KUNZ TH, WILLIG MR, RACEY PA. 2009. Carpe noctem: The importance of bats as bioindicators. Endangered Species Research 8:93–115.

JUNG TS, SLOUGH BG. 2011. Body condition of a free-ranging Little Brown Bat (*Myotis lucifugus*) with a broken humerus. American Midland Naturalist 166:234–238.

JUNG TS, SLOUGH BG, NAGORSEN DW, DEWEY TA, POWELL T. 2006. First record of the Northern Long-eared Bat, *Myotis septentrionalis*, in the Yukon Territory. Canadian Field-Naturalist 120:39–42.

KALCOUNIS MC, BRIGHAM RM. 1995. Intraspecific variation in wing loading affects habitat use by Little Brown Bats (*Myotis lucifugus*). Canadian Journal of Zoology 73:89–95.

KURTA A, BELL GP, NAGY KA, KUNZ TH. 1989a. Energetics of pregnancy and lactation in free-ranging Little Brown Bats (*Myotis lucifugus*). Physiological Zoology 62:804–818.

KURTA A, BELL GP, NAGY KA, KUNZ TH. 1989b. Water balance of free-ranging Little Brown Bats (*Myotis lucifugus*) during pregnancy and lactation. Canadian Journal of Zoology 67:2468–2472.

LAUSEN CL, BARCLAY RMR. 2006. Benefits of living in a building: Big Brown Bats (*Eptesicus fuscus*) in rocks versus buildings. Journal of Mammalogy 87: 362–370.

LOEB SC, O'KEEFE JM. 2011. Bats and gaps: The role of early successional patches in the roosting and foraging ecology of bats. In: Greenberg CH, Collins B, Thompson III FR, editors. Sustaining young forest communities. New York, NY: Springer. p 167–189.

LUČAN RK, RADIL J. 2010. Variability of foraging and roosting activities in adult females of Daubenton's Bat (*Myotis daubentonii*) in different seasons. Biologia 65:1072–1080.

LUNDE RE, HARESTAD AS. 1986. Activity of Little Brown Bats in coastal forests. Northwest Science 60:206–209.

MACDONALD SO, COOK JA. 2007. Mammals and amphibians of Southeast Alaska. Special Publication, Museum of Southwestern Biology 8:1–191.

MICHAELSEN TC, JENSEN KH, HÖGSTEDT G. 2011. Topography is a limiting distributional factor in the soprano pipistrelle at its latitudinal extreme. Mammalian Biology 76:295–301.

MILNE DJ, FISHER A, RAINEY I, PAVEY CR. 2005. Temporal patterns of bats in the Top End of the Northern Territory. Australia. Journal of Mammalogy 86:909–920.

MURRAY SC, KURTA A. 2004. Nocturnal activity of the endangered Indiana Bat (*Myotis sodalis*). Journal of Zoology 262:197–206.

NWCG FIRE WEATHER WORKING TEAM. 2005. National fire danger rating system weather station standards. National Wildfire Coordinating Group, PMS 426-3. 26 p.

O'FARRELL MJ, MILLER BW, GANNON WL. 1999. Qualitative identification of free-flying bats using the Anabat detector. Journal of Mammalogy 80:11–23.

OLSON CR, BARCLAY RMR. 2013. Concurrent changes in group size and roost use by reproductive female Little Brown Bats (*Myotis lucifugus*). Canadian Journal of Zoology 91:149–155.

PARKER DI, COOK JA. 1996. Keen's Long-eared Bat, *Myotis keenii*, confirmed in Southeast Alaska. Canadian Field-Naturalist 110:611–614.

PARKER DI, COOK JA, LEWIS SW. 1996. Effects of timber harvest on bat activity in southeastern Alaska's temperate rainforests. In: Barclay RMR, Brigham RM, editors. Bats and forests symposium. Victoria, BC: Canada Research Branch, BC Ministry of Forestry. p 277–292.

PARKER DI, LAWHEAD BE, COOK JA. 1997. Distributional limits of bats in Alaska. Arctic 50: 256–265.

PATRIQUIN KJ, BARCLAY RMR. 2003. Foraging by bats in cleared, thinned and unharvested boreal forest. Journal of Applied Ecology 40:646–657.

RANDALL LA. 2009. The effect of forest disturbance on bats of the southwestern Yukon [thesis]. Calgary, AB: University of Calgary. 88 p.

RANDALL LA, BARCLAY RMR, REID ML, JUNG TS. 2011. Recent infestation of forest stands by spruce beetles does not predict habitat use by Little Brown Bats (*Myotis lucifugus*) in southwestern Yukon, Canada. Forest Ecology and Management 261:1950–1956.

RANDALL LA, JUNG TS, BARCLAY RMR. 2014. Roost-site selection and movements of Little Brown Myotis (*Myotis lucifugus*) in southwestern Yukon. Northwestern Naturalist 95:312–317.

REBELO H, TARROSO P, JONES G. 2010. Predicted impact of climate change on European bats in relation to their biogeographic patterns. Global Change Biology 16:561–576.

REICHARD JD, KUNZ TH. 2009. White-nose syndrome inflicts lasting injuries to the wings of Little Brown Myotis (*Myotis lucifugus*). Acta Chiropterologica 11:457–464.

RYDELL J, ENTWISTLE AC, RACEY PA. 1996. Timing of foraging flights of three species of bats in relation to insect activity and predation risk. Oikos 76:243–252.

RYDELL J, MCNEILL DP, EKLÖF J. 2002. Capture success of Little Brown Bats (*Myotis lucifugus*) feeding on mosquitoes. Journal of Zoology 256:379–381.

SACHANOWICZ K, WOWER A, BASHTA A-T. 2006. Further range extension of *Pipistrellus kuhlii* (Kuhl, 1817) in central and eastern Europe. Acta Chiropterologica 8:543–548.

SCANLON AT, PETIT S. 2008. Effects of site, time, weather, and light on urban bat activity and richness: Considerations for survey effort. Wildlife Research 35:821–834.

SIKES RS, GANNON WL, AUAC COMMITTEE. 2011. Guidelines of the American Society of Mammalogists for the use of wild mammals in research. Journal of Mammalogy 92:235–253.

SLOUGH BG. 2009. Behavioral thermoregulation by a maternity colony of Little Brown Bats in the Yukon. Northwestern Naturalist 90:47–51.

SLOUGH BG, JUNG TS. 2008. Observations on the natural history of bats in the Yukon. The Northern Review 29:127–150.

SLOUGH BG, JUNG TS, LAUSEN CL. 2014. Acoustic surveys reveal Hoary Bat (*Lasiurus cinereus*) and Long-legged Myotis (*Myotis volans*) in Yukon. Northwestern Naturalist 95:176–185.

SPEAKMAN JR. 1991. Why do insectivorous bats in Britain not fly in the daylight more frequently? Functional Ecology 5:518–524.

SPEAKMAN JR, RYDELL J, WEBB PI, HAYES JP, HAYS GC, HULBERT IAR, MCDEVITT RM. 2000. Activity patterns of insectivorous bats and birds in northern Scandinavia (69°N), during continuous midsummer daylight. Oikos 88:75–86.

TALERICO JM. 2008. The behaviour, diet and morphology of the Little Brown Bat (*Myotis lucifugus*) near the northern extent of its range in Yukon Canada [thesis]. Calgary, AB: University of Calgary. 104 p.

TESSLER DF, SNIVELY ML, GOTTHARDT TA. 2014. New insights on the distribution, ecology, and overwintering behavior of the Little Brown Myotis (*Myotis lucifugus*) in Alaska. Northwestern Naturalist 95: 251–263.

TURNER GG, REEDER DM, COLEMAN JT. 2011. A five-year assessment of mortality and geographic spread of white-nose syndrome in North American bats and a look to the future. Bat Research News 52:13–27.

USDA FOREST SERVICE. 2002. Revised Land and Resource Management Plan. Chugach National Forest. R10-MB0480c. Anchorage, AK: USDA Forest Service. http://agdc.usgs.gov/cnf.

WEST EW, SWAIN U. 1999. Surface activity and structure of a hydrothermally-heated maternity colony of the Little Brown Bat, *Myotis lucifugus*, in Alaska. Canadian Field-Naturalist 113:425–429.

WHITAKER JR JO, LAWHEAD B. 1992. Foods of *Myotis lucifugus* in a maternity colony in central Alaska. Journal of Mammalogy 73:646–648.

WOLCOTT KA, VULINEC K. 2012. Bat activity at woodland/farmland interfaces in central Delaware. Northeastern Naturalist 19:87–98.

Submitted 5 April 2013, accepted 18 November 2013. Corresponding Editor: Thomas Jung.

APPENDIX

Location and habitat type of sampling sites on the Chugach National Forest and surrounding areas July–August, 2011. Sites with an * were also mist-net sites.

Site name	Latitude, Longitude	Habitat type
Ptarmagin Creek	60.4095, −149.3564	Stream
Primrose Creek Trail	60.3365, −149.3720	Forest trail
Meridian Trailhead East*	60.2760, −149.3443	Stream
Dave's Creek*	60.5312, −149.5574	Stream
Crescent Creek	60.4961, −149.6791	Stream
Moose Creek*	60.5010, −149.9314	Stream
Private Residence*	60.3606, −149.3530	Maternity roost
Brown Bear Adit	60.3384, −149.3421	Mine opening
Lost Lake Trailhead	60.1724, −149.4116	Forest trail
Granite Creek Campground	60.7298, −149.3277	Pond
Jerome Lake Road	60.5510, −149.5883	Forest Road
Moose Flats Day Use Area	60.8120, −148.9420	Pond
North Fork Williwaw Creek	60.7871, −148.8871	Stream
Five Fingers Campground	60.7919, −148.9039	Stream
Moose Flats Day Use Area	60.8147, −148.9452	Forest Trail
Summit Creek Road	60.6159, −149.5354	Forest Road
Girdwood Transfer Station	60.9502, −149.1607	Wetland
Girdwood Catholic Church	60.9718, −149.1068	Wetland
Winner Creek	60.9711, −149.0919	Stream
Girdwood Campground	60.9613, −149.1391	Stream
California Creek	60.9686, −149.1366	Stream
Turnagin Rest Stop	60.7802, −149.2123	Stream
Water Wheel Creek	60.4893, −149.3695	Stream
Vagt Lake	60.4458, −149.3527	Lake
Bean Creek	60.4960, −149.8850	Forest Road