



Occurrence of Temperate Bat Species at Three National Parks in the Great Lakes Region

Natural Resource Technical Report NPS/GLKN/NRTR–2008/128



ON THE COVER

Left to right: Northern bat (*Myotis septentrionalis*), sunset at Apostle Islands National Lakeshore, Anabat acoustic recording equipment. All photos by: L. Kruger



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Natural Resource Technical Report NPS/GLKN/NRTR–2008/128

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Executive Summary

Lack of information about and the recognized importance of temperate bats as key components of northern Great Lakes ecosystems have placed bats as a high priority for biological inventories at three national parks within the Great Lakes Inventory and Monitoring Network (GLKN). In 2003, acoustic (Anabat II) sampling and mist netting were conducted at Pictured Rocks National Lakeshore (PIRO), Michigan; Apostle Islands National Lakeshore (APIS), Wisconsin; and Grand Portage National Monument (GRPO), Minnesota. Six of a probable seven species of bats were verified in all three parks. We verified the little brown bat (*Myotis lucifugus*), northern bat (*M. septentrionalis*), eastern red bat (*Lasiurus borealis*), hoary bat (*L. cinereus*), silver-haired bat (*Lasionycteris noctivagans*), and the big brown bat (*Eptesicus fuscus*). The only bat not verified was the eastern pipistrelle (*Pipistrellus subflavus*), a fairly uncommon summer species in the Lake Superior region. Mist netting and acoustic sampling in combination were effective for documenting species presence. Neither method was capable of independently verifying all bat species. We created a bat call reference library for bat species of the Great Lakes region, which will aid in future acoustic inventory and monitoring efforts. While our efforts have successfully documented bat species presence in each of the three parks, future monitoring is needed to determine how they interact with the surrounding ecosystems of each park. Specifically, monitoring efforts should concentrate on important population limiting factors of temperate bat species, such as available roosting and foraging habitat.

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Introduction

There is a paucity of information on temperate bat species in the Lake Superior region. Past studies have focused almost exclusively on winter use of abandoned mines (Stones and Fritz 1969; Long 1976; Kurta 1982, 1996; Nordquist and Birney 1985). Consequently, we know little about the abundance, distribution, and habitat requirements of various species, particularly during the summer months.

Factors that limit the distribution of bats generally include the availability of daytime, nighttime, and maternity roost sites and the quantity and quality of available prey (Fenton 1997; Racy and Entwistle 2003). Although we know that the bat species of the Lake Superior region are insectivorous and highly mobile, we know very little about limiting factors for and resource utilization by bat species in northern forested ecosystems. Furthermore, we have little understanding of how anthropogenic activities in these ecosystems are affecting bat populations. It is important for managers to know which bat species are present and how they move through the landscape and partition available resources. Only then can managers protect critical habitats and assess factors that may limit species distribution.

To help provide more information for managers, the Great Lakes Inventory and Monitoring Network (GLKN) commissioned a baseline inventory of bat species in three Lake Superior national parks: Pictured Rocks National Lakeshore (PIRO) in the Upper Peninsula of Michigan, Apostle Islands National Lakeshore (APIS) in Wisconsin, and Grand Portage National Monument (GRPO) in Minnesota. There have been few inventories of bats in these three parks. Prior to this study, only one of a potential seven bat species had been verified at PIRO, two had been verified at GRPO, and five species had been verified at APIS. Only one species, the little brown bat (*Myotis lucifugus*), had been documented at all three parks (Table 1).

The goal of this inventory is to provide baseline information that will enhance the future survival of bats in these parks and in the region. Specifically, the objectives are:

1. To verify the occurrence of bat species in each of three parks by using existing data and new field investigations.
2. To document and describe important bat habitats encountered during survey work, including feeding areas, day or seasonal roosts, maternity sites, and hibernacula.

Table 1. Status of bat species prior to this inventory in three national parks of the Great Lakes Network: Grand Portage National Monument (GRPO); Apostle Islands National Lakeshore (APIS); and Pictured Rocks National Lakeshore (PIRO). Bat presence is verified (X), likely (L), or unknown (U).

Common Name	Scientific Name	APIS	GRPO	PIRO
Little brown bat	<i>Myotis lucifugus</i>	X	X	X
Northern bat*	<i>Myotis septentrionalis</i>	L	L	L
Eastern pipistrelle**	<i>Pipistrellus subflavus</i>	L	U	U
Big brown bat	<i>Eptesicus fuscus</i>	X	L	L
Silver-haired bat	<i>Lasionycteris noctivagans</i>	X	L	L
Eastern red bat	<i>Lasiurus borealis</i>	X	L	L
Hoary bat	<i>Lasiurus cinereus</i>	X	X	L
Percent Verified		71	33	17

*Species of special concern in Minnesota and Wisconsin.

** Species of special concern in Wisconsin and Michigan.

Study Areas

We conducted an inventory of bat species at Pictured Rocks National Lakeshore (PIRO), Michigan; Apostle Islands National Lakeshore (APIS), Wisconsin; and Grand Portage National Monument (GRPO), Minnesota (Figure 1). Although all three parks are located on the Lake Superior shoreline, they differ in size and forest ecosystem structure.

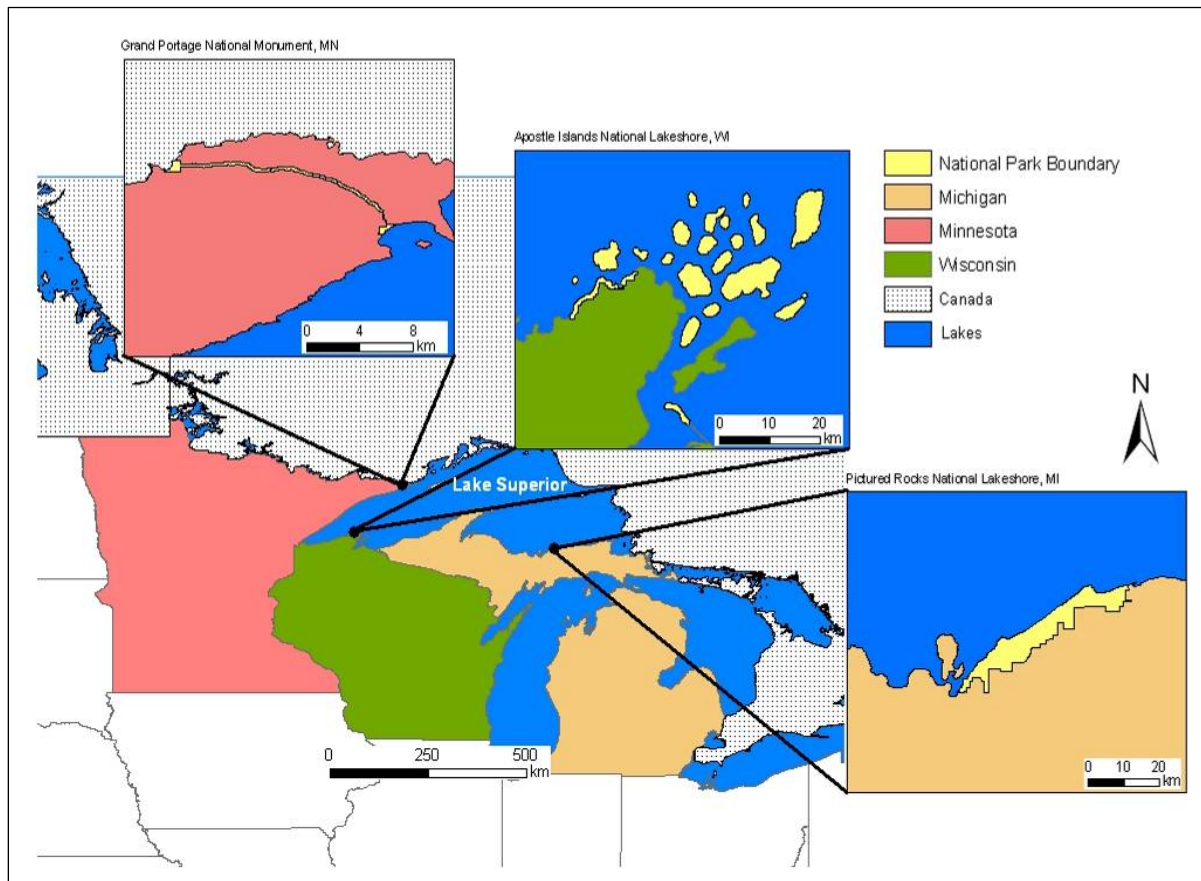


Figure 1. The Lake Superior Region and the national parks selected for bat inventory: Grand Portage National Monument, Minnesota; Apostle Islands National Lakeshore, Wisconsin; Pictured Rocks National Lakeshore, Michigan.

PIRO, located in the eastern Upper Peninsula of Michigan, is the largest of the three parks, encompassing 28,824 ha (71,397 acres). PIRO is divided into two management zones: a shoreline zone and an inland buffer zone. The shoreline zone is comprised of 13,543 ha (33,548 acres), all in federal ownership, that are managed to preserve scenery and outstanding natural features (Pictured Rocks National Lakeshore 2004). The inland buffer zone is composed of 39,306 acres of land that borders the shoreline zone and is set aside for added protection of the Lake Superior watershed. The park contains 19 short, named streams that drain directly into Lake Superior, 14 named inland lakes, and numerous wetlands (Lafrancois

and Glase 2005). The vegetation is transitional between boreal and eastern deciduous forest. Hardwood species predominate, but conifers are prevalent in some areas. Timber harvest is not permitted in the shoreline zone, but sustainable-yield forestry is permitted in the inland buffer zone.

APIS includes 21 of 22 islands off the north coast of Wisconsin and a 12-mile long “mainland unit” along the northern tip of Wisconsin’s Bayfield Peninsula. The park comprises a total of 28,073 ha (69,372 acres), with land acreage of 17,053 ha (42,140 acres). The Sand River bisects the mainland strip, and small perennial and intermittent streams are found on several of the islands (Lafrancois and Glase 2005). The park is on the southern fringe of the boreal forest, and northern hardwood species predominate. Remnant old-growth forests are present on several of the islands.

GRPO is located within the boundary of the Grand Portage Band of Minnesota Chippewa Reservation and is the smallest of the three parks with area of 287 ha (710 acres). GRPO consists of a 13.7 km (8.5 mi) trail with a 91.4 m (300 ft) buffer. The trail crosses three perennial streams and approximately 8 ha (20 acres) of wetland habitat (Lafrancois and Glase 2005). The forests of GRPO contain boreal and mixed deciduous tree species.

Methods

Sampling Sites

In order to maximize the number of species documented at each park, sampling sites were placed in areas of known or predicted bat activity. These areas included bat travel and feeding corridors such as lake shorelines, river/stream corridors, hiking trails, and dirt roads (Wilson et al. 1996). The number of sampling sites at each park was based on the size of the park and logistical constraints. Six sites were sampled at PIRO (Sand Point, Miners Castle, Chapel Falls trail head, Beaver Lakes Campground, Kingston Lake Campground, and Grand Sable), four sites were sampled at APIS (Little Sand Bay, Stockton Island, Outer Island, and Devil's Island), and three sites were sampled at GRPO (the Stockade, Poplar Creek, and Fort Charlotte; Figure 2). Most sites were sampled for two consecutive nights during June, July, and August 2003 (Appendix A). Once chosen, each site was described by forest type, water availability, and presence of bat travel corridors. High winds, rain, or cold temperatures prevented sampling on some nights. It was not possible to sample sites simultaneously within and among parks because of logistical and equipment constraints. Therefore, the data cannot be used to evaluate temporal variation in bat activity between parks or between sites within a park.

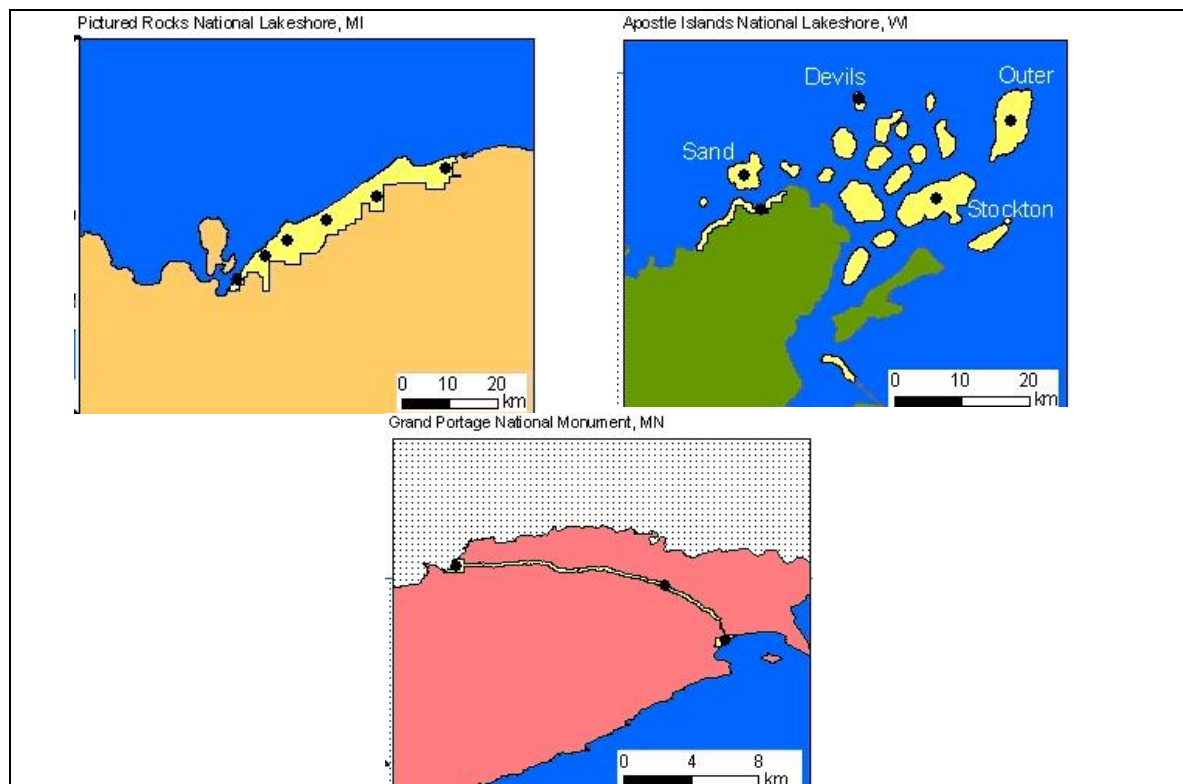


Figure 2. Locations (indicated by black dots) of bat capture and acoustic sampling sites at Pictured Rocks National Lakeshore, MI, Apostle Islands National Lakeshore, WI, and Grand Portage National Monument, MN, in 2003.

Mist Netting

Each sampling site contained three net stations, each with one mist net. All mist nets were 2.6 m tall, with a 38mm mesh size. Net placement and length of net used (6, 9, or 18 m) varied according to the structure of the habitat at each sampling site. Nets were commonly placed perpendicular to trail or stream corridors and under overhanging tree branches to aid in funneling bats into nets (Kunz and Kurta 1988). Nets were deployed approximately ½ hr before sunset and were checked approximately every 20 min for up to 5 hr after sunset. Because different net sizes and/or sampling times resulted in unequal capture effort between parks (Table 2), we standardized the data by expressing total bat captures as the number of bats per 12 net-meters per hour (Jones et al. 1996).

Table 2. Number of mist netting nights and hours per night at Pictured Rocks National Lakeshore (PIRO), MI, Apostle Islands National Lakeshore (APIS), WI, and Grand Portage National Monument (GRPO), MN, 2003.

Location	Number of mist netting nights	Hours per night	
		Mean	Range
PIRO	30	4.23	1.58-5.13
APIS	20	4.05	1.37-5.88
GRPO	15	3.16	2.00-4.42
Total	65		

Captures

All handlers had prior bat-handling experience and pre-exposure rabies vaccinations. Bats captured in mist nets were removed and placed in individual cloth holding bags until they could be processed. Individuals were identified to species using Kurta (2001), sexed, aged (juvenile or adult), and assessed for reproductive status (females only). Age was determined by assessing the extent of ossification of the epiphyseal plates in the wing joints (Wilson et al. 1996). Reproductive status was determined by palpation of the abdomen and visual observation of the mammarys (Racey 1988). Ear height, tragus height, forearm length, foot length, and weight were also recorded for each individual. When possible, guano samples were collected as a genetic voucher from at least one specimen of each species in each park and from additional individuals that were of questionable identity (e.g., the *Myotis* species). Guano samples were collected by placing individual bats in marked holding bags until they defecated, but no bat was held longer than the duration of the sampling period (Table 2, “Hours per night”). A different bag was used for each bat to ensure no mixing of genetic material. Guano samples were preserved in sealed plastic vials with desiccant until further genetic analysis could be completed. Genetic analysis was done at Portland State University, where excess samples that were not destroyed during analysis were archived (J. Zinck, pers. comm.). When applicable, chi-square analysis was used to test for differences in captures between males and females at each park ($\alpha=0.05$, Zar 1999).

Acoustic Sampling

Bat calls were recorded at all sampling sites using acoustic recording systems. These systems included an Anabat II detector coupled with a compact flashcard storage ZCAIM (Zero-Crossings Analysis Interface Module; Titley Electronics, Balina, New South Wales, Australia). After each night of sampling, bat calls were downloaded from the flashcard to a computer for subsequent analysis. Most sites were monitored for two consecutive nights during June, July, and August 2003 to detect seasonal differences in bat activity. Both active and passive acoustic sampling methods were utilized at each sampling site.

Active Sampling

We conducted active acoustic sampling by walking transects throughout the sampling site and directing the microphone toward bat activity (Britzke 2002). Active acoustic sampling was used to maximize the area sampled and number of bat species detected. Transects began at sunset and continued for approximately 2 hours. In some cases, transects were not completed due to inclement weather. Transects were typically along trails, roads, shorelines, or other bat travel corridors.

Passive Sampling

We selected one stationary point for passive acoustic sampling at each sampling site within a park (Figure 2). To maximize the number of species detected, we placed the stationary point in potential bat travel corridors (trails, forest openings) or in feeding areas (ponds, streams). At each passive acoustic sampling point, we placed an Anabat detector and storage ZCAIM in a waterproof container and mounted the container on a tripod 1 m above the ground, with the reflector tube positioned at a 45-degree angle above horizontal (Figure 3). Because of equipment constraints, the same acoustic recording systems were used for both active and passive sampling at a site. Therefore, we set up the passive sampling systems immediately after the active sampling transect was completed (approximately 2 hr after sunset). Acoustic systems were programmed to start recording immediately and to stop recording at sunrise. When there was no active sampling, the acoustic equipment was programmed to start recording at sunset and to stop recording at sunrise. Sunset and sunrise times were determined using AnaSun software (Corben 2001, version 1.0a).

Bat Call Reference Library

To aid in identification of bat species from acoustic data we created a bat call reference library by recording the



Figure 3. Stationary acoustic sampling system set-up (Photo: L. Kruger).

calls of previously identified, hand-released bats. Captured bats were identified and released in an open area where there was minimal or no other bat activity. Calls were recorded with Anabat systems immediately after each bat was released. We also obtained known-species reference calls by recording bats that were identified on the fly with the aid of a spotlight. Bat researchers in the Lake Superior region (C. Corben; K. Francl, University of Notre Dame Research Center; G. Nordquist, Minnesota Department of Natural Resources) also provided known-species bat calls. We analyzed selected call parameters of the reference bat calls using Analook software (Corben 2005, version 4.9j) to generate call descriptors for bat species of the Lake Superior region. We defined a “call” as a single sound emitted from a bat, and a “call sequence” as a series of continuous calls (Fenton 1999; Gannon et al. 2004). Bat call sequences often consist of three distinct phases - the search, the approach, and the feeding buzz (Figure 4). For species identification we used only the search-phase sequence because of its uniformity and identifiable characteristics specific to individual species (O’Farrell et al. 1999; Corben 2004). Only search-phase sequences consisting of five or more calls were included in the library. Averaged call parameters and examples of time-frequency displays for each species are shown in Appendix B.

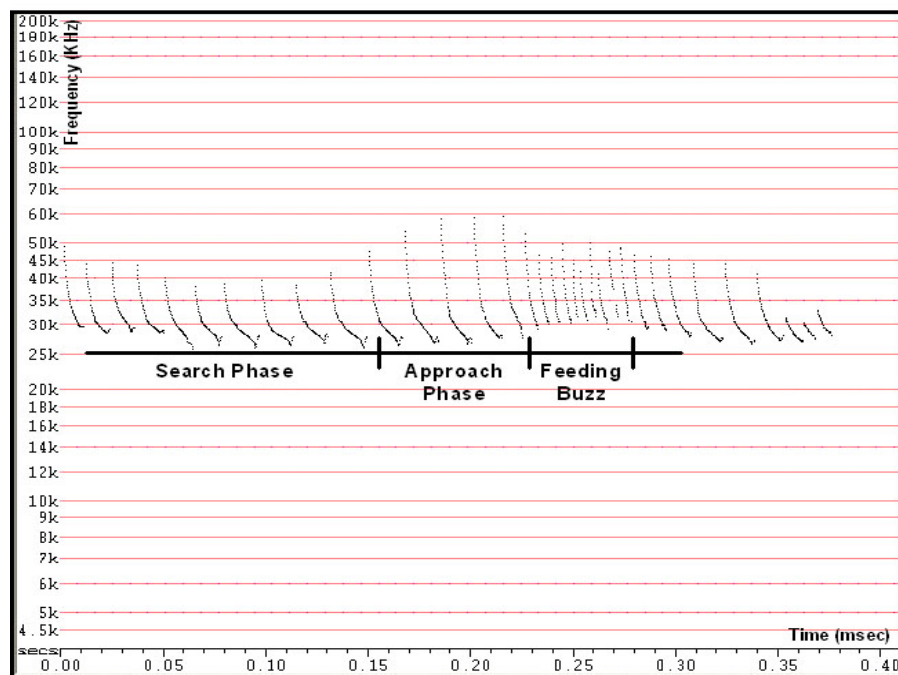


Figure 4. Three phases of a bat call sequence. Each individual pulse is a "call," and a string of calls (as seen above) is a “call sequence.”

Identification of Bat Calls

Using Analook software, we scanned all recorded files for those containing extraneous noise (e.g., from insects, wind, and light rain). Files without bat call patterns and files that

contained call sequences of less than five calls were removed from analysis. The remaining files were categorized to species by qualitative identification (Erickson and West 1996; O'Farrell et al. 1999). This technique requires visual inspection of each unknown call to compare maximum and minimum frequency, changes in slope, and call shape (O'Farrell et al. 1999) with known-species calls. The two *Myotis* species of the Lake Superior region, little brown bat (*M. lucifigus*) and northern bat (*M. septentrionalis*), produce calls that are structurally similar and hence difficult to distinguish (Krusic and Neefus 1996). We created one category, *Myotis* spp., for call sequences that could have been from either of the two *Myotis* species. Bat call sequences that we could not identify to species were placed in an "unidentifiable" category. We treated each file meeting the above-mentioned criteria as an independent event and used the number of files recorded per hour as an index of bat activity (Britzke et al. 1999). Because it is not possible to distinguish call sequences from individual bats, this index is a measure of overall bat activity, but not bat population sizes.

Roost Surveys

When possible, known or probable roost sites in buildings (e.g., barns, sheds, and housing units) were examined internally and/or externally for bat use. We searched inside buildings for evidence of bat use (e.g., guano, staining, or bats present) and observed bats emerging from buildings at dusk. Whenever possible, we used a flashlight to count bats exiting a structure. A harp trap (Palmeirim and Rodrigues 1993) was used at some building sites to capture bats exiting or entering the structure.

Results

Six of the seven bat species thought to occur in each of the three parks were verified by capture and/or acoustic identification (Table 3). The eastern pipistrelle was not captured or detected acoustically at any of the parks. We captured a total of 153 bats comprising four species (little brown bat, northern bat, red bat, and silver-haired bat). All four species were captured at APIS and GRPO, and three species were captured at PIRO (the silver-haired bat, though not captured, was confirmed at PIRO by acoustic recording). Capture success was highest at GRPO (64 bats total, 0.60 bats/12 net-meters/hr, followed by PIRO (67 bats total, 0.28 bats/12 net-meters/hr), and APIS (22 bats total, 0.18 bats/12 net-meters/hr). Genetic vouchers were obtained from three species of bats at APIS and GRPO, and from two species of bats at PIRO.

The big brown bat and the hoary bat were verified at all three parks by Anabat acoustic recordings (Table 3). Average number of files recorded per hour was highest at PIRO (37 files/hr in 33 sampling nights), followed by APIS (20 files/hr in 45 sampling nights) and GRPO (14 files/hr in 17 sampling nights). At each of the three parks, *Myotis* spp. were recorded more frequently than other species (Figure 5).

Park-specific Results

Pictured Rocks National Lakeshore (PIRO)

A total of 67 bats comprising three species (little brown bat, northern bat, and red bat) were captured at PIRO. Neither the northern nor the red bat had been documented previously within the park. The little brown bat was the most frequently captured species overall, and it was captured at all sampling locations (Figure 6). The little brown bat comprised 84% of all captures in the park (n=56), followed by the northern bat (15%, n=10) and red bat (1%, n=1). The northern bat was captured at all sampling sites except Kingston Lake, and the red bat was captured only at Chapel. Overall, the largest number of bats was captured at Sand Point, and the least number of bats captured was at Kingston Lake. Although not statistically significant, we captured more female little brown bats than males at PIRO (1.5 females:1 male; n=56, P=0.109). The sex ratio for northern bats was 1:1 (n=10), and the only red bat captured was a male (Table 4). Captures of reproductively active females and juveniles confirm the presence of reproductive populations of little brown bats and northern bats (Table 4). Genetic vouchers were verified and banked for the little brown bat and the northern bat (Appendix C).

Table 3. Bat species verified in 2003 by mist-net capture, acoustic identification from recorded bat calls, and genetic analysis at Apostle Islands National Lakeshore (APIS), WI, Grand Portage National Monument (GRPO), MN, and Pictured Rocks National Lakeshore (PIRO), MI.

Location	Species	# Acoustic Files	# Captures	Genetic Voucher
APIS	Little brown bat	1060*	3	✓
	Northern bat		14	✓
	Big brown bat	173	0	
	Red bat	765	3	✓
	Silver-haired bat	355	2	
	Hoary bat	563	0	
	Eastern pipistrelle	0	0	
	APIS Total	2916	22	
GRPO	Little brown bat	851*	27	✓
	Northern bat		29	✓
	Big brown bat	12	0	
	Red bat	29	1	
	Silver-haired bat	275	7	✓
	Hoary bat	28	0	
	Eastern pipistrelle	0	0	
	GRPO Total	1195	64	
PIRO	Little brown bat	6420*	56	✓
	Northern bat		10	✓
	Big brown bat	195	0	
	Red bat	182	1	
	Silver-haired bat	207	0	
	Hoary bat	1574	0	
	Eastern pipistrelle	0	0	
	PIRO Total	8578	67	
TOTAL		12,689	153	

* Combined results for little brown bat and northern bat, which were indistinguishable by acoustic methods.

Table 4. Number of male (M), female (F), and juvenile (Juv.) bats captured in mist nets in 2003 at Pictured Rocks National Lakeshore (PIRO), MI, Apostle Islands National Lakeshore (APIS), WI, and Grand Portage National Monument (GRPO), MN. Numbers in parentheses are numbers of reproductively active female bats.

Species	Park											
	PIRO			APIS			GRPO			All locations		
	M ¹	F ¹	Juv.	M ¹	F ¹	Juv.	M ¹	F ¹	Juv.	M ¹	F ¹	Juv.
Little brown bat	22	34(11)	4	3	0	1	20	7(1)	1	45	41(12)	6
Northern bat	5	5(4)	0	12	2(1)	0	12	17(3)	6	29	24(8)	6
Red bat	1	0	0	1	2	0	1	0	0	3	2	0
Silver-haired bat	0	0	0	2	0	0	5	2	0	7	2	0

¹ Includes all age classes

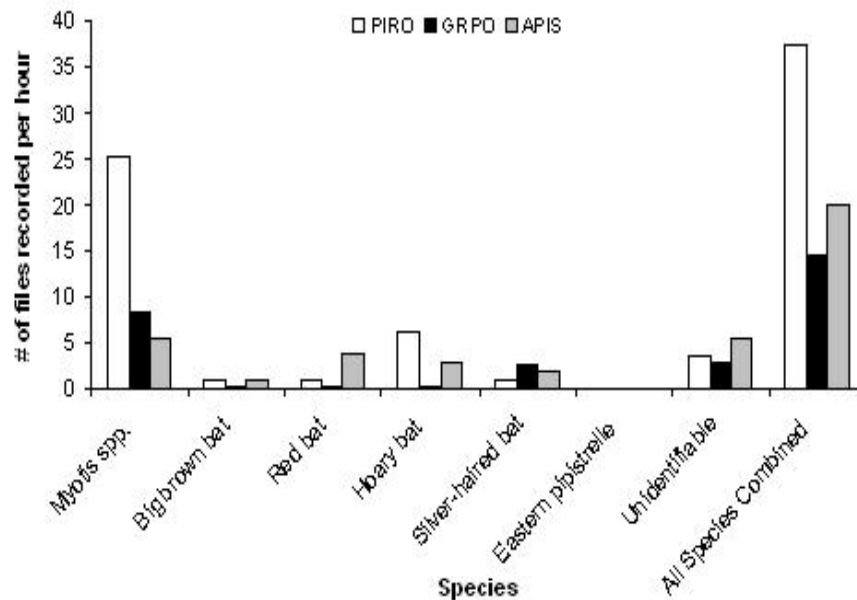


Figure 5. Number of files recorded per hour in 2003 by stationary Anabat systems at Apostle Islands National Lakeshore (APIS), WI, Grand Portage National Monument (GRPO), MN, and Pictured Rocks National Lakeshore (PIRO), MI.

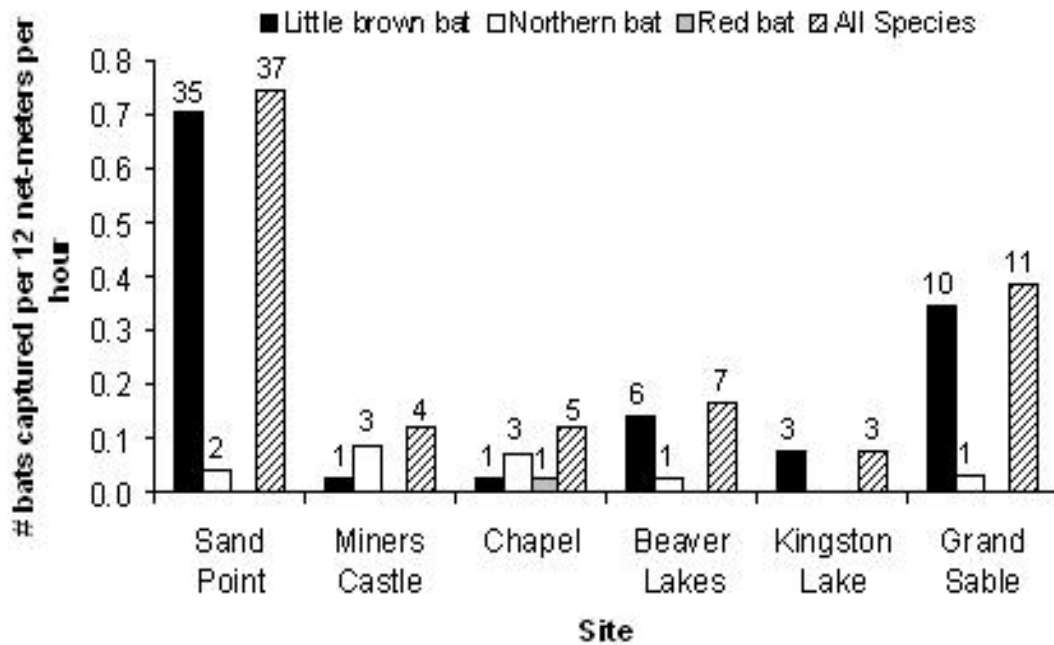


Figure 6. Number of bats captured per 12 net-meters per hour at each sampling location at Pictured Rocks National Lakeshore, MI, in 2003. Numbers above bars are total numbers of bats captured.

A total of 9,480 acoustic files (254.0 total recording hours) were recorded at PIRO (Table 5). Acoustic sampling detected a total of six species, three of which were not captured in mist nets (big brown bat, hoary bat, and silver-haired bat; Table 3). More than half of the recordings were *Myotis* spp. (67.7%, n=6,420 files), followed by the hoary bat (16.6%, n=1,574 files), silver-haired bat (2.2%, n=207 files), big brown bat (2.1%, n=195 files), and red bat (1.9%, n=182 files). Unidentifiable bat call sequences accounted for 9.5% (n=902 files) of the total activity. At two sites, active acoustic sampling detected species that were not detected at the stationary acoustic sampling stations. A total of 21.73 hr of active acoustic sampling at PIRO detected the red bat and hoary bat at Chapel and the red bat at Beaver Lakes. Overall bat activity was highest at Grand Sable (103.0 files recorded/hr) and lowest at Chapel (0.5 files recorded/hr; Figure 7). Bat activity was highest during sampling period 3 (Figure 8).

Table 5. Number of acoustic files recorded in 2003 at stationary Anabat sampling sites in Pictured Rocks National Lakeshore, MI. Numbers in parentheses are the number of files recorded per hour and are standardized by the total number of recording hours for that site.

Site	Recording hours	Number of acoustic files recorded							
		Myotis spp.	Red bat	Hoary bat	Silver-haired bat	Big brown bat	Eastern pipistrelle	Unidentifiable	All species
Sand Point	45.92	237 (5.16)	12 (0.26)	33 (0.72)	32 (0.70)	19 (0.41)	0 (0)	96 (2.09)	429 (9.34)
Miners Castle	48.73	2368 (48.59)	24 (0.49)	1127 (23.13)	90 (1.85)	78 (1.60)	0 (0)	385 (7.90)	4072 (83.56)
Chapel	37.80	13 (0.34)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	6 (0.16)	19 (0.50)
Beaver Lake	45.92	135 (2.94)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	24 (0.52)	159 (3.46)
Kingston Lake	37.83	294 (7.77)	84 (2.22)	375 (9.91)	78 (2.06)	2 (0.05)	0 (0)	71 (1.88)	904 (23.89)
Grand Sable	37.83	3373 (89.15)	62 (1.64)	39 (1.03)	7 (0.19)	96 (2.54)	0 (0)	320 (8.46)	3897 (23.89)
Total	254.04	6420 (25.27)	182 (0.72)	1574 (6.20)	207 (0.81)	195 (0.77)	0 (0)	902 (3.55)	9480 (37.32)

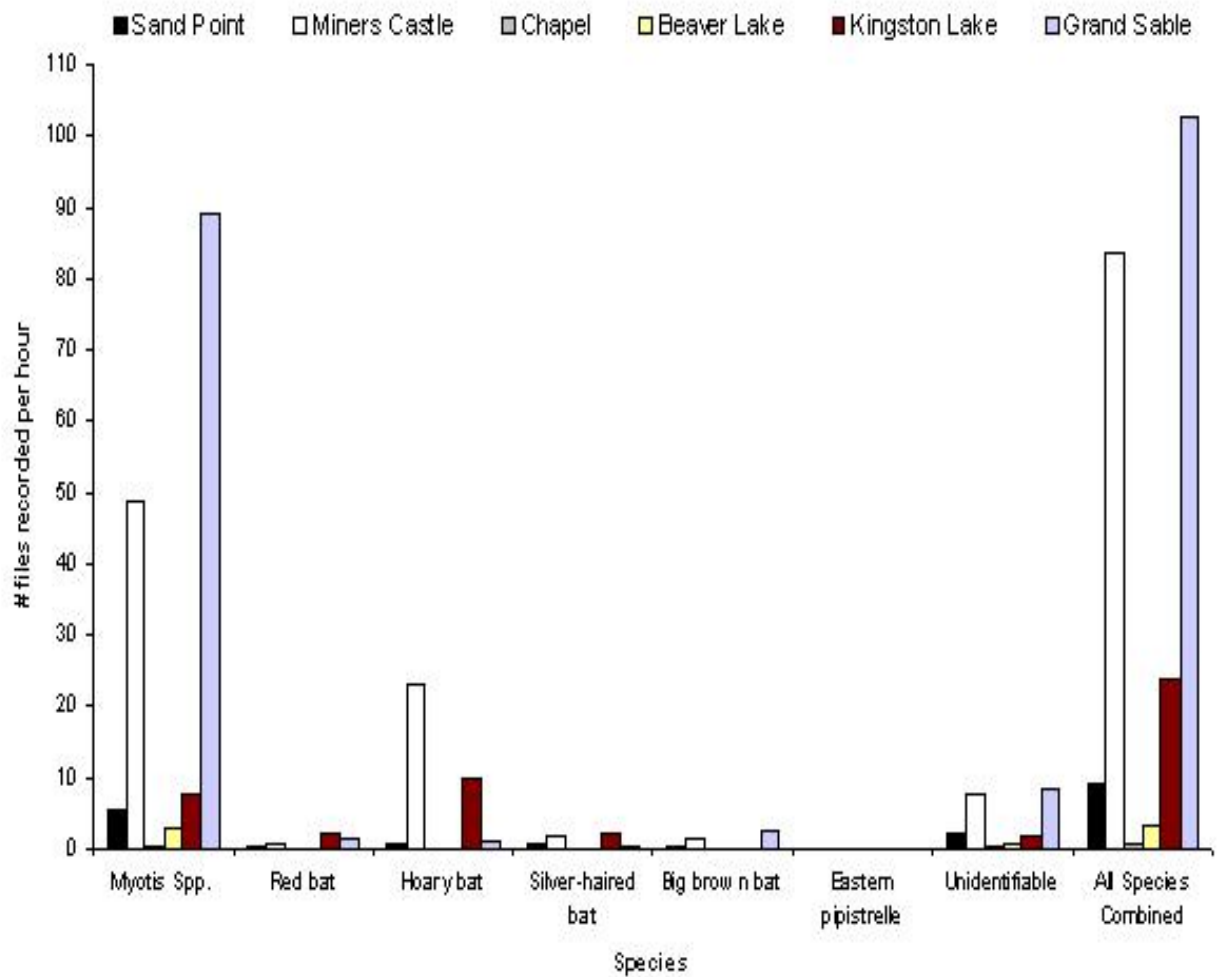


Figure 7. Number of files recorded per hour in 2003 at stationary Anabat sampling locations in Pictured Rocks National Lakeshore, MI.

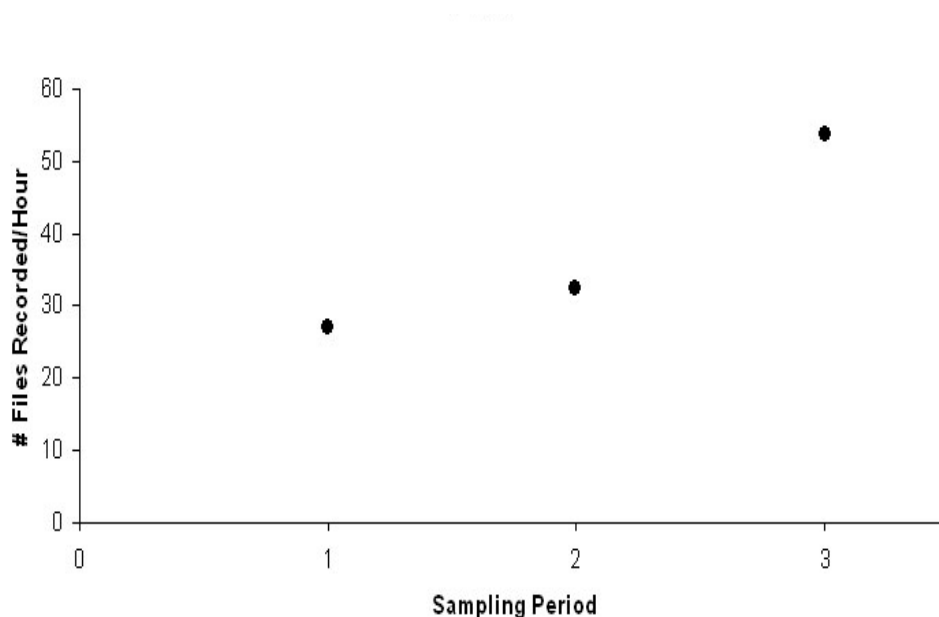


Figure 8. Total number of files recorded per hour for all species and sites combined at Pictured Rocks National Lakeshore, MI, during each sampling period: 1 (6/3-6/13), 2 (6/30-7/11), and 3 (7/28-8/8).

At the Grand Sable sampling site we examined both the interior and exterior of the Abrahamson barn (previously known to have a colony of bats) for bat use. We located bat entry points, at the roof peaks on the east and west ends of the barn. We found three major deposition piles of guano and two deceased bats on the floor of the loft. We also observed bats roosting at the peak of the roof between an older wooden roof and the overlying metal roof. Roof height prevented identification or capture of roosting individuals. We monitored both entry/exit points for 2 hr on one July night and counted 295 bats exiting the west end of the barn. Most of the bats exited using the same path, heading northwest into the trees, toward Grand Sable Creek and the sand dunes. In June 2004 we counted exiting bats again and observed 399 bats leaving the barn. A harp trap just outside the main entrance to the barn captured primarily little brown bats and two northern bats. Additionally, during mist netting at the Sand Point site, bats were observed emerging from a vent at the peak of the front porch of the Sand Point seasonal housing unit.

Apostle Islands National Lakeshore (APIS)

At APIS we captured a total of 22 bats representing four species (little brown bat, northern bat, red bat, and silver-haired bat). The northern bat had not been documented previously within the park and was the most frequently captured species. The northern bat comprised 64% of the total captures ($n=14$), followed by the little brown bat (14%, $n=3$), red bat (14%, $n=3$), and silver-haired bat (9%, $n=2$). Only the northern bat was captured at all sampling locations. The red bat, silver-haired bat, and little brown bat were captured at only two of the four sampling locations (Figure 9). The site with the highest overall rate of capture was Stockton, while the site with the lowest capture rate was Devil's Island (Figure 9). The sex ratio of northern bats captured at APIS was disproportionate, with a higher frequency of males (6 males:1 female; $n=14$, $P<0.008$). All

captured little brown bats (n=3) and silver-haired bats (n=2) were male (Table 4). We captured two female red bats and one male red bat. The capture of one juvenile little brown bat and one reproductive female northern bat confirmed the presence of reproductive populations of these two species (Table 4). Genetic vouchers were verified and banked for the little brown bat, northern bat, and red bat (Appendix C).

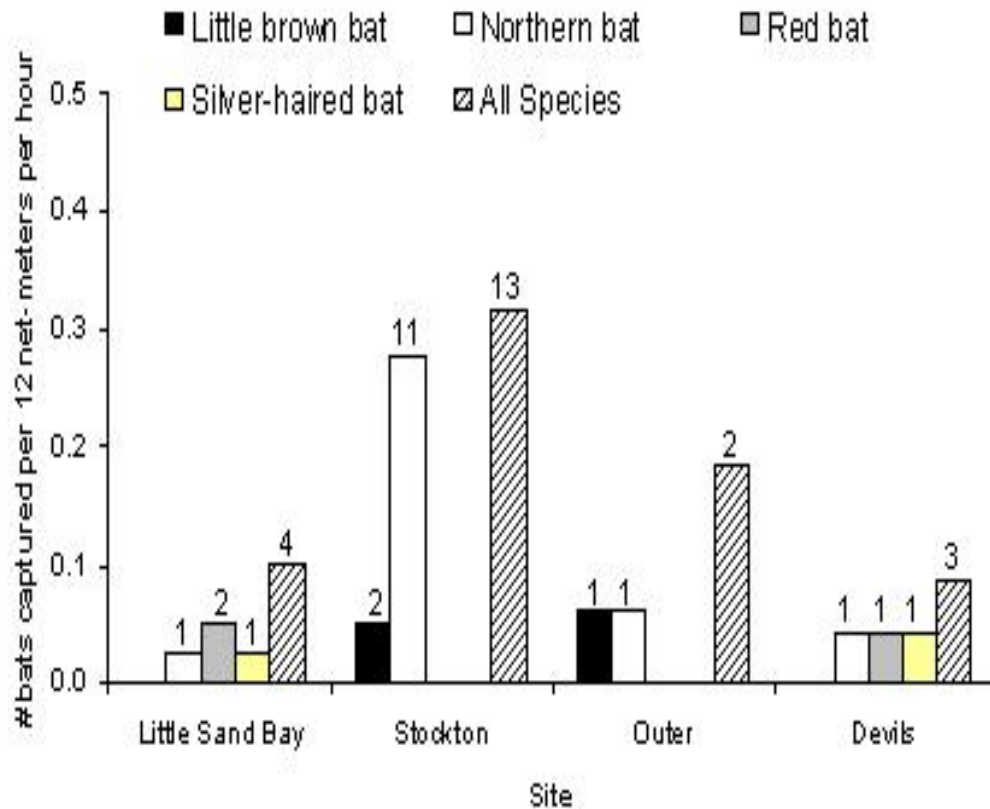


Figure 9. Number of bats captured per 12 net-meters per hour at each sampling location at Apostle Islands National Lakeshore, WI, in 2003. Numbers above bars are total numbers of bats captured.

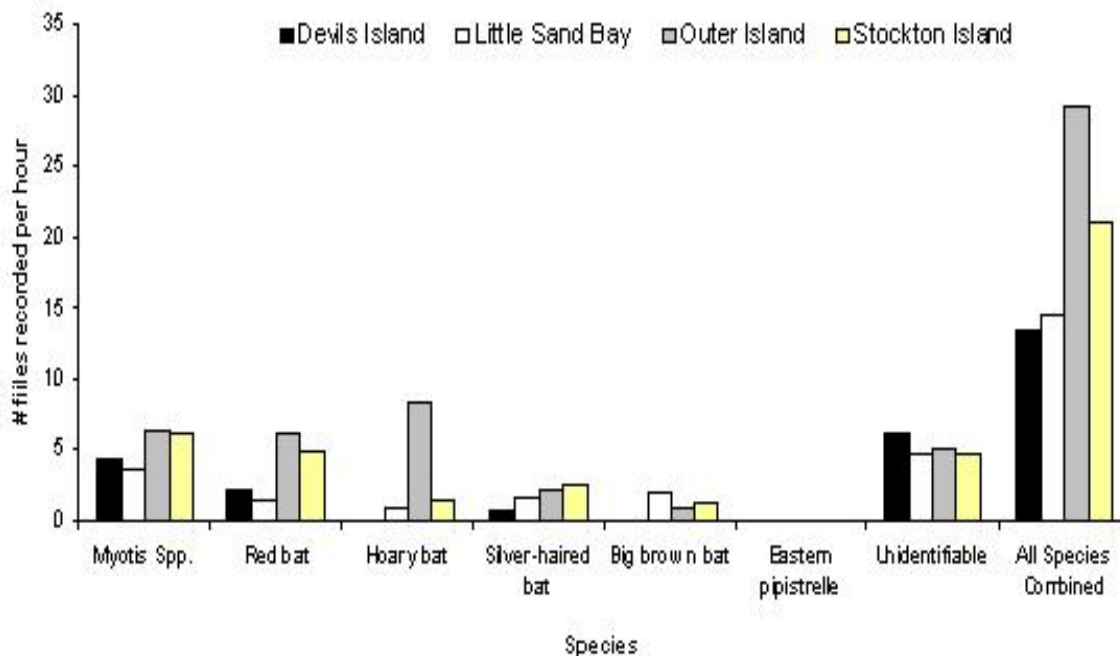


Figure 10. Number of acoustic files recorded per hour in 2003 at stationary Anabat sampling locations in Apostle Islands National Lakeshore, WI.

A total of 3,990 acoustic files (203.78 total recording hours) were recorded at APIS (Table 6). *Myotis* spp. accounted for 26.6% of the activity (n=1,060 files), followed by the red bat (19.2%, n=765 files), hoary bat (14.1%, 563 files), silver-haired bat (8.9%, n=355 files), and big brown bat (4.3%, n=173 files). Unidentifiable call sequences accounted for 26.9% (n=1,074 files) of the total activity. Acoustic sampling detected a total of six species, two of which were not captured in mist nets (big brown bat and hoary bat; Table 3). A total of 78.40 hr of active acoustic sampling did not detect any additional species (as compared to the passive sampling stations) at any of the sampling sites. Overall, bat activity was highest at Outer Island (29.2 files recorded/hr) and lowest at Devil's Island (13.5 files recorded/hr; Figure 10). Bat activity was higher during sampling periods 2 and 3 than during sampling period 1 (Figure 11).

Prior to this survey, a few buildings on Michigan Island were surveyed in 2002 for bat use. Multiple possible entrances were available to bats in the "New Keeper's Quarters," and guano deposits were observed around the entrance to the chimney and in the attic, but no bats were observed in the building. Two vents were available as entry points to the generator building, and a total of 14 individuals were observed roosting in the attic (including one female with a juvenile). Bats (probably little brown bats) were crowded at the peak of the roof. We captured two individuals at the old lighthouse (one male and one female) and observed guano piles scattered throughout the basement and first floor.

Table 6. Number of acoustic files recorded in 2003 at stationary Anabat sampling sites in Apostle Islands National Lakeshore, WI. Numbers in parentheses are the number of files recorded per hour and are standardized by the total number of recording hours for that site.

Site	Recording hours	Number of acoustic files recorded							
		<i>Myotis</i> spp.	Red bat	Hoary bat	Silver-haired bat	Big brown bat	Eastern pipistrelle	Unidentifiable	All species
Devils Island	68.18	301 (4.41)	146 (2.14)	1 (0.01)	56 (0.82)	0 (0)	0 (0)	418 (6.13)	922 (13.52)
Little Sand Bay	36.05	131 (3.63)	57 (1.58)	33 (0.92)	61 (1.69)	72 (2.00)	0 (0)	170 (4.72)	524 (14.54)
Outer Island	55.38	356 (6.43)	344 (6.21)	469 (8.47)	120 (2.17)	49 (0.88)	0 (0)	277 (5.00)	1615 (29.16)
Stockton Island	44.17	272 (6.16)	218 (4.94)	60 (1.36)	118 (2.67)	52 (1.18)	0 (0)	209 (4.73)	929 (21.03)
Total	203.78	1060 (5.20)	765 (3.75)	563 (2.76)	355 (1.74)	173 (0.85)	0 (0)	1074 (5.27)	3990 (19.58)

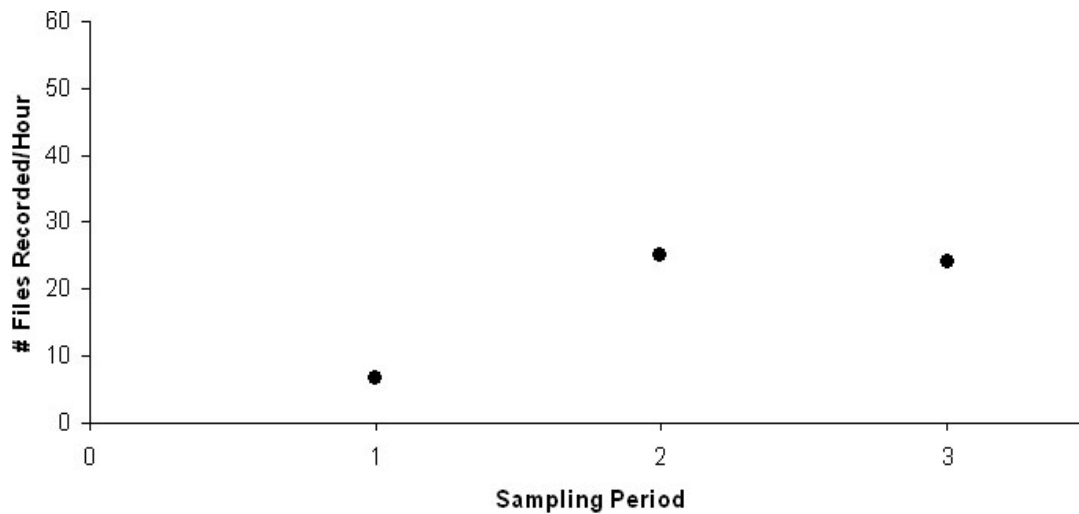


Figure 11. Total number of files recorded per hour for all species and sites combined at Apostle Islands National Lakeshore, WI, during the 2003 sampling periods: 1 (6/9-6/26), 2 (6/30-7/24), and 3 (7/29-8/21).

Grand Portage National Monument (GRPO)

A total of 64 bats comprising four species (little brown bat, northern bat, red bat, and silver-haired bat) were captured at GRPO. The northern bat, red bat, and silver-haired bat had not been documented previously within the park. The little brown bat and northern bat were captured at all sampling locations. The most frequently captured species was the northern bat (45%, $n=29$), followed by the little brown bat (42%, $n=27$), silver-haired bat (11%, $n=7$), and red bat (2%, $n=1$). The silver-haired bat was captured only at the Stockade, while the red bat was captured only at Fort Charlotte (Figure 12). Capture rates per 12 net-meters per hour were highest at the Stockade and lowest at Fort Charlotte (Figure 12). The sex ratio for captured little brown bats was disproportionate, with a higher frequency of males captured (2.9 males:1 female; $n=27$; $P=0.012$). The only red bat captured was male, and the sex ratio for silver-haired bats was 2.5 males:1 female ($n=7$, Table 4). The sex ratio for captured northern bats was not significantly different from parity at 1.4 females:1 male ($n=29$; $P=0.353$). The capture of juveniles and reproductively active females confirmed the presence of reproductive populations of little brown bats and northern bats (Table 4). Genetic vouchers were verified and banked for the little brown bat, northern bat, and silver-haired bat (Appendix C). Several bats captured at the Stockade (five little brown bats and one silver-haired bat) and at Poplar Creek (one little brown bat) had chiggers on either ears or tragus (Figure 13). These chiggers were most likely *Euschoengastia pipistrelli* or *Leptotrombidium myotis* (J. Whittaker, Indiana State University, pers. comm.).

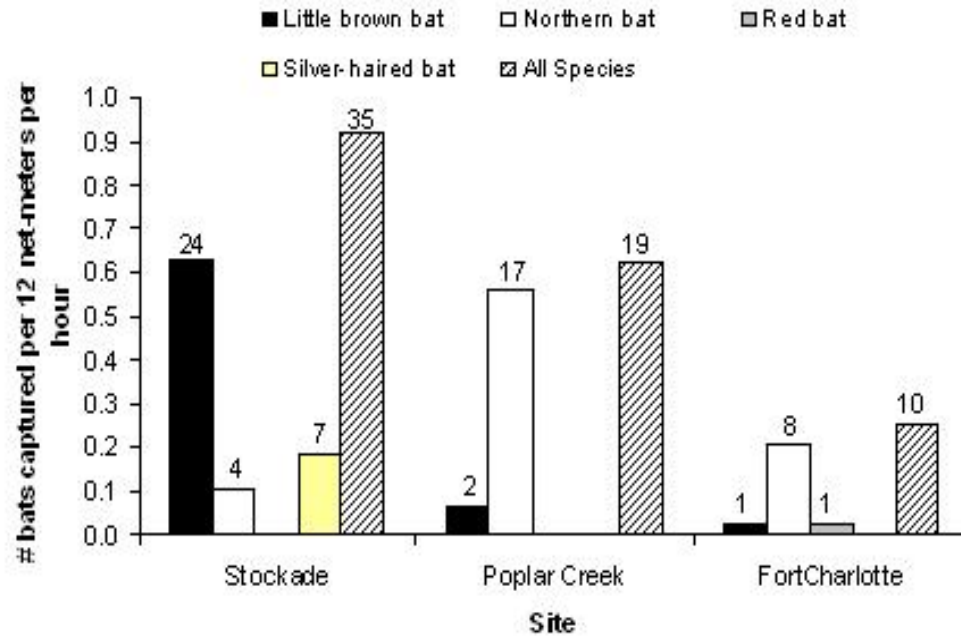


Figure 12. Number of bats captured per 12 net-meters per hour at each sampling location at Grand Portage National Monument, MN, in 2003. Numbers above bars are total numbers of bats captured.



Figure 13. Little brown bat with chigger species (*Euschoengastia pipistrelli* or *Leptotrombidium myotis*) on leading edge of right ear (red circle). Bat was captured at Stockade sampling site, Grand Portage National Monument, MN, 2003.

A total of 1,488 files (103.5 total recording hours) were recorded at GRPO (Table 7). More than half of this activity was the *Myotis* spp. (57.2%, n=851 files), followed by the silver-haired bat (18.5%, n=275 files), red bat (1.9%, n=29 files), hoary bat (1.9%, 28 files), and big brown bat (0.8%, n=12 files). Unidentifiable call sequences accounted for 19.7% (n=293 files) of the total activity. Acoustic sampling detected a total of six species, two of which were not captured in mist nets (big brown bat, hoary bat; Table 3). A total of 24.90 hr of active acoustic sampling did not detect any additional species (as compared to the passive sampling stations) at any of the sampling sites. Bat activity was highest at the Stockade (17.4 files recorded/hr) and lowest at Fort Charlotte (9.5 files recorded/hr; Figure 14). Bat activity was highest during sampling period 3 (Figure 15).

At the Stockade sampling site, we examined the great hall and kitchen buildings (previously known to have bats present) both internally and externally for presence of bats. Internally, we found no bat sign. Externally, there were a few guano and bat urine stains on the walls of the great hall (porch side) and near the roof/wall intersection. In July 2003, G. Nordquist (Minnesota Department of Natural Resources, pers. comm.) did a brief external survey around the great hall and kitchen buildings at the Stockade. She observed several bats foraging throughout the yard, but no evidence of bats emerging from any of the buildings. She used an Anabat system to record bat calls and documented the presence of the little brown bat, northern bat, and big brown bat.

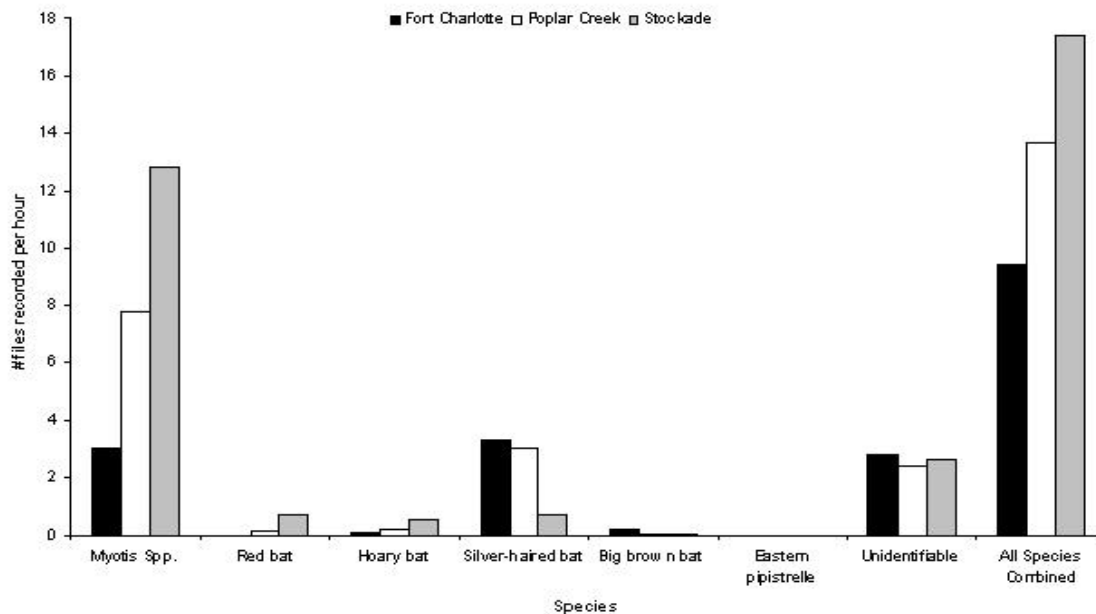


Figure 14. Number of acoustic files recorded per hour in 2003 at stationary Anabat sampling locations in Grand Portage National Monument, MN.

Table 7. Number of acoustic files recorded in 2003 at stationary Anabat sampling locations in Grand Portage National Monument, MN. Numbers in parentheses are the number of files recorded per hour and are standardized by the total number of recording hours for that site.

Site	Recording hours	Number of acoustic files recorded							
		<i>Myotis</i> spp.	Red bat	Hoary bat	Silver-haired bat	Big brown bat	Eastern pipistrelle	Unidentifiable	All species
Fort Charlotte	38.60	118 (3.06)	0 (0)	4 (0.10)	127 (3.29)	8 (0.21)	0 (0)	108 (2.80)	365 (9.46)
Poplar Creek	40.28	313 (7.77)	6 (0.15)	7 (0.17)	124 (3.08)	2 (0.05)	0 (0)	99 (2.46)	551 (13.68)
Stockade	32.83	420 (12.79)	23 (0.70)	17 (0.52)	24 (0.73)	2 (0.06)	0 (0)	86 (2.62)	572 (17.42)
Total	111.72	851 (7.62)	29 (0.26)	28 (0.25)	275 (2.46)	12 (0.11)	0 (0)	293 (2.62)	1488 (13.32)

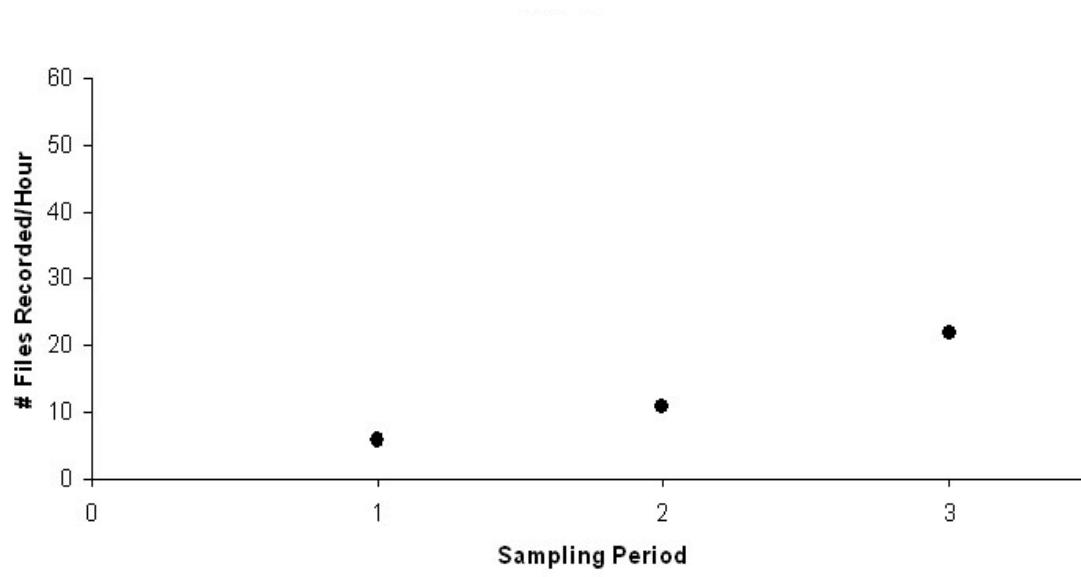


Figure 15. Total number of acoustic files recorded per hour for all species and sites combined in Grand Portage National Monument , MN, during each sampling period: 1 (6/16-6/21), 2 (7/14-7/19), and 3 (8/18-8/23).

Discussion

We verified six bat species at PIRO, APIS, and GRPO (Table 3). The eastern pipistrelle may occur in the region, but we were unable to document its presence. The eastern pipistrelle is thought to be fairly uncommon in the Lake Superior region due to the cold climate (Kurta 2001), and a lack of suitable hibernacula (e.g., caves) may limit its northern distribution (Brack and Mumford 1984). However, abandoned underground mines of the Lake Superior region may provide suitable surrogate hibernacula (Stones and Haber 1965; Long 1976; Barron 1981; Kurta 1996). Further efforts to document the presence of the eastern pipistrelle in the parks of the Great Lakes region should focus on foraging habitat, such as stream corridors, ponds, small inland lakes, and forest gaps (Davis and Mumford 1962; Brack and Mumford 1984; Krusic and Neefus 1996); and on surveys of abandoned mines during winter, particularly at the Keweenaw National Historical Park, Michigan.

Acoustic sampling and mist netting in combination provided an effective method for inventorying bats in the Lake Superior region. Acoustic sampling alone verified the presence of more species than did mist netting (Table 3), but mist netting was also an important sampling tool. Mist netting provided the opportunity to collect demographic and physical data from captured individuals and made it possible to develop a reference call library of known bat species. However, mist netting requires many hours of sampling effort and may not capture certain bat species. For example, the hoary bat and big brown bat, although documented at all three parks by acoustic sampling, were not captured in mist nets at any of the parks. This outcome may be a result of the foraging preferences of these species. Both the hoary bat and big brown bat are adapted to foraging in open, uncluttered areas, often above the forest canopy (Norberg and Rayner 1987; Hart et al. 1993) at heights above the reach of ground-placed mist nets.

Acoustic sampling of bats in the Lake Superior region augmented mist netting by identifying additional species which were not captured in mist nets (Table 3). Identification of bat species from their calls was accomplished using qualitative methods (Erickson and West 1996; O'Farrell et al. 1999). There are, however, some caveats to this method that should be taken into consideration. First, bat calls are not static; they vary both within and between species (Brigham et al. 1989; O'Farrell et al. 2000; Murray et al. 2001; Barclay and Brigham 2004) and also vary depending on the habitat in which a bat is foraging (Jacobs 1999). This inherent variability of bat calls introduces difficulty in species identification, especially for those species whose calls are structurally similar. In this inventory, we partially addressed this issue by grouping the two *Myotis* species into one category. Although we lost some resolution in verifying the presence of the two species, we are confident of their presence, as both species were captured frequently with mist nets at each park.

Another caveat to qualitative identification of bat calls is the difficulty of quantifying identification error. Although we did not quantify this error, we minimized it by having one trained individual identify all bat calls with the aid of a reference call library. Finally, bat activity levels are at best only estimates when using Anabat equipment. It is not possible to determine the number of bats from any given quantity of call sequences. Recorded call sequences for any given night could have been produced by a few individuals or by many individuals.

We have established that temperate bat species found in the Lake Superior region are widely distributed throughout PIRO, APIS, and GRPO. Although not directly addressed in this inventory, the mosaic of habitats available within each park seems to provide adequate foraging and roosting requirements for temperate bat species. All three parks contained typical bat foraging areas, such as ponds, streams, inland lakes, and forest gaps. Our surveys of buildings showed that all three parks also had available roosting habitat that in most cases was being used by bats. Additionally, an increase in bat activity at each park was observed from June through August (Figure 8, Figure 11, and Figure 15). Increased bat activity in late July and August was most likely a product of fledging juveniles and/or migratory individuals.

Park-specific Discussion

Pictured Rocks National Lakeshore (PIRO)

The distribution and activity levels of bat species varied greatly across sampling sites at PIRO. Some of this variation is likely due to the diversity of habitats available at each site. Sampling sites that had high bat activity and species diversity (e.g., Miner's Castle and Grand Sable; Figure 7) had a variety of roosting and foraging habitat combined with available water resources. At the Miner's Castle sampling site, a large beaver pond offers both foraging and water resources. Additionally, numerous standing snags throughout the beaver pond, as well as the surrounding forest, offer roosting habitat. Abrahamson barn, which is located at the Grand Sable sampling site, provides an ideal roosting environment for hundreds of bats. Large open fields, sand dunes, and Grand Sable Creek offer foraging habitat in the vicinity of the barn.

Bat activity levels at Chapel were the lowest of all six sampling sites (Figure 7). This site had the least habitat diversity, with only a small, fast-moving creek that traveled through homogenous hardwood forest. Of the very few bats observed at this site, most were flying above the canopy or in the adjacent backcountry parking lot. Interestingly, the only red bat captured at PIRO was at the Chapel sampling site. The red bat is a solitary species that typically roosts in tree foliage (Kurta 2001). Red bats prefer to forage in open areas, often in edge habitats such as streams, lakes, and forest clearcuts (Hart et al. 1993). The red bat we captured was in a mist net that crossed the creek. This bat was most likely using the creek as a travel corridor or to obtain water.

In addition to the diversity of habitats, the structure of habitats also plays a role in bat species presence and activity levels. For example open areas such as clearcuts and ponds are known to have high bat activity and species diversity (Krusic and Neefus 1996). Both open-area adapted foragers (red bat, silver-haired bat, and hoary bat) and species adapted to foraging in more cluttered habitats (little brown bat, northern bat, and big brown bat) are able to exploit this type of habitat, while a closed forest may exclude some species that are better adapted for foraging in less cluttered areas. Although not directly addressed in this inventory, our data suggest similar patterns. Sites at which sampling was focused on open and/or water habitats (e.g., Miner's Castle, Kingston Lake, Grand Sable, and Sand Point) appeared to have higher bat activity levels and species diversity than sites with more closed-canopy, cluttered habitats (e.g., Chapel and Beaver Lakes; Figure 7).

The Abrahamson barn proved to be ideal roosting habitat for both the little brown bat and the northern bat. Ideally, this roosting site should be preserved. However, this barn is utilized by

park staff and guano deposition poses a potential health risk. Any efforts to exclude bats from this building should follow humane, safe guidelines and should be done when bats are not using the building.

Apostle Islands National Lakeshore (APIS)

At Apostle Islands, the species diversity at the mainland site (Little Sand Bay) was similar to all but one island site. This was not surprising as bats are capable of traveling approximately 20 km (12.4 mi) in one night in search of food, water, and alternative roosts (Pierson 1998). Islands of APIS range from about 2 km (1.2 mi) to approximately 34 km (21 mi) from the Wisconsin mainland. At the Devil's Island sampling site, the big brown bat was not detected acoustically or by capture, and bat activity levels in general were low. Of all islands sampled, Devil's Island was the smallest and had the least habitat diversity, which may explain the low bat activity levels we found. Bat activity levels were highest at Outer Island. Outer Island is one of the largest islands sampled and has a diverse habitat. Foraging habitats were available in the form of small lakes, streams, and trail corridors. Additionally, on the northern end of Outer Island, remnant old-growth forest offers roosting habitat for some species. Although not directly assessed with our inventory efforts, our data suggest that size of island and the availability of habitat are better predictors of bat presence than distance from the mainland.

The northern bat was the only bat species captured at all sampling locations, while the red and silver-haired bat were captured only at Little Sand Bay and Devil's Island, and the little brown bat was only captured at Stockton and Outer Islands. This variability in species captured at each sampling location is most likely a result of the scope and duration of the mist netting efforts, as all species listed above were detected acoustically at each sampling location.

The only building-roost surveys conducted for this inventory were done on Michigan Island. Those buildings that showed signs of bat use should be monitored periodically to assess species presence. Buildings on other islands (as well as the mainland) should also be surveyed for bat use. Additionally, inventories of bats on other islands of APIS would give a more complete picture of the distribution of bats throughout the park. Another interesting habitat feature at APIS are sea caves, which are located in the sandstone outcrops of the mainland, Devil's Island, and Sand Island. These caves are known to provide temporary roosting sites for bats throughout the summer (personal communication, J. Van Stappen, Apostle Islands National Lakeshore). Further efforts to assess habitat utilization of bats at APIS, including possible use of sea caves, were completed in 2004 and will be documented in an additional report (Kruger et al. in prep.).

Grand Portage National Monument (GRPO)

The shape and small size of GRPO make it very different from APIS and PIRO. Yet, we verified the same six species of bats in the park. Although species diversity was similar between all three sampling sites, bat activity levels appeared to be higher at the Stockade, followed by Poplar Creek and Fort Charlotte (Figure 14). Compared to the other sampling sites, the Stockade site has diverse habitat features that may have resulted in higher bat activity. This site was in the vicinity of both water and foraging resources, as it was located on the shoreline of Lake Superior near the mouth of Grand Portage Creek. Additionally, there was a parking lot nearby with street lights. Bats are known to forage around lights at night because of the insects that accumulate around them (Furlonger et al. 1987). Indeed, we observed numerous bats foraging around the

lights at the Stockade sampling site. Roosting habitat was available in the surrounding deciduous forest and Stockade building structures.

Bat activity levels appeared to be higher at Poplar Creek than at Fort Charlotte. This was somewhat surprising because the habitat at Fort Charlotte appeared more conducive to bats. However, bat activity may have been more concentrated at our Poplar Creek sampling site than at our Fort Charlotte sampling site. The only open fly-ways and foraging areas at the Poplar Creek site are along the creek corridor. At Fort Charlotte the bat activity may have been more widely dispersed due to higher habitat diversity and more available foraging areas.

The silver-haired bat was detected acoustically at all sampling sites but was only captured at the Stockade site. Interestingly, the site where it was captured was the same site where the species was captured during a GRPO faunal mammal survey in 1995 (Graetz et al. 1995). This site was located on Grand Portage Creek, upstream from the Stockade. The silver-haired bat typically forages over forested streams like Grand Portage Creek, as well as over ponds and forest openings (Kurta 2001).

The red bat was not detected acoustically at Fort Charlotte, but specimens were captured with mist nets at the site. The species may be present at the site in low abundance. However, the Anabat system was focused on a trail intersection adjacent to Pigeon River, and it is possible that the red bat uses the river corridor more frequently than the trails.

No bats were observed using any of the building structures at the Stockade site, although they are known to have used them in the past (2002; S. Gucciardo, pers. comm.). Prior to this survey, guano deposits were removed from the upstairs floor of the great hall by park maintenance staff. Internal observation revealed some potential bat entry areas. To keep any future bats from inhabiting the buildings, all available points of entry should be sealed. This should be done late in the year, after bat migration (October-November) to ensure that any bat residents are out of the building.

Recommendations

This inventory was designed primarily to verify the presence of all bat species thought to occur in each park. It was not designed to describe use and partitioning of the habitat by the various species. Future investigations are needed to quantify habitat use patterns and habitat partitioning between the species. Specifically, investigations should concentrate on important population limiting factors such as available roosting and foraging habitat (Racey and Entwistle 2003). It is also important to remember that bat species of the Lake Superior region are highly mobile and are likely using habitat features outside of park boundaries as well. Thus, park resource managers need to examine how land use practices outside the park may affect bats, as well as the role their park ecosystems play in the life history of temperate bat species overall. Because none of the three parks have large hibernacula, summer foraging and roosting areas seem to be the primary habitats that can be directly affected by park managers. However, management of temperate bats in parks of the GLKN ultimately needs to consider the requirements of the entire bat community at the landscape level in order to meet the diversity of foraging and roosting requirements.

The following recommendations are for future efforts aimed at inventory and monitoring of bats in these and other parks in the Great Lakes Network:

1. *Sampling duration*: The sampling of bats during June, July, and August was mainly a result of availability of time and resources. We recommend extending sampling into September if possible (or even October), as bats are still active during this time period. Furthermore, bats are migrating during this time, in search of winter roosting sites. Parks in this study may offer important stop-over sites for migrating individuals. Bats have been known to migrate along the Lake Superior shoreline (G. Nordquist, pers. comm.) and to use the Apostle Islands as stop-over sites (T. Doolittle, pers. comm.). Anabat systems could be set up along the shoreline of Lake Superior parks to quantify bat activity and year-to-year trends during the migration period.

2. *Species verification*: Mist netting and acoustic sampling combined offer a robust means to sample bats in an area. We argue that sampling sites should be located in areas of probable high bat activity in order to maximize verification of species. Results from our inventory efforts suggest that sites with diverse foraging habitat, especially those sites containing riparian areas, tend to have high bat activity and species diversity. Such sampling should take into account the habitat requirements of each of the possible species to increase the chances of documenting them. Additionally, it is important to remember that bat foraging sites are typically located in the vicinity of roosting habitat. Therefore, sites with diverse foraging habitat components that are located near suitable bat roosting habitat (older buildings, older-aged forest stands that have trees with loose bark, rock outcrops with crevices, caves, and mines) should be considered valuable to the bat community.

3. *Acoustic sampling*: Acoustic sampling proved to be an important tool for verifying species presence. The efficacy of this method, however, is dependent upon construction of a reference call library. It is important to keep this library updated and to add to it continually. Future efforts should strive to obtain reference calls from:

- All representative species in the GLKN
- Both males and females

- Bats hand-released in different habitats. Bat calls are influenced by the amount of clutter through which a bat is flying. It is therefore important to obtain representative reference calls from bats released not only in open areas, but also from areas of all represented habitats of interest (trails, interior forest, etc.; Tibbels 1999).

Active and passive acoustic methods were used in this inventory. Active acoustic sampling was used to maximize species detection at a sampling site by walking along predetermined transects. Conversely, active acoustic sampling could be carried out by automobile, allowing for greater survey coverage of an area. This method is also useful in determining areas of high bat activity. Future bat inventory efforts at other parks in the GLKN should use active acoustic sampling to locate areas of high bat activity, which could then be used as long-term passive acoustic sampling sites. Passive sampling is often used for bat habitat comparisons, achieved by establishing sampling stations in each habitat. If this method is used, comparability between habitats can be increased by sampling sites simultaneously to control for among-night variation in bat activity (Britzke 2002).

4. *Identification of unknown bat calls*: Recently, there have been advances in identifying unknown bat calls using quantitative, rather than qualitative, methods (Krusic and Neefus 1996; Lance et al. 1996; Vaughan et al. 1997; Parsons and Jones 2000; Gannon et al. 2004). Quantitative identification involves application of statistical methods (e.g., discriminant function analysis or artificial neural networks) to species-specific call parameters. This method removes some of the subjectivity associated with qualitative identification of bat calls and provides a means of quantifying the degree of uncertainty in acoustic identification (Vaughan et al. 1997). Future efforts to identify acoustic recordings to the species level should consider using quantitative methods.

5. *Roost availability*: One of the main priorities for bat management in parks of the GLKN is the protection of important roost sites. We were only able to document some of the more prominent and accessible man-made structures that are available as bat roosting habitat. Those buildings at each park that showed evidence of bat use should be monitored periodically to assess the species population sizes present in each structure. In PIRO, APIS, and GRPO, we know very little about where bats are roosting other than buildings surveyed in this inventory. Future survey efforts in these parks should strive to document and characterize the types of roosts that are being utilized by bats in the forest (e.g., tree cavities), in order to preserve this roosting habitat effectively. Radio telemetry would aid in elucidating bat roosting habits in the forest, as well as providing information on critical foraging areas and flyways.

6. *Importance of repeated sampling*: Assessing the variability within each site is critical for a full understanding of bat activity at each park and for statistical comparison among sampling sites. Furthermore, establishing sites at each park for long-term, repeated monitoring would provide park managers with information pertaining to species occurrence and population trends within each park.

Park-specific Recommendations

Pictured Rocks National Lakeshore (PIRO)

One of the primary management concerns at PIRO is the influence of silvicultural practices on the fauna of the park. Future investigations and/or long-term monitoring efforts at PIRO should focus on what effects forest management practices are having on bat populations in the inland buffer zone of the park.

There has been some concern about the population of bats that reside in Abrahamson barn during summer and fall months of the year. Ideally, it would be best if bats could continue to use this roosting site. However, if eventually required, any effort to exclude bats from Abrahamson barn should be done during late October-early November to ensure all bats have left the barn. It is also highly recommended that the exclusion be done by reputable individuals that specialize in bat exclusions. Abrahamson barn will be a challenging structure from which to evict bats, as there are many places for bats to enter the building. Information on excluding bats can be obtained from Bat Conservation and Management (www.batmanagement.com) or Bat Conservation International (www.batcon.org).

Apostle Islands National Lakeshore (APIS)

At APIS, future efforts should focus on inventorying bats on islands in addition to those surveyed in this inventory. Additionally, sea cave habitat on the mainland, Sand Island, and Devil's Island should be examined for bat use. Utilization of sea caves by bats is a management concern, as sea caves are frequently visited during the summer months by kayakers and hikers. Continual disruption from visitors could discourage bats from using these caves.

Also of possible interest to resource managers at APIS is the use of islands as migratory stop-over sites. Long-term acoustic monitoring stations, perhaps placed at each lighthouse or along protected shorelines during bat migration (April-May and/or late August-October), would provide some insight on the importance of the islands to migratory bats.

Grand Portage National Monument (GRPO)

Future efforts at GRPO should focus on long-term monitoring of the already established sampling sites. Furthermore, surveys outside of GRPO boundaries may aid in a better understanding of the role GRPO plays in bat species occurrence and distribution in the larger landscape. This would require collaboration with the Grand Portage Band of Minnesota Chippewa to allow access on adjacent reservation property.

Migratory movements of bats in the Lake Superior region are poorly understood. It has been suggested that large numbers of bats may use the north shore of Lake Superior as a migratory pathway. The Minnesota Department of Natural Resources is using acoustic monitoring at some sites along the Lake Superior shoreline in Minnesota to investigate migratory activity (G. Nordquist, pers. comm.). Its location on the Lake Superior shoreline makes the Stockade area of GRPO an ideal location for such acoustic monitoring. A long-term acoustic monitoring station could be established to monitor bat activity during both spring and fall migration.

Literature Cited

- Barclay, R. M., and R. M. Brigham. 2004. Geographic variation in the echolocation calls of bats: a complication for identifying species by their calls. Pages 144-149 in R. M. Brigham, E. K. V. Kalko, G. Jones, S. Parsons, and H. J. G. A. Limpens, editors. Bat echolocation and research: Tools, techniques and analysis. Bat Conservation International, Austin, TX.
- Barron, R. J. 1981. Second record of the eastern pipistrelle, *Pipistrellus subflavus*, in Michigan. Jack-Pine Warbler **59**:68.
- Brigham, R. M., J. E. Cebek, and M. B. C. Hickey. 1989. Intraspecific variation in the echolocation calls of two species of insectivorous bats. Journal of Mammalogy **70**:426-428.
- Brack, V., Jr. and R. E. Mumford. 1984. The distribution of *Pipistrellus subflavus* and the limit of the Wisconsinan Glaciation: An interface. American Midland Naturalist **112**(2):397-401.
- Britzke, E. R. 2002. Designing monitoring programs using frequency-division bat detectors: Active versus passive sampling. Pages 79-82 in R. M. Brigham, E. K. V. Kalko, G. Jones, S. Parsons, and H. J. G. A. Limpens, editors. Bat echolocation and research: Tools, techniques and analysis. Bat Conservation International, Austin, TX.
- Britzke, E. R. 1999. Measuring bat activity with the Anabat II system. Bat Research News **40**(1):1-3.
- Corben, C. 2001. ANASUN [computer software]. Version 1.0a.
- Corben, C. 2004. Zero-crossings analysis for bat identification: An overview. Pages 95-106 in R. M. Brigham, E. K. V. Kalko, G. Jones, S. Parsons, and H. J. G. A. Limpens, editors. Bat echolocation and research: Tools techniques and analysis. Bat Conservation International, Austin, TX.
- Corben, C. 2005. ANALOOK [computer software]. Version 4.9j. Available at: <http://www.hoarybat.com>.
- Davis, W. H., and R. E. Mumford. 1962. Ecological notes on the bat *Pipistrellus subflavus*. American Midland Naturalist **68**(2):394-398.
- Erickson, J. L., and S. D. West. 1996. Managed forests in the western Cascades: The effects of seral stage on bat habitat use patterns. Pages 185-198 in R. M. R. Barclay and R. M. Brigham, editors. Bats and forests symposium, Victoria British Columbia, Canada, October 19-21, 1995.
- Fenton, M. B. 1997. Science and the conservation of bats. Journal of Mammalogy **78**(1):1-14.

- Fenton, M. B. 1999. Describing the echolocation calls and behavior of bats. *Acta Chiropterologica* **1**:127-136.
- Furlonger, C. L., H. J. Dewar, and M. B. Fenton. 1987. Habitat use by foraging insectivorous bats. *Canadian Journal of Zoology* **65**:284-288.
- Gannon, W. L., M. J. O'Farrell, C. Corben, and E. J. Bedrick. 2004. Call character lexicon and analysis of field recorded bat echolocation calls. Pages 478-484 in J. A. Thomas, C. F. Moss, and M. Vater, editors. *Echolocation in bats and dolphins*. University of Chicago Press, Chicago, IL.
- Gannon, W. L., R. E. Sherwin, and S. Haymond. 2003. On the importance of articulating assumptions when conducting acoustic studies of habitat use by bats. *Wildlife Society Bulletin* **31**(1):45-61.
- Graetz, J. L., R. A. Garrott, and S. R. Craven. 1995. A faunal survey of Grand Portage National Monument: A report to the National Park Service. University of Wisconsin, Madison.
- Hart, J. A., G. L. Kirkland, Jr., and S. C. Grossman. 1993. Relative abundance and habitat use by tree bats, *Lasiurus* spp., in southcentral Pennsylvania. *The Canadian Field-Naturalist* **107**:208-212.
- Jacobs, D. S. 1999. Intraspecific variation in wingspan and echolocation call flexibility might explain the use of different habitats by the insectivorous bat, *Miniopterus schreibersii* (Vespertilionidae: Miniopterinae). *Acta Chiropterologica* **1**:93-103.
- Jones, C., W. J. McShea, M. J. Conroy, and T. H. Kunz. 1996. Capturing mammals. Pages 115-155 in D. E. Wilson, F. R. Cole, J. D. Nichols, R. Rudran, and M. S. Foster, editors. *Measuring and monitoring biological diversity: Standard methods for mammals*. Smithsonian Institution, Washington, D.C.
- Krusic, R. A., and C. D. Neefus. 1996. Habitat associations of bat species in the White Mountain National Forest. Pages 185-198 in R. M. R. Barclay and R. M. Brigham, editors. *Bats and forests symposium*, Victoria British Columbia, Canada, October 19-21, 1995.
- Kunz, T. H., and A. Kurta. 1988. Capture methods and holding devices. Pages 1-29 in T. H. Kunz, editor. *Ecological and behavioral methods for the study of bats*. Smithsonian Institution Press, Washington, D.C.
- Kurta, A. 1982. A review of Michigan bats: Seasonal and geographic distribution. *Michigan Academician* **15**:295-312.
- Kurta, A. 1996. Preliminary survey of bats hibernating in mines of the Upper Peninsula. Report to Michigan Department of Natural Resources.

- Kurta, A. 2001. Mammals of the Great Lakes region. The University of Michigan Press, Ann Arbor, MI.
- Lafrancois, B. M., and J. Glase. 2005. Aquatic studies in National Parks of the upper Great Lakes states: Past efforts and future directions. Water Resources Division Technical Report, NPS/NRWRD/NRTR-2005/334. National Park Service, Denver, Colorado.
- Lance, R. F., B. Bollich, C. L. Callahan, and P. L. Leberg. 1996. Surveying forest-bat communities with Anabat detectors. Pages 175-184 in R. M. R. Barclay and R. M. Brigham, editors. Bats and forests symposium, Victoria British Columbia, Canada, October 19-21, 1995.
- Long, C. A. 1976. The occurrence, status and importance of bats in Wisconsin with a key to the species. Wisconsin Academy of Sciences, Arts and Letters **64**:62-82.
- Murray, K., E. R. Britzke, and L. W. Robbins. 2001. Variation in search-phase calls of bats. Journal of Mammalogy **82**(3):728-737.
- Norberg, U. M., and J. M. V. Rayner. 1987. Ecological morphology and flight in bats Mammalia: Chiroptera: Wing adaptations, flight performance, foraging strategy and echolocation. Philosophical Transactions of the Royal Society of London **316**:335-427.
- Nordquist, G., and E. C. Birney. 1985. Distribution and status of bats in Minnesota. Final Project Report, Minnesota Department of Natural Resources Nongame Wildlife Program.
- O'Farrell, M. J., C. Corben, and W. L. Gannon. 2000. Geographic variation in the echolocation of calls of the hoary bat (*Lasiurus cinereus*). Acta Chiropterologica **2**(2):185-196.
- O'Farrell, M. J., B. W. Miller, and W. L. Gannon. 1999. Qualitative identification of free-flying bats using the Anabat detector. Journal of Mammalogy **80**:11-23.
- Palmeirim, J. M., and L. Rodrigues. 1993. The 2-minute harp trap for bats. Bat Research News **34**(2&3):60-64.
- Parsons, S., and G. Jones. 2000. Acoustic identification of twelve species of echolocating bat by discriminant function analysis and artificial neural networks. Journal of Experimental Biology **203**:2641-2656.
- Pictured Rocks National Lakeshore. 2004. General management plan and wilderness study environmental impact statement. Pictured Rocks National Lakeshore, Munising, Michigan.
- Pierson, E. D. 1998. Tall trees, deep holes, and scarred landscapes: Conservation biology of North American bats. Pages 309-325 in T. H. Kunz and P. A. Racey, editors. Bat biology and conservation. Smithsonian Institution Press, Washington, D.C.

- Racey, P. 1988. Reproductive assessment in bats. Pages 31–45 *in* T. H. Kunz, editor. Ecological and behavioral methods for the study of bats. Smithsonian Institution Press, Washington, D.C.
- Racey, P. A., and A. C. Entwistle. 2003. Chapter 15: Conservation ecology of bats. *In* T. Kunz and M. B. Fenton, editors. Bat ecology. The University of Chicago Press, Chicago, IL.
- Stones, R. C., and W. Fritz. 1969. Survey of winter bat populations in search of the Indiana bat in the western Upper Peninsula of Michigan. Endangered and Threatened Species Committee report, Michigan Department of Natural Resources.
- Stones, R. C., and G. C. Haber. 1965. Eastern pipistrelle in Michigan. *Journal of Mammalogy* **46**:608.
- Tibbels, A. 1999. Do call libraries reflect reality? *Bat Research News* **40**(4):153-154.
- Vaughan, N., G. Jones, and S. Harris. 1997. Identification of British bat species by multivariate analysis of echolocation call parameters. *Bioacoustics* **7**:189-207.
- Wilson, D. E., F. R. Cole, J. D. Nichols, R. Rudran, and M. S. Foster. 1996. Measuring and monitoring biological diversity: Standard methods for mammals. Smithsonian Institution Press, Washington and London.
- Zar, J. H. 1999. Biostatistical analysis, 4th edition. Prentice Hall, Upper Saddle River, New Jersey.

Appendix A. Site Coordinates

Table A1. Geographic coordinates of sampling locations and 2003 sampling dates at Pictured Rocks National Lakeshore, MI; Apostle Islands National Lakeshore, WI; and Grand Portage National Monument, MN.

Pictured Rocks National Lakeshore - 2003					
Site	Sampling locations		Sampling dates		
	Latitude	Longitude	June	July	August
Sand Point	46.44944	86.60361	2, 3, 30	1, 28, 29	
Miner's Castle	46.46139	86.54444	4,5	2, 3, 30, 31	
Chapel	46.51917	86.46222	7	5,6	1,2
Beaver Lakes	46.55800	86.35758	8,9	7,8	3,4
Kingston Lake	46.58622	86.22644	11	9,10	5,6
Grand Sable	46.65758	86.02236	12,13	11	7,8

Apostle Islands National Lakeshore - 2003					
Site	Sampling locations		Sampling dates		
	Latitude	Longitude	June	July	August
Little Sand Bay	46.94835	90.88529	3, 4	7, 8, 28, 29	
	46.89962	91.03840	5	9, 10, 30,31	
Stockton Island	46.92775	90.55115	9, 10	1, 2	11, 12
	46.94030	90.55772	11, 12, 30		13
	46.91239	90.54956			14
Outer Island	46.99962	90.45626	16, 17	15, 16	4, 5
	47.00159	90.46317	18, 19	17	
	47.07391	90.42394			6, 7
Devil's Island	47.07024	90.72765	23, 24	21, 22	18, 19
	47.07908	90.72623	25, 26	23, 24	21

Grand Portage National Monument - 2003					
Site	Sampling locations		Sampling dates		
	Latitude	Longitude	June	July	August
Stockade	47.96233	89.68447	16, 17	18, 19	22, 23
Poplar Creek	47.99289	89.06972	20, 21	14, 15	18, 19
Fort Charlotte	48.00308	89.82833	18, 19	16, 17	20, 21

Appendix B. Time-frequency displays and call characteristics for bat species in the Lake Superior region.

Appendix B contains summarized data for recorded bat species in a bat call library constructed for the study. Bat calls were obtained from hand-released bats and from bats identified and recorded while they were airborne. A sample time-frequency graph is provided for each species.

We used the following steps to extract call parameters for each species:

1. We cleaned the call sequences to remove fragmented calls and extraneous noise (e.g., insects or wind). This involved the use of filters in the Analook software, as well as manual editing using the “mark to exclude” option in the edit mode of Analook.
2. Whenever necessary, search-phase portions of calls were identified visually and were manually isolated from approach-phase or feeding buzz portions of calls (Figure 4). Only search-phase portions of call sequences with five or more calls were used.
3. Using the Analook software, we extracted the following parameters for each cleaned call sequence and calculated mean values for each species: duration (dur), maximum frequency (Fmax), minimum frequency (Fmin), mean frequency (Fmean), time at the knee (Tk), frequency at the knee (Fk), characteristic frequency (Fc), time at the characteristic frequency (Tc), initial slope (S1), and characteristic slope (Sc). For an in-depth description of the call parameters, see O’Farrell et al. (2000).

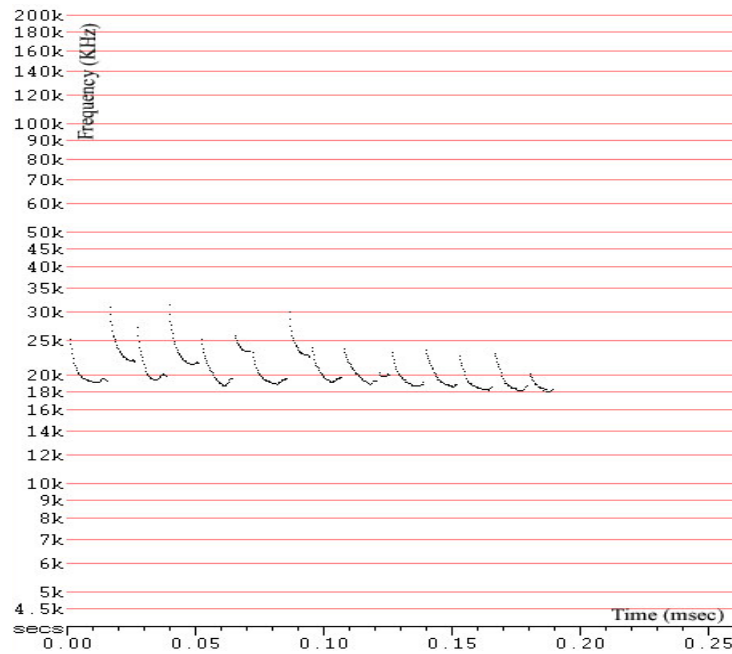


Figure B1. Time-frequency display of hoary bat (*Lasiurus cinereus*) calls. Time between calls is compressed to allow more calls per screen.

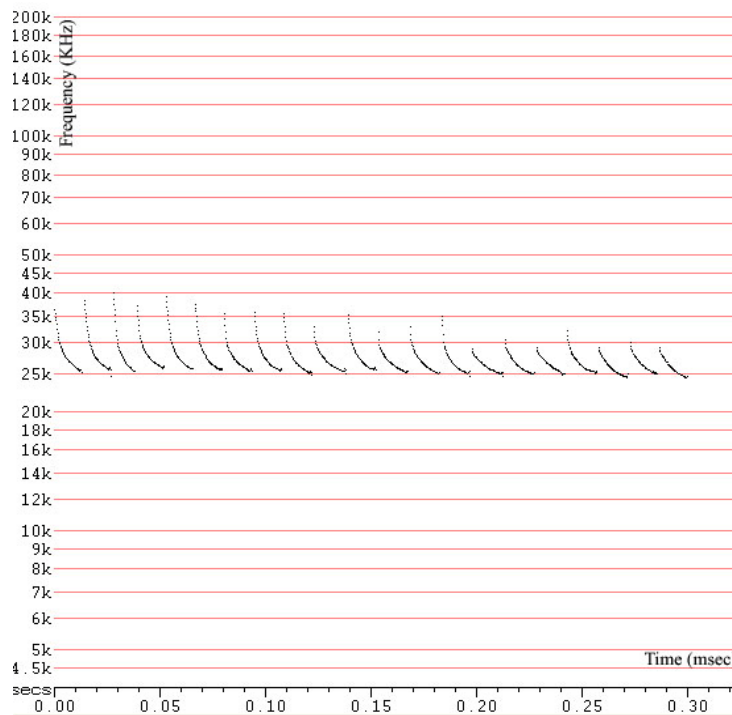


Figure B2. Time-frequency display of silver-haired bat (*Lasionycteris noctivagans*) calls. Time between calls is compressed to allow more calls per screen.

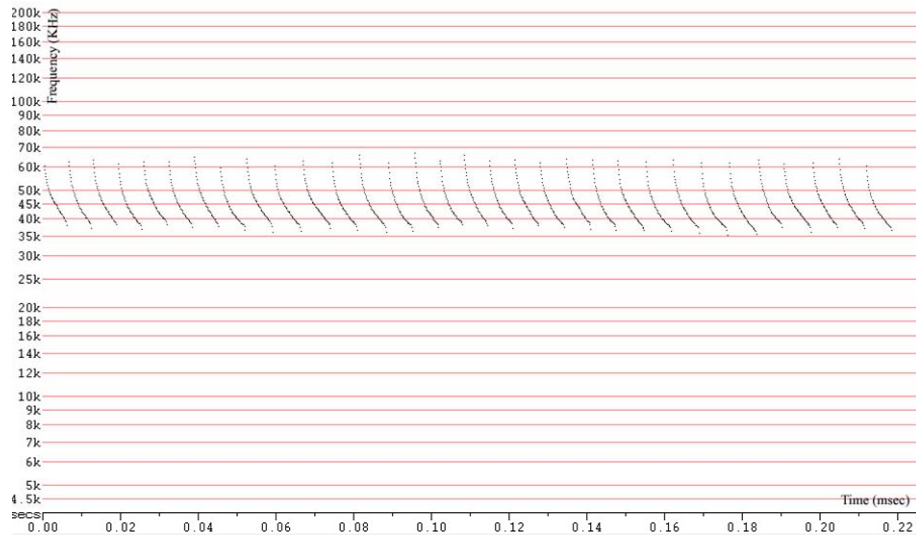


Figure B3. Time-frequency display of little brown bat (*Myotis lucifugus*) calls. Time between calls is compressed to allow more calls per screen.

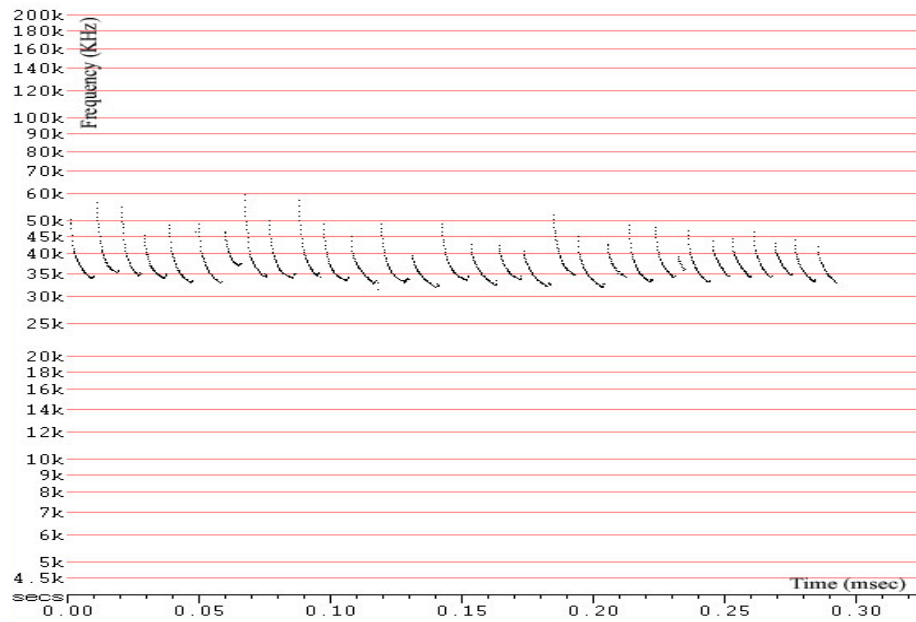


Figure B4. Time-frequency display of eastern red bat (*Lasiurus borealis*) calls. Time between calls is compressed to allow more calls per screen.

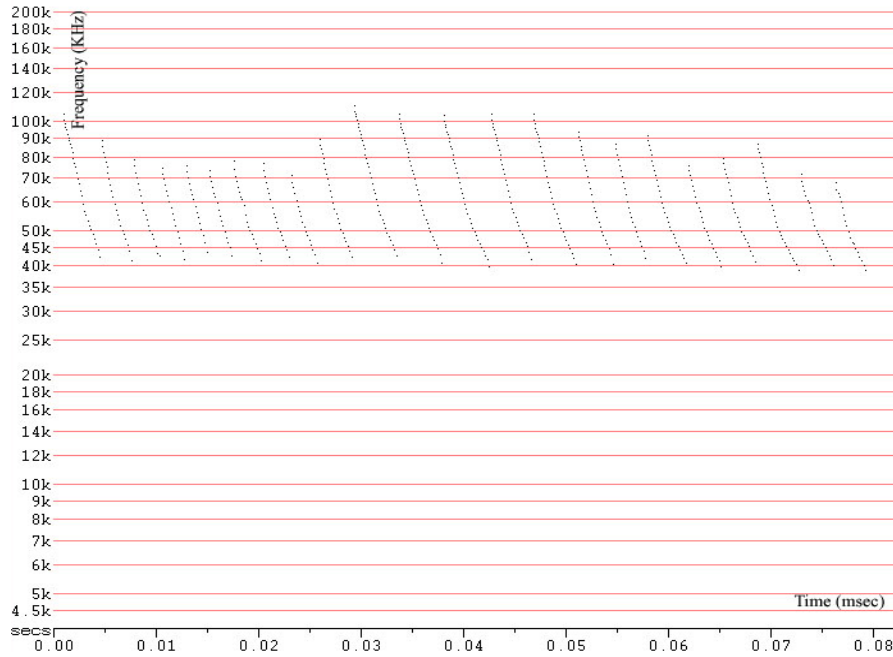


Figure B5. Time-frequency display of northern bat (*Myotis septentrionalis*) calls. Time between calls is compressed to allow more calls per screen.

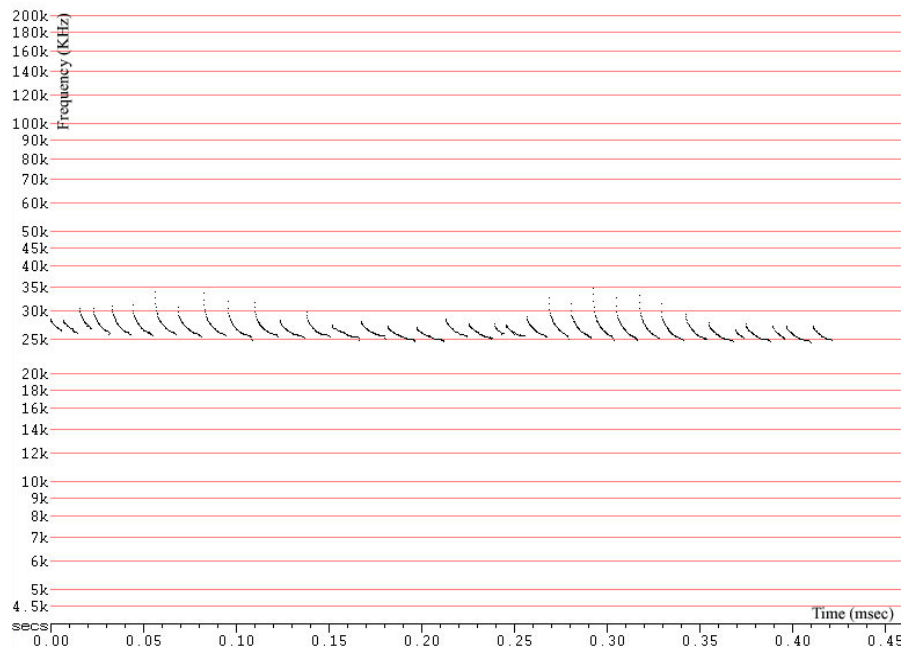


Figure B6. Time-frequency display of big brown bat (*Eptesicus fuscus*) calls. Time between calls is compressed to allow more calls per screen. Call sequence from K. Francl, Notre Dame Research Center, upper Michigan.

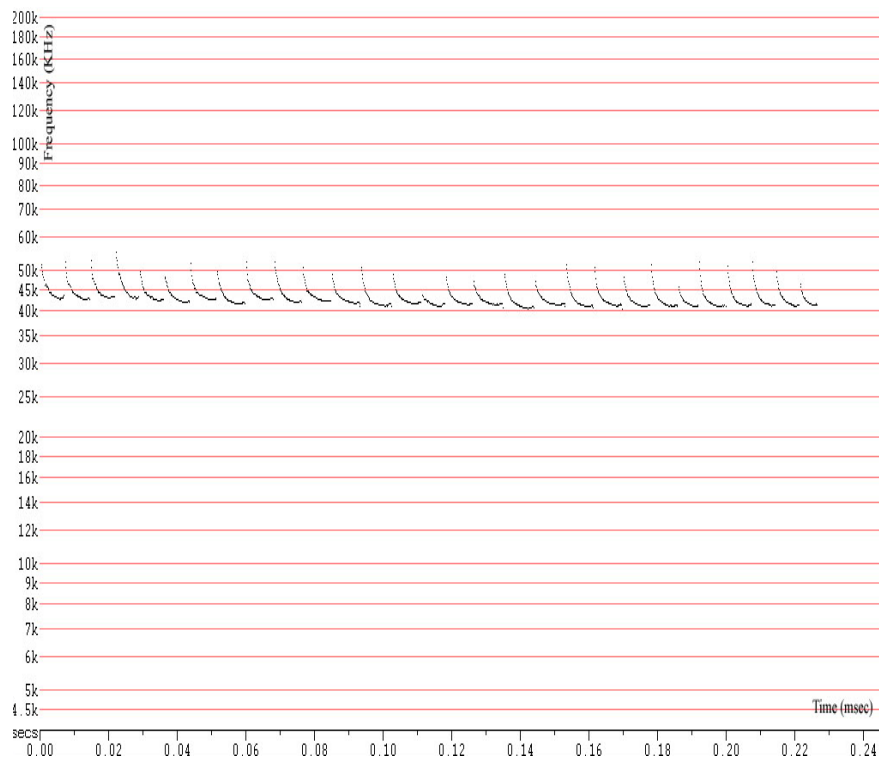


Figure B7. Time-frequency display of eastern pipistrelle (*Pipistrellus subflavus*) calls. Time between calls is compressed to allow more calls per screen. Call sequence from Hunter's Cave, Missouri, 2003 (C. Corben).

Table B1. Mean ($\pm$ 1SE) call parameters of search-phase call sequences for the seven species in the bat call reference library: duration (Dur), maximum frequency (Fmax), minimum frequency (Fmin), mean frequency (Fmean), time at the knee (Tk), frequency at the knee (Fk), characteristic frequency (Fc), time at the characteristic frequency (Tc), initial slope (S1), and characteristic slope (Sc).

Species	Number of calls	Dur (msec)	Fmax (KHz)	Fmin (KHz)	Fmean (KHz)	Tk (msec)	Fk (KHz)	Tc (msec)	Fc (KHz)	S1	Sc
<i>L. cinereus</i>	552	6.75 $\pm$ 0.09	26.06 $\pm$ 0.27	20.23 $\pm$ 0.09	21.64 $\pm$ 0.13	2.22 $\pm$ 0.05	21.85 $\pm$ 0.11	6.34 $\pm$ 0.09	20.31 $\pm$ 0.10	153.71 $\pm$ 4.89	30.96 $\pm$ 0.80
<i>L. noctivagans</i>	490	9.98 $\pm$ 0.14	37.36 $\pm$ 0.26	26.46 $\pm$ 0.04	28.81 $\pm$ 0.06	3.50 $\pm$ 0.06	28.78 $\pm$ 0.05	9.33 $\pm$ 0.13	26.62 $\pm$ 0.04	221.56 $\pm$ 5.58	24.64 $\pm$ 1.00
<i>M. lucifugus</i>	856	3.78 $\pm$ 0.05	62.35 $\pm$ 0.41	40.28 $\pm$ 0.10	47.14 $\pm$ 0.15	1.90 $\pm$ 0.03	46.04 $\pm$ 0.13	3.53 $\pm$ 0.05	41.42 $\pm$ 0.13	325.93 $\pm$ 6.20	118.70 $\pm$ 1.78
<i>L. borealis</i>	472	6.41 $\pm$ 0.09	58.33 $\pm$ 0.57	38.30 $\pm$ 0.15	42.44 $\pm$ 0.20	2.83 $\pm$ 0.05	41.07 $\pm$ 0.16	5.98 $\pm$ 0.08	38.51 $\pm$ 0.15	301.18 $\pm$ 8.33	33.47 $\pm$ 1.18
<i>M. septentrionalis</i>	1250	2.50 $\pm$ 0.03	70.62 $\pm$ 0.45	41.54 $\pm$ 0.10	51.19 $\pm$ 0.19	1.39 $\pm$ 0.03	50.38 $\pm$ 0.19	1.87 $\pm$ 0.03	46.61 $\pm$ 0.16	445.78 $\pm$ 4.07	283.28 $\pm$ 3.60
<i>P. subflavus</i> *	507	7.01 $\pm$ 0.07	48.51 $\pm$ 0.22	41.28 $\pm$ 0.06	42.86 $\pm$ 0.07	1.71 $\pm$ 0.04	43.40 $\pm$ 0.07	6.63 $\pm$ 0.07	41.54 $\pm$ 0.06	166.48 $\pm$ 5.53	14.77 $\pm$ 0.46
<i>E. fuscus</i>	441	10.12 $\pm$ 0.16	33.81 $\pm$ 0.34	24.61 $\pm$ 0.09	27.17 $\pm$ 0.12	2.97 $\pm$ 0.07	27.56 $\pm$ 0.09	9.67 $\pm$ 0.15	24.83 $\pm$ 0.09	151.79 $\pm$ 6.11	28.66 $\pm$ 1.26

* *P. subflavus* parameters were provided by C. Corben and are from call sequences at Hunter's Cave, Missouri, 2003.

Appendix C. Genetic voucher results.

Table C1. Genetic voucher results for bat species captured in 2003 at Pictured Rocks National Lakeshore (PIRO), MI; Apostle Islands National Lakeshore (APIS), WI; and Grand Portage National Monument (GRPO), MN. Genetic analysis was done at Portland State University, where excess samples that were not destroyed during analysis were archived (J. Zinck, pers. comm.).

Lab ID	Sample ID	Field ID	Genetic Species ID	Extract	Re-do	PCR	SEQ
APIS-02.1	APIS-7/17/02-9-1-1			1/20/2004		1/21/2004	
APIS-02.2L	APIS-7/17/02-9-1-CL		<i>Myotis lucifugus lucifugus</i>	1/20/2004	1/27/2004	1/21/2004	2/11/2004
APIS-02.3G	APIS-7/17/02-9-2-CG		<i>Myotis lucifugus lucifugus</i>	1/20/2004		1/21/2004	2/11/2004
APIS-03.1	APIS-6/24/03-8-2-1		<i>Myotis septentrionalis</i>	1/20/2004		1/21/2004	2/11/2004
APIS-03.2	APIS-6/26/03-8-2-1		<i>Myotis lucifugus lucifugus</i>	1/20/2004		1/21/2004	2/11/2004
APIS-03.3	APIS-7/1/03-3-1-1		<i>Myotis septentrionalis</i>	1/20/2004		1/21/2004	2/11/2004
APIS-03.4	APIS-7/1/03-3-1-2			1/20/2004		1/21/2004	2/11/2004
APIS-03.5	APIS-7/1/03-3-1-3			1/20/2004	1/27/2004	1/21/2004	
APIS-03.6	APIS-7/1/03-3-1-4		<i>Myotis septentrionalis</i>	1/20/2004	1/27/2004	1/21/2004	2/11/2004
APIS-03.7	APIS-7/1/03-3-1-5		<i>Myotis septentrionalis</i>	1/20/2004		1/21/2004	2/11/2004
APIS-03.8	APIS-7/1/03-3-1-6			1/20/2004	1/27/2004	1/21/2004	
APIS-03.9	APIS-7/8/03-1-1-2		<i>L. borealis</i>	1/20/2004		1/21/2004	2/11/2004
APIS-03.10	APIS-7/8/03-1-2-1			1/20/2004		1/21/2004	
APIS-03.11	APIS-7/18/03-5-1-1		<i>Myotis lucifugus lucifugus</i>	1/20/2004		1/21/2004	2/11/2004
GRPO-03.1	GRPO-6/17/03-1-1-6	<i>M. lucifugus</i>	<i>Myotis lucifugus lucifugus</i>	1/16/2004		1/20/2004	2/11/2004
GRPO-03.2	GRPO-6/17/03-1-2-3	<i>M. lucifugus</i>	<i>Myotis lucifugus lucifugus</i>	1/16/2004		1/20/2004	2/11/2004

Table C1. Genetic voucher results for bat species captured in 2003 at Pictured Rocks National Lakeshore (PIRO), MI; Apostle Islands National Lakeshore (APIS), WI; and Grand Portage National Monument (GRPO), MN. Genetic analysis was done at Portland State University, where excess samples that were not destroyed during analysis were archived (J. Zinck, pers. comm.) (continued).

Lab ID	Sample ID	Field ID	Genetic Species ID	Extract	Re-do	PCR	SEQ
GRPO-03.3	GRPO-6/20/03-3-3-1	<i>M. septentrionalis</i>	<i>Myotis septentrionalis</i>	1/16/2004		1/20/2004	2/11/2004
GRPO-03.4	GRPO-6/20/03-3-1-3	<i>M. septentrionalis</i>	<i>Myotis septentrionalis</i>	1/16/2004		1/20/2004	2/11/2004
GRPO-03.5	GRPO-7/15/03-3-3-1	<i>M. septentrionalis</i>	<i>Myotis septentrionalis</i>	1/16/2004		1/20/2004	2/11/2004
GRPO-03.6	GRPO-7/17/03-2-3-1	<i>M. septentrionalis</i>	<i>Myotis septentrionalis</i>	1/16/2004		1/20/2004	2/11/2004
GRPO-03.7	GRPO-7/18/03-1-1-3	<i>L. noctivagans</i>	<i>L. noctivagans</i>	1/16/2004		1/20/2004	2/11/2004
GRPO-03.8	GRPO-7/18/03-1-1-5	<i>M. lucifugus</i>	<i>Myotis lucifugus lucifugus</i>	1/16/2004	1/27/2004	1/20/2004	2/11/2004
GRPO-03.9	GRPO-7/18/03-1-1-4	<i>M. lucifugus</i>		1/16/2004	1/27/2004	1/20/2004	
GRPO-03.10	GRPO-8/18/03-3-3-7	<i>M. septentrionalis</i>	<i>Myotis septentrionalis</i>	1/16/2004	1/27/2004	1/20/2004	2/11/2004
GRPO-03.11	GRPO-8/19/03-3-1-1	<i>M. lucifugus</i>	<i>Myotis lucifugus lucifugus</i>	1/16/2004	1/27/2004	1/20/2004	2/11/2004
GRPO-03.12	GRPO-8/19/03-3-3-3	<i>M. septentrionalis</i>	<i>Myotis septentrionalis</i>	1/16/2004		1/20/2004	2/11/2004
GRPO-03.13	GRPO-8/20/03-2-2-2	<i>L. Borealis</i>		1/16/2004	1/27/2004	1/20/2004	2/11/2004
GRPO-03.14	GRPO-8/21/03-2-1-1	<i>M. septentrionalis</i>		1/16/2004	1/27/2004	1/20/2004	
GRPO-03.15	GRPO-8/22/03-1-3-3	<i>L. noctivagans</i>		1/16/2004		1/20/2004	2/11/2004
GRPO-03.16	GRPO-8/22/03-1-3-6	<i>L. noctivagans</i>	<i>L. noctivagans</i>	1/16/2004	1/27/2004	1/20/2004	2/11/2004
GRPO-03.17	GRPO-8/22/03-1-3-1	<i>M. lucifugus</i>		1/20/2004		1/21/2004	
GRPO-03.18	GRPO-8/23/03-1-1-1	<i>luci?/humeralis?</i>	<i>Myotis lucifugus lucifugus</i>	1/20/2004		1/21/2004	2/11/2004
GRPO-03.19	GRPO-8/23/03-1-1-2	<i>M. lucifugus</i>	<i>Myotis lucifugus lucifugus</i>	1/20/2004		1/21/2004	2/11/2004
GRPO-03.20	GRPO-8/23/03-1-2-11	<i>M. septentrionalis</i>	<i>Myotis septentrionalis</i>	1/20/2004		1/21/2004	2/11/2004

Table C1. Genetic voucher results for bat species captured in 2003 at Pictured Rocks National Lakeshore (PIRO), MI; Apostle Islands National Lakeshore (APIS), WI; and Grand Portage National Monument (GRPO), MN. Genetic analysis was done at Portland State University, where excess samples that were not destroyed during analysis were archived (J. Zinck, pers. comm.) (continued).

Lab ID	Sample ID	Field ID	Genetic Species ID	Extract	Re-do	PCR	SEQ
PIRO-03.1	PIRO-6/3/03-1-3-1	<i>N. myotis</i>	<i>Myotis lucifugus lucifugus</i>	1/21/2004		1/22/2004	2/11/2004
PIRO-03.2	PIRO-6/4/03-2-3-2	<i>M. septentrionalis</i>		1/21/2004		1/22/2004	
PIRO-03.3	PIRO-6/4/03-2-3-1	<i>M. septentrionalis</i>	<i>Myotis septentrionalis</i>	1/21/2004		1/22/2004	2/11/2004
PIRO-03.4	PIRO-6/6/03-3-3-1	missing					
PIRO-03.5	PIRO-6/9/03-4-2-3	<i>M. lucifugus</i>	<i>Myotis lucifugus lucifugus</i>	1/21/2004		1/22/2004	2/11/2004
PIRO-03.6	PIRO-6/9/03-4-2-2	<i>M. lucifugus</i>	<i>Myotis lucifugus lucifugus</i>	1/21/2004		1/22/2004	2/11/2004
PIRO-03.7	PIRO-6/11/03-5-3-1	<i>M. lucifugus</i>	<i>Myotis lucifugus lucifugus</i>	1/21/2004	1/27/2004	1/22/2004	2/11/2004
PIRO-03.8	PIRO-6/13/03-6-2-3	<i>M. lucifugus</i>	<i>Myotis lucifugus lucifugus</i>	1/21/2004		1/22/2004	2/11/2004
PIRO-03.9	PIRO-6/13/03-6-2-4	<i>M. lucifugus</i>		1/21/2004		1/22/2004	
PIRO-03.10	PIRO-7/28/03-1-2-1	<i>M. lucifugus</i>	<i>Myotis lucifugus lucifugus</i>	1/21/2004		1/22/2004	2/11/2004
PIRO-03.11	PIRO-7/28/03-1-2-5	<i>M. lucifugus</i>	<i>Myotis lucifugus lucifugus</i>	1/21/2004		1/22/2004	2/11/2004
PIRO-03.12	PIRO-7/28/03-1-2-12	<i>M. septentrionalis</i>	<i>Myotis septentrionalis</i>	1/21/2004		1/22/2004	2/11/2004
PIRO-03.13	PIRO-7/29/03-1-2-15	<i>M. lucifugus</i>	<i>Myotis lucifugus lucifugus</i>	1/21/2004		1/22/2004	2/11/2004
PIRO-03.14	PIRO-7/29/03-1-2-6	<i>M. lucifugus</i>	<i>Myotis lucifugus lucifugus</i>	1/21/2004		1/22/2004	2/11/2004
PIRO-03.15	PIRO-8/2/03-3-1-1	<i>M. septentrionalis</i>	<i>Myotis septentrionalis</i>	1/21/2004		1/22/2004	2/11/2004
PIRO-03.16	PIRO-8/2/03-3-2-2	<i>M. septentrionalis</i>	<i>Myotis septentrionalis</i>	1/21/2004		1/22/2004	2/11/2004
PIRO-03.17	PIRO-8/3/03-4-2-1	<i>M. septentrionalis</i>	<i>Myotis septentrionalis</i>	1/21/2004	1/27/2004	1/22/2004	2/11/2004
PIRO-03.18	PIRO-8/7/03-6-1-1	<i>M. lucifugus</i>	<i>Myotis lucifugus lucifugus</i>	1/21/2004		1/22/2004	2/11/2004

Table C1. Genetic voucher results for bat species captured in 2003 at Pictured Rocks National Lakeshore (PIRO), MI; Apostle Islands National Lakeshore (APIS), WI; and Grand Portage National Monument (GRPO), MN. Genetic analysis was done at Portland State University, where excess samples that were not destroyed during analysis were archived (J. Zinck, pers. comm.) (continued).

Lab ID	Sample ID	Field ID	Genetic Species ID	Extract	Re-do	PCR	SEQ
PIRO-03.19	PIRO-8/7/03-6-1-2	<i>M. lucifugus</i>	<i>Myotis lucifugus lucifugus</i>	1/21/2004		1/22/2004	2/11/2004
PIRO-03.20	PIRO-8/8/03-6-1-4	<i>M. lucifugus</i>	<i>Myotis lucifugus lucifugus</i>	1/21/2004		1/22/2004	2/11/2004
PIRO-03.21	PIRO-8/8/03-6-2-2	<i>M. lucifugus</i>	<i>Myotis lucifugus lucifugus</i>	1/21/2004		1/22/2004	2/11/2004

Appendix D. Data sets from 2003 bat inventory.

Data sets associated with this inventory include: (1) Geographic Information Systems (GIS) layers showing net station and Anabat stationary system locations; (2) Microsoft Access database containing all descriptive site data for net station and Anabat system locations, as well as all data associated with bats captured during the inventory; and (3) Anabat recording files, both original and edited/identified calls.

(1) GIS Layers

Pns2003_utm83_16 (.dbf, .prj, .sbn, .sbx, .shp, .shx): Locations of net stations for PIRO.

Pas2003_utm83_16 (.dbf, .prj, .sbn, .sbx, .shp, .shx): Locations of stationary Anabat systems for PIRO.

Ans2003_utm83_16 (.dbf, .prj, .sbn, .sbx, .shp, .shx): Locations of net stations for APIS.

Aas2003_utm83_16 (.dbf, .prj, .sbn, .sbx, .shp, .shx): Locations of stationary Anabat systems for APIS.

Gns2003_utm83_16 (.dbf, .prj, .sbn, .sbx, .shp, .shx): Locations of net stations for GRPO.

Gas2003_utm83_16 (.dbf, .prj, .sbn, .sbx, .shp, .shx): Locations of stationary Anabat systems for GRPO.

(2) Microsoft Access Database (NPS Bat Data)

(3) Anabat Files

Appendix E. Sampling site maps.

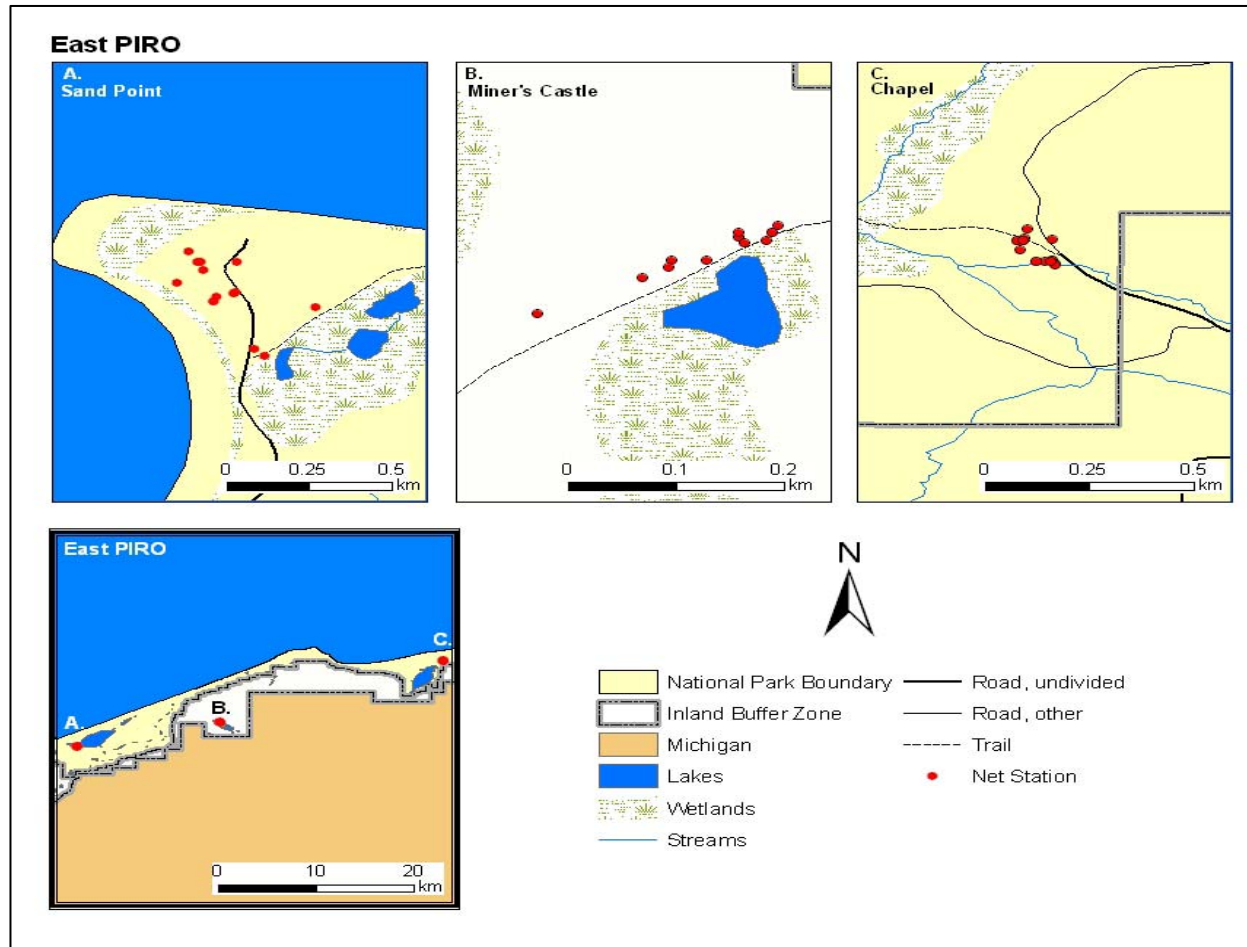


Figure E1. Location of mist-net stations for capturing bats at three sites in eastern Pictured Rocks National Lakeshore, MI, 2003.

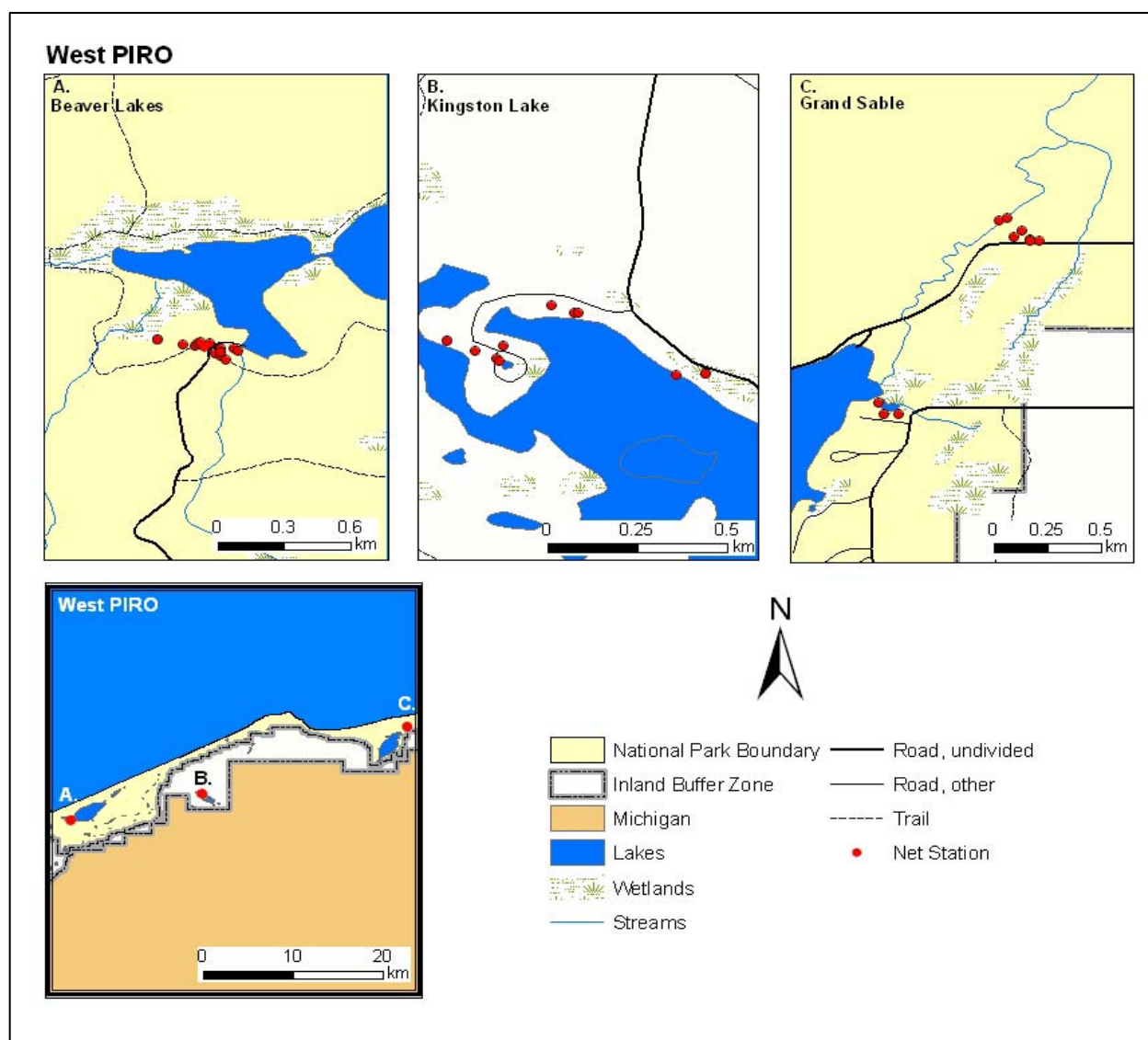


Figure E2. Location of mist-net stations for capturing bats at 3 sites in western Pictured Rocks National Lakeshore, MI, 2003.

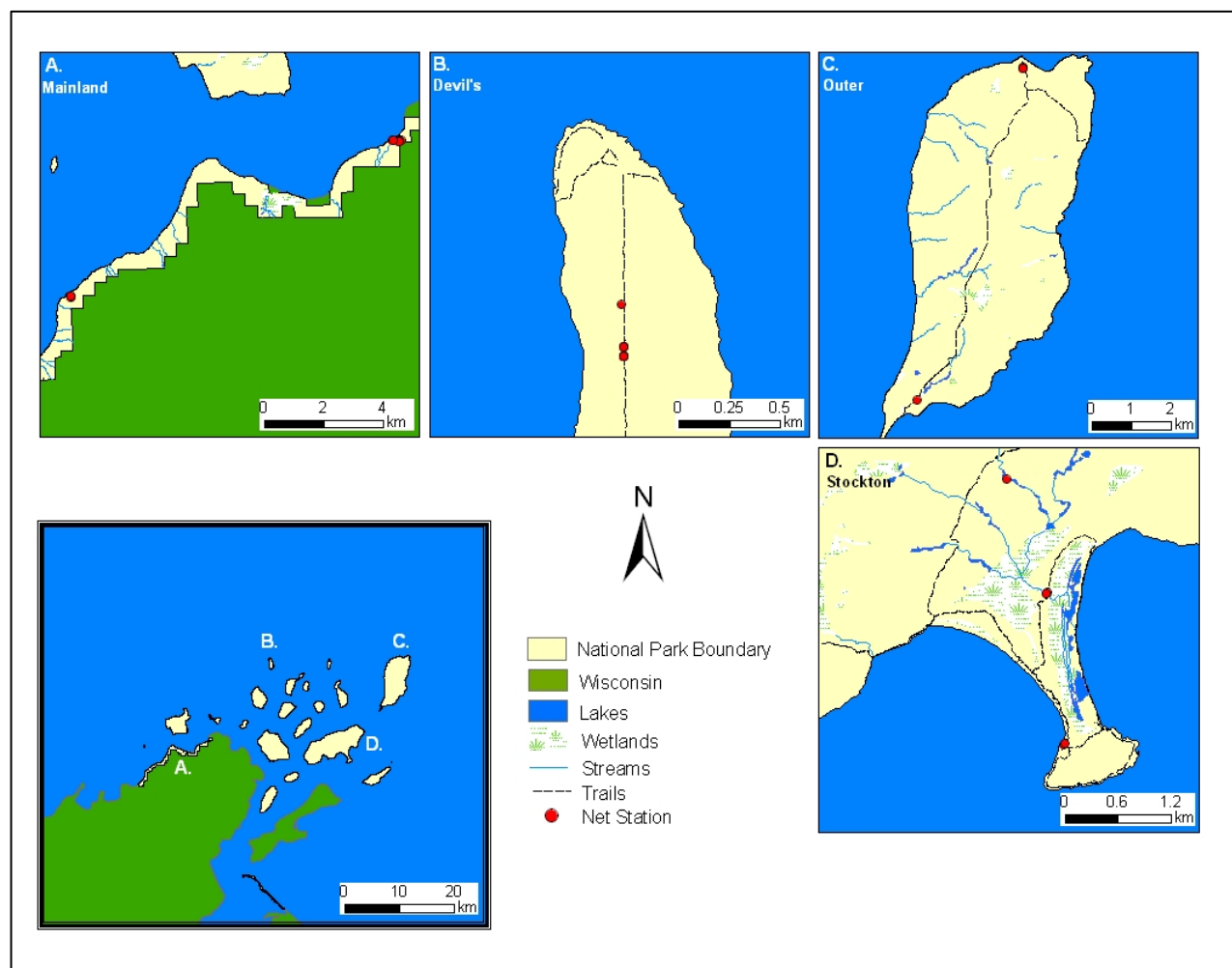


Figure E3. Location of mist-net stations for capturing bats at 4 locations in Apostle Islands National Lakeshore, WI, 2003.

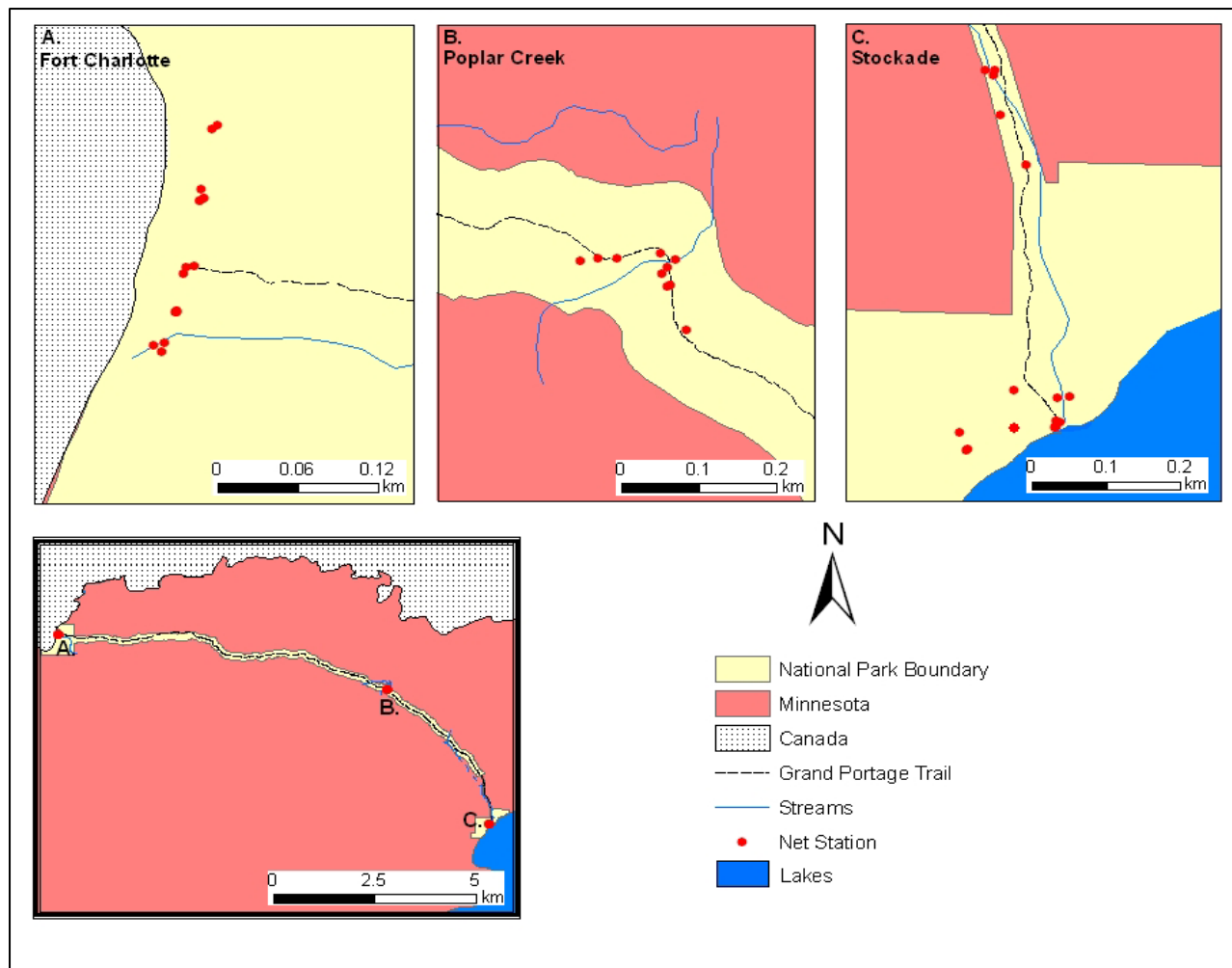


Figure E4. Location of mist-net stations for capturing bats at 3 sites in Grand Portage National Monument, MN, 2003.

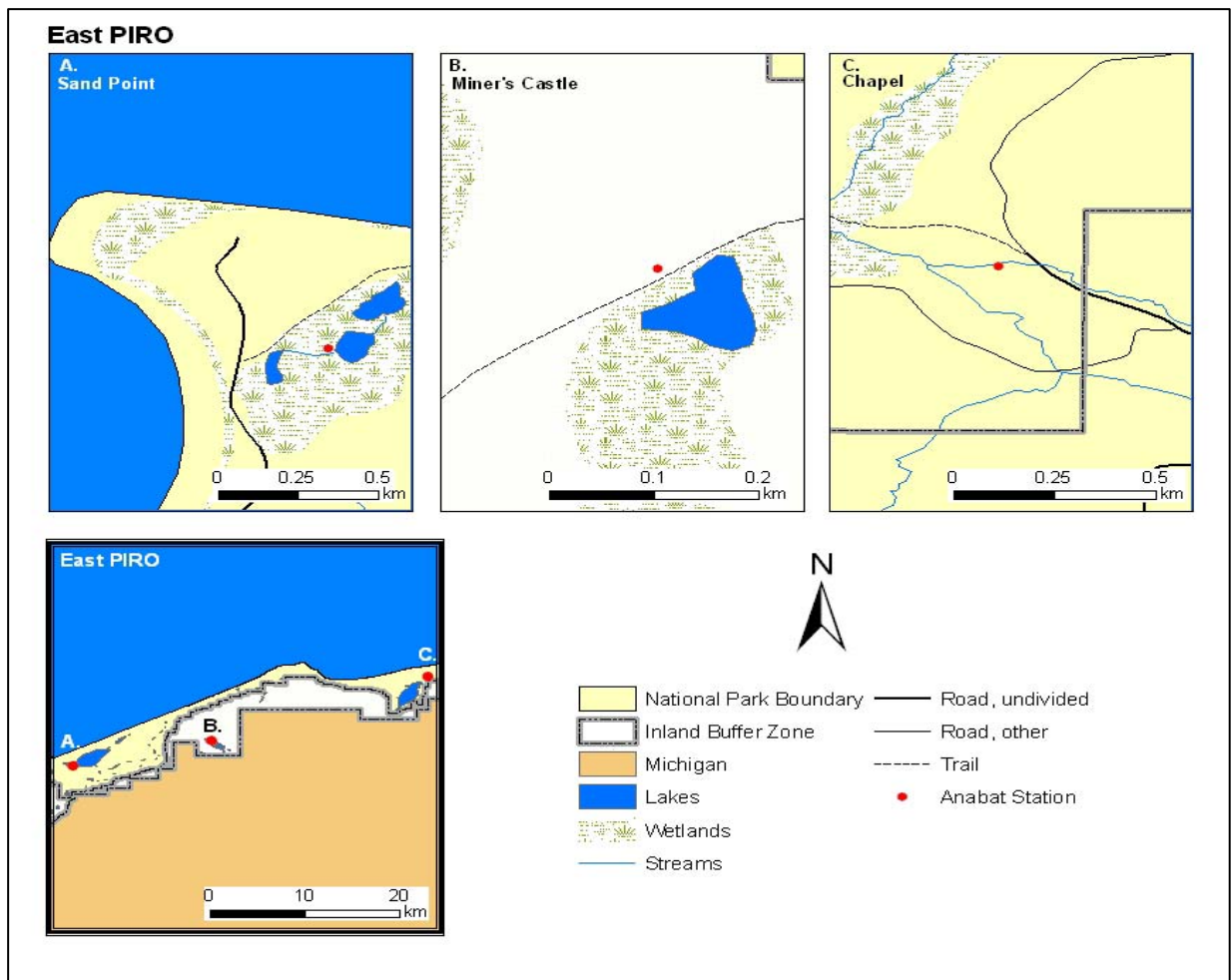


Figure E5. Stationary Anabat system locations for recording bat calls at 3 sites in eastern Pictured Rocks National Lakeshore, MI, 2003.

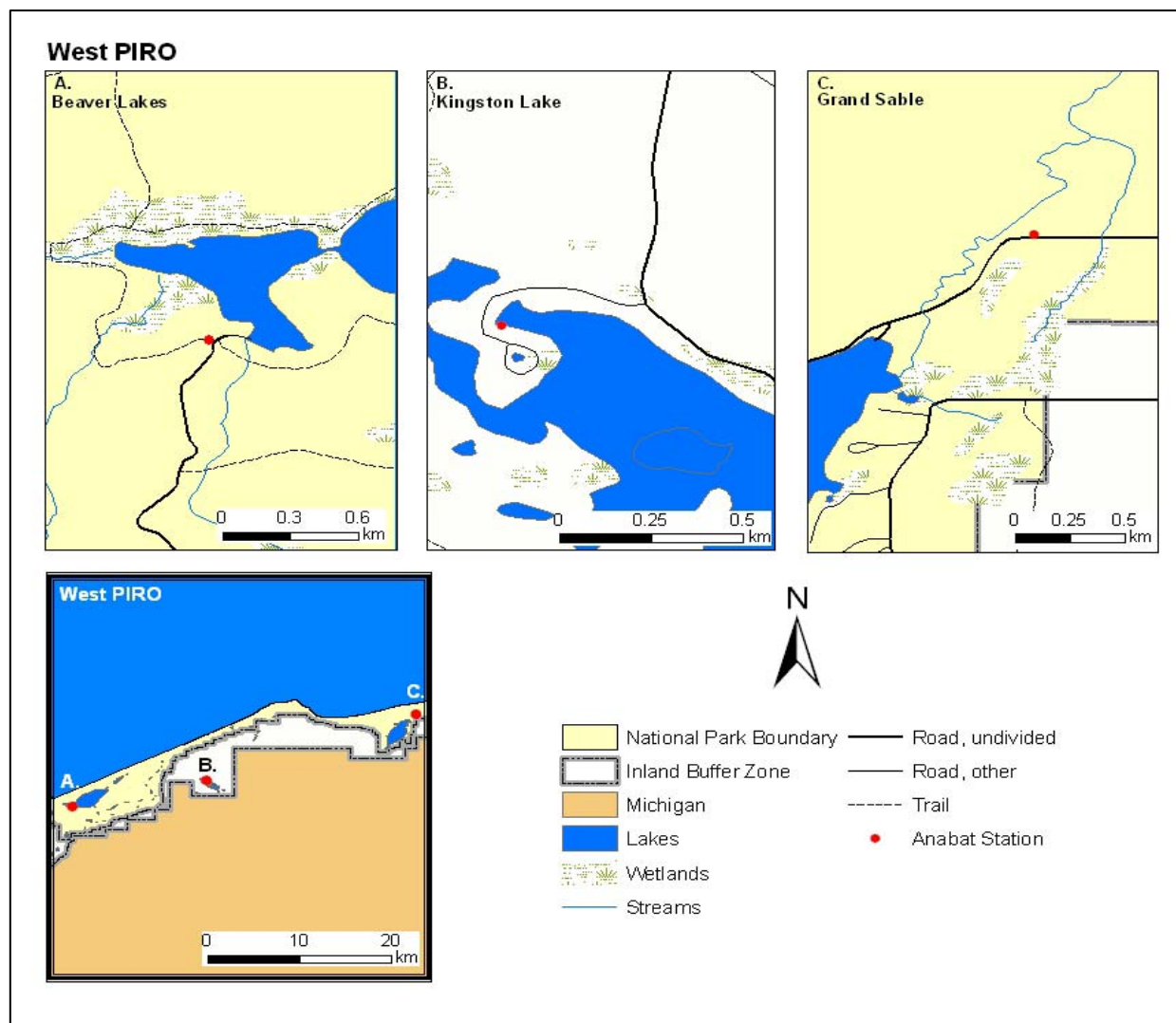


Figure E6. Stationary Anabat system locations for recording bat calls at 3 sites in western Pictured Rocks National Lakeshore, MI, 2003.

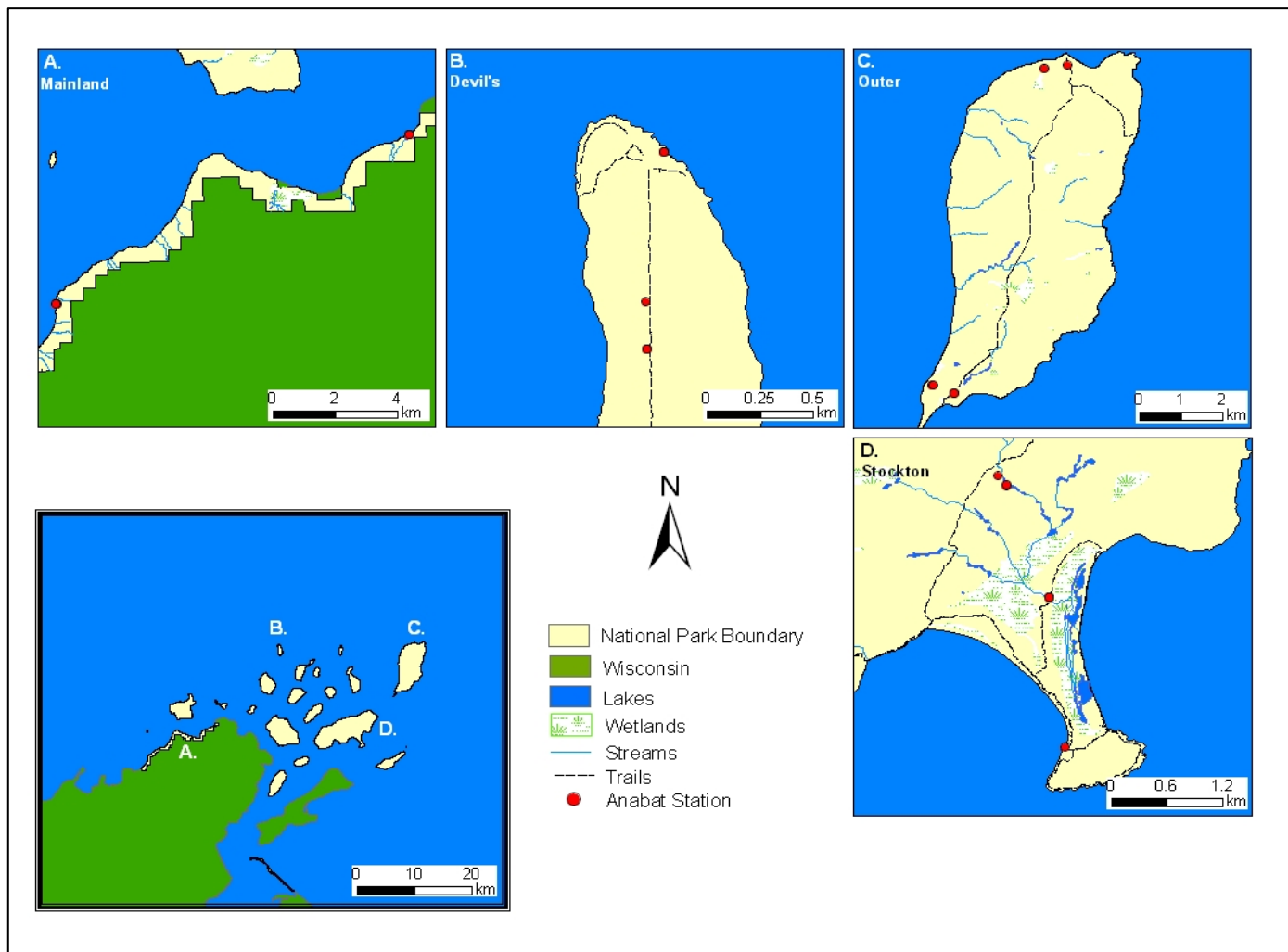


Figure E7. Stationary Anabat system locations for recording bat calls at 4 sites in Apostle Islands National Lakeshore, WI, 2003.

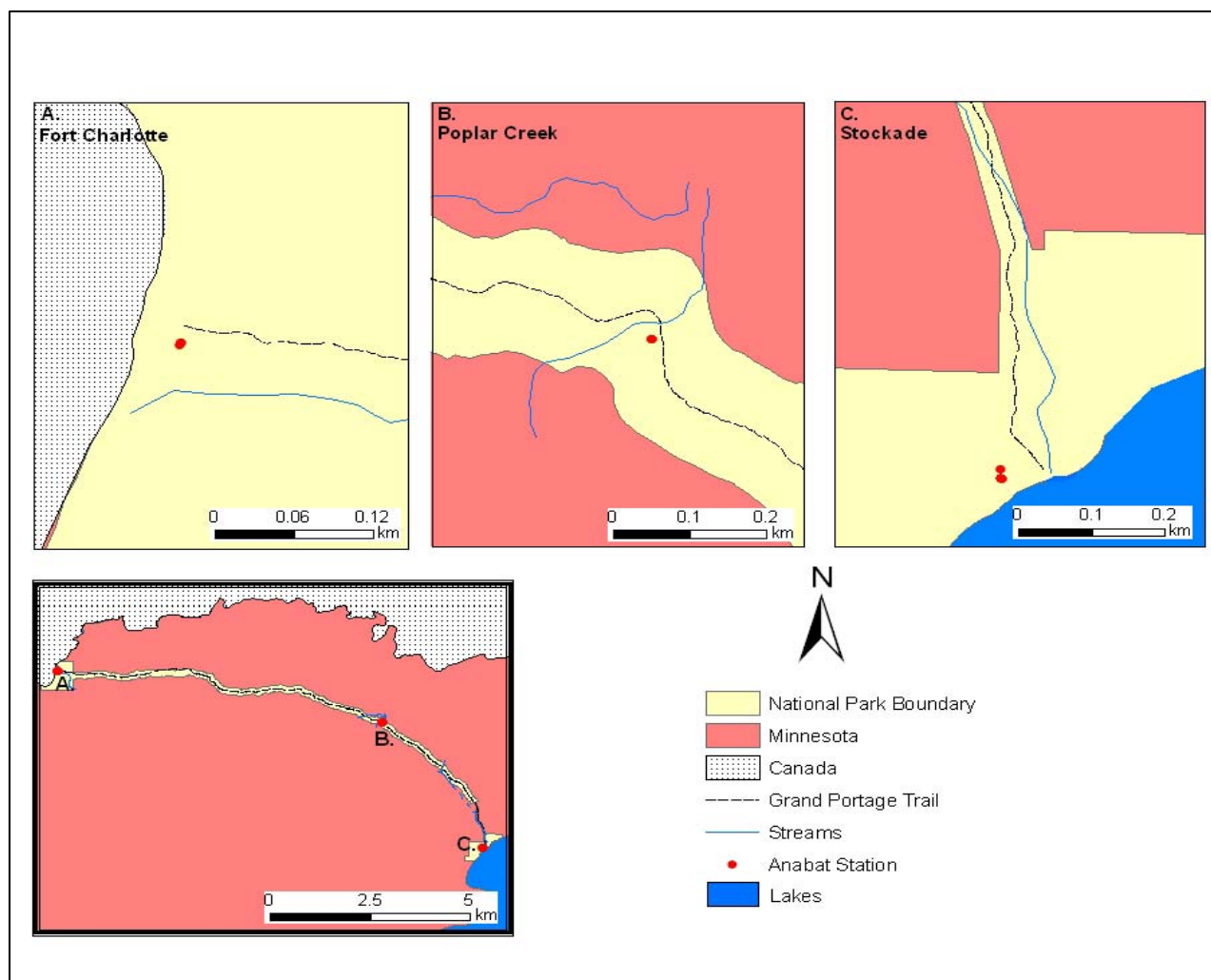


Figure E8. Stationary Anabat system locations for recording bat calls at 3 sites in Grand Portage National Monument, MN, 2003.

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