New Insights on the Distribution, Ecology, and Overwintering Behavior of the Little Brown Myotis (*Myotis lucifugus*) in Alaska

Author(s): DF Tessler and ML SnivelyTA Gotthardt
Source: Northwestern Naturalist, 95(3):251-263. 2014.
Published By: Society for Northwestern Vertebrate Biology
DOI: http://dx.doi.org/10.1898/13-12.1
URL: http://www.bioone.org/doi/full/10.1898/13-12.1

NEW INSIGHTS ON THE DISTRIBUTION, ECOLOGY, AND OVERWINTERING BEHAVIOR OF THE LITTLE BROWN MYOTIS (*MYOTIS LUCIFUGUS*) IN ALASKA

DF TESSLER AND ML SNIVELY

Alaska Department of Fish and Game, Wildlife Diversity Program, 333 Raspberry Road, Anchorage, AK 99518 USA

TA GOTTHARDT

Alaska Natural Heritage Program, University of Alaska Anchorage, 707 A Street, Anchorage, AK 99501 USA

ABSTRACT—We initiated the citizen science-based Alaska Bat Monitoring Project in 2004 to investigate the distribution, habitat use, and seasonal ecology of the Little Brown Myotis in Southcentral, Central, and Western Alaska. As of 2012, we received reports of bats from 252 unique locations across the focus area, including Kotzebue, White Mountain, Saint Michael, and the Semidi Islands, which represent significant range extensions for bats in the state. Ninety-seven percent of 111 roosts were located in human structures. Maternity colonies were identified in 48 locations, all in human structures. The majority of observations were reported in late July, August, and September, but we received observations every month of the year. We received reports of bats in 25 unique locations during the winter period from October to April. Winter bats were all associated with buildings unless observed flying outdoors; no hibernacula in natural substrates were documented. Timing and locations of winter observations imply that bats in the most northerly areas are likely non-migratory and overwinter in human structures, while winter observations in Southcentral Alaska suggest both migratory and non-migratory behavior. Despite the limitations and bias inherent in the data set, these reports represent a significant contribution to our understanding of the distribution and ecology of the Little Brown Myotis in Alaska and provide a basis for future directed research efforts.

Key words: Alaska, citizen science, distribution, Little Brown Myotis, maternity colonies, *Myotis lucifugus*, winter

Six species of bat are known to occur in Alaska (Parker and others 1997; Olson and others 2014). Five species [Keen's Myotis (*Myotis keenii*), Long-legged Myotis (*M. volans*), California Myotis (*M. californicus*), Yuma Myotis (*M. yumanensis*), and the Silver-haired Bat (*Lasionycteris noctivagans*)] are restricted to Southeast Alaska. While there is 1 record of a Big Brown Bat (*Eptesicus fuscus*) from central Alaska, the species is not currently believed to be a resident (Reeder 1965; Parker and others 1997). The Little Brown Myotis (*M. lucifugus*) is the most common and widely distributed bat species in Alaska and is the only bat known to occur north and west of the Alaska ''panhandle'' (Parker and others 1997). Although the range of *M. lucifugus* has been broadly described, the locations of roosts, maternity colonies, and hibernacula remain almost entirely unknown throughout Southcentral, Central, and Western Alaska. Furthermore, the general ecology and habitat associations of this species are poorly characterized throughout Alaska.

Much of what is currently known about the statewide distribution of this species is based on a relatively small number of samples collected at even fewer sites. The distributional limits of the Little Brown Myotis as described by Parker and others (1997) were derived from 279 specimens collected at 54 sites dating from 1881 onward. Just 94 of these historical museum specimens from 25 locations and a handful of observational accounts were used to describe the distribution of this species outside Southeast Alaska: 7 locations in Southcentral, 10 locations in Central, and 8 locations from Western Alaska (Parker and others 1997). The distribution of *M.*

lucifugus described in ''Recent Mammals of Alaska'' (MacDonald and Cook 2009) cites 397 specimen records for the state, most of which were collected in Southeast Alaska. And while specimen collections continue to grow, to this day there remain few specimens of the Little Brown Myotis collected from Alaskan locations beyond the panhandle.

Only 2 maternity colonies beyond Southeast Alaska, both found in buildings, have been described previously; 1 in Salcha southwest of Fairbanks (Whitaker and Lawhead 1992; Rydell and others 2002) and 1 anecdotal account at Mentasta Lake, southwest of Tok (Parker and others 1997). The only winter accounts of Little Brown Myotis outside Southeast Alaska are of 5 bats collected on Kodiak Island on 12 February 1883, bats seen flying on Afognak Island March 1954 and November 1956 (Mossman and Clark 1958), and an anecdotal account of bats sighted in Fairbanks in early October (Parker and others 1997). Although the Little Brown Myotis has been shown to use natural roosts such as rock crevices in the Yukon Territory (Slough and Jung 2008; Slough 2009) and in British Columbia, Canada (Nagorsen and Brigham 1993), all previous accounts of day roosts, maternity colonies, and hibernacula throughout this part of Alaska have been associated with buildings. There is some speculation that the widely dispersed northern summertime population migrates to coastal areas south of the 0°C isotherm (where annual surface air temperature averages 0°C) to concentrate in as-yet-unidentified winter hibernacula. However, neither these large-scale movements nor the presence of hibernating concentrations have been identified in Southcentral, Central, or Western Alaska (Parker and others 1997).

The current lack of information on the distribution, habitat associations, life history, and ecology of the Little Brown Myotis in Alaska represents a serious impediment to its conservation with respect to understanding and managing the consequences of white-nose syndrome (WNS), wind energy development, and other existing and potential threats. Knowing where bats are on the landscape, where they hibernate, and whether or not they migrate are critical information gaps that must be filled in order for resource managers to determine the appropriate actions and levels of effort necessary to fulfill their public trust responsibilities for this species.

Methods

In 2004 we developed the Alaska Bat Monitoring Project (ABMP), a citizen-science-based approach for collecting baseline information on the locations of bats, roosts, and hibernacula to use as the basis for more intensive, directed research efforts. The aim of this ongoing project is to encourage the general public and natural resource professionals across the state to report any and all encounters with bats. Because the information we seek is quite basic, and bats are charismatic and easily distinguished from other organisms, the project is an excellent subject for citizen science. Although the ABMP is statewide in scope, we report here only results from Southcentral, Central, and Western Alaska, because the Little Brown Myotis is the only species known in these parts of the state to date (Parker and others 1997). However, the difficulty in correctly identifying *Myotis* species, coupled with the relatively small number of locations represented by voucher specimens, means that additional species may indeed be present.

To enlist volunteer participation, we conduct extensive public outreach efforts as well as ''inreach'' to academics, agency researchers, and other natural resource professionals working in the field around the state. We employ a variety of mass-media elements to publicize the project and to target audiences in specific locations. Outreach efforts emphasize live presentations for the general public, civic organizations, and school groups to educate Alaskans about bat ecology and conservation and to promote participation in the project. We developed the Website www.akbats.net to provide a ''self-service'' alternative for those we are unable to reach in person. The Website mirrors material covered in our public presentations and includes background on the biology of Alaska's bats and the conservation issues they face, as well as a full description of the project, with specific instructions, data sheets, and contact information.

The goal of the ABMP is to collect baseline information on the locations of bats; it is not intended to be a systematic inventory effort, nor is it an actual monitoring program. Volunteers are not assigned survey locations, but are simply asked to submit data describing their observations wherever they encounter bats. Volunteers are asked to record the number of bats observed, whether the observation was of flying or roosting bats, and substrate type (if roosting), as well as date and time, elevation, latitude and longitude, and physical directions to the observation site. The simple data sheet also coaches volunteers to provide basic site and habitat descriptions for each observation. Photographs to validate observations are requested but remain optional; those including unambiguous images of bats are deposited as ''observations'' to the Mammal Collection at the University of Alaska Museum (UAM) and made available through UAM's online database, Arctos (http://arctos.database.museum). Occasionally observations include dead bats, which are analyzed for rabies and *Pseudogymnoascus destructans* (the fungus associated with WNS) by the Alaska Department of Fish and Game or the Alaska Department of Health and Social Services Section of Epidemiology. To be considered, all observation forms must include the name and personal contact information of the observer, including phone number, physical address, and email. Each submission is reviewed by staff for quality control before being entered into the project database, maintained by the Wildlife Diversity Program, Alaska Department of Fish and Game. Incomplete or unusual submissions or those that raise any concerns or questions about the data are flagged for correspondence with the submitting volunteer and withheld from inclusion in the database unless all concerns are resolved. Only unambiguous, complete submissions are retained. Observation locations are assigned an accuracy score depending on the precision of the location and how it was obtained. Each observation is given a subjective qualitative ''confidence score'' (Very High, High, Moderate, Low) based on the type of observation, details of the report, whether or not a voucher photo or specimen was provided, and observer experience.

Data are transferred on an annual basis to the Alaska Natural Heritage Program (AKNHP), University of Alaska Anchorage. The data are accessible by request from AKNHP (http://aknhp.uaa.alaska.edu/maps/biotics/#). Certain data are restricted to protect personal information of volunteers, as well as the locations of sites on private property and sensitive areas.

RESULTS

Spatial Distribution

Between 2004 and 2012, we received reports of bats from 252 unique locations in Southcentral ($n = 191$), Central ($n = 34$), and Western Alaska ($n = 27$). In many instances there are multiple observations throughout a season or in successive years from a single location. The majority of reports are clustered along road corridors and near population centers, but many reports were also received from remote villages off of the road system. Overall, bats were reported throughout the state south of the Brooks Range. The northernmost observation in Kotzebue, the westernmost in White Mountain and St. Michael, and the southernmost from the Semidi Islands group represent significant range extensions for the species (Fig. 1). Observations ranged from sea level to 1280 m. The highest elevation reports were in the mountains near Nelchina along the Glenn Highway (830 m), in the subalpine forests near Tok and the old Tok Cutoff Road (940 m), and in alpine valleys of the Yanert Fork River near Denali National Park (from 950 to 1280 m).

Observation Types

Most reports were of 3 or fewer bats (67%, 168 of 252). Volant bats were reported from 145 locations (58%), with roosting bats observed at 107 locations (42%). Dead bats were the only bats observed in 10 reports (6 found dead roosting inside buildings, 2 found outside on the ground, 2 killed by cats), although many reports of multiple bats also included 1 or more dead bats. Sixty percent of encounters (152 of 252) took place inside human structures. Seventy indoor reports described bats that were flying at the time of the observation (generally within buildings), 12 of which described lone bats that had apparently flown into houses. Roosting bats (107 locations) used a variety of substrates, but less than 3% (3 of 107), all of which were lone bats, were roosting on ''natural'' surfaces: 1 in a rock crevice and 2 others in trees. The remaining 97% (104 of 107) of roosting locations were associated with various ''human structures,'' including 4 bat houses (Table 1). In 5 roost locations, bats were observed roosting on more than 1 distinct substrate. At each of 4 locations with occupied bat houses and 1 location where a bat was seen

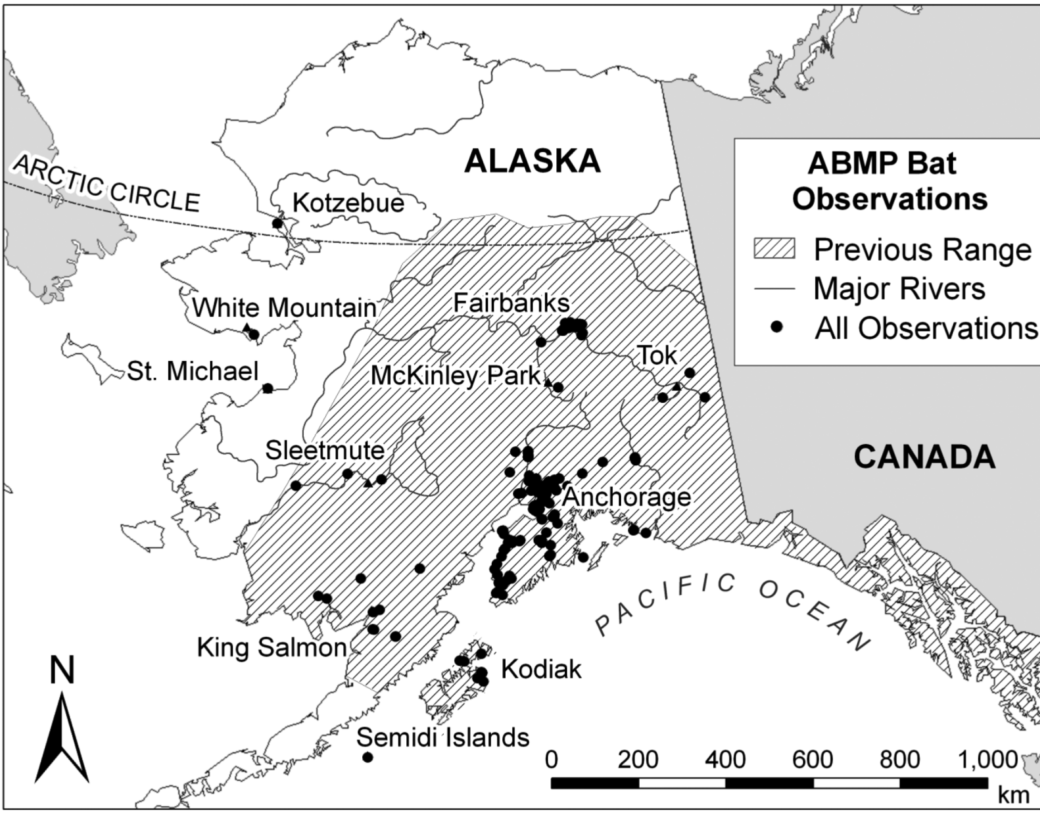

FIGURE 1. Locations of bat observations in Southcentral, Central, and Western Alaska submitted to the Alaska Bat Monitoring Program (ABMP), 2004 to 2012. The grey hatched area represents the range of the species as described previously by Fenton and Barclay (1980) and Parker and others (1997). GIS file of previous range provided by NatureServe and Patterson and others (2007). ▲ on map represents town-village locations.

roosting in a woodpile, bats were also roosting in adjacent or nearby buildings, bringing the total number of roosts identified to 112. Observations were verified with photos at 28 locations; these have been deposited to the University of Alaska Museum and have been assigned catalog numbers UAMObs:Mamm:150 to UAMObs:Mamm:180.

Maternity Roosts

We received 48 reports of maternity roosts, all of which were associated with human structures (Table 1). Roosts were only classified as maternity colonies if pups were confirmed roosting with adults ($n = 8$) or if 20 or more bats were observed roosting together ($n = 40$). In Central Alaska, maternity colonies were located in the communities of Fairbanks, Tok, Northway, Copper Center, and Talkeetna (Fig. 2). In Southcentral Alaska, they were found in the towns of Big Lake, Wasilla, Palmer, Sutton, Girdwood, Hope, Summit Lake, Cooper Landing, Moose Pass, Nikiski, Soldotna, Kenai, Kasilof, Ninilchik, Clam Gulch, Anchor River, Homer, Bear Cove, Seldovia, and Cordova (Fig. 2). Nursery roosts in Southwest Alaska were identified in Nondalton, Koliganek, Nunavaugaluk, Aleknagik, Naknek, King Salmon, locations in Katmai National Park, and on Kodiak Island.

Seasonality

Bats were observed in every month of the year in our focus area, with 76% (192 of 252) of observations occurring July through September (Fig. 3). We received reports from 26 locations during the ''winter period,'' which we defined as October through April (Fig. 4) based on earlier

TABLE 1. Roosting substrates. The table illustrates the types of substrates on which bats were observed roosting. The right side describes substrates used for maternity colonies only; the left side includes both nursery and non-nursery roosts. All substrates listed were words chosen by volunteers in their descriptions. Other refers to structures that were reported as roosts only once and included: chicken coop, chimney, outhouse, plywood, sailboat, school, tent, warehouse, and wood pile.

Roosting bat substrates	No. obs.	Maternity colony substrates	No. obs.
Natural substrates	3	Natural substrates	0
rock crevice	1		
tree	2		
Human structures	109	Human structures	48
house	52	house	25
building	18	building	5
cabin	16	cabin	9
bat house	4	bat house	3
barn	3	barn	2
lodge	2	lodge	2
umbrella	3	plywood	1
shed	2	school	1
other	9		

work on the Little Brown Myotis at more southerly latitudes by Fenton (1969) in Ontario and Davis and Hitchcock (1965) at Aeolus Cave in East Dorset, Vermont. Winter locations included: White Mountain, St. Michael, McKinley Park, Petersville, Wasilla, Palmer, Chugiak, Anchorage, Girdwood, Sterling, Anchor Point, Homer, Chenega Bay, King Salmon, and Kodiak Island. Twelve winter observations were inside buildings, and included 4 lone dead bats hanging in roosting position, 3 live hibernating bats, and 5 reports of bats flying indoors apparently roused from hibernation by disturbance. Fourteen winter reports were of bats seen outside, either flying ($n = 11$) or roosting ($n = 3$).

Six of 11 October observations reported bats continuing to fly outside at numerous locations across the state (White Mountain, McKinley Park, Palmer, Sterling, Chenega Island, and Kodiak Island). October reports also included a bat found apparently hibernating in a warehouse in St. Michael, a single bat roosting in a shallow rock crevice along the Petersville Road, several bats found flying inside a building on Kodiak Island, a bat roosting outside on the exterior of a house in Anchorage, and 2 dead bats found in homes in Anchorage and Homer. November reports included a dead bat found in a chimney in Chugiak, a number of bats found flying inside a lodge in Wasilla, and a bat flying outside at an air temperature of 2.7°C at Chenega Bay. The single December report was of a lone bat flying out of a woodpile after being disturbed outside a home in Homer. In January, 1 bat was found dead in a chimney in King Salmon, 1 bat was reported flying inside a home crawlspace in Anchorage after being disturbed, and 10 bats were seen flying together near an Anchorage road overpass. The single February sighting was also of a small group of bats flying outside in Anchorage. The 2 reports from March were of single bats flying inside homes in Anchorage and Girdwood. April reports included 2 from Anchorage of single bats hibernating indoors, 1 of which was described as ''acting as if coming out of hibernation.'' Other April encounters were all outside, including a lone bat roosting on the deck of an Anchorage house, 2 bats seen flying near a busy roadway in Wasilla, and a cloud of hundreds of bats seen flying near Anchor Point.

DISCUSSION

Data Limitations

The data collected through the Alaska Bat Monitoring Program are imperfect and inherently biased. These incidental observations do not have the same evidentiary value as ultrasonic acoustic recordings or physical specimens. Nonetheless, they remain extremely valuable if we recognize their limitations and apply caution in their interpretation. Because we collected only reports of observations and not physical specimens, we cannot conclusively identify the species observed in any account. Although we excluded all reports from Southeast Alaska to maximize the likelihood that we are only describing observations of the Little Brown Myotis, it is possible that other bat species occur in our focal area and that some reports could possibly refer to other taxa. Slough and Jung (2008) identified 2 previously undetected species in the Yukon, the Big Brown Bat (*Eptesicus fuscus*) and Northern Long-eared Myotis (*Myotis septentrionalis*), based on acoustic survey data, and speculated that these taxa had gone undetected simply due to lack of study effort. They also suggested that the ranges of some bat species may be expanding. However, given that the Little Brown Myotis remains the only bat confirmed in our study area to date, it

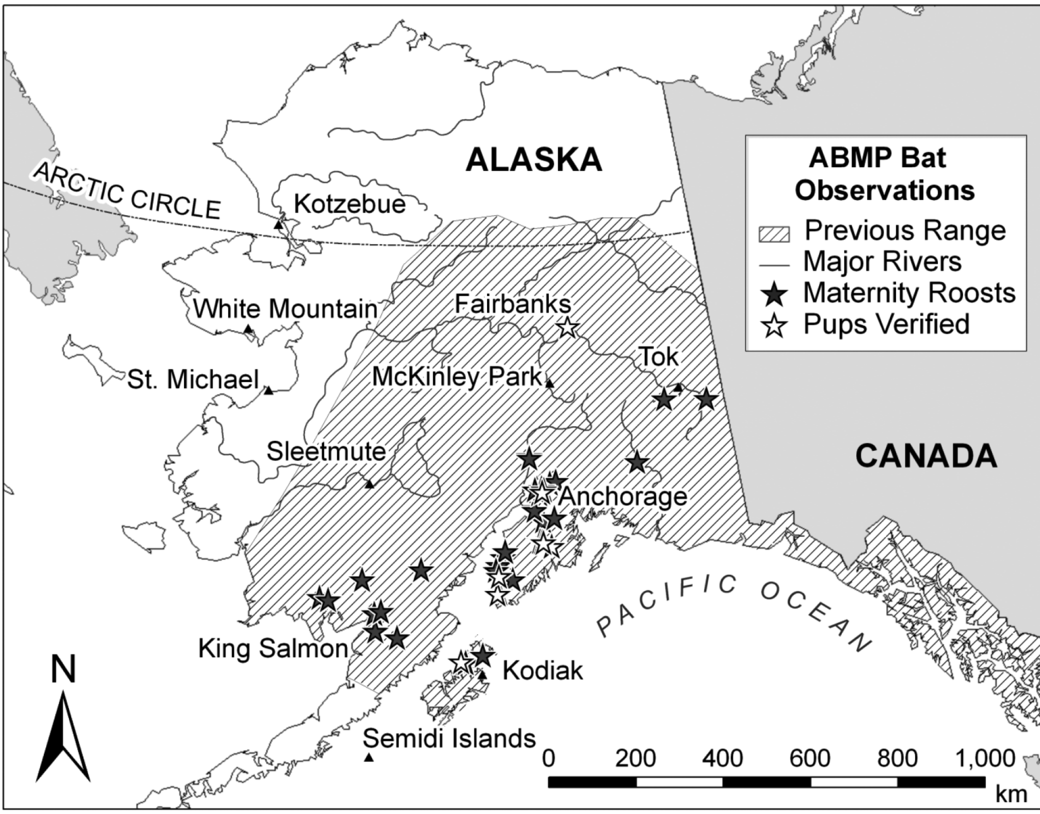

FIGURE 2. Locations of bat maternity colonies in Southcentral, Central, and Western Alaska identified by the Alaska Bat Monitoring Program (ABMP), 2004 to 2012. Black stars represent locations with >20 bats roosting together that are assumed to be maternity colonies. Hollow stars indicate locations where pups have been observed roosting with adults. ▲ on map represents town-village locations.

is likely that many if not all of our reports are of this species. One observer suggested a bat reported in Fairbanks might have been a Silver-haired Bat, but the submitted photograph was inconclusive and we were unable to dispatch staff to the location in time to evaluate the claim. An observation submitted by National Park Service personnel in Katmai National Park suggested that accompanying ultrasonic audio recordings may be indicative of the Yuma Myotis (*M. yumanensis*), though this was never confirmed and the current whereabouts of the Park Service recordings are unknown to the authors. The Yuma Myotis is exceedingly difficult to distinguish from the Little Brown Myotis based solely on morphology and acoustics, but recent reports in Southeast Alaska (Olson and others 2014) suggest that the occurrence of *M. yumanensis* from more northerly localities cannot be dismissed outright.

It is also possible that some of our reports may refer to organisms other than bats. We assign higher confidence to repeat observations made at close range and over a longer period of time, such as bats found in houses or observed roosting, than we do for reports of flying bats glimpsed briefly from a distance. In instances in which an observer reported seeing a bat or bats only once briefly and from a distance, it is conceivable that swallows or other species were misidentified as bats. Two reports from Anchorage of groups of bats flying outside in January and February are low-confidence observations that could possibly be other taxa, but the presence of bats in the vicinity is verified by specimens (Parker and others 1997) and their occurrence in the

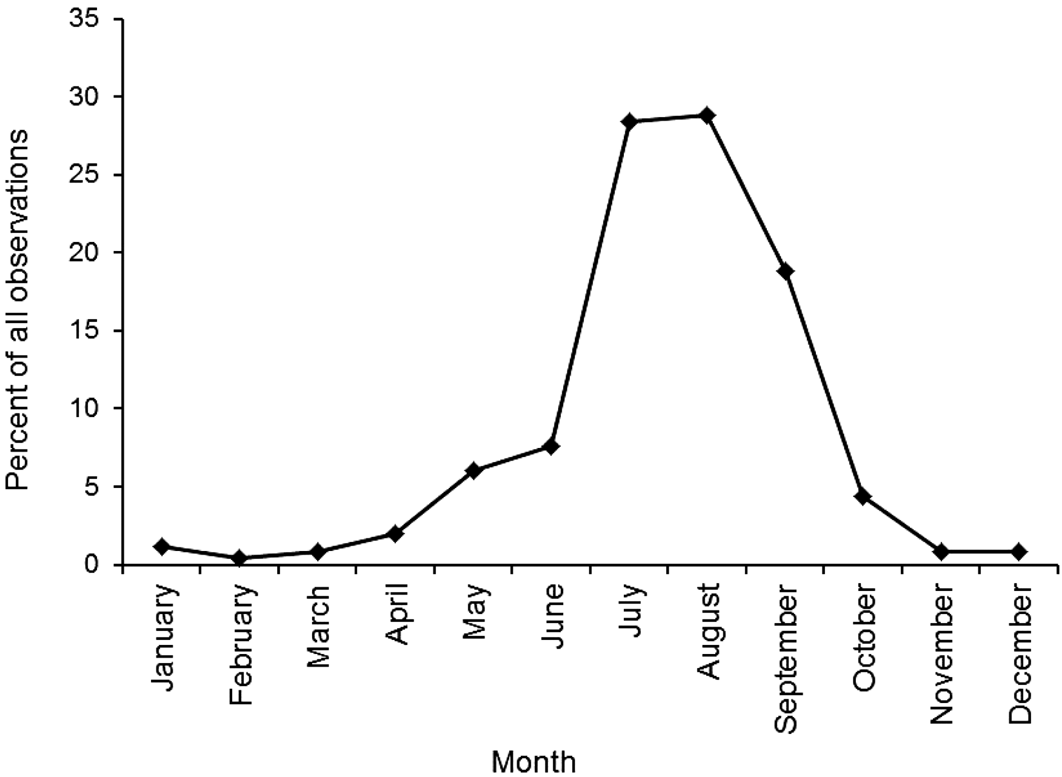

FIGURE 3. Seasonal distribution of bat observations for Southcentral, Central, and Western Alaska submitted to the Alaska Bat Monitoring Program, 2004 to 2012. Graph represents the percentage of total submissions by month (n = 281).

area during the winter is supported by other high-confidence ABMP observations. The vast majority of our observations were made at close range and were either indoors (n = 152) or involved roosting bats (n = 107). Of the 75 reports of bats observed only while flying outdoors, only 15 did not involve close range observations made over multiple hours, days, weeks, or years. The range extensions, maternity colonies, and winter locations we describe are based on reports in which we have high to very high confidence. Finally, it is also possible that some reports are pure fabrications, although it is unlikely that fakes account for any appreciable number of accounts. Nonetheless, because we do not have physical voucher specimens to substantiate the reports, we cannot entirely discount the possibility of misidentification or fabrication.

The data come from incidental observations, not systematic surveys, and include no ''negative data'' or reports of where bats were not encountered. Consequently, the data may reflect only where people are likely to encounter bats and not necessarily where bats are more likely to occur. The data cannot be analyzed in any statistically defensible fashion to assess habitat preferences, but they remain useful for elaborating distributional limits, identifying maternity colonies and roosts, and examining seasonal occurrence, provided that the reports themselves are accurate. Consistent with findings from the Yukon where the majority of known bat roosts were found in buildings (Slough and Jung 2008), bats in our study area regularly used human structures for roosts and hibernacula. Although we had very few reports of bats roosting on natural substrates, the bias in our data prevents us from concluding that bats through these portions of Alaska are restricted to human structures or even that they use human structures most of the time. As such, we cannot

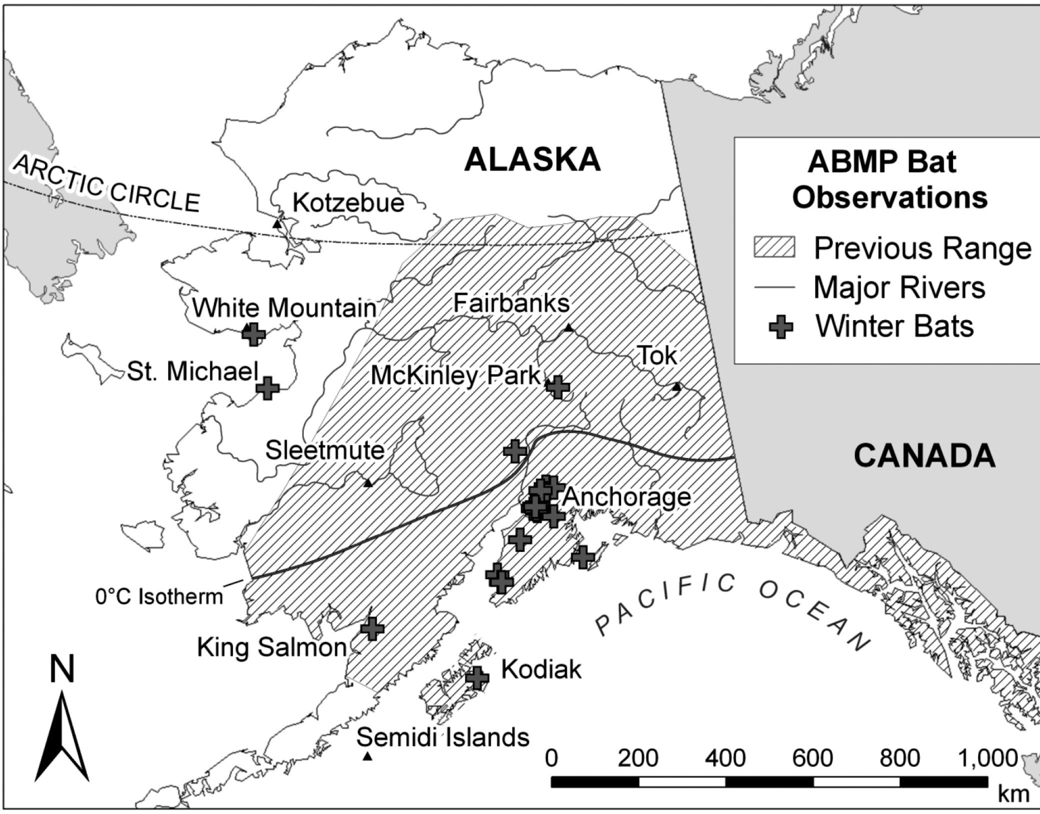

FIGURE 4. Locations of winter (October through April) bat observations in Southcentral, Central, and Western Alaska submitted to the Alaska Bat Monitoring Program (ABMP), 2004 to 2012. The grey hatched area represents the range of the species as described previously by Fenton and Barclay (1980) and Parker and others (1997). GIS file of previous range provided by NatureServe and Patterson and others (2007). The heavy black line represents approximate location of the 0°C isotherm where annual surface air temperature averages 0°C as interpolated from Johnson and Hartman (1969) and Stafford and others (2000). ▲ on map represents town-village locations.

discount the possibility that bats in these regions of Alaska roost in natural substrates (caves, rock crevices, and trees) in addition to human structures, as they are known to do in British Columbia (Nagorsen and Brigham 1993).

Despite the admitted limitations of these data, the citizen science approach yielded data with a geographic scope and temporal sweep that would be extraordinarily, if not prohibitively, expensive to acquire using more traditional field methods for such exploratory research. This project and these data are not intended to supplant acoustic surveys and voucher collection, but rather to inform and guide more rigorous research efforts using these gold-standard methods in the future.

Distribution

We have documented reports that suggest the distribution of the Little Brown Myotis extends beyond limits reported previously (Fenton and Barclay 1980; Parker and others 1997, Patterson and others 2007). Range limits reported by Parker and others (1997) were derived from a limited and spatially clumped sample, and the authors acknowledged they likely did not represent the full geographic range of the species. We are confident in the validity of the observations in Kotzebue, White Mountain, St. Michael, and Semidi Islands that represent the greatest extensions of known range: each of these observations were validated either with photos, made by trained professionals, or occurred in a setting that allowed the subjects to be identified unambiguously as bats. The bat in Kotzebue was reported by a wildlife education specialist with the Prince William Sound Science Center who has previously presented bat education programs for the ABMP. The bat was observed inside the entryway of a public building and described as seemingly looking for a spot to roost. The White Mountain observation came from a teacher in the Bering Sea School District who reported a ''very cold and lethargic'' bat seen on 10 October that had flown overhead and landed on a rock where it spent the next several hours trying to wedge itself into a crack. The bat was not seen after 6 November. In St. Michael, an employee of the Alaska Department of Transportation found a bat apparently hibernating inside a warehouse on 31 October, when the bat began to stir as the temperature rose in the warehouse. The Semidi Islands observation came from a wildlife technician with the US Fish and Wildlife Service Maritime National Wildlife Refuge stationed at a field camp on Chowiet Island. The technician reported seeing upwards of 30 bats feeding in the evenings from August to September. However, because we have only a single report at each of these locations, it is impossible to determine whether these observations represent persistent populations versus casual or accidental occurrences. The reports from White Mountain and St. Michael were of lone bats near a shipping facility and a warehouse, respectively; it is possible the presence of a single bat might be the consequence of human transport. Taken together, the observations in Kotzebue, White Mountain, and St. Michael suggest that far Western Alaska is indeed within the current range of the Little Brown Myotis.

Maternity Colonies

The 48 maternity colonies reported here represent an improvement in our understanding of the Alaska breeding distribution of the Little Brown Myotis, described previously from 1 known roost and another anecdotal account (Whitaker and Lawhead 1992; Parker and others 1997). We feel secure in our assumption that roosts of 20 or more bats represent maternity colonies because larger aggregations of bats are composed mostly of females: male Little Brown Myotis roost singly or in very small groups while females are gregarious and roost in larger numbers (Menaker 1969), and while males may be present in the same structure as maternity colonies, they are fewer in number and roost individually away from females (Kurta and Kunz 1988; Nagorsen and Brigham 1993). While we received other reports that were very likely nursery roosts, pups were either not confirmed or the number of bats did not exceed our self-imposed and conservative minimum size of 20 adults. Maternity colonies for this species are often described numbering in the hundreds to thousands (Anthony and others 1981), although those from similar latitudes have been much smaller: maternity colonies in Whitehorse, Yukon ranged from 12 to 400 adult females (Slough and Jung 2008; Slough 2009) and a maternity roost in Salcha, Alaska, ranged from about 200 adults in 1992 to only a few individuals in 2000 (Rydell and others 2002). Maternity colonies in our reports ranged in size from 3 to over 300 bats. That all maternity roosts were found in buildings may be an artifact of the incidental nature of the observations. In British Columbia and the Yukon, Little Brown Myotis maternity colonies have been found in natural substrates (rock crevices and caves) as well as buildings (Nagorsen and Brigham 1993; Slough and Jung 2008). Interestingly, there were no maternity roosts reported in Anchorage, although Alaska's largest city had the greatest number (n = 40) of locations with bats reported.

Seasonality

Our seasonal peak in citizen science observations from mid-July to September corresponds with Barclay and others (1980), who found that most human-bat encounters occur after maternity colonies begin to disperse and as juvenile bats explore novel roosting possibilities, often in the open or in buildings not otherwise used by bats. We suggest that the relatively heavy reporting in late summer and autumn in Alaska is also due to 2 additional factors: (1) the near-doubling of apparent bat numbers at maternity colonies in buildings as the juveniles first become volant; and (2) the gradual overlapping of human and bat activity patterns as daylight hours shorten and bats become active while more people are awake. Little Brown Myotis in the Yukon become active 0.5 to 1.0 h after sunset, and nightly emergence becomes progressively earlier in the evening following the summer solstice as hours of darkness increase (Slough and Jung 2008). Astronomical and civil twilight are limited or non-existent throughout much of Alaska near the summer solstice, and bat activity in mid-summer is expected to be largely restricted to the very late night and early morning hours. However in the autumn, twilight occurs during the waking hours of most people.

The unobtrusive nature of hibernating bats is partially responsible for the limited number of winter observations we received. Small numbers of hibernating bats, even those inhabiting buildings, attract little attention and are likely to remain unnoticed unless actively sought. What is surprising is not that we received so few reports of wintering bats but that we received very many at all. Despite being few in number, the 26 reports between October and April are challenging to interpret. That most of our October and April reports were of active bats observed outside suggests that these months are either outside the normal hibernation period or that these bats were roused from nearby hibernacula. In northern Ontario, hibernation lasts from September until early or mid-May (Fenton and Barclay 1980), while in British Columbia hibernation is suspected to begin in September or October and last until April or early May, depending on climate (Nagorsen and Brigham 1993). Most of our focal area lies north of 60°N latitude, where average annual temperatures range between −6.1 and 2.2°C, and there are between 30 and 90 frost-free days (NOAA 2013). We speculated that the hibernation interval across Alaska would be at least as long as that described at Aeolus Cave in Vermont, where the annual average temperature is 6.2°C and there are between 90 and 120 frost free days, or in British Columbia with 60 to 240 frost free days (Department of Energy Mines and Resources Canada 1981). Yet early- and late-season observations indicate the hibernation period in some locations in Alaska may be shorter than in many locales to the south. One possible explanation for a shorter hibernation period is that many bats in the most northerly portions of the range are hibernating locally in buildings and not migrating. In the Yukon, some female Little Brown Myotis are known to begin occupying maternity colonies as early as the last 2 wk of April, but maximum adult female occupancy doesn't occur until late May (Slough and Jung 2008). The early occupancy and length of the colony growth period leaves open the possibility that individual colonies in the Yukon may consist of both local and migratory bats.

Parker and others (1997) proposed that hibernation sites in natural substrates such as caves or even mines would be unlikely where the mean annual temperature is below 0°C. The White Mountain, St. Michael, and McKinley Park winter sites are located well north and west of the 0°C isotherm (Johnson and Hartman 1969; Stafford and others 2000), and the Petersville site lies just north of it. Although prior to the 1980s, Little Brown Myotis were not known to roost in buildings (Fenton and Barclay 1980), we suggest that hibernacula in these more northerly locales are limited to human structures. Similar early and late-season observations in the Yukon have led to speculation that bats there may hibernate locally in buildings, though hibernating bats have not yet been found (Slough and Jung 2008). South of the 0°C isotherm, we have reports of live bats inside buildings during the winter period in Wasilla, Anchorage, Girdwood, and Kodiak. And although several winter reports describe bats flying about indoors after being disturbed, 2 Anchorage observations clearly describe bats hibernating in buildings. By contrast, the Little Brown Myotis is not known to hibernate in buildings in British Columbia, where most hibernation records are associated with a few individuals using old mines in the interior (Nagorsen and Brigham 1993). Nonetheless, the whereabouts of most Little Brown Myotis winter populations in Alaska, the Yukon, and British Columbia remain unknown.

Bats from the more northerly sites in Kotzebue, White Mountain, and St. Michael would have to migrate 500 to 900 km to reach the 0°C isotherm, let alone any established (but as-yet-undocumented) hibernacula. These distances approach or exceed the longest migrations documented for this species; Fenton (1969) documented an 800-km migration of 1 banded male Little Brown Myotis in Ontario, and Norquay and others (2013) described a 647-km movement, also in Ontario. Migratory distances for this species are more commonly reported to be less than 300 km (Davis and Hitchcock 1965; Fenton 1970). The length of the required migration, coupled with late October observations from some of the more northerly sites (White Mountain, McKinley Park, Petersville), reinforce our supposition that bats in these northernmost areas are likely not migratory.

Further to the south, some observations remain congruent with migratory behavior. Slough and Jung (2008) suggested that groups of bats observed flying over the glaciers of the St. Elias Mountains in the Yukon may have been returning from coastal hibernacula. Our report of a cloud of bats in Anchor Point in April 2007 is consistent with a migrating coastal group as well. A regularly contributing volunteer described a large, dark cloud of undetermined species composition appearing in the distance during the late morning and moving towards the observer's home. The cloud continued to approach and from a distance of 15 m was clearly resolved as a large group of bats. Upon reaching the house, 2 bats broke off from the group and entered the home (at the peak of the roofline where bats had been seen entering and exiting the building for years) while the cloud continued to fly in the direction of Kachemak Bay.

Some bats that summer close to the 0°C isotherm may hibernate locally in buildings, while others migrate elsewhere, possibly to concentrate in undiscovered hibernacula in caves or mines. A 10-y-old cabin in Sutton that hosted a maternity colony in the roof for at least 5 y had only a single mummified bat when roofing materials were removed in April 2013 (for remediation of bat urine and guano). In this instance, it is likely that the bats left the maternity colony for the winter, but it is unknown whether they hibernate locally or migrate.

Bats were observed outdoors during the winter south of the 0°C isotherm in Wasilla, Palmer, Anchorage, Sterling, Homer, and Chenega Bay, leaving open the possibility that bats in those locales may have been using some unknown natural hibernacula in addition to buildings. The availability of large caves is limited in Central Alaska, but caves or mines near the 0°C isotherm may be suitable for hibernation (Parker and others 1997). However, repeated warm-season surveys of several abandoned hardrock mines in the Chugach National Forest in Southcentral Alaska found no evidence of winter use despite climatic conditions conducive to hibernation (Sherwin 2005). Summer climatic conditions in these mines were not suitable for maternity colonies, and while still within the acceptable range for bachelor males, only a single mine showed even slight circumstantial evidence (moth wings floating on water) of summer use as a night roost. As yet there are no documented hibernacula in natural substrates near to or south of the 0°C isotherm in Southcentral or Western Alaska.

While we propose that at least some bats in the northernmost portions of their range are non-migratory and dependent on human structures for hibernacula, it remains unclear to what degree bats throughout central Alaska hibernate in place or migrate and concentrate in caves or mines for the winter. This element of their ecology is likely a function of the recent natural history of bats in the region and whether they were extant at the time of western cultural contact or if bats followed European settlement across the region, as some have suggested (Slough and Jung 2008). There are likely different answers to these questions for different populations around the state. We suggest that human development is probably facilitating continued expansion of the Little Brown Myotis into areas where it could not have survived previously, especially in the far north and northwest. At the same time, bat exclusion, control, and remediation efforts in buildings are likely to result in the loss of summer roosting sites, maternity colonies, and hibernacula, though we are unaware of any data concerning the extent to which these efforts are undertaken in the state. However, in areas of Central and Western Alaska reasonably close to the 0°C isotherm, bats may well have been present at the time of contact. Relatively recent exploitation of human structures for hibernacula may mean that "older" migratory populations now coexist with "newer" emerging residential populations in some areas.

Next Steps

Conserving Alaska's bats and managing for the consequences of WNS and expanded wind energy development will require a concerted effort to fill the large gaps remaining in our understanding of their ecology, habitat use, migration, and overwintering behavior. Ascertaining whether or not the Little Brown Myotis is in fact the lone species throughout Southcentral, Central, and Western Alaska will require a coordinated effort to capture bats around the state to make careful morphological measurements, record voucher calls, collect tissue samples for molecular analyses, and collect voucher specimens for museum archival. Targeted acoustic monitoring and trapping surveys are necessary to determine the extent to which areas in the far north and west (where few bats have yet been observed) are actually used by bats. Randomized acoustic surveys, ideally undertaken through different parts of the year, are required to derive valid habitat associations.

Determining if bats migrate and concentrate in caves or mines is of paramount importance in evaluating the potential danger posed by WNS in the region. Studies using PIT (passive integrated transponder) tags, radio telemetry, harmonic radar, genetics, and other technologies will be necessary to further evaluate seasonal activity patterns and overwinter use, locate hibernacula, describe migratory behavior, and evaluate the population structure and the natural history shaping it. Given their geographic dispersion and persistence through time, many of the nursery colonies we have identified would be ideal subjects for the next generation of intensive research that is required.

ACKNOWLEDGEMENTS

We wish to thank K Larson, K Kuzina, T McCoy, R Ford, A Poe, T Zeller, and K Walton for their contributions to this project and to the Alaska Citizen Science Program. Thanks to S MacDonald, D Parker McNeill, and L Olson for their constructive reviews that greatly improved this manuscript. Previous distribution data were provided by NatureServe in collaboration with B Patterson, W Sechrest, M Tognelli, G Ceballos, The Nature Conservancy—Migratory Bird Program, Conservation International—CABS, World Wildlife Fund—US, and Environment Canada—WILDSPACE.

LITERATURE CITED

ANTHONY ELP, STACK MH, KUNZ TH. 1981. Night roosting and the nocturnal time budget of the Little Brown Bat, *Myotis lucifugus*: Effects of reproductive status, prey density, and environmental conditions. Oecologia 51:151–156.

BARCLAY RMR, THOMAS DW, FENTON MB. 1980. Comparison of methods used for controlling bats in buildings. Journal of Wildlife Management 44: 502–506.

DAVIS WH, HITCHCOCK HB. 1965. Biology and migration of the bat, *Myotis lucifugus*, in New England. Journal of Mammalogy 46:296–313.

DEPARTMENT OF ENERGY, MINES AND RESOURCES CANADA. 1981. Canada frost-free period. In: The national atlas of Canada, 5th edition. Ottawa, ON: Geographical Services Directorate, Surveys and Mapping Branch.

FENTON MB. 1969. Summer activity of *Myotis lucifugus* (Chiroptera:Vespertilionidae) at hibernacula in Ontario and Quebec. Canadian Journal of Zoology 47:597–602.

FENTON MB. 1970. Population studies of *Myotis lucifugus* (Chiroptera: Vespertilionidae) in Ontario. Life Sciences Contributions Royal Ontario Museum 77:1–34.

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

JOHNSON PR, HARTMAN CW. 1969. Environmental atlas of Alaska. College, Institute of Arctic Environmental Engineering, Institute of Water Resources, University of Alaska [1971, c1969].

KURTA A, KUNZ TH. 1988. Roosting metabolic rate and body temperature of male Little Brown Bats (*Myotis lucifugus*) in summer. Journal of Mammalogy 69:645–651.

MACDONALD SO, COOK JA. 2009. Recent mammals of Alaska. Fairbanks, AK: University of Alaska Press. 387 p.

MENAKER M. 1969. Heat acclimation of summer bats. American Midland Naturalist 82:289–290.

MOSSMAN AS, CLARK WK. 1958. Winter records of bats in Alaska. Journal of Mammalogy 39:585.

NAGORSEN DW, BRIGHAM RM. 1993. Bats of British Columbia. Royal British Columbia Museum Handbook. Vancouver, BC: University of British Columbia Press.

[NOAA] NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION. 2013. National freeze frost maps. National Climate Data Center. http://www.ncdc.noaa.gov/oa/climate/freezefrost/frostfreemaps.html. Accessed 29 March 2013.

NORQUAY KJO, MARTINEZ-NUÑEZ F, DUBOIS JE, MONSON KM, WILLIS CKR. 2013. Long-distance movements of Little Brown Bats (*Myotis lucifugus*). Journal of Mammalogy 94:506–515.

OLSON LE, GUNDERSON AM, MACDONALD SO, BLEJWAS KM. 2014. First records of Yuma Myotis (*Myotis yumanensis*) in Alaska. Northwestern Naturalist 95:228–235.

PARKER DI, LAWHEAD BE, COOK JA. 1997. Distributional limits of bats in Alaska. Arctic 53:256–265.

PATTERSON BD, CEBALLOS G, SECHREST W, TOGNELLI MF, BROOKS T, LUNA L, ORTEGA P, SALAZAR I, YOUNG BE. 2007. Digital distribution maps of the mammals of the Western Hemisphere, version 3.0. NatureServe, Arlington, Virginia, USA.

REEDER WG. 1965. Occurrence of the Big Brown Bat in southwestern Alaska. Journal of Mammalogy 46: 332–333.

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

*SHERWIN RE. 2005. Bat surveys of abandoned mines on the Chugach National Forest: Final Report. 50 p. Available from Chugach National Forest, 161 East 1st Avenue, Door #8, Anchorage, AK 99501.

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.

STAFFORD JM, WENDLER G, CURTIS J. 2000. Temperature and precipitation of Alaska: 50 year trend analysis. Theoretical and Applied Climatology 67:33–44.

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

Submitted 21 May 2013, accepted 10 February 2014. Corresponding Editor: Link Olson.

APPENDIX.

List of all Alaska Bat Monitoring Project observation locations. Precision of locations has been limited to the second decimal of degrees latitude and longitude to protect personal information of volunteers and the locations of sites on private property and sensitive areas.

Southcentral Alaska (191 locations): Matanuska Glacier (1) 61.79°N 147.74°W; Sutton (8) 61.73°N 148.77°W; Palmer (17) 61.68°N 148.99°W; Hatcher Pass (1) 61.69°N 149.24°W; Skwentna (1) 61.92°N 150.92°W; Willow (5) 61.83°N 150.08°W; Wasilla (29) 61.67°N 149.26°W; Big Lake (5) 61.59°N 149.82°W; Susitna (1) 61.48°N 150.59°W; Chugiak (10) 61.44°N 149.37°W; Peter's Creek (1) 61.40°N 149.42°W; Eklutna (1) 61.39°N 149.46°W; Eagle River (10) 61.35°N 149.54°W; Anchorage (40) 61.22°N 149.80°W; Girdwood (9) 61.00°N 149.08°W; Portage (1) 60.81°N 148.98°W; Hope (2) 60.92°N 149.65°W; Summit Lake (1) 60.64°N 149.49°W; Moose Pass (1) 60.37°N 149.35°W; Seward (3) 60.18°N 149.38°W; Cooper Landing (5) 60.49°N 149.83°W; Sterling (2) 60.51°N 150.61°W; Nikiski (3) 60.72°N 151.31°W; Kenai (3) 60.72°N 151.36°W; Soldotna (6) 60.52°N 151.07°W; Kasilof (2) 60.35°N 151.26°W; Clam Gulch (1) 60.20°N 151.42°W; Ninilchik (1) 60.04°N 151.63°W; Anchor Point (1) 59.81°N 151.62°W; Homer (11) 59.94°N 151.73°W; Bear Cove (1) 59.73°N 151.05°W; Tutka Bay (1) 59.39°N 151.44°W; Seldovia (2) 59.47°N 151.63°W; Valdez (1) 61.13°N 146.24°W; Cordova (3) 60.52°N 145.78°W; Chenega Bay (1) 60.06°N 148.02°W.

Central Alaska (34 locations): Fairbanks (16) 64.93°N 147.61°W; North Pole (2) 64.82°N 147.41°W; Nenana (1) 64.58°N 149.11°W; McKinley Park (1) 63.61°N 148.48°W; Petersville (1) 62.34°N 150.62°W; Talkeetna (6) 62.31°N 150.06°W; Tok (2) 63.56°N 142.29°W; Northway (1) 63.00°N 141.80°W; Glenallen (1) 62.00°N 145.33°W; Copper Center (2) 61.99°N 145.36°W; Nelchina (1) 61.99°N 146.78°W.

Western Alaska (27 locations): Kotzebue (1) 66.89°N 162.59°W; White Mountain (1) 64.54°N 163.02°W; St. Michael (1) 63.47°N 162.04°W; Sleetmute (1) 61.87°N 158.10°W; Stony River (1) 61.78°N 156.58°W; Kalskag (1) 61.54°N 160.31°W; Nondalton (1) 59.97°N 154.85°W; Koliganek (1) 59.72°N 157.28°W; Nunavaugaluk (1) 59.30°N 158.98°W; Aleknagik (1) 59.27°N 158.62°W; Katmai National Park (3) 59.09°N 156.45°W; King Salmon (3) 59.03°N 156.72°W; Kodiak Island (10) 58.19°N 152.36°W; Semidi Islands (1) 56.03°N 156.70°W.

* Unpublished