Observations on the Natural History of Bats in the Yukon

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Abstract: Until recently, bats have not been well surveyed or studied in the Yukon. The little brown bat was known to range north to Mayo and Dawson City in the summer, but little was known of its biology or natural history, or if other species occurred. In this article we report from studies conducted between 1997 and 2008, funded in part by the Northern Research Institute. Current studies are answering questions about bat species that occur in the Yukon, their daily and seasonal activity patterns, foraging and roosting habitats, and population dynamics within roosts and roosting areas. We studied bats by detecting and interpreting ultrasonic echolocation calls (acoustic surveys) and by live capture. Acoustic surveys were conducted at over 100 sites across the little brown bat's range in the Yukon, where over 7,000 bat passes were recorded. Most of them were little brown bats but we also recorded northern long-eared and big brown or silver-haired bats. We have banded 1,043 little brown bats at twelve maternity colonies in buildings, bat houses, and rock crevices. Locations of hibernating sites remain unknown, but the bat species that occur in the Yukon are migratory and may hibernate a great distance from their summer range. The annual timing of birth of the little brown bat in the Yukon, at the northern edge of their range, is typical for the species. Recaptures of banded bats has documented roost fidelity and the use of multiple roosts within a larger foraging area. We have also documented cohesive movements of colonies during roost switching, long distance dispersal to new roosts, and survival for at least twelve years. Further research is needed to address the substantial gaps in our knowledge about bats in the Yukon.

Study Objectives

The first studies directed at bats in the Yukon were initiated as recently as 1997. The primary objective of these field studies was to determine bat species diversity and distribution in the Yukon. Secondary objectives of the work were to investigate the biology and ecology of bats in the Yukon, including daily and seasonal activity patterns, possible migration routes and hibernating sites, foraging and roosting habitats, and maternity colony population dynamics within roosts and roosting areas. During the course of this study, data were also obtained on the use of bat houses.

Bats were seen by us as an interesting group of species to study in the Yukon because:

- extremely little was known of the species diversity and distribution in the Yukon (Jung et al. 2006);
- they posed an interesting species to study in relation to forest health and management practices (reviewed in Brigham 2007);
- they are useful as a biological indicator of climate change because they may respond predictably to climate warming (Humphries et al. 2002);
- they provide an interesting biological paradox, being a nocturnal species that lives in “the Land of the Midnight Sun”; and
- most importantly, Yukoners appeared to be quite interested in learning more about the natural history of these mysterious mammals.

Historical Bat Surveys

Until recently, bats have not been surveyed or well studied in the Yukon (Jung et al. 2006). Early biological surveys reported on the distribution of the little brown bat (*Myotis lucifugus*) but nothing on their biology or natural history. Little brown bats were first reported in the southern Yukon by Osgood (1900) during his biological reconnaissance of 1899. Osgood (1900:45) reported that “bats were first seen at Caribou Crossing (Carcross), and from that point were occasionally noticed at various places to our camp, 50 miles below Fort Selkirk, where they were last seen” (figure 1). Two specimens were secured for the Smithsonian National Museum of Natural History in Washington, DC. Keele (reported by Rand 1945) secured a specimen from Mayo Landing in 1907, which is held at the Canadian Museum of Nature, in Ottawa, Ontario. Clarke observed bats, believed to be little brown bats, at Squanga Lake and the Rancheria River in 1943 (reported by Rand 1945). A little brown bat was collected at Kathleen Lake in 1949 (Cameron 1952). Youngman (1975:53) reviewed sixty-one specimens and three observations from fourteen locations, from his and previous surveys during the 1960s, to map the distribution of the little brown bat as “the southern half of the Yukon at least as far north as Dawson” (figure 1).

Rand (1945) was the first to speculate that other species may occur in the Yukon; a long-legged bat specimen (*M. volans*) was obtained near Atlin Lake, British Columbia (Swarth 1936). Youngman (1975) also noted the possibility of the big brown bat (*Eptesicus fuscus*) occurring in the Yukon given that a specimen was known from Alaska, 240 km west of Dawson City (Reeder 1965). Slough and Jung (2007) reviewed records of bats in adjacent Alaska, Northwest Territories, and British Columbia, and noted that seven other species have been reported near the Yukon in these jurisdictions and may also occur in the Yukon, specifically: silver-haired bat, (*Lasionycteris noctivagans*), big brown bat, long-legged bat, northern long-eared bat (*M. septentrionalis*), western long-eared bat (*M. evotis*), hoary bat (*Lasiurus cinereus*), and eastern red bat (*L. borealis*). Keen's long-eared bat (*M. keenii*) and the California bat (*M. californicus*) occur in southeast Alaska (Parker and Cook 1996); however they are likely restricted to coastal forests.

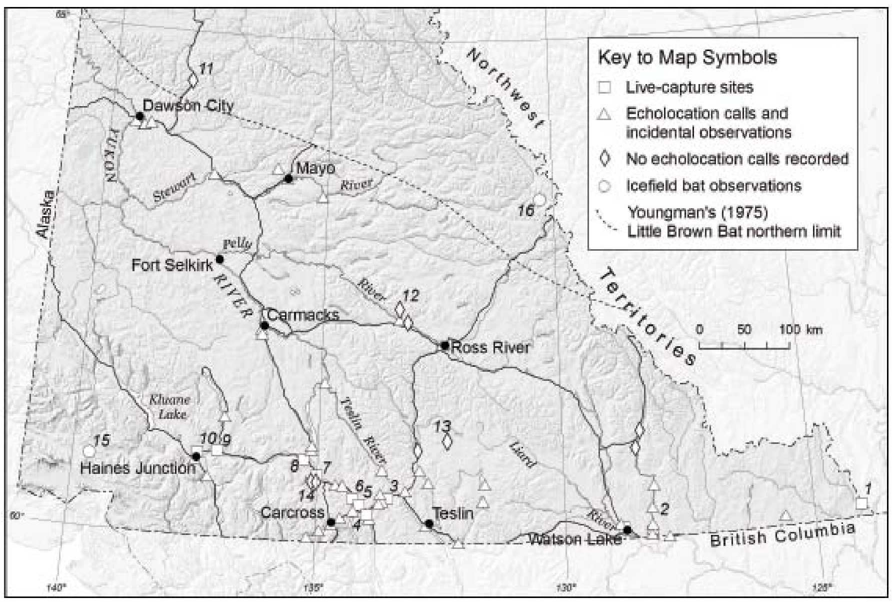


Figure 1. Bat live capture, echolocation survey and observation sites.

□ Live-Capture sites

1. La Biche River
2. Watson Lake
3. Salmo Lake
4. Little Atlin Lake
5. Judas Creek
6. Marsh Lake
7. Chadburn Lake, Miles Canyon & Wolf Cr.
8. Echo Lake
9. Canyon
10. Pine Lake

△ Echolocation calls and incidental observations

◊ No echolocation calls recorded

11. North Klondike River
12. Rose Creek
13. Red River Lake
14. Upper Wolf Creek Basin

○ Icefield bat observations

15. St. Elias Mountains
16. Keele Peak

Methods

Acoustic Surveys

Tuneable heterodyne bat detectors[1] were used to transform the ultrasonic bat calls into audible frequencies in areas such as flyways, potential foraging habitats, roosts, and capture sites. A frequency division bat detector[2] (Anabat) was also used to record bat calls at locations of interest. Calls were converted to sonogram displays on a personal computer, shown as a frequency vs. time graph using AnalookW. Bat detectors were placed on the ground, or on a tripod (1.4 m high, oriented at 30–45°) and directed towards the least structural clutter in the habitat. The use of a stand maximizes detector sensitivity (Weller and Zabel 2002). Calls are detected as a bat passes the microphone's cone-shaped field of detection, and recordings are made during continuous passes. A pass is a sequence of two or more echolocation calls and passes are plotted as sonograms. Some species or groups of species are identifiable from these sonograms through characteristics such as maximum and minimum frequency (kHz), average frequency, call duration (milliseconds), and time between calls. The effective range of the microphone decreases with higher call frequencies, which attenuate more quickly, and lower call intensity. For example, little brown and big brown bats may be detected at distances >30 m, while northern and western long-eared bats may be detected at <5 m (O'Farrell and Gannon 1999). Patriquin et al. (2003) found that vegetation density did not affect the ability to detect 40 kHz transmission, typical of the little brown bat, but 25 kHz calls (e.g., big brown bats and silver-haired bats) attenuated in dense vegetation.

Bat activity was compared between study sites, or between dates at a single site, using numbers of passes (sequences of two or more echolocation calls) per night and per hour foraging (time between first and last recorded calls). Digital file size (i.e., bytes) of Anabat recorded passes was also used (Broders 2003)—file size is a quantitative measure of bat echolocation activity. Feeding buzzes, which have distinct high pulse repetition rates, were estimated for each recording session. Recorded calls were compared with voucher calls of little brown bats live-captured and released during this study. Calls that were not characteristic of little brown bats were compared with voucher calls or call keys of species from other areas of North America. Sunrise, sunset, and twilight times were calculated using Moonrise.

Capture Surveys

Bats were captured in mist nets and harp traps (modeled after Palmeirim and Rodrigues 1993)[3]. Nets and traps were set in roost exits in cabins, in front of rock crevice roosts and bat houses, and in foraging habitats during the peak period of bat activity, usually 0.5–3 hours after sunset. Captured bats were held in cloth bags. Bats were aged and sexed, and reproductive status of females was assessed. Juvenile bats were distinguished from adults by swollen finger joints (unossified epiphyses of the metacarpal-phalangeal joints: see Anthony 1988). This character is less reliable after mid-August, but juveniles retain a dark, glossy coat and waxy appearing wing membranes. Adult males have a conspicuous penis, and lactating females have worn fur around the nipples. The presence of a foetus can be determined by palpating the abdomens of females. A numbered aluminum band was attached to the forearm[4] to identify recaptures.

Study Areas

We surveyed for bats at over 100 sites (figure 1), most of which were surveyed acoustically. Many of the echolocation surveys were conducted in remote locations. Seven maternity colonies were studied more intensively with live capture of bats. The logistic constraints of conducting research on bats in natural roosts (Kunz and Reynolds 2003) places added value on what can be learned from studying building-roosting bats (Brigham 2007). Our long-term study of population dynamics and roosting areas included colonies using cabins at Salmo Lake, Marsh Lake (Judas Creek subdivision), Chadburn Lake (colony also uses a bat house attached to the cabin), Echo Lake, and Canyon (cabin on Aishihik River). Other sites included bat houses at Squanga Lake, Salmo Lake, Little Atlin Lake, Judas Creek, Wolf Creek, Watson Lake's decommissioned airport control tower and rock crevice roosts in Miles Canyon on the Yukon River near Whitehorse, and Pine Lake near Haines Junction. All study colonies were maternity colonies, which typically select roosts with warm and stable temperatures to promote the pre- and post-natal growth of young. Maternity colonies of bats typically contain few adult males, which roost alone or in small bachelor colonies. Bats were live-captured at roosts once per year except Chadburn Lake, Marsh Lake, and Watson Lake, which were sampled up to three times per year, Wolf Creek was sampled up to eight times, and Salmo Lake was sampled up to twelve times. In this article we also report on unpublished observations from others, which had been personally communicated.

Bat Houses

Bat houses, installed at Wolf Creek and Chadburn Lake in 1999, were constructed based on the plans of Tuttle et al. (2004) for a four-chamber nursery house (approximately 61 cm high x 44 cm wide x 13 cm deep) modified for colder climates (M. Kiser, pers. comm.) with black staining, no venting, and mounting at least 4.5 m above ground on the south facing wall of buildings. The Wolf Creek bat house was heated with a seedling heat mat or battery heat pad connected to an electronic thermostat[5] with the temperature sensor placed in the upper interior. The temperature control was set on heating mode and programmed to shut off at 30° C. Observations at the Wolf Creek bat house were sometimes made with an infrared night vision video camera[6] monitored on a PC using XtraSense motion-detecting software. Additional, larger (approximately 120 cm high x 90 cm wide by 13 cm deep) four-chamber bat houses were erected on poles at Salmo Lake and Little Salmon Lake in 2007, and Squanga Lake and Watson Lake in 2008.

Results and Discussion

We caught and handled over 1,800 bats at twelve maternity colonies and, of these, over 1,000 were banded. These bats were recaptured 255 times (table 1).

Species Diversity

Over 7,000 bat passes have been recorded using the Anabat detector in over 100 locations across the Yukon (figure 1), all of which were *Myotis* species, likely the little brown bat, with the following exceptions.

At about 0230 to 0345 on 12 September 1999, one of us (BGS) recorded sixty-nine passes of a big brown bat or silver-haired bat at the Morley River outflow of Morris Lake. Based on call characteristics of the two species, which are similar (Betts 1998), the Morris Lake calls are more likely to be those of a big brown bat (C. Corben pers. comm., Keinath 2004). The calls, recorded in low clutter, are irregularly spaced, exhibit a variable minimum frequency, and some fall below 25 kHz and have "fish-hook" ends, unlike silver-haired calls.

In June 1999, one of us (BGS) recorded call sequences characteristic of northern long-eared bats at the La Biche River. These calls have higher maximum and minimum frequencies, shorter call duration, and the sonogram has a steeper slope than those of the little brown (Broders et al. 2004). On 28-29 July 2004, Jung et al. (2006) captured three northern long-eared bats there. The species has since been captured near Watson Lake (Lausen et al. 2008) and likely ranges throughout the Liard Basin in the Yukon, including Coal River Springs Territorial Park (Lausen et al., unpubl. data).

These new species have gone undetected due to the lack of study; however, some species may be expanding their range. Whitaker and Gummer (1992) suggested that big brown bat populations are expanding north with the availability of suitable winter hibernacula in buildings with heated attics.

Jung et al. (2006) noted that with continued survey effort, additional bat species are likely to be found in the Yukon.

Distribution of the Little Brown Bat

Bat call surveys conducted in wilderness and settled areas throughout the range of the little brown bat confirm their ubiquitous occurrence up to 1000 m elevation such as Wolf Lake (990 m) and Morris Lake (993 m) (figure 1, table 2). Bats were not found at Rose Creek near Faro (62.3°N, elevation 1075 m), Red River Lake north of Teslin (61.0°N, elevation 1050 m), or the upper Wolf Creek basin near Whitehorse (60.6°N, elevation 1190 m). Other locations for acoustic surveys included various wetlands in the Mary Lake-Wolf Creek area, Lewes Marsh (Yukon River), Marsh Lake, the Squanga Lake area, and Bennett Lake in southwest Yukon; the Nisutlin River, La Biche River, Larsen Lake, Hyland River, and Blind Lake in the south-central and southeast; and Nogold Creek and Horseshoe Slough on the Stewart River in the central Yukon (figure 1, table 2).

Our efforts confirm the range proposed by Youngman (1975). We did not record any bats during acoustic surveys on the North Klondike River, nor were they observed on the Wind (1981), Snake (1992), Bonnet Plume (1997), and Peel rivers of the northern Yukon. Observations of others reported to me suggest that the species ranges further north in the Selwyn Mountains of the eastern Yukon—approximately twenty-five bats were observed frozen in a glacier on Keele Peak near the upper Hess River in the 1980s (figure 1: 16; R. Markel and P. Henstridge, pers. comm.). That has been the only sighting north of Youngman's (1975) proposed limit. Summer night sightings have been reported from the Dawson City area for at least fifty years (F. Berger, D. Thornington, and J. Russell, pers. comm.) and maternity colonies have been confirmed near Mayo (K. Sinnott and M. O'Donoghue, pers. comm.). Both Dawson City and Mayo are near the northern range limit of the little brown bat.

The northern limit of the little brown bat could be constrained by habitat, temperature, summer daylight, or migration distances from hibernation sites. It is known to occur as far north as Fort Simpson (61°46'N) in the Northwest Territories (van Zyll de Jong 1985, Fournier 1997, Lausen 2006) but likely ranges further north in the Mackenzie Valley. It occurs near Fairbanks, Alaska (65°N), and is suspected to occur as far north as Fort Yukon (66°32'N) (Parker et al. 1997). Parker et al. (1997) speculated that temperature, the availability of summer and winter roosts, and the extent of forested habitat have more influence on bat distribution than precipitation, summer daylight, or prey abundance. Humphries et al. (2002) predicted that current climatic conditions are suitable for little brown bat hibernation in the extreme southern Yukon and that climate change in the next century will extend this to the central Yukon if hibernation sites are available.

Table 1. Summary of bat capture data from maternity colonies, 1997–2008.

Colony	Year	Bats Captured	Bats Banded	Adult Females Banded	Re-captures from Same Year	Re-captures from Previous Years	Adult Female Pop'n Est.
Canyon	1999	15	15	15	0	0	30; 10 in 2000[1]
Chadburn L.	1997	10	10	6	0	0	10 in '97 & '98
	2000	1	1	1	0	0	5
	2001	9	8	7	0	1	9
	2003	2	0	0	0	0	14
	2004	1	0	0	0	1 (Echo Lake)	12
	2005	5	5	4	0	0	5
	2006	50	44	36	1	5	30
	2007	77	46	45	11	20	30
	2008	26	10	6	0	14	21
	Sub-total	181	124	105	12	41	
Echo L.	2000	1	1	1	0	0	Not est.
Judas Cr.	1997	1	1	0	0	0	Not est.
Little Atlin L.	2007	200	11	11	0	2 (Salmo Lake)	200 in bat house; 100+ in shed
Marsh L.	1997	1	1	1	0	0	30
	1998	24	24	14	0	0	30
	1999	23	22	17	0	1	100
	2000	17	16	14	0	1 (male)	>50
	2007	42	38	36	3	1	50-100
	Sub-total	107	101	82	3	3	
Miles Canyon	2007	9	7	5	2 (Chadburn)	2 (Chadburn)	30
	2008	11	8	8	0	3 (2 Chadburn)	25
	Sub-total	20	15	13	2	5	

Colony	Year	Bats Captured	Bats Banded	Adult Females Banded	Re-captures from Same Year	Re-captures from Previous Years	Adult Female Pop'n Est.
Pine L.	2006	13	13	13	0	0	14
	2007	4	3	2	0	1	4
	2008	2	2	2	0	0	2
	Sub-total	19	18	17	0	1	
Salmo L.	2001	30	30	24	0	0	>50
	2003	70	0	0	0	0	≤100
	2004	50	48	29	0	2	≤100
	2005	238	213	187	18	7	≤400
	2006	104	83	63	1	20	≤200
	2007	150	5	5	2	22	≤200[2]
	2008	110	42	42	0	8	≤200
	Sub-total	752	421	350	21	59	
Squanga L.	2008	47	12	12	0	1 (Salmo Lake)	35[3]
Watson L.	2004	50	50	22	0	0	200
	2005	68	64	60	1	1 (male)	200
	2006	112	5	5	0	8	150[4]
	Sub-total	230	119	87	1	9	
Wolf Cr.	2003	5	0	0	0	0	5
	2004	1	1	0	0	0	5
	2005	32	27	14	5	0	6
	2006	83	68	52	6	9 (2 banded as juveniles; 1 Chadburn)	21
	2007	111	68	57	28	16 (1 Chadburn)	20–45
	2008	87	56	51	6	32 (1 male, 7 Chadburn)	10–50
	Sub-total	319	220	174	45	57	
Total		1872	1043	854	82	173	

1. abandoned in 2001
2. cabin replaced with 2 bat houses
3. not including unknown number in picnic shelter
4. J. Talerico, unpublished data

Seasonal Activity Patterns

Our results, together with the observations communicated by others indicate that females typically begin to occupy maternity colony roosts in the Yukon during the last two weeks of April. The first activity noted at the Wolf Creek bat house near Whitehorse was between 16 and 29 April (2003–2008). The Chadburn Lake roost has been vacant as late as 14 May (1998). Activity was reported at Mayo on 25 April 2003 (M. Wozniak, pers. comm.). There are unconfirmed reports of bat activity on 22 March 2008 near Whitehorse (C. Hrenchuk; pers. comm.) and 28 March 2003 (P. Sparling, pers. comm.) near Marsh Lake.

Nightly emergence, documented by echolocation call or video recordings, was sporadic for the first week or two after arrival, as the bats remained inactive and likely torpid (reduced metabolism and body temperature) during cool weather when insect abundance is low. Maternity colonies continued to increase as individuals or small groups arrived throughout May and early June. Numbers of females at the Wolf Creek roost reached maximum numbers by 24 May 2006 and 24 June 2007. Roost switching, discussed below, produced dramatic shifts in number of bats at roosts.

Pups were born from late June through mid-July, suggesting that ovulation occurred late April to mid May. Lactating females have been captured as early as 24 June 2007 at Wolf Creek and pregnant females have been noted as late as 22 July 2007 at Salmo Lake. About 87.5% of females in maternity colonies were pregnant annually. Half of these gave birth by the first week of July. Neilson and Fenton (1994) found a similar reproductive rate in building-roosting little brown bats in New York. We know from the literature on populations elsewhere, that little browns mate prior to or during hibernation and ovulation occurs the following spring after hibernation (Fenton and Barclay 1980).

Juveniles were first captured on 16 July 2005 at Wolf Creek and 19 July 2007 at Pine Lake, and could fly by about three weeks, typically late July through early August in the Yukon. Maternity colonies began to disband in early August with only a few bats, mainly juveniles, remaining by late-August or September. Numbers of bats present at the Wolf Creek roost dropped from a 2006 summer high of twenty-one to eleven by 4 August, two by 15 August and zero on 29 August. The Chadburn Lake roost was vacant by 28 August 1997. Despite the abandonment of summer roosts by most bats, activity was noted in foraging habitats until late September. The last activity at Wolf Creek was 30 September 2007. Emergence was sporadic by mid September, when night-time temperatures frequently dropped below 0°C. Unconfirmed activity has been reported near Marsh Lake in early October

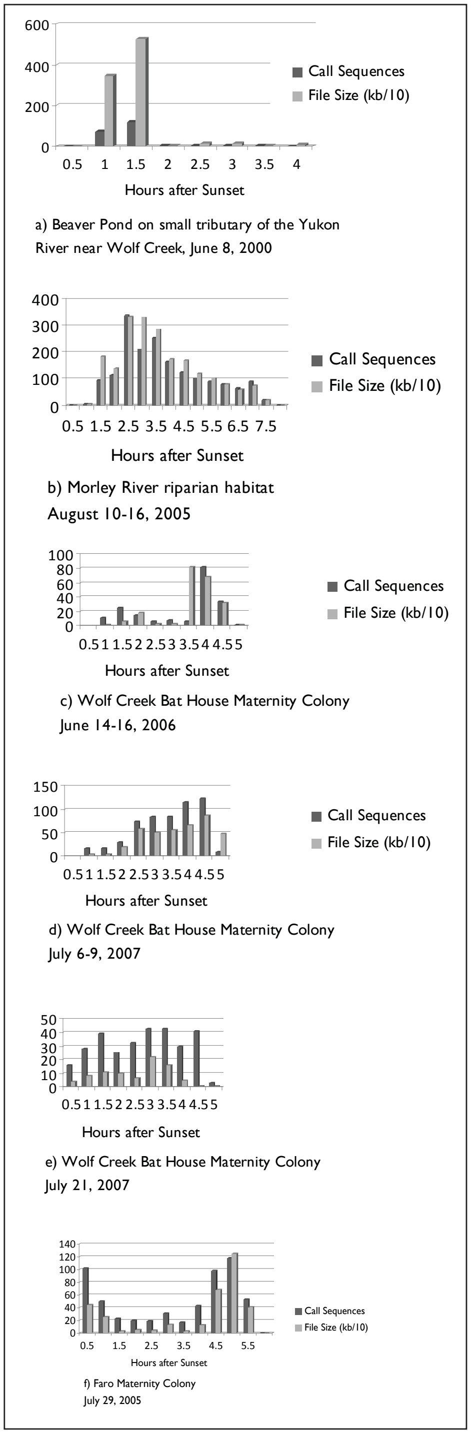
(P. Sparling, pers. comm.), at Beaver Creek, where twenty to thirty bats were flying during snowfall in early November 1999 (C. Laporte, pers. comm.), and near Whitehorse on 24 November 1998 (J. Johnstone, pers. comm.). Unconfirmed early- and late-season observations lead to speculation and questions regarding the timing of migration, and whether bats are attempting to hibernate locally.

The timing of births is determined largely by weather at the hibernacula and the corresponding need for torpor, where fertilization occurs, and to a lesser degree by ambient temperatures after bats leave hibernation (Fenton and Barclay 1980). Populations at higher elevations and latitudes are expected to have delayed reproductive cycles relative to southern populations (Fenton and Barclay 1980, Nagorsen and Brigham 1993); however, the annual cycle of the little brown bat in the Yukon, at the northern edge of their range, appears to be typical. We adduce that the Yukon environment provides suitable temperatures, especially at maternity roosts, and that food resources are adequate and abundant.

Hibernation

Hibernating bats have not been found in the Yukon. We suspect that hibernation occurs elsewhere, such as the karstland caves of Prince of Wales Island of Southeast Alaska, 400 km south of the Yukon (Lewis 1997, Parker et al. 1997). Little brown bats and other species are known to hibernate in karst terrain in Wood Buffalo National Park (500 km east of the Yukon; Parks Canada 1984) and in the Rocky Mountains near Cadomin and Nordegg (Schowalter 1979). Little brown bats are known to migrate up to 800 km in Ontario (Fenton 1969). We speculate that the limiting factor for bat hibernation in the Yukon is not the cold temperatures or lack of caves, rather it is because the winters there are not humid enough to prevent them from dehydrating during the long hibernation.

There are unsubstantiated reports of bats hibernating in artificially heated structures near Fairbanks, Alaska including a Quonset hut at Salcha, which was heated to 1°C (Whitaker and Lawhead 1992, Rydell et al. 2002), a heated garage at the same residence, and a heated underground utility corridor at Eielsen Air Force Base (K. Price, pers. comm. to D. Parker McNeill). The bats were apparently observed licking frost from their fur to avoid dehydration (K. Price, pers. comm. to D. Parker McNeill). Reports of bats hibernating in buildings in the Yukon are based solely on early and late-season observations of active bats; not on winter observations of hibernating bats. Little brown bats are not known to hibernate in buildings in Alberta (Schowalter 1979). The northernmost winter record for little browns in British Columbia is



a) Beaver Pond on small tributary of the Yukon River near Wolf Creek, June 8, 2000

b) Morley River riparian habitat August 10-16, 2005

c) Wolf Creek Bat House Maternity Colony June 14-16, 2006

d) Wolf Creek Bat House Maternity Colony July 6-9, 2007

e) Wolf Creek Bat House Maternity Colony July 21, 2007

f) Faro Maternity Colony July 29, 2005

Figure 2. Nightly Bat Activity
a) sunset 2327, sunrise 0432 (4.9 hrs);
b) sunset 2154–2138, sunrise 0554–0608 (8-8.5 hrs);
c) sunset 2232, sunrise 0428 (5.0 hrs);
d) sunset 2327–2323, sunrise 0443–0448 (5.3 hrs);
e) sunset 2301, sunrise 0512 (6.2 hrs)
f) sunset 2247, sunrise 0513 (6.4 hrs)

Williams Lake; however more northerly hibernacula likely occur (Nagorsen et al. 1993).

Some Yukon bats migrate in the spring as indicated by groups of bats observed passing over the St. Elias Mountains and glaciers (Figure 1: 2; M. Williams, pers. comm.), perhaps returning from coastal hibernacula. The twenty-five Keele Peak bats (R. Markel and P. Henstridge, pers. comm.) found frozen in a glacier may have been migrating.

Daily Activity Patterns

We found that bats in the southern Yukon emerged from maternity roosts 0.5–1 hour after sunset, with emergence becoming progressively later, relative to sunset, for five weeks prior to the summer solstice, and then progressively earlier following the solstice. There is no true darkness (i.e., astronomical twilight when the sun is 18° or more below the horizon) in the southern Yukon between 20 April and 23 August and there is no civil twilight (when the sun is 6° or more below the horizon) between 18 and 25 June. At the northern limit for bats near Dawson City there is no true darkness between 11 April and 2 September, and no civil twilight between 21 May and 24 July. They typically return thirty to seventy-five minutes before sunrise, and there does not appear to be a seasonal pattern to the end of foraging. However in the Yukon we found no evidence for two foraging periods separated by an interval of night roosting as found in the United States (Anthony et al. 1981).

Bats foraging at a small beaver pond near Whitehorse on 8 June 2000 displayed a short burst of activity early in the night (figure 2a), possibly taking advantage of calm winds or high insect abundance. We speculate that this may have also been group feeding behaviour near a roost, that shifted elsewhere later. Activity began thirty-seven minutes after sunset, peaked at 1–1.5 hours after sunset, and ended seventy minutes before sunrise. Late summer activity at Morley River in 2005 peaked 2.5 to 4 hours after sunset (first activity 68.6 minutes after sunset, range 58–84 minutes; last activity 73 minutes before sunrise, range 57–129 minutes; figure 2b).

Exits and entrances from the Wolf Creek bat house from mid-June through late July 2006 and 2007 (figure 2c-2e) suggest increasing night roosting at the bat house and a reduced total period of activity by lactating females. Later emergence occurred near the solstice. From 14–16 June, first emergence was 41–85 minutes after sunset and the last return was 31–32 minutes before sunrise, or about 5.0 hours of activity. Emergence was earlier on 6–9 July (39–49 minutes after sunset) and activity ended earlier (48–64 minutes before sunrise) making the activity period 3.6–3.9 hours. This increased to 5.0 hours again on 21 July, when juveniles became volant, or able to fly (bats emerged 28 minutes after sunset and returned 40 minutes before sunrise). There was often intense pre-dawn activity, as bats circled near the roost.

Exits and entrances at a maternity colony in a house in Faro on 29 July 2005 was intense during the first hour after sunset (first emergence 23 minutes after sunset; figure 2f) and again when bats returned 0.5–2 hours before sunrise (last return 35 minutes before sunrise, 6.4 hours of activity). Night roosting at the maternity roost declined when juveniles began to fly. Activity levels at bat roosts increased dramatically, especially before dawn, when juveniles began taking practice flights in late July to early August.

Evening emergence times of bats appears to be a function of prey abundance and minimizing the risk of avian predation and harassment/competition (Jones and Rydell 1994). Flight by small dipterans peaks at dusk when avian predators and competitors of bats may still be active. Bats that eat nocturnal insects such as moths, or glean flightless insects from plants, water, or other surfaces can emerge later when predation risk is lower. Little brown bats in the Yukon emerge after sunset but before darkness likely to exploit high insect abundance, and then continue to forage when light levels (and probably insect levels) are low, even when there is no darkness, probably to avoid avian predation or competition similar to northern Europe (Rydell et al. 1996, Speakman et al. 2000). Energetic considerations may also influence emergence timing, with bats under energetic stress, such as pregnant females, emerging earlier (Duvergé et al. 2000). In contrast, females in the Yukon emerge later near the solstice, even though most females are pregnant. In Alaska, Rydell et al. (2002) found that bats foraged in shaded areas to reduce predation risk in daylight.

Evening emergence from maternity roosts occurs over a relatively brief period (0.5 to 1 hour), with bat activity peaking after sunset and declining throughout the night (Figure 2c-e). The level of late night activity is likely correlated with ambient temperature (Broders et al. 2003). According to the literature, bats may use separate night roosts, but most pregnant or nursing females return to their maternity roosts to digest food, remaining homothermic between foraging flights (Anthony et al. 1981).

Roost Characteristics

The vast majority of known bat roosts in the Yukon were maternity roosts in buildings. Few natural roosts such as in trees or rock crevices have been observed. Some have suggested that little brown bat numbers have increased in the Yukon with European settlement over the past century. Nonetheless, little brown bats were found to occur where buildings were not used or were unavailable, so some colonies must use natural roosts to some extent. Natural roosts that have been reported include behind the exfoliating bark of a fire-killed white spruce (*Picea glauca*: S. Gilbert, pers. comm.), and in rock crevices at Pine Lake (horizontal crevice under overhanging rock; D. Carew and M. Alford, pers. comm.) and Miles Canyon (series of mainly vertical crevices in basalt columns; figure 3; C. Hedgecock, pers. comm.).

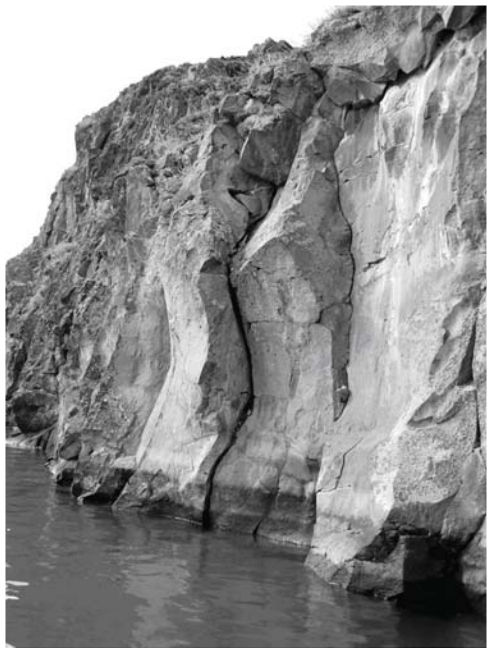


Figure 3. Crevices in Miles Canyon columnar basalt on the Yukon River near Whitehorse are used for roosting by a little brown bat maternity colony. Horizontal crevices are used for basking.

Twelve bat houses were known to be occupied in the Haines Junction and Whitehorse-Southern Lakes areas. In eight cases they were mounted on buildings, and modified to increase and buffer temperature. After an abandoned cabin used by a large maternity colony (Jung and Slough 2005) was burned down at Salmo Lake in fall 2005, two pole-mounted bat houses were erected and used the following season by hundreds of bats from the evicted colony. The same colony also uses a picnic shelter and bat house at the Squanga Lake campground. Evicted colonies in New York did not join existing colonies or occupy replacement bat houses (Neilson and Fenton 1994) as they did here.

We have observed, and have received numerous reports of, early- and late-season use of exposed diurnal roosts on the walls of buildings. Most occurrences were in late summer (August-September) and were mostly juveniles that may not have yet learned the entrance to the roost, although the behaviour was observed at Watson Lake airport in early June. According to the literature, bats using exposed roosts are generally solitary, protected from the sun, and slow to arouse when in torpor (Riskin and Pybus 1998).

The physical suitability of roosts may change over the time, such as the Canyon roost in a deteriorating log cabin, which was vacated when the roof and walls collapsed. Ironically, the colony at Chadburn Lake has grown since the City of Whitehorse's attempt to exclude the bats by sealing the windows and doors. Vandals broke an upper window, which improved access for the bats. Colonies occupying bat houses typically grew for several years after establishment. An unusual case of mortality was observed at the Salmo Lake colony in 2004, when a homemade multiple-catch rodent trap, consisting of a bucket of water with a wire strung across and through a baited can, captured 53 bats, 37 of which were believed to be juveniles based on forearm length (Jung and Slough 2005).

Foraging Habitats

The highest bat echolocation call and feeding activity, based on the number of passes and feeding buzzes per night or per hour of bat activity, occurred in riparian and lacustrine habitats, including shorelines and over water, at elevations <1000 m (table 2). Lower activity levels were observed in forested habitats ≤500 m from water. According to the literature, riparian areas are important foraging and drinking areas for insectivorous bats, especially females (Grindal et al. 1999).

Maternity Colony Population Dynamics

Colony Size and Sex Ratio

Colony size varied between sites, ranging from 12–400 adult females (table 1). With a mean pregnancy rate of 85%, colonies increased to 22–740 bats in July, including pups. Colony size also varied between and among years at roosts.

Maternity colonies were comprised almost entirely of adult females and their pups. We did not find roosts of adult males. Grindal et al. (1999) found males more commonly at higher elevations, where we did not attempt to capture bats. Little is known about adult male behaviour outside of the Yukon. Three little brown bats captured over a pond in the La Biche valley were adult males (Jung et al. 2006). All thirty-eight adult bats handled at Pine

Table 2. Bat echolocation call surveys in foraging habitats. Includes nightly surveys with >13 passes as recorded by the Anabat detector.

Location	Habitat	Elevation (m)	Date	No. Passes (buzzes)	Activity Period (hrs)1	Passes/hr
Bennett Lake - Partridge River	delta & shore	740	Aug 16, 2004	61 (2)	6.5	9.4
			Aug 17, 2004	70 (7)	5.8	12.0
Blind Lake	shore & water	695	Jun 26, 2003	115 (3)	3.6	27.5
			Jun 27, 2003	32	2.4	13.5
Chadburn Lake	shore & water	715	Jun 15, 1998	34 (1)	2.4	14.3
La Biche River	stream marsh	445	Jun 10, 1999	23 (4)	2.13	11.0
			Jul 29, 2004	163 (37)	0.63	281.0
Marsh Lake	marsh	705	Jun 18, 1998	125 (36)	2.22	102.5
Morley River	shore & water	840	Aug 10, 2005	63 (3)	4.9	13.0
			Aug 11, 2005	120 (4)	6.1	19.7
			Aug 12, 2005	200 (5)	5.8	34.6
			Aug 13, 2005	185 (5)	5.9	31.5
			Aug 14, 2005	324 (9)	5.9	55.1
			Aug 15, 2005	395 (29)	6.5	61.0
			Aug 16, 2005	445 (49)	6.1	71.0
Morris Lake	shore & pond	995	Sep 8, 1999	25 (1)	7.03	3.6
	shore & water (Morley R. outflow)	995	Sep 11, 1999	158 (7)	6.32	25.2
	Mixed pine, spruce, fir, aspen forest	995	Sep 12, 1999	29 (1)	6.2	4.7
Salmo Lake	shore & pond	795	May 17, 2005 May 18, 2005 May 20, 2005	57 (0) 31 (0) 31 (1)	3.0 1.7 2.0	19.2 18.0 15.7
Squanga Lake	shore & pond (east of lake)	860	Aug 17, 2000	34 (0)	6.3	5.4
Squanga Lake	shore & pond (beaver pond on Squanga Cr inflow)	830	Sep 6, 2000	114 (15)	1.23	92.7
Stewart River	shore & pond (Horseshoe Slough)	535	Jul 26, 2000	67 (0)	2.5	26.8
Yukon River tributary near Wolf Creek	shore & water (beaver pond)	750	Jun 8, 2000 Jun 11, 2000 Jun 11, 2000	207 (45) 53 (5) 269 (41)	3.3 3.3 1.03	62.7 16.0 274.5

1. Time between first and last pass; 2. Session ended prematurely at end of cassette tape

Lake, Canyon and Miles Canyon were female. Three of six bats handled at Wolf Creek in 2003 and 2004 were adult males, and three females were non-reproductive. The roost became a maternity colony in 2005 and all but one of the 169 adults handled thereafter were females. An adult male, banded as a juvenile male in 2007, was captured in 2008. Colonies at Salmo Lake were 98.6% female; Marsh Lake was 98% female, with one of the two adult males banded as a juvenile. One out of 123 adults (0.8%) handled at Chadburn Lake was male. Watson Lake (49 adults) was 96% female, with one male captured in two successive years.

Parker et al. (1997) found sexually unbiased populations in coastal southeast Alaska. Female-biased populations in New Brunswick are thought to occur where weather and prey abundance are suitable to meet energetic requirements (Broders et al. 2006), however female-biased populations occurred in western Newfoundland at sites with low productivity, low ambient temperature, and short summers (Grindal 1998).

Roost Fidelity, Movements and Survival

Recapture rates of adult females banded in previous years varied from 7–13% at Salmo Lake to 28–37% and 42–50% at Chadburn Lake and Wolf Creek respectively, reflective of roost fidelity (philopatry). The mortality rate of banded bats that were not recaptured was unknown, but the use of multiple roosts by colonies, and roost switching by some banded individuals, was documented.

Species using permanent roosts, such as buildings, caves, and rock crevices, were more philopatric than those in trees (Lewis 1995). Fidelity was also inversely related to roost availability. Benefits to roost fidelity for little brown bats include avoiding the cost of annually searching for roosts, and maintaining the thermoregulatory advantages of colonial roosting. Little brown bats roosting in tree cavities switch roosts often (Crampton and Barclay 1998).

Some colonies use multiple roosts in a roosting area (Willis and Brigham 2004). We found that multiple roosts were being used at the Salmo Lake, Marsh Lake, and three Whitehorse area roosts (Wolf Creek, Chadburn Lake and Miles Canyon) based on the fluctuating numbers of bats present over a given summer, the frequent turnover of individuals in roosts, and movements between roosts. At Wolf Creek, the population was stable at twenty-one in 2006, but sixty-one different adult females were captured during the summer. The population was as high as forty in 2007, when seventy-three adult females were handled. At Chadburn Lake, with an estimated population of thirty in 2006 and 2007, forty-one adult females were handled in 2006, and sixty-five were handled in 2007.

We recorded a case of bats moving among three roosts in a roosting area: two adult females banded at Wolf Creek in 2007 were recaptured the same year at Chadburn Lake. Two bats banded at Chadburn Lake in 1997 were captured at Wolf Creek 2006 to 2008. Seven females banded initially at Chadburn Lake were occupying the Wolf Creek bat house in 2008, representing 22% of the recaptures at that roost. Two bats banded at Chadburn Lake in 2001 and 2006, both of which had been present at Chadburn Lake in 2007, were recaptured at the Miles Canyon roost in 2007. Chadburn is 2.7 km from Miles Canyon and 4.4 km from Wolf Creek. Miles Canyon roost is 5.9 km from Wolf Creek. Lausen and Barclay (2006) found big brown bats benefited by roosting in buildings compared to rock crevices. Bats roosting in the warmer microenvironments of buildings used torpor less but achieved lower body temperatures during torpor, possibly due to a lesser need for vigilance against predators, resulting in shorter gestation and faster juvenile growth. Evidence from the Chadburn Lake cabin and Miles Canyon crevice roosts in the Yukon suggest that the two were used impartially by bats.

We found three pairs of adult females banded during the same session at either Wolf Creek or Chadburn Lake were subsequently trapped together after a roost switch. Two of these switches were within years (2007) and one was between (2006 and 2007).

Bats banded as juveniles were rarely recaptured, but three males banded as juveniles at Marsh Lake and Wolf Creek were recaptured the following year as adults. Two females banded as juveniles at Wolf Creek returned the following year and one successfully reproduced.

We recorded three long-distance movements by adult females. One banded at Echo Lake in 2000, was captured at Chadburn Lake, 25 km to the southwest in 2004 (figure 1: 7 and 8). Two females banded at Salmo Lake in 2005 moved 29 km to a bat house on Little Atlin Lake in 2007 (figure 1: 3 & 4).

Willis and Brigham (2004) proposed a fission-fusion social model for the big brown bat, where social relationships could be maintained among individuals who switched roosts. The occupancy of the Salmo Lake bat houses is evidence for the cohesive movement of that colony. The bat houses were erected in May 2007, by which time most bats would have returned from hibernation, but were vacant until early July when five to eight bats were present. An estimated 300 bats, including pups and many adults banded at the former roost, were present in July 2007. Large within-year fluctuations in numbers were also noted at the original Salmo roost and at intensively studied colonies at Wolf Creek and Chadburn Lake.

Recaptures among years suggest a high survival rate of the little brown bat in the Yukon (table 1). Four females banded as adults at Chadburn Lake in 1997 were recaptured in 2007 (one at Wolf Creek) making them at least eleven years old. One was recaptured in 2008 at the minimum age of twelve years. Continuing research on these study animals should help establish longevity of bats here. The longevity record for the little brown bat is thirty-four years (Davis and Hitchcock 1995), and a record of forty-one years for the genus was recorded for Brandt's bat (*M. brandtii*) in Russia (Podlutsky et al. 2005).

Conclusions

Substantial gaps remain in our knowledge about Yukon bats. Difficulties inherent in bat research are the main constraints to acquiring this knowledge.

Our work, particularly banded bats, provides an opportunity for future research on population dynamics, longevity, foraging area fidelity, and movements. A library of bat echolocation calls including known little brown bat calls is available for further analysis.

The Yukon public displays a high level of interest in bats. We have received requests for information on the biology and ecology of bats, public health concerns, excluding problem bats and attracting bats with bat houses. The demand for information has resulted in presentations requested by conservation organizations, naturalist groups, the City of Whitehorse, and school groups. A series of bat talks is given by the Department of Environment and an information pamphlet on bats of the Yukon has been produced.

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Notes

1. Mini-3, Ultrasound Advice, London, UK
2. Anabat II, Titley Electronics, Ballina, Australia
3. 2.6 x 3 - 18 m, 38 mm mesh; Avinet, Inc., Dryden, NY) four-shelved nylon mist nets set on 2.7–3.7 m poles and in harp traps, with an area of 1 m^2
4. 4.0 x 0.38 mm, 2.9 mm internal diameter, Lambournes Ltd., Birmingham, UK or Porzana Ltd., Icklesham, UK; or 5.0 x 0.64 mm, 3.0 mm internal diameter, Gey Band & Tag Co., Inc., Norristown, PA
5. 22.9 x 48.3 cm, 17-watt seedling Model AM101, Lee Valley Tools Ltd., Ottawa, ON or a 12.7 x 17.8 cm, 40-watt battery heat pad. Thermostat model ETC-111000-000, Ranco Corp., Plain City, OH
6. Bathouse Spy Cam, Bat Conservation International, Austin, T X

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