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FIRST RECORDS OF YUMA MYOTIS (*MYOTIS YUMANENSIS*) IN ALASKA

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ABSTRACT—A review of bat specimens housed at the University of Alaska Museum confirms the occurrence of the Yuma Myotis (*Myotis yumanensis*) in Southeast Alaska. This represents only the 7th bat species known from the state and its 1st new bat in >40 y. All known specimens of the Yuma Myotis were collected in the early 1990s. Reasons why this species escaped detection until now are discussed and include its close morphological resemblence to the more common and widespread Little Brown Myotis (*Myotis lucifugus*), the general inaccessibility of much of Southeast Alaska, and a historical paucity of field and specimen-based studies of bats from this region. The presence of the Yuma Myotis in Alaska, while not surprising, suggests that we still have much to learn about the basic biology, ecology, and biogeography of this and other bat species in and around Alaska. Such information is critical if we are to monitor the effects of climate change and other anthropogenic factors on organisms at the limits of their geographic distributions.

Key words: Alaska, distribution, Little Brown Myotis, *Myotis lucifugus*, *Myotis yumanensis*, Revillagigedo Island, Yuma Myotis

With only 6 species, Alaska's bat fauna is the most depauperate of any state in the continental United States. Parker and others (1997) provided the most recent comprehensive review of bat distribution records in Alaska. In the subsequent 17 years, no published range extensions have been confirmed with voucher specimens and 1 marginal record has since been questioned (MacDonald and Cook 2009). Bats remain Alaska's most poorly studied group of mammals. Recently, growing concern over the potential spread of white-nose syndrome to Alaska, as well as the need to track shifts in species ranges in response to climate change, have revitalized interest in collecting baseline information on Alaska's bats, including occurrence data. Alaska's most common and widespread bat species, the Little Brown Myotis (*Myotis lucifugus*), is found throughout much of the state south of the Brooks Range (MacDonald and Cook 2009), and occurs farther north than any other bat in North America. Throughout much of its western range south of Alaska, it is sympatric with the Yuma Myotis (*Myotis yumanensis*), a species previously undocumented in Alaska but known to occur in adjacent British Columbia (Nagorsen and Brigham 1993; Fig. 1). The 2 species are notoriously difficult to differentiate morphologically (for example, Harris and Findley 1962; Parkinson 1979; van Zyll de Jong 1985), and for decades were implicitly assumed to be closely related and possibly capable of interbreeding (Barbour and Davis 1969), although evidence for the latter has been mixed (Parkinson 1979; Herd and Fenton 1983). More recent molecular phylogenetic studies have consistently placed the 2 species in different (and divergent) clades of New World *Myotis* bats, with the Yuma Myotis in a clade composed of species with predominately neotropical distributions and the Little Brown Myotis in a clade with more northerly distributions (Ruedi and Mayer 2001; Stadelmann and others 2007; Ruedi and others 2013). Molecular

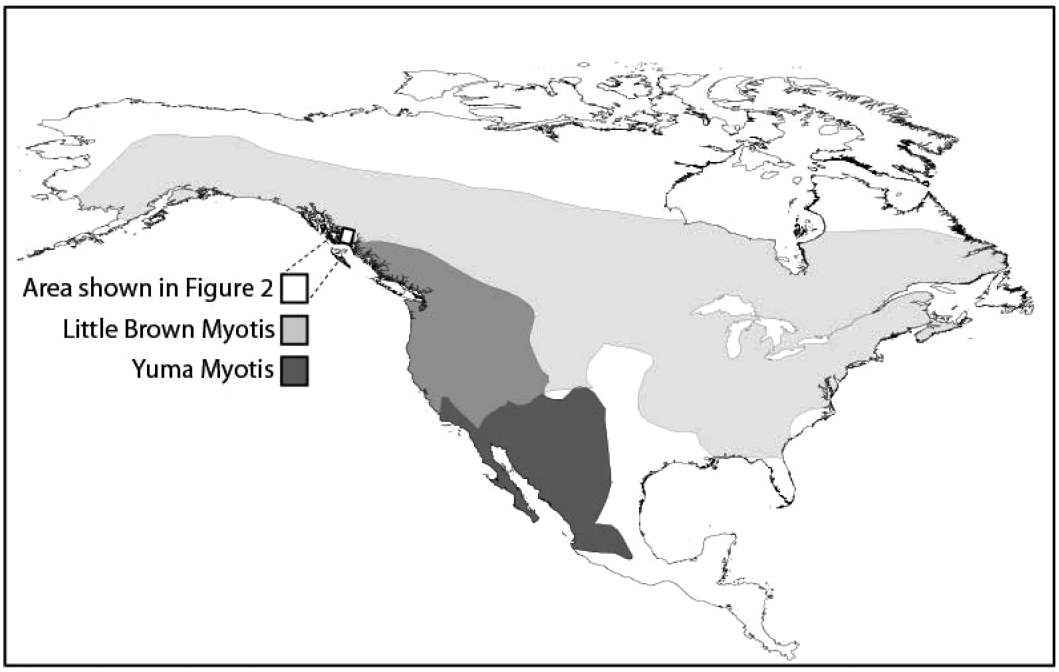

FIGURE 1. Ranges of Little Brown Myotis (*Myotis lucifugus*) and Yuma Myotis (*M. yumanensis*). Intermediate shading indicates range overlap.

clock estimates suggest these 2 clades diverged from their common ancestor ca. 10 mya (Stadelmann and others 2007), making it unlikely that members of one clade are able to reproduce with members of the other. Molecular differentiation between the 2 species is therefore expected to be unambiguous.

Given the difficulty in identifying the 2 species morphologically and the proximity of *M. yumanensis* populations in British Columbia to Southeast Alaska (and hence the possibility that the species might occur in Alaska; Fig. 1), we reexamined all *Myotis* specimens from Southeast Alaska housed at the University of Alaska Museum using published morphological criteria for differentiating *M. lucifigus* and *M. yumanensis*. Indeterminate specimens or those suggestive of *M. yumanensis* based on morphological criteria were subjected to DNA extraction and sequencing.

METHODS

Of the 418 Alaskan *Myotis* specimens in natural history collections throughout North America (LE Olson, unpubl. data), over 300 are housed in the mammal collection at the University of Alaska Museum (UAM). To the extent possible based on published keys, we examined and identified all UAM *Myotis* specimens collected from Southeast Alaska south of Yakutat (n = 63; Table 1, Appendix). Of the 4 species of *Myotis* known to occur in Alaska (California Myotis [*M. californicus*], Keen's Myotis [*M. keenii*], Little Brown Myotis [*M. lucifugus*], and Long-legged Myotis [*M. volans*]; Parker and others 1997), 2 possess prominent keels on their calcars (*M. californicus* and *M. volans*) and are generally readily distinguishable on that basis. *Myotis lucifugus* and *M. keenii*, which lack prominent keels, are differentiated from one another based on ear length, cranial measurements, and forehead profile (for example, van Zyll de Jong 1985; Nagorsen and Brigham 1993), although misidentifications are common. Characters traditionally used to distinguish *M. lucifugus* and *M. yumanensis* are summarized in Table 2. Greatest skull length as figured in Bogdanowicz (2009) and forearm length on study skins (right side unless damaged or inaccessible) were measured to the nearest 0.01 mm using digital calipers. Digital photographs of select

TABLE 1. Yuma Myotis (*Myotis yumanensis*) specimens from Southeast Alaska. All specimens collected in mist nets.

UAM catalog	Preparation[1]	Reproductive condition[2]	Sex	Date collected	Locality[3]	External measurements[4]	FA[5]	GSkl[6] (mm)
20580[7]	ssk	Testes=3	m	13 June 1992	Loring	81-36-10-13≡5.5	X (35.0)	13.9
20581[7]	ssk	Pregnant (CR=17)	f			86-34-11-12≡7	X (35.6)	-
22140[7]	ssk	Pregnant (CR=22)	f			79-36-9-12≡8.5	X (35.1)	13.6
22141[7]	ssk	Testes =3	m			77-34-10-15≡5.5	X (34.7)	13.9
30936[7]	ssk	Testes =7×4	m	25 July 1993	Chickamin River	79-30-9-14≡5.4	35 (33.7)	-
53197[7]	alc	-	m	8 July 1993	Hugh Smith Lake	66-29-7-11≡6.2[8]	32	-
53198	alc	No embryos	f			75-26-9-14≡6.9[8]	35	-
18776	sko	Testes small	m	10 June 1990	Hyder (house attic)	86-35-10-13≡6.2	35 (34.6)	14.0
18778	sko	Testes =1	m		Hyder (house attic)	X-33-9-13≡X	36 (35.6)	13.7
18791	sko	Testes =1	m		Hyder	85-37-10-14≡5.2	36	13.9
18817	sko	-	m	12 June 1990	Hyder	87-35-10-12≡5.6	35	13.9
18809	sko	Testes =3	m	21 June 1990	Salmon River	83-33-9-14≡5.9	36 (35.1)	14.1

[1] ssk=skin, skull, and postcranial skeleton; alc=fluid-preserved carcass; sko=skull and postcranial skeleton.
[2] Length (and width, when recorded) and embryo crown-rump (CR) length given in mm.
[3] See Figure 2.
[4] Total length (mm)-tail length (mm)-hindfoot length (mm)-ear from notch (mm) ≡weight (g) as recorded by either collector or preparator. X=not recorded at time of collection or preparation.
[5] Forearm length (mm). Measurements in parentheses were taken on prepared study skin by 1st author.
[6] Greatest length of skull.
[7] Mitochondrial cytochrome-*b* gene sequenced; see text for GenBank accession numbers.
[8] Weight includes wing band of unspecified make or model.

skulls can be viewed on UAM's online database (arctos.database.museum; Appendix).

Specimens lacking a prominent keel on their calcar (as evident on study skins, when present, or indicated in field notes), that were within published ranges of measurements for *M. yumanansis* as summarized in Table 2, or had steeply sloping foreheads (subjectively determined) were selected for DNA sequencing as an independent means of species determination. Few loci have been sequenced for both *M. lucifugus* and *M. yumanensis* and deposited on GenBank; we chose the mitochondrial cytochrome-*b* gene as it has featured prominently in recent molecular phylogenetic studies of New World *Myotis* and is therefore relatively well represented on GenBank for both our focal species and several other phylogenetically related taxa. Genomic DNA was extracted and subjected to PCR amplification and sequencing following methods provided in Lanier and Olson (2009). A 753-bp region of the mitochondrial cytochrome-*b* gene was amplified and sequenced using a truncated version (GCAAGCTTCTACCATGAGGA) of primer L15162 (Irwin and others 1991) and H15149 of Kocher and others (1989). Resulting sequences were subjected to BLAST searches (Altschul and others 1990) and have been deposited to GenBank (accession numbers KM370991–KM370996).

RESULTS

Twelve specimens provisionally identified as either *Myotis lucifugus* or *Myotis* spp. fell within published ranges of forearm or greatest skull length for the Yuma Myotis, possessed steeply sloped foreheads, or both (Fig. 2, Fig. 3, Table 1). Of these, 6 (top 6 rows of Table 1) are associated with fresh tissues, and their resulting cytochrome-*b* sequences, when subjected to BLAST searches, were 94–100% identical to *M. yumanensis* sequences on GenBank (and no more than 94% identical to any other sequence on GenBank, including *M. lucifugus*). The remaining 6 specimens in Table 1, while not readily amenable to DNA sequencing, fell within the broader range of *M. yumanensis* measurements given in Armstrong (1972) and possessed foreheads more steeply sloped than sympatric specimens of *M. lucifugus* (Fig. 3). We provisionally recognize these as *M. yumanensis*. Additional data associated with these

TABLE 2. Features used to distinguish Little Brown Myotis (*Myotis lucifugus*) and Yuma Myotis (*M. yumanensis*). Emphasis added.

Source	*M. lucifugus*	*M. yumanensis*
Armstrong (1972, p 56)	''Hairs of dorsum having burnished tips; forearm 35 to 40 [mm]; greatest length of skull 14.3-15.3 [mm]''	''Hairs of dorsum lacking burnished tips; forearm 32 to 37 [mm]; greatest length of skull 13.2 to 14.2 [mm]''
Hall (1981, p 185)	''Greatest length of skull *usually* more than 14 [mm]; fur *usually* glossy''	''Greatest length of skull *usually* less than 14 [mm]; fur *usually* dull, not glossy''
Nagorsen and Brigham (1993, p 55)	''Forehead with a gradual slope. . ., skull length *usually* greater than 14 mm''	''Forehead with a steep slope. . ., skull length *usually* less than 14 mm.''
Verts and Carraway (1998, p 76)	''Pelage on dorsum glossy; total length of skull *usually* >14 mm; forearm *usually* ≥35 mm; skull sloped gradually from rostrum to braincase''	''Pelage on dorsum dull; total length of skull *usually* <14 mm; forearm *usually* <35 mm; skull sloped steeply from rostrum to braincase''

specimens, including coordinates, can be found on the University of Alaska Museum's online database (arctos.database.museum).

All 12 newly recognized *M. yumanensis* specimens were collected in June or July between 1990 and 1993 from 5 localities in extreme Southeast Alaska (Fig. 1, Table 1). Two males and 2 females were captured on Revillagigedo Island in mist nets set across a boardwalk in Loring approximately 30 km north of Ketchikan on 13 June 1992. Neither of the males were reported to have enlarged testes, but both females (UAM 20581 and 22140) were pregnant with single embryos measuring 17 and 22 mm, respectively, from crown to rump. One male (UAM 53197) and 1 female (UAM 53198) were collected from an unspecified site at or near Hugh Smith Lake in Misty Fiords National Monument on 8 July 1993; reproductive condition was not recorded. A single male (UAM 30936) with enlarged testes (7 × 4 mm) was collected in a mist net near the Wolf Cabins at the mouth of the Chickamin River on 25 July 1993. Four males (UAM 18776, 18778, 18791, 18817) collected 10–12 June 1990 in Hyder were not reported to be reproductively active. A single male (UAM 18809) collected on 21 June 1990 along the Salmon River near Hyder was recorded as having testes measuring 3 mm, presumably length.

DISCUSSION

The occurrence of *M. yumanensis* in Southeast Alaska is not surprising given that it has been previously reported from Kimsquit (320 km SE of Alaska); Princess Royal Island (225 km SSE of Alaska); and, most recently, the Ecstall River (95 km SE of southeasternmost Alaska), all in British Columbia (Nagorsen and Brigham 1993; van Zyll de Jong 1985; http://www.env.gov.bc.ca/atrisk/toolintro.html, respectively). No obvious biogeographic or climatic barriers preventing its occurrence farther north in Alaska or adjacent British Columbia are known. Its proclivity for crossing open bodies of water suggests the species' range may extend farther into Alaska than our study suggests. *Myotis yumanensis* is often associated with bodies of freshwater, more so than most, if not all, other North American bats (Barbour and Davis 1969), and has purportedly been observed flying over saltwater in the Pacific Northwest more often than other bat species (Nagorsen and Brigham 1993). Nonetheless, its discovery in Alaska marks the 1st new mammal for the state since the discovery of the Western Heather Vole (*Phenacomys intermedius*) in Southeast Alaska in 1995 (MacDonald and others 2004), and the 1st new bat in Alaska since the 1st Silver-haired Bat (*Lasionycteris noctivagans*) specimen was collected in the state in 1964 (Barbour and Davis 1969).

That *M. yumanensis* is only now being reported from Southeast Alaska is likely due to 2 related factors. The first involves the relative dearth of bat research conducted in the area, particularly in the southeasternmost region of the state. The second may be a combination of the difficulty in differentiating *M. yumanensis* from the more common (in Alaska) and broadly distributed *M. lucifugus*, and the simple, if circular, phenomenon of biologists not being attuned to a species that isn't known to occur in a given area, particularly when the species in question is not a conserva-

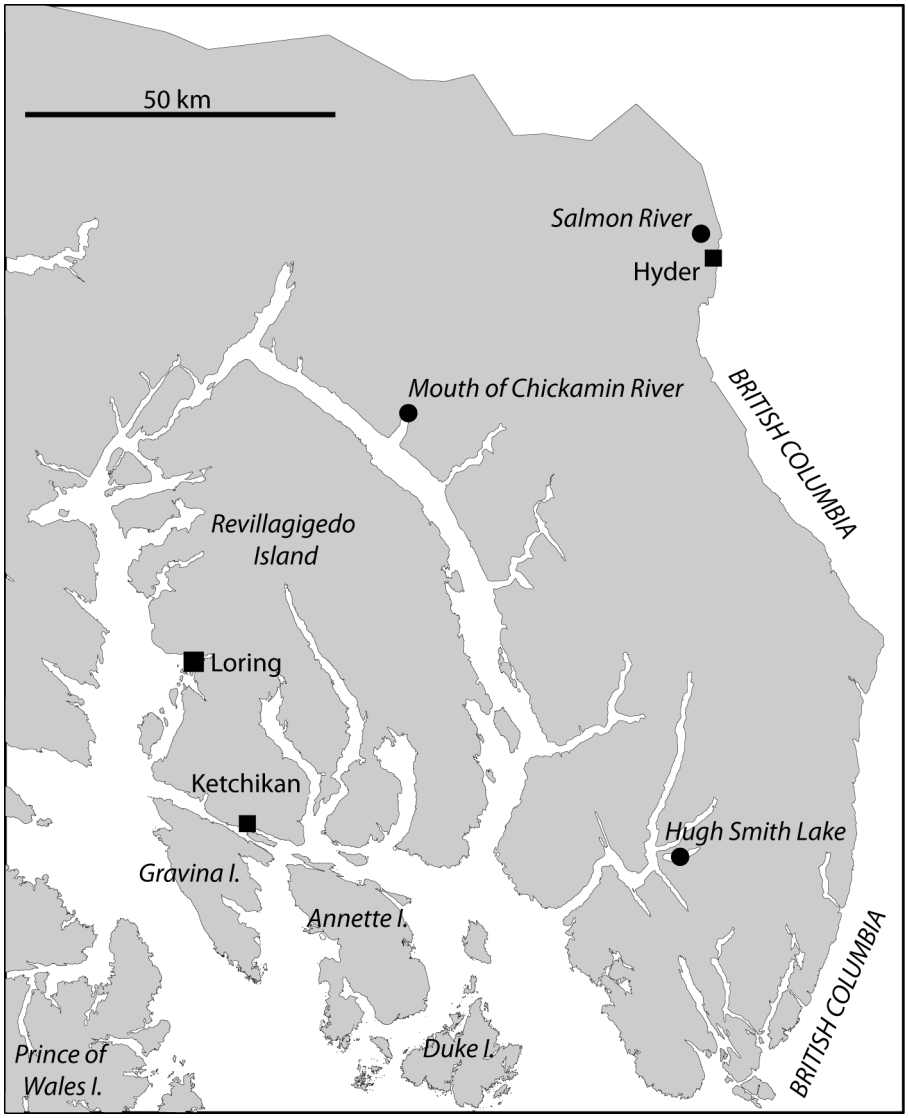

FIGURE 2. Map of Southeast Alaska showing towns (squares) and localities (circles) discussed in text.

tion priority. Indeed, we suspect additional Alaskan specimens of *M. yumanensis* may already exist in collections that were not surveyed in this study.

The issue of confidently identifying Yuma Myotis and Little Brown Myotis warrants additional discussion here and in future empirical studies. *Myotis yumanensis* has traditionally been distinguished from *M. lucifigus* on the basis of its relatively diminutive size (as measured by greatest skull length and forearm length), steeply sloping forehead, and dull pelage (Table 2). Many published keys acknowledge intermediacy if not overlap between these taxa in all of these characters (Table 2; reviewed by Parkinson 1979). Observed clinal variation in body size has cast further doubt on the utility of linear measurements (Harris 1974). Similarly, an allometric relationship between cranial size and forehead shape has been noted, with larger specimens of *M. yumanensis* exhibiting shallower foreheads (Parkinson 1979). Not included in Table 2 is the more onerous method proposed by van Zyll de Jong (1985), which

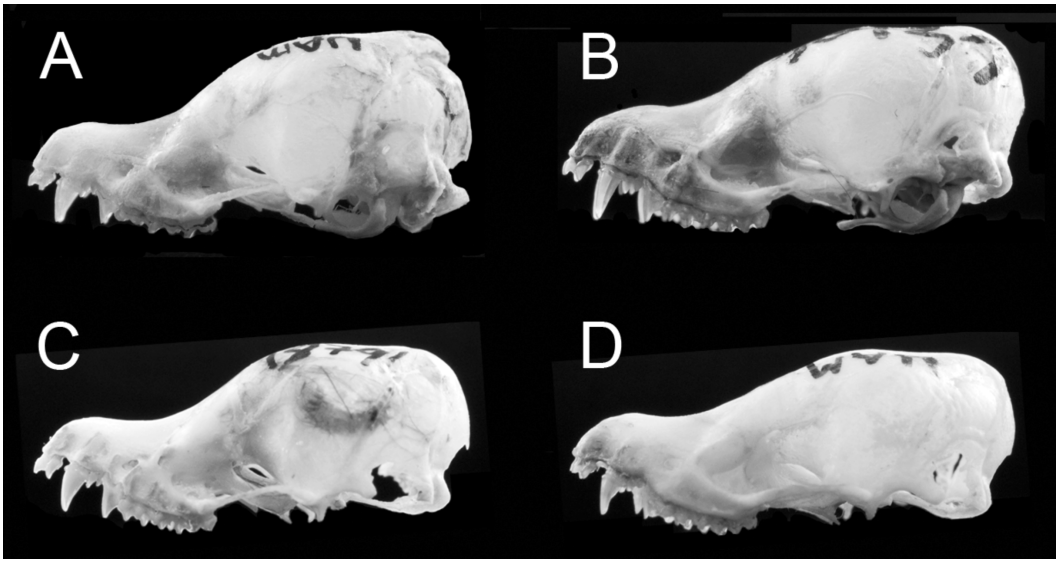

FIGURE 3. Skulls of (A) Yuma Myotis (*Myotis yumanensis*, UAM 30936) and (B) Little Brown Myotis (*M. lucifugus*, UAM 30937) collected from the mouth of the Chickamin River; and (C) Yuma Myotis (UAM 18791) and (D) Little Brown Myotis (UAM 18782) collected from Hyder showing relative steepness of foreheads in the Yuma Myotis.

involves plotting mastoid width against a ''slope index'' derived from the intersection of a straight line tangential to the flattest region of the forehead (in lateral profile) with the upper toothrow. This attempt to quantify the relative slope of the forehead has not, to our knowledge, been widely followed, nor has it been tested with an explicitly defined sample of independently identified specimens. Our own experience suggests that forehead slope is unreliable. Likewise, pelage sheen has never, to our knowledge, been quantitatively evaluated in these 2 taxa, although recent advances in digital photography and its application to taxonomic questions such as this may clarify the utility of pelage color as a key character (Stevens and others 2007; McKay 2013). Finally, neither forearm length nor skull length are, by themselves, sufficient (Table 1, Table 2).

A recent study by Rodhouse and others (2008) attempted to evaluate the relative utility of 4 published external characters (forearm length, pelage sheen, ear color, and forehead slope) in differentiating *M. lucifugus* and *M. yumanensis* captured (and subsequently released) in Central Oregon. Our findings echo theirs in that no single feature or combination of features allowed reliable field identification, which they tested via post hoc DNA sequencing of biopsied wing tissue. However, 89 of the 101 individuals (of 1 species or the other) they captured were correctly identified with at least 1 external morphological feature. Pelage sheen, subjectively and dichotomously characterized by a single observer in all individuals, was most successful (96% success). Interestingly, because the traits they used did not predictably covary, adding characters reduced accuracy. However, the authors did not collect any voucher specimens or deposit their wing biopsies or extracted DNA in a museum or other repository, and the DNA sequences from their study were not published and have not been submitted to GenBank (see Carraway 2009 and Rodhouse and others 2009).

In addition to the difficulties in differentiating *M. lucifugus* and *M. yumanensis*, another likely reason *M. yumanensis* has gone unnoticed in Alaska is the lack of field studies focusing on bats in extreme southernmost Alaska. Boland and others (2009) surveyed bats throughout much of Southeast Alaska using a combination of mist nets, harp traps, and bat detectors, but did not detect *M. yumanensis*. However, they did not sample anywhere in the region shown in Figure 2; the 2 closest sites where these authors reported capturing or observing bats

were on Prince of Wales Island and Wrangell Island, approximately 80 km northwest and 100 km NNW of Ketchikan, respectively. It may be that their sampling sites fell outside the current range of *M. yumanensis*. The authors purportedly sequenced an unspecified region of the cytochrome-*b* gene from all 308 bats they captured and reported that ''[i]dentifications from DNA analyses confirmed all identifications made in the field.'' Since many of the *M. yumanensis* cytochrome-*b* sequences on GenBank were submitted and published prior to 2009, it can be assumed that none of the *M. lucifugus* captured and sequenced by Boland and others (2009) were actually *M. yumanensis*. However, the authors did not publish or submit their sequences to GenBank, nor did they deposit samples of their biopsies or DNA extracts to a 3rd-party repository, so the concerns raised by Carraway (2009) regarding repeatability apply here as well.

Despite the small number of specimens of *M. yumanensis* now known from Alaska, some ecological and life history inferences can be drawn. First, the species was captured in association with *M. lucifigus* at 3 of the 5 localities shown in Figure 2. At the mouth of the Chickamin River, a Little Brown Myotis specimen (UAM 30937) was collected on the same night as a *M. yumanensis* specimen (UAM 30936; Fig. 3); both were males with enlarged testes and were captured in adjacent mist nets. Likewise, specimens of both species were collected on 21 June 1990 from along the Salmon River NNW of Hyder and in a house attic in Hyder on 10 June 1990. *Myotis yumanensis* is widely known to use man-made structures for summer roosts and hibernacula (Nagorsen and Brigham 1993). Both species have previously been reported to forage in syntopy (Parkinson 1979; Herd and Fenton 1993) and share summer day roosts (Verts and Carraway 1998). Two of the 3 female Yuma Myotis specimens were pregnant at the time of capture (13 June 1992), with embryos measuring 17–22 mm (crown-rump). A series of pregnant female Little Brown Myotis specimens collected from the attic of a house in Hyder on 10 June 1990 had embryos measuring 3–18 mm, providing very limited evidence that pregnancy and lactation in *M. yumanensis* occurs slightly earlier than in *M. lucifigus* in Southeast Alaska, as has been previously reported in southern British Columbia (Herd and Fenton 1983). The presence of late-term pregnant females in Loring suggests a nearby maternity colony and the enlarged testes of the male specimen from the Chickamin River further supports that *M. yumanensis* is breeding in Alaska.

For most of the 20th century Alaska lagged far behind the contiguous United States with respect to baseline distributional data on its mammal fauna. This began to rapidly change in the 1990s, largely due to systematic mammal inventories commenced by the University of Alaska Museum in collaboration with state and federal management agencies (MacDonald and Cook 2009). However, as evidenced by our results, much remains to be learned. Of particular importance is the resolution of northern range boundaries (of species in the northern hemisphere), as these are already undergoing northward shifts (Parmesan 2006). Over 40 species of North American terrestrial mammal species reach their northernmost extent somewhere in Alaska (IUCN; natureserve.org). Additional surveys and the continued collection of voucher specimens are therefore not merely necessary but urgently needed to track the effects of climate change and other phenomena on natural populations in the rapidly changing North.

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APPENDIX. Additional specimens examined in this study (see also Table 1). Numbers represent catalog numbers in the Mammal Collection at the University of Alaska Museum (UAM), Fairbanks, Alaska. Data associated with specimens can be found on the UAM online database, Arctos (http://arctos.database.museum/). 10357, 18773, 18774, 18775, 18777, 18779, 18780, 18781, 18782, 18783, 18784, 18785, 18786, 18787, 18788, 18789, 18790, 18792, 18793, 18794, 18795, 18796, 18797, 18798, 18799, 18800, 18801, 18802, 18803, 18804, 18805, 18806, 18807, 18808, 18810, 18811, 18812, 18813, 18814, 18815, 18816, 20592, 22929, 24818, 24819, 30933, 30937, 50573, 53199, 53200, 55944.