

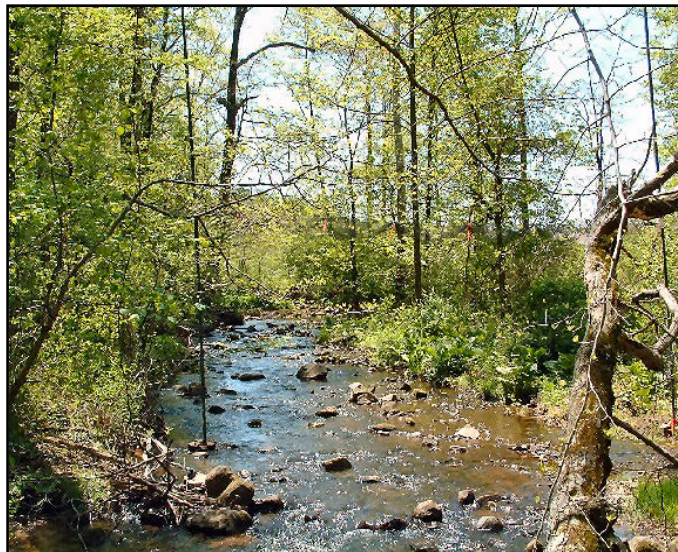
National Park Service
U.S. Department of the Interior

Northeast Region
Philadelphia, Pennsylvania



Inventory of Bat Community Composition at Hopewell Furnace National Historic Site

Technical Report NPS/NER/NRTR--2006/054



ON THE COVER

Photographs of a little brown bat (*Myotis lucifugus*), a northern long-eared bat (*Myotis septentrionalis*), and a survey site along French Creek just below the Hopewell Dam, Hopewell Furnace National Historic Site, during the 2004–2005 bat inventory. Photographs by: James A. Hart.

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James A. Hart

The Nature Conservancy
Pennsylvania Natural Heritage Program
208 Airport Drive
Middletown, PA 17057

September 2006

U.S. Department of the Interior
National Park Service
Northeast Region
Philadelphia, Pennsylvania

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Abstract and Keywords

During 2005, mist-netting surveys were conducted in the Hopewell Furnace National Historic Site (NHS) to predict and detect bat communities. Five sites were mist-netted for bats during 10 nights for a total of 46 netnights (the total number of nets set up multiplied by the total number of nights) and resulted in an average capture of 0.4 bats per netnight. A total of 18 bats comprised of four species were captured, including six little brown bats, *Myotis lucifugus* (four males and two females), three big brown bats, *Eptesicus fuscus* (two males and one female), two red bats, *Lasiurus borealis* (one male and one female), and seven northern long-eared bats, *Myotis septentrionalis* (three males and four females). No federally listed species were captured, although the northern long-eared bat is presently considered to be vulnerable in Pennsylvania and the northeast region of the U.S. Although all sites were set up along likely travel and foraging corridors, those sites where canopy closure and bank vegetation was greatest produced the most bats and the greatest diversity of species. Possible maternity colony sites in barns and outbuildings were also investigated through visual inspection. Although there were reports of solitary bats being excluded from several structures on the property, only the original horse barn had a permanent colony, which appeared to be wholly made up of little brown bats, numbering around 150–200 individuals.

Recommendations for future research include spring and fall surveys for silver-haired bats (*Lasionycteris noctivagans*), to ascertain whether this species uses parts of the park as “temporary stopover” sites, and more intensive surveys for use of forests by tree bats such as red and hoary (*Lasiurus cinereus*) bats. Determining habitat appropriateness for the northern long-eared bat should also be a focus for future surveys. The results of future research could be used to create a management plan that ensures that adequate habitat remains for these species and to promote continued survival of the other species. Artificial habitat in the form of bat boxes and possibly a bat “condo” could also be set up to sustain the present populations.

Keywords: NPS, inventory, monitoring, bats, *Myotis lucifugus*, *M. septentrionalis*, *Eptesicus fuscus*, *Lasiurus borealis*, Hopewell Furnace National Historic Site, endangered, conservation

Summary

Although the fauna of Pennsylvania has been studied extensively across much of the state, it has been investigated only recently in NPS properties such as the Hopewell Furnace National Historic Site (NHS). This study was initiated to predict and determine the bat communities within the park unit and to generate recommendations that would ensure that adequate habitat exists for these species without impacting the historical significance the site. To that end, five sites were surveyed over the course of ten nights for a total of 46 “netnights” and resulted in the capture of 18 bats of four species. The most common species captured were the northern long-eared (*Myotis septentrionalis*) and little brown (*M. lucifugus*) and big brown (*Eptesicus fuscus*) bats, comprising 88% of all bats captured and released. Although no known maternity colonies were found, the preponderance of the northern long-eared bat may indicate that the habitat within Hopewell Furnace NHS supports a stable population of this species

Recommendations for continued research include more surveys to assess use of forests by tree species such as the red (*Lasiurus borealis*) and hoary (*Lasiurus cinereus*) bats, spring and fall mist-netting for the silver-haired bat (*Lasionycteris noctivagans*), and continued monitoring of possible maternity sites. Recommendations also include the creation of artificial roost sites for bats in areas where the historical significance of the parks will not be impaired.

Acknowledgments

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Introduction

Background and Rationale

During the early 1970's Charles Mohr reported that bat species across the United States appeared to be in a serious decline (Mohr 1972). Although this study focused primarily on those species found hibernating in caves, mines, tunnels, and other underground sites, the article signaled an awareness that all bat species were most likely at risk due to a variety of factors, including habitat loss, disturbance to hibernacula and other winter sites, and loss of summer roosting sites. A concerted effort was begun throughout the United States to assess bat populations through visual inspection of winter hibernacula and examinations of buildings for indications of use by maternity colonies (O'Shea and Bogan 2003). In Pennsylvania, this took the form of bat hibernacula surveys conducted by PA Game Commission personnel and summer concentration counts primarily conducted by volunteers (Pennsylvania Game Commission, 1984 to present).

During the summer of 1999, the federally endangered Indiana bat (*Myotis sodalis*) was found roosting in an old church in Blair County along with over 20,000 little brown bats (*Myotis lucifugus*) (Butchkoski and Hassinger 2001). Although Cheng (2003) reported the discovery of Indiana bats using an historical barn in Iowa, the detection of the colony in Blair County indicated a need to survey for alternative summer roosting sites in the northeastern portion of the United States where known Indiana bat maternity sites normally occur in more traditional natural settings. Mist-netting surveys, across the state, and radio-tracking of banded Indiana and little brown bats were begun in order to determine the habitats used by these species and other summer resident bat species. Although the majority of these surveys and studies were conducted on private and state-owned property, comparative effort did not occur until relatively recently on property owned by federal agencies such as the National Park Service; however, several intensive studies were conducted in the Allegheny National Forest (Sanders Environmental, Inc. 2005, USDA-FS 2005).

Inventorying and monitoring programs and surveys are currently underway, or have been completed, at many Department of the Interior properties, including one at the Hopewell Furnace National Historic Site (NHS) directed at either assessing small mammal communities (Yahner et al 1997) or establishing terrestrial vertebrate survey protocols (Yahner et al 1994). Other recent studies include completed research on reptile and amphibians (Tiebout 2003) and avian communities (Yahner et al. 2001). Yahner et al. (2005) surveyed mammal communities at Valley Forge National Historical Park, but did not attempt to survey bat species occurrence due to the nature of conducting these types of surveys and the need for specially trained personnel. Prior to the present study there has been little to no research on Chiropteran communities at Hopewell Furnace NHS. This study was initiated to assess bat species occurrence within Hopewell Furnace NHS, but not to establish population numbers.

Predicted Species Occurrence

Eleven species of bats have been reported historically from Pennsylvania (Merritt 1987). Of these, the Seminole bat (*Lasiurus seminolis*) is considered an "accidental," most likely having entered the state from farther south during periods of stormy weather (Doutt et al. 1977). There

are currently only a few historic records of this species from the southeastern portion of the state (Roberts and Early 1952). Poole (1932) reported on a single capture of this species by Wishnieski during surveys conducted at the Hopewell Dam (Berks County) in 1931. No current records exist for the Seminole bat in Pennsylvania. Another species, the silver-haired bat (*Lasionycteris noctivagans*), is considered a “migratory” species, only occurring within the state during its migration to and from Canada and the New England states (Whitaker and Hamilton 1998). Although there are several current records from the interior portion of Pennsylvania (Kirkland and Hart 1999; Butchkoski, unpublished data, Pennsylvania Game Commission), all of these are during the migratory period and it remains unknown whether this species breeds in Pennsylvania or is resident during the summer months. Historical records from around Hopewell Furnace NHS are reported by Poole (1932) and Roberts and Early (1952). The evening bat (*Nycticeius humeralis*) has been reported from the southwestern (Grimm and Roberts 1950) and the southeastern (Rhoads 1903) portions of Pennsylvania, but there are no recent records for this species and it is believed extirpated from Pennsylvania (Genoways and Brenner 1985).

The remaining eight species have all been recently reported from many portions of Pennsylvania and include the little brown bat, northern long-eared bat (*Myotis septentrionalis*), eastern small-footed bat (*M. leibii*), Indiana bat, big brown bat (*Eptesicus fuscus*), eastern pipistrelle (*Pipistrellus subflavus*), eastern red bat (*Lasiurus borealis*), and hoary bat (*L. cinereus*). Of these eight species, it is unlikely that the Indiana bat would form summer colonies within Hopewell Furnace NHS due to an appreciable lack of adequate forest roosting habitat and large floodplain foraging habitat, although there is the possibility that migrating individuals may show up during spring or fall. Recently, it has been discovered that the small-footed bat forms maternity roost sites in rock outcrops (Veilleux 2005). An appreciable lack of such habitat in and around Hopewell Furnace NHS would most likely exclude the small-footed bat or limit populations to dispersing males and subadults in low numbers.

Historical Information

The most extensive surveys conducted around Hopewell Furnace NHS include those by S. Wishnieski during 1930–31, as reported by Poole (1932), concerning captures of the silver-haired, Seminole, and hoary bats along the Hopewell Dam.

Although it is known to be a summer resident, tree-roosting species such as the hoary bat are rarely captured in Pennsylvania. The PGC Bat Trapping and Netting Database contains only 24 records for this species. Hart et al. (1993) reported on the capture of two specimens of this species during research conducted by the Shippensburg University Vertebrate Museum. This bat is a fast flyer that is not very maneuverable and is usually not captured in net sets that are positioned to increase the chances of capture of greater numbers of species during basic inventories. Even though there are several open areas within HOFU where this species would likely be captured, these areas were not focused on to any appreciable degree due to the nature of the present study; although one site along a forest/field ecotone was surveyed.

Although bats have suffered from an unjustified reputation because of a wealth of bad press, the truth is that Pennsylvania’s bat fauna is wholly beneficial to agriculture as well as to visitors at Hopewell Furnace NHS. Able to consume upwards of 30 percent of its body weight in small insects, a little brown bat can consume as many as 150 mosquitoes in less than 15 minutes

(Fenton 1983; Tuttle 1988). It has been reported that large concentrations of bats are capable of controlling agricultural pests by consuming upwards of 250,000 lbs of insects in a single evening's foraging period (Tuttle 1988), as is the case at Bracken Cave, Texas. Although the species of bats found in Pennsylvania differ significantly from those occurring in Texas, they are still capable of having a substantial positive economic impact on agriculture, if conserved in sufficient numbers.

Study Area

General Description

Located approximately 10 km (6 mi) northwest of Pottstown, PA, the Hopewell Furnace National Historic Site encompasses around 350 ha (865 ac) (Yahner et al. 2001). Hopewell Furnace NHS occurs within the Piedmont Upland and Conestoga Valley sections of the Piedmont Province (Yahner et al. 2001; Tiebout 2003). Podniesinski et al. (2005) reported that mixed oak forest dominates the landscape and is comprised of white, chestnut, black, red, and scarlet oaks. Other deciduous species include ash, elm, tulip poplar, red maple, and black walnut. The shrub layer ranges from sparse within most forested areas to dense along portions of French Creek.

As mentioned, forested habitats of an early to mid-successional stage dominate approximately 78% of the land area, with 14% managed grasslands or agriculture, and a further 8% in developed lands (Podniesinski et al. 2005). The area is well drained, except along French Creek where floodplain shrublands and forest occur. Elevations range from 280 m (920 ft) in the northeast portion of the property to 140 m (460 ft) along French Creek (Tiebout 2003).

Drainage of the area is dominated by French Creek, although Baptism Creek drains the east central portion of Hopewell Furnace NHS and empties into French Creek. Other small, undefined intermittent tributaries empty into French Creek in many portions of Hopewell Furnace NHS but remain unnamed.

Site Selection

Site selection was begun during late winter and early spring by reviewing ArcGIS layers compiled by Pennsylvania Natural Heritage Program personnel (Podniesinski et al. 2005); i.e., Mr. SID views, digital ortho-quarter quads, and relative vegetation layers. This resulted in the description of five possible survey sites (depicted in Figure 1). Survey sites were then selected based on site visits and general guidelines established by Kunz and Kurta (1988). Mist-netting of bats is more productive when canopy closure is between 50–100%, shrub cover along stream banks is appreciable thick, and there is some form of vegetative structure to the area where the net will be placed. This structure can take the form of either downed trees or tree limbs or shrubs hanging over the stream and serving to break up the outline of the nets. An example of how such a survey site might appear is shown in Figure 2. Upon completion of site visits several of the proposed sites were deemed not suitable, due to either an appreciable lack of canopy or because access to the site would be problematical.

Sites were also selected where an elevated netting system could be used. In this case, canopy height was higher and more open than at sites using single high nets. An unobstructed view of what the elevated, or canopy, netting system looks like is depicted in Figure 3 and is intended as an illustrative example of the placement of the system. Five sites were selected for sampling upon completion of site inspections. Sampling locations and general habitat and stream descriptions are listed in Table 1. This information can be accessed in an accompanying database as mentioned under the Methods section.

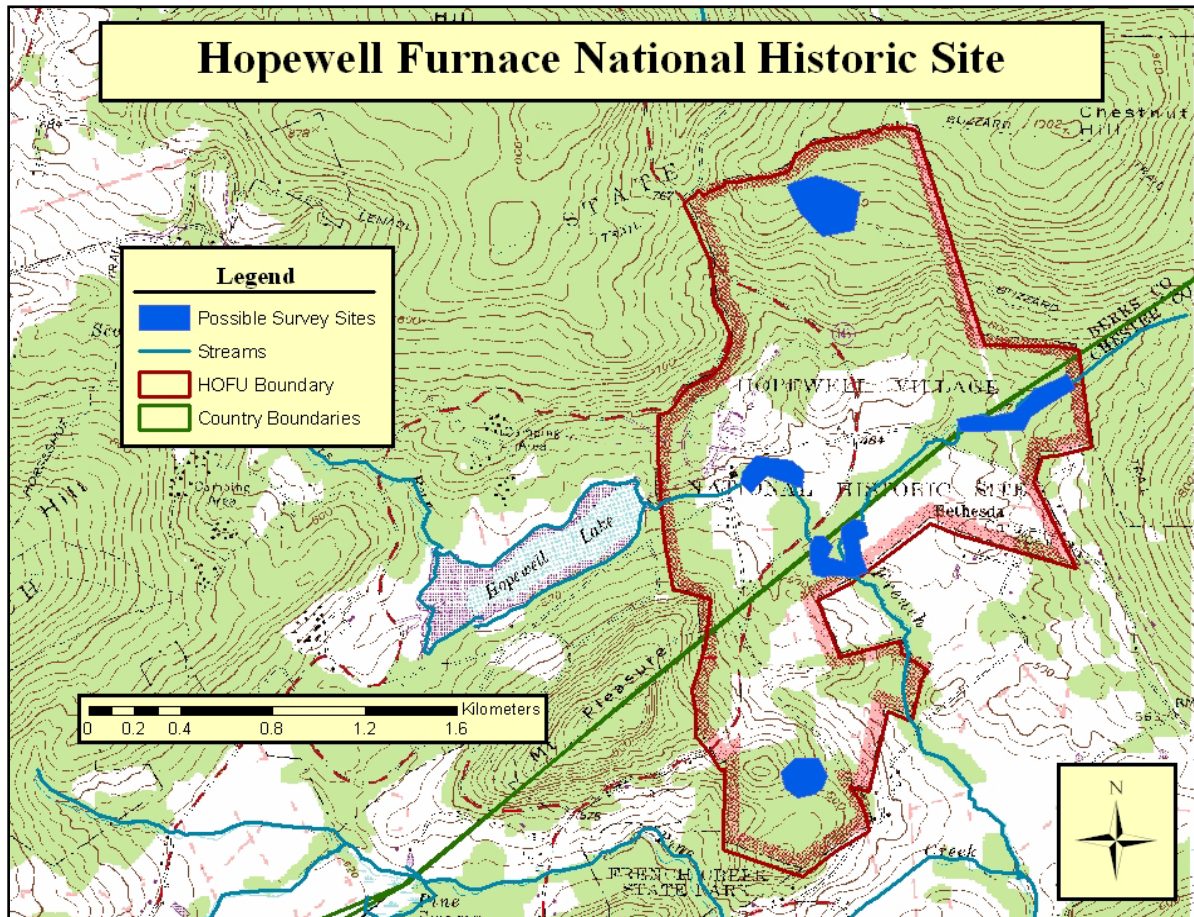


Figure 1. Potential sampling sites for the 2005 Hopewell Furnace NHS bat inventory.



Figure 2. An example of a site along French Creek, Hopewell Furnace NHS, where mist nets were placed. Canopy closure for this site is approximately 60–70% . The downed tree toward the right of the picture serves to break up the outline of the net. Shrub cover along the bank serves as a funnel, directing bats into the net.



Figure 3. Example of a 9 m high elevated/canopy system erected with three 6 m wide nets attached. This is similar to how the system would be set up at a predetermined mist-netting site.

Table 1. Habitat descriptions for all sites surveyed at Hopewell Furnace NHS during the 2005 bat inventory.

Site Number	Lat/Long, Elevation	Cardinal Directions	Basic Habitat Description	Habitat Formation	Stream Description
HOFU_BATS_HOFU01 French Creek #1	40-12-16.7/ 75-46-36.9 145 m	5.0km E. of Giegerstown,	Small stream emptying from the Hopewell Dam bordering Hopewell Furnace NHS. Habitat is primarily a young forest that shows varying degrees of disturbance. Forest is composed of American beech, yellow birch, red maple, sugar maple, white oak, tulip poplar, and sycamore with serviceberry, ironwood, redbud, multiflora rose, greenbrier, and poison ivy in the shrub layer.	I.B.2.N.a Lowland/submontane cold-deciduous forest	Primarily a small stream with varying canopy closure and steep banks to the north. A fairly flat, forest covered area lies to the south with the dam to the west and Hopewell Village to the east. Banks on either side are fairly flat right next to the stream, but the north bank slopes steeply uphill to the trail and than the road.
HOFU_BATS_HOFU02 Baptism Creek #1	40-12-32.3/ 75-45-29.3 160 m	5.7km N., 6.4km E. of Elverson	A small riparian corridor along Baptism Creek in a primarily maple/ash/hickory/poplar/oak forest. The surrounding habitat is mostly the same as the habitat bordering Baptism Creek. Shrub cover consists mostly of seedlings of the dominant tree species along with some greenbrier. Very little other shrubbery occurs except for some blueberry.	I.B.2.N.a Lowland/submontane cold-deciduous forest	This is a very small stream bordered by a relatively young forest. It is fairly shallow, narrow, and of low flow. Banks are mostly flat except in some places where they range from gently sloping to steep. They are mostly open and not covered by shrubs except where increasing sunlight occurs.
HOFU_BATS_HOFU03 French Creek #2	40-12-06.6/ 75-46-08.7 140 m	4.9km N., 5.5km E., Elverson.	Riparian corridor along French Creek. Floodplain forest extends from 15 to 50 m on both sides of stream. The surrounding forest is basically a very young successional, floodplain forest.	I.B.2.N.a/ I.B.2.N.e A mixture of lowland/submontane and seasonally flooded cold-deciduous forest	Deeply cut, meandering stream with high banks in spots and very level banks in other spots. Banks are generally 0.5–1.5 m high and very steep in some spots.
HOFU_BATS_HOFU04 Baptism Creek #2	40-12-27.7/ 75-45-36.8 150 m	5.6km N., 6.2km E. of Elverson.	A small riparian corridor along Baptism Creek in a primarily maple/ash/hickory/poplar/oak forest. This site was much the same as HOFU02 except that the understory and shrub layer is sparser. Canopy closure is a bit higher. The surrounding habitat is mostly the same as the habitat bordering Baptism Creek.	I.B.2.N.a Lowland/submontane cold deciduous forest	This is a very small stream bordered by a relatively young forest. It is fairly shallow, narrow, and of low flow. This site had several spots where the banks were a bit higher and steeper than HOFU02. Banks are mostly flat, except in some places where they range from gently sloping to steep. They are mostly open and not covered by shrubs except where increasing sunlight occurs.
HOFU_BATS_HOFU05 Harrison Loyd field	40-11-52.8/ 75-46-18.3 175 m	4.1km N., 5.2km E. of Elverson	Basically a series of grasslands surrounded by woodlands. There are tree lines separating the fields from each other and the woods are fairly young in age and successional in nature. The surrounding habitat is much the same as above with French Creek lying down slope by about 200 m to the north.	I.B.2.N.a Lowland/submontane cold deciduous forest	This was primarily a forest/agricultural field combination of habitats. No stream existed within approximately 250 m.

Methods

USFWS Guidelines and Basic Netting Protocols

The United States Fish and Wildlife Service (1999) created guidelines specific for the survey of Indiana bats (See Appendix A). Due to the nature of this particular survey, however, these guidelines were modified to suit a basic inventory of bat species occurrence.

Field sampling was conducted during July and September of 2005. Two to four ground net sets and either stacked (two or more nets stacked one above the other) or elevated nets (extended poles with a pulley system as depicted in Figure 3) were employed in places where the canopy closure permitted set up of a higher system. The nets were 50 denier and ranged in size from 4–6 m (13–20 ft) in width. The nets were opened at dusk and closed no later than 2400 hrs. Each site was surveyed for two nights. Presence of bats was confirmed as either seen foraging in the vicinity of the netting site or heard on a Skye[®] (Skye Instruments Ltd.) bat detector. The nets were checked every 10 minutes or less, depending on the activity level of the bats and the number being captured. Bats were put into holding bags after being identified as to species, sex, age, and reproductive condition. Bats were held until the end of the evening to preclude the chances of being recaptured. Prior to release all bats were measured and weighed.

Although this method of survey generally follows the accepted protocols used by the USFWS in surveying for the federally endangered Indiana bat, it differed somewhat in that mist netting was not extended past 2400 hrs. Also, it is unlikely that the Indiana bat occupies any permanent roosts during the summer due to a lack of available summer roosting habitat at Hopewell Furnace NHS, as the forest is primarily early to mid- successional with an open understory due mainly to heavy and persistent browse by deer.

It should be noted that the use of an Anabat (Titley Electronics[®]) bat detecting system was not employed. The goal of this project was to provide an inventory of species occurring within Hopewell Furnace NHS. The Anabat[®] system is unable to differentiate between the *Myotis* species that occur in Pennsylvania without the creation of an extensive call database with which statistical comparisons can be made. Since the cost of the system and the creation of the call library would be prohibitive for this study, it was decided that traditional methods using mist nets would produce adequate results.

Data Acquisition and Recording

Habitat data, weather information, site location, and other pertinent information was recorded on standard forms created by the Wildlife Diversity Section of the Pennsylvania Game Commission's (PGC) Bureau of Wildlife Management. The survey sites were GPS'd with a Garmin GPS III+ to an estimated precision of 3–9 m and a Positional Dilution of Precision of 1.5–2.0. All GIS information was saved in UTM NAD 83, Zone 18. The nature of these surveys did not require any closer precision than mentioned, so acquired GPS points were not differentially corrected.

Individual bats were measured with digital calipers (Sylvac S.A., Switzerland) and data directly input into an Excel spreadsheet (Microsoft[®]) using Gagewedge[®] (Fred V. Fowler Co., Inc)

software. Just prior to release bats were weighed on an Ohaus[®] CS 200 scales (Ohaus Corporation, NJ) and data was hand entered into the Excel spreadsheet. A researcher taking measurements with digital calipers is shown in Figure 4. Other data entered included the species captured, age classified as either juvenile or adult based upon presence of epiphyseal closure (Anthony 1988), sex, and reproductive condition. Reproductive condition included either active or inactive males, based on the condition of the epididymis, or pregnant, lactating, post-lactating, and inactive females. Voucher digital photographs were taken of all PA state-listed species. No federal species were captured.

Habitat information collected included stream width and depth in meters, percent canopy closure, condition of stream banks, percent shrub and ground cover, description of typical vegetation, and general descriptions of habitat within 100 m (328 ft) of site and that greater than 100 m (328 ft), if different (Table 1).

Database Creation

Data collected during the surveys was entered into the PGC's Bat Trapping and Netting Database. A copy of this database was created containing only the information gathered during the present survey. All information entered was submitted to the Wildlife Diversity Section, Bureau of Wildlife Management, Pennsylvania Game Commission, for inclusion with the PGC database and as general information for the PGC Annual Report concerning bat surveys conducted in Pennsylvania (Pennsylvania Game Commission 1984–present).

A habitat profile database was created using Microsoft Access XP[®] (Microsoft Corporation). This database has descriptions of the habitat surveyed as well as fields containing information on several habitat variables such as stream width, depth, canopy closure, and vegetation types. The database is set up to be linkable with the PGC database and includes descriptive photos of the sites surveyed.

Maternity Colony Investigations

Two species expected to occur in Hopewell Furnace NHS, little brown and big brown bats, are known to form maternity colonies in buildings. These colonies can range in size from a couple dozen to well over 20,000 bats (Pennsylvania Game Commission 1984–present). Barns and outbuildings were checked for signs of use by bats during the course of the present investigation. This sign normally takes the form of locating large guano deposits and/or actually seeing and counting bats during evening counts. While the occasional “wandering” bat has been reported from several of the buildings at Hopewell Furnace NHS, only the horse barn currently contains a moderately sized population of around 150–200 individuals.



Figure 4. A researcher taking the measurement of the forearm of a big brown bat during inventories at Hopewell Furnace NHS, 2005.

Results

Five sites were surveyed for bats during the project (Figure 5). Dispositions of nets at each survey site are depicted in Appendix B for future reference.

Over the course of ten nights of surveys, 46 “netnights” were accumulated. A “netnight” can be described as the total number nets put up at a site multiplied by the number of nights the site was surveyed. Results of these surveys are depicted in Table 2.

A total of 18 bats of four species were captured for an average of 0.4 bats/netnight (2.3 bats per 100 net-meter hour). Species captured included three big brown bats (two male and one female), six little brown bats (four male and two female), two red bats (one male and one female), and seven northern long-eared bats (three male and four female).

As previously mentioned, only the horse barn contained a maternity colony of bats. There are no current plans to either evict this colony or otherwise disturb the bats. Although no census counts of this colony were conducted, an estimation of between 150–200 bats was made by visual inspection during daylight hours. An exterior picture of the horse barn is shown in Figure 6. A covered wagon with some bird droppings and bat guano on the covering is shown in Figure 7.

The sites mist-netted ranged from a small stream (Baptism Creek) of no more than 1–1.5 m (3–5 ft) in width with depths of less than 0.5 m (1.5 ft) to a moderately-sized stream (French Creek) over 2–4 m (6.5–13 ft) wide with a depth of up to 1 m (3 ft) (Table 1). In most cases, the canopy was closed, ranging from around >50% to over 75% and in several cases greater than 90%. In only one case where the elevated system was situated along the interface of a forest trail and agricultural field on the Harrison Loyd site was the canopy closure low. Information concerning the general habitat at each site can be found in Table 1.

Descriptive statistics for all adult bats captured at Hopewell Furnace NHS during the surveys conducted from May through September 2005 are contained in Table 3. Numbers denoted in **bold** are means that differ from those found in the literature. In all cases, these means were a bit lower than those found in the cited literature and may be accounted for by measurement error or by a lack of specimens caught in this study. In some cases, the means may be affected by geographical differences, but it is unknown just how much this may affect bat species at Hopewell Furnace NHS, as the length of the project was not long enough to ascertain these differences. No measurements were included for those individuals that were seen to be either subadults or juveniles as classified by visual inspection of the epiphysis of the wing.

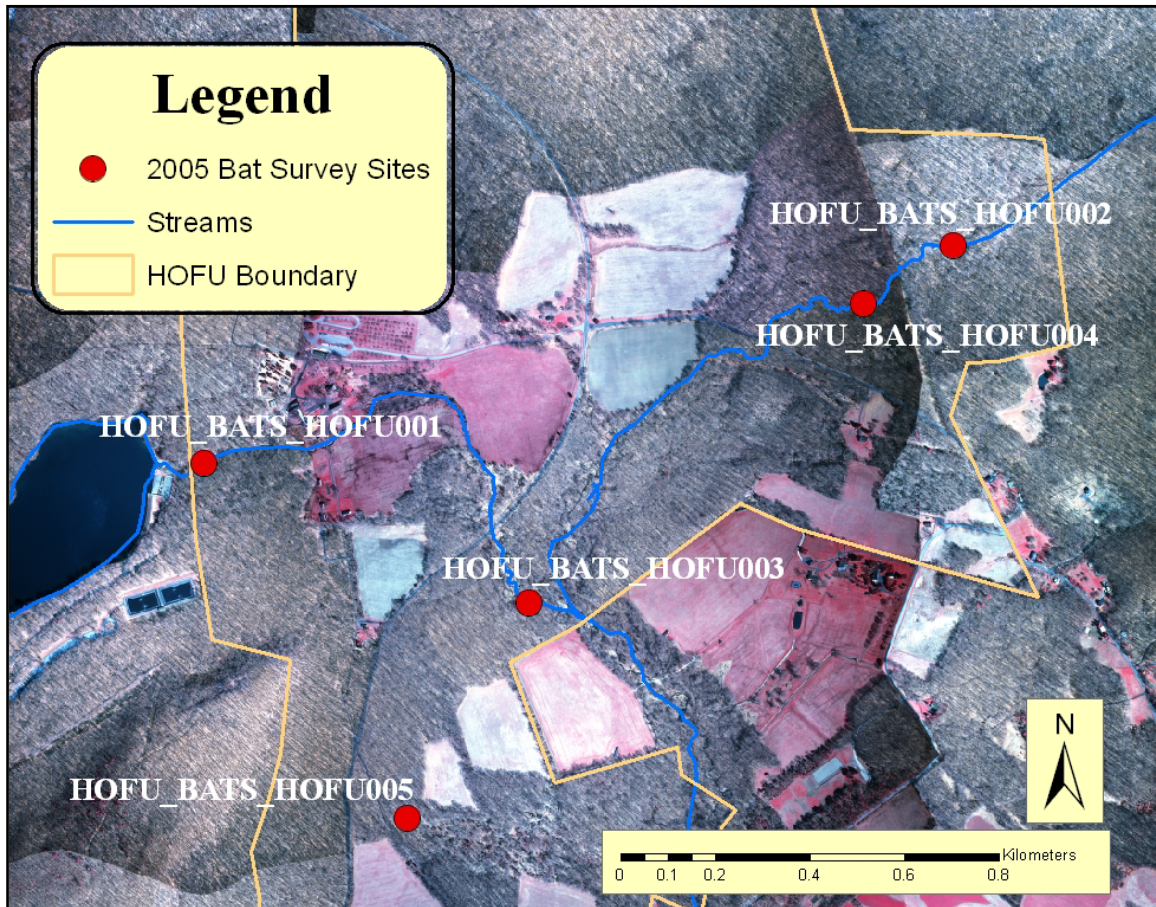


Figure 5. Location of mist-netting survey sites in Hopewell Furnace NHS during the bat inventory of 2005.

Table 2. Results of mist-netting surveys at Hopewell Furnace NHS during 2005.

Site Surveyed	Site #	Effort ¹	Date	Species ²								Total
				Labo		Mylu		Epfu		Myse		
				M	F	M	F	M	F	M	F	
Hopewell Dam (French Creek)	HOFU01	175.5 nmh	5/9–5/10, 2005			2	2			1	1	6
Baptism Creek #1	HOFU02	126.0 nmh	6/5–6/6, 2005			1				1		2
French Creek	HOFU03	120.0 nmh	7/11–7/12, 2005									0
Baptism Creek #2	HOFU04	156.0 nmh	8/1–8/2, 2005	1	1	1		1			3	7
Harrison Loyd Site	HOFU05	210.0 nmh	9/12–9/13, 2005					1	1	1		3
Subtotals (by sex)				1	1	4	2	2	1	3	4	18
Totals				2		6		3		7		

¹Effort is reported as net-meter hours.

²Labo- *Lasiurus borealis*, Mylu- *Myotis lucifugus*, Epfu- *Eptesicus fuscus*, Myse- *M. septentrionalis*, M- Male, F- Female, Netnights are explained in the text.



Figure 6. The horse barn at Hopewell Furnace NHS where a small maternity colony of little brown bats occurs.



Figure 7. This covered wagon sits directly below the maternity colony in the horse barn at Hopewell Furnace NHS. Note the droppings on the cover consisting of both bird droppings and some bat guano.

Table 3. Descriptive statistics for all bats captured during 2005 mist netting surveys at Hopewell Furnace NHS.

Species	Stat	Hind Foot (mm)	Ear (from notch) (mm)	Forearm (mm)	Tragus (mm)	Weight (g)
<i>Myotis lucifugus</i>	Mean	7.17	11.50	37.58	5.73	7.02
	Medium	7.29	11.08	37.22	5.48	6.80
	Maximum	7.41	13.68	38.92	7.31	8.20
	Minimum	7.14	9.72	37.06	4.49	5.80
<i>Eptesicus fuscus</i>	Mean	7.52	14.65	45.02	6.48	19.70
	Medium	7.41	14.16	45.60	6.52	20.30
	Maximum	8.10	16.17	47.22	6.73	21.60
	Minimum	7.05	14.16	42.23	6.18	17.20
<i>Lasiurus borealis</i>	Mean	6.94	9.73	41.53	3.54	14.90
	Medium	6.94	9.73	41.53	3.54	14.90
	Maximum	6.94	9.73	41.53	3.54	14.90
	Minimum	6.94	9.73	41.53	3.54	14.90
<i>Myotis septentrionalis</i>	Mean	6.39	16.32	35.40	8.57	6.07
	Medium	6.45	16.45	35.08	8.62	5.80
	Maximum	7.34	17.48	34.57	9.87	5.30
	Minimum	5.39	15.03	36.54	7.23	7.10

Note- Mean measurements in bold differ from those means as listed in various publications including Barbour and Davis 1969, Caceres and Barclay 2000, Fenton and Barclay 1980, Kurta and Baker 1990, Shump and Shump 1982 and Whitaker and Hamilton 1998.

Discussion

In a landscape where habitat is being lost at alarming rates everyday (Steiner et al. 2000), any protected setting that may serve as refugia for native wildlife should be comprehensively inventoried and a plan for monitoring of the results initiated. The NPS has been charged with “preserving, conserving, and managing natural resources in all of the national parks.” Although, in some cases, various species assemblages may be overlooked due to their secretive nature or the fact that basic inventories may be difficult and time consuming. Historically, National Park Service units in Pennsylvania have not garnered the attention that National Forest lands have when it comes to inventories of the faunas occurring on them. In order to meet the requirements of future wildlife conservation of both federal- and state-listed species of concern, inventorying and monitoring strategies have been, or are being developed for all NPS units, including the Hopewell Furnace NHS.

During the period between May and September of 2005 mist-netting surveys were conducted along streams in Hopewell Furnace NHS. Although only 18 individuals of four species were captured, the capture of one pregnant and one post-lactating female northern long-eared bat suggests that forest resources within Hopewell Furnace NHS are adequate for the formation of small maternity colonies of this species.

Overall, however, forest age and structure is such that cavity availability for roosting bats is relatively low and competition for the limited resources may currently restrict the chiropteran community and populations. Humphrey (1975) showed that habitat structure and roost site availability were important contributing factors to maintaining a diverse community as well as sound populations. In the present study, very little snag formation was found throughout most of the available forests and mid-canopy type structure was lacking. The lack of both a viable shrub layer and mid-canopy may be the result of heavy browse by deer as well as long-term impacts from the intensive cutting that took place during furnace operations when the area was mostly denuded. Snags, which appear to be lacking in much of the forested portions of Hopewell Furnace NHS, are very important to bats as summer roosting sites. They also serve as night roost sites when bats are foraging and need protected sites as temporary thermal-neutral roosts (Neuweiler 2000). In several portions of the eastern United States, snags have been created by girdling unwanted tree species to provide the necessary cavities and flaking bark for the formation of maternity and night roosts (Saugey 1991; Noteman 1998).

Another type of roost site lacking in the vicinity of Hopewell Furnace NHS are winter hibernacula. The nearest known hibernaculum of substantial size occurs approximately 80 km (50 mi) to the northeast at Durham Mine in Bucks County, a site which contains over 8,000 bats of five species (Pennsylvania Game Commission 1984–present). As the distance between summer and winter habitat increases and populations have greater areas to disperse across, populations found at sites like Hopewell Furnace NHS remain comparatively low when compared to areas where winter hibernacula are nearby. Although a few small caves and mines occur nearby, none of these are adequate as hibernacula or are so disturbed that bats are excluded from them (Pennsylvania Game Commission 1984–present).

Yahner et al. (1994) erroneously based the prediction of occurrence of a bat species on range maps found in Burt and Grossenheider (1980), a relatively poor source for this type of information due to the scale of maps used and the out-of-date nature of the publication. More current and accurate sources of information are available, including Hall (1981), Kurta (1995), and Whitaker and Hamilton (1998). Another factor determining predicted bat community structure in a given area is the availability of both foraging and roosting habitat (Findley 1993). Although the range of a species may extend into the study area, the lack of specific temporal roost sites (maternity roosts during summer for females, temporary night roosts used between feeding bouts, winter hibernacula, etc.) serves to restrict the number of species that may occur within a specific portion of the predicted range.

In many instances the community present at a specific point in time will be determined by a variety of factors, including temperature, prey availability, and overall habitat structure (Barclay 1985). Because of these factors, predicting the overall bat community expected to occur within Hopewell Furnace NHS at any given point in time may be problematical. Although this may best be overcome by increasing the number of sites surveyed and spreading the survey of a single site over an extended seasonal timeframe, varying insect hatches offsite, temperature, wind speed, and many other factors may hinder the capture of rarer species.

As mentioned in the Introduction, both the Seminole bat and the silver-haired bat have previously been taken in the vicinity of the Hopewell Dam. It is likely that the Seminole bat was an “accidental” that may have come onshore and inland after heavy storms during the 1930s, as it has not been reported since. The silver-haired bat, however, has been taken in several portions of Pennsylvania, including the southcentral and southwestern regions (Kirkland and Hart 1999), and was captured during surveys conducted by consultants in the northern regions, as reported in the Pennsylvania Game Commissions Bat Trapping and Netting Database maintained by the Wildlife Diversity Section (Pennsylvania Game Commission 1984–present). All specimens of the silver-haired bat were taken when this species was most likely migrating through Pennsylvania, either to northern summer roosts or southern winter roosts. It is possible that intensive surveys conducted along French Creek could produce a specimen of the silver-haired bat, but that would not provide evidence of residency in Pennsylvania unless captured during the summer in breeding condition.

Two species that could occur at Hopewell Furnace NHS, although unlikely, are the small-footed bat, listed as threatened in Pennsylvania (Genoways and Brenner 1985), and the Indiana bat, listed as federally endangered. As mentioned previously, the roosting ecology of the small-footed bat is becoming a bit clearer with the likelihood that they use rock outcrops to form nursery colonies (Veilleux 2005). Although it remains unknown where adult males spend the majority of their summer, there is some evidence that male small-footed bats may use a variety of roost sites during portions of the summer, including tree cavities, rock outcrops, and buildings (Best and Jennings 1997); however, this information remains anecdotal at best. Preferred habitat for female small-footed bats at Hopewell Furnace NHS is extremely limited or nonexistent. It is unlikely that this species would be an important component of the present chiropteran fauna.

The Indiana bat is not known to ever have occurred within the vicinity of Hopewell Furnace NHS. This species needs very specific habitat for both summer maternity roosts and winter hibernacula, none of which currently occur within or around Hopewell Furnace NHS. Forest age

and type presently do not provide adequate roost sites for this species, while the nearest winter hibernacula lies over 150 km (93 mi) to the north in Luzerne County within a coal mine (Pennsylvania Game Commission 1984–present).

Of the species recorded during the survey, the one that appears to be of the most interest is the northern long-eared bat. Although the northern long-eared bat has been listed in Pennsylvania as “at risk” (Genoways and Brenner 1985), and most recently as “rare” (Kirkland and Krim 1990), recent information suggests that it is more common than formerly believed. Although it has been suggested that this species be removed from the Pennsylvania “Species of Special Concern” list as developed by the Mammal Technical Committee of the Pennsylvania Biological Survey, the decline of bat populations in general throughout the northeastern United States warrants continued protection.

The northern long-eared bat was the most prevalent bat recorded during the surveys and was nearly 1:1 in terms of sex ratio. This would appear to indicate that adequate habitat for this species occurs at Hopewell Furnace NHS. Caceres and Barclay (2000) report that researchers have found that this species favors early to mid-successional forests where large diameter trees may be in an early stage of decay with more open canopy. In some cases, Caceres and Barclay found females roosting in small groups in buildings. It is unknown whether any northern long-eared bats occur within the colony found in the horse barn. One reason for the number of northern long-eared bats taken, in comparison to other species, is possibly that this species prefers to forage along open corridors where it can either hawk prey or glean it off of some form of substrate (Kirkland 1997), making it more likely to be captured. It is feasible that this species would benefit by the introduction of some artificial roosting boxes (Burke 1999) within the forest so that competition with other bat species for limited roosting sites does not occur.

The remaining three species, the eastern red bat, little brown bat, and big brown bat, are all species that have a widespread occurrence throughout Pennsylvania. During this entire project (in Hopewell Furnace NHS, Valley Forge NHS, Gettysburg NMP, and Eisenhower NHS) these species accounted for over 85% of the bats captured. All these species are listed as secure in Pennsylvania, but, as with other species of bats, populations are believed to be depressed when compared to likely historical numbers (Mohr 1972).

One species missing from the list of captured bats is the eastern pipistrelle. This species is widespread throughout much of Pennsylvania, but is less likely to be captured in mist nets than the species captured during this survey. Although Fujita and Kunz (1984) note that this species forms maternal colonies in buildings, none are known to occur in Pennsylvania except for a number of very small colonies at several state parks located in forested areas (Pennsylvania Game Commission 1984–present). The majority of these occur in small, non-residential outbuildings. Although it remains unknown what the primary foraging habitat is for this species, it is most often caught over water in areas where canopy cover is fairly dense. It is a slow, fluttery flier and its ability to detect and maneuver around nets often precludes its capture (Barbour and Davis 1969). Several eastern pipistrelles, however, were captured in the Eisenhower National Historic Site during this project in mist nets set along Marsh Creek (Hart 2005). This was a very wide stream with a moderate canopy, except in the area where this species was captured where overhanging branches and background shrubs served to break up the outline of the nets. Since French Creek provides the habitat necessary for the eastern pipistrelle,

further surveys conducted along the stream may reveal the presence of this species at Hopewell Furnace NHS.

When comparing the sites investigated, Baptism Creek and French Creek in the vicinity of the dam produced the most bats, while Baptism Creek was the most diverse in terms of species captured. It is likely that habitat structure played a role in providing both foraging corridors and roosting sites within these areas. The canopy at both sites was fairly closed and full, and structure between mid- to upper-canopy was diverse. Although shrub cover was low to moderate within the forest, along the streams it was appreciable higher, although quantitatively unstudied. It is likely that some form of forest management at these sites as well as other sites across Hopewell Furnace NHS can improve habitat for bats over time as the forest matures.

Prey base for foraging bats is an item that was not studied in this present project. Relationships between the existing habitat and the biomass of prey available to the present bat community may be a factor in limiting what species and populations exist within Hopewell Furnace NHS at the present time. One question that remains unasked is the impact of large deer populations on insect prey populations and availability. It is likely that low ground and shrub cover limit both insect species diversity and biomass, and this, in turn, may limit the chiropteran species community. Capture rates may be affected appreciably by bats searching for viable foraging areas that lie off of the project site. Long-term, quantifiable studies comparing changes in deer population size to insect biomass using off-park control sites may serve to explain possible differences in bat community structure and numbers within Hopewell Furnace NHS and may produce a better understanding of how to provide adequate habitat for bat communities in southeastern Pennsylvania. Studies that incorporate measures of insect availability, deer herd size, changes in vegetation, and long-term monitoring of bat populations and community need to be designed to further understand the ecology of the bats that occur at Hopewell Furnace NHS.

Conclusions

Although the number of bats and species captured during this investigation was low, the fact that bat populations across Pennsylvania and much of the United States have declined warrants that any habitat supporting bat populations be conserved to some degree. It is likely that the limiting causes for the low capture rates and diversity at Hopewell Furnace NHS are a combination of factors; i.e., limited roost site availability and habitat disturbance from natural causes, such as overbrowse from deer as well as unknown temporal and spatial effects. There is adequate habitat in the form of successional forest to support a diverse bat community at Hopewell Furnace NHS. This habitat is situated primarily along French Creek and Baptism Run, although large tracts of agricultural openings and meadow-like areas provide good foraging sites. While the primary forested habitat appears to be a bit marginal, aging of these forests will likely, in the future, provide the habitat necessary for formation of maternity colonies of all species captured as well as the temporary roost sites necessary for foraging bats.

An option for the creation of roosting habitat is to build a bat condo (as seen in Appendix C) in one of the secluded meadow-like areas. These “condos” have been set up at several sites throughout Pennsylvania and provide maternity housing for over 2,000 bats, including both big brown and little brown bats. They have served as points of educational interest and have garnered support from the public as awareness of bat conservation increases. Also, in the forests surrounding these “out-of-the-way” sites, large unwanted trees could be girdled so that as they die they provide roosting space as bark separates from the tree and cavities form.

Another form of artificial roosting habitat are “rocket boxes” (Burke 1999). These are narrow but deep boxes set on 3–4 m (10–13 ft) poles amid forested patches of the landscape. These boxes can serve as maternal roosting sites for northern long-eared bats, as well as night roosts for bats during dispersal or while they are foraging.

Basic artificial bat boxes like those designed by the Pennsylvania Game Commission can be set up on various barns in the appropriate manner and painted to be unobtrusive to the cultural landscape and historical integrity of the structures. These boxes are extremely successful when placed properly and can house between 500–1,000 bats, including the northern long-eared, little brown, and big brown bats. These boxes may also serve as habitat for the eastern pipistrelle.

Management Recommendations

Enhance roost site availability within the various forest tracts of Hopewell Furnace NHS. This can include both the creation of natural and man-made roost sites, as well as the girdling of selected trees during thinning processes.

Build artificial bat roosts. A “bat condo” (such as the one in Appendix C) could be built to hold a population in excess of 1,500 bats, including both little and big brown bats. Other types of artificial habitat, such as smaller bat boxes and “rocket boxes” could also be used within forested areas.

Install conventional bat boxes built to Bat Conservation International, Inc. and Pennsylvania Game Commission standards on any structure that exhibits usage by bats, both past and present. These boxes can be painted in such a manner as to be unobtrusive to the cultural landscape and have a negligible impact on the historical integrity of the structures.

Begin a long-term bat and insect monitoring program by establishing permanent monitoring sites and several off-park control sites to investigate the impacts of severe browsing by white-tailed deer and other disturbances on the bat community at Hopewell Furnace NHS.

Conduct early spring and mid-fall mist-netting surveys to assess use of Hopewell Furnace NHS habitats by migrating silver-haired bats. These surveys may also produce more data concerning species not presently listed, such as the eastern pipistrelle and hoary bat.

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Appendix A. Indiana Bat Mist Netting Guidelines (from Revised Recovery Plan, USFWS, 1999)

Rationale

A typical mist-netting survey is an attempt to determine presence or probable absence of the species; it does not provide sufficient data to determine population size or structure. Following these guidelines will standardize procedures for mist netting. It will help maximize the potential for capture of Indiana bats at a minimum acceptable level of effort. Although the capture of bats confirms their presence, failure to catch bats does not absolutely confirm their absence. Netting effort as extensive as outlined below usually is sufficient to capture Indiana bats. However, there have been instances in which additional effort was necessary to detect the presence of the species.

Netting Season

May 15–August 15

These dates define acceptable limits for documenting the presence of summer populations of Indiana bats, especially maternity colonies. Several captures, including adult females and young of the year, indicate that a nursery colony is active in the area. Outside these dates, even when Indiana bats are caught, data should be carefully interpreted: If only a single bat is captured, it may be a transient or migratory individual.

Equipment

Mist nets - Use the finest, lowest visibility mesh commercially available:

1. In the past, this was 1-ply, 40 denier monofilament - denoted 40/1
2. Currently, monofilament is not available and the finest on the market is 2-ply, 50 denier nylon - denoted 50/2
3. Mesh of approximately $1\frac{1}{2}$ (1¼ - 1%) in (~38 mm)

Hardware - No specific hardware is required. There are many suitable systems of ropes and/or poles to hold the nets. See NET PLACEMENT below for minimum net heights, habitats, and other netting requirements that affect the choice of hardware. The system of Gardner et al. (1989) has met the test of time.

Net Placement

Potential travel corridors such as streams or logging trails typically are the most effective places to net. Place the nets approximately perpendicular across the corridor. Nets should fill the corridor from side to side and from stream (or ground) level up to the overhanging canopy. A typical set is seven meters high consisting of three or more nets “stacked” on top one another and up to 20 m wide. (Different width nets may be purchased and used as the situation dictates.) Occasionally it may be desirable to net where there is no good corridor. Take caution to get the nets up into the canopy. The typical equipment described in the section above may be inadequate for these situations, requiring innovation on the part of the observers.

Recommended Net Site Spacing

- Stream corridors - one net site per km of stream.
- Non-corridor land tracts - two net sites per square km of forested habitat.

Minimum Level of Effort

Netting at each site should consist of:

- at least three net nights (unless bats are caught sooner) (one net set up for one night = one net night)
- a minimum of two net locations at each site (at least 30 m [98 ft] apart, especially in linear habitat such as a stream corridor)
- a minimum of two nights of netting
- a sampling period beginning at sunset and netting for at least 5 hr
- checking each net approximately every 20 min
- no disturbance near the nets, other than to check nets and remove bats

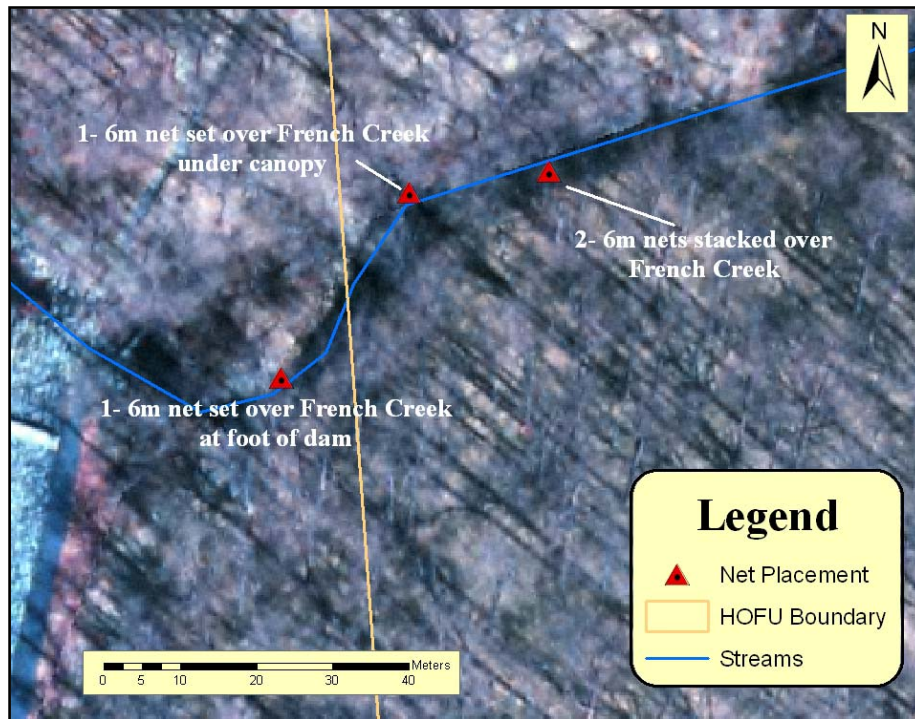
Weather Conditions

Severe weather adversely affects capture of bats. If Indiana bats are caught during weather extremes it is probably because they are at the site and active despite inclement weather. On the other hand, if bats are not caught, it may be that there are bats at the site but they may be inactive due to the weather. Negative results combined with any of the following weather conditions throughout all or most of a sampling period are likely to require additional netting:

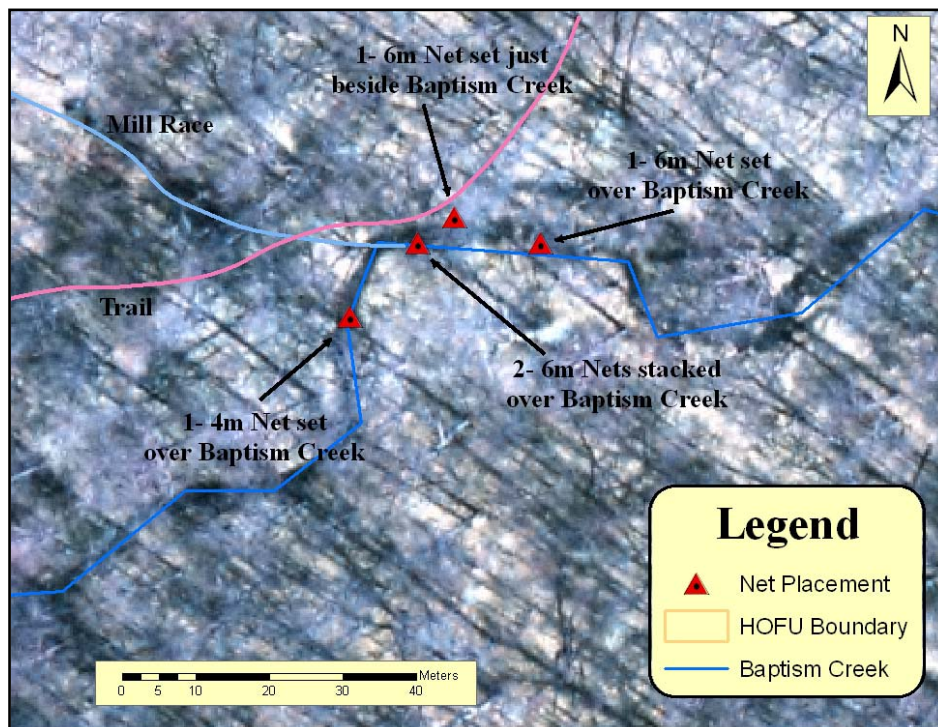
- Precipitation
- Temperatures below 10°C
- Strong winds (Use good judgment: moving nets are more likely to be detected by bats.)
- Moonlight

There is some evidence that small myotome bats avoid brightly-lit areas, perhaps as predator avoidance. It is typically best to set nets under the canopy where they are out of the moonlight, particularly when the moon is half-full or greater.

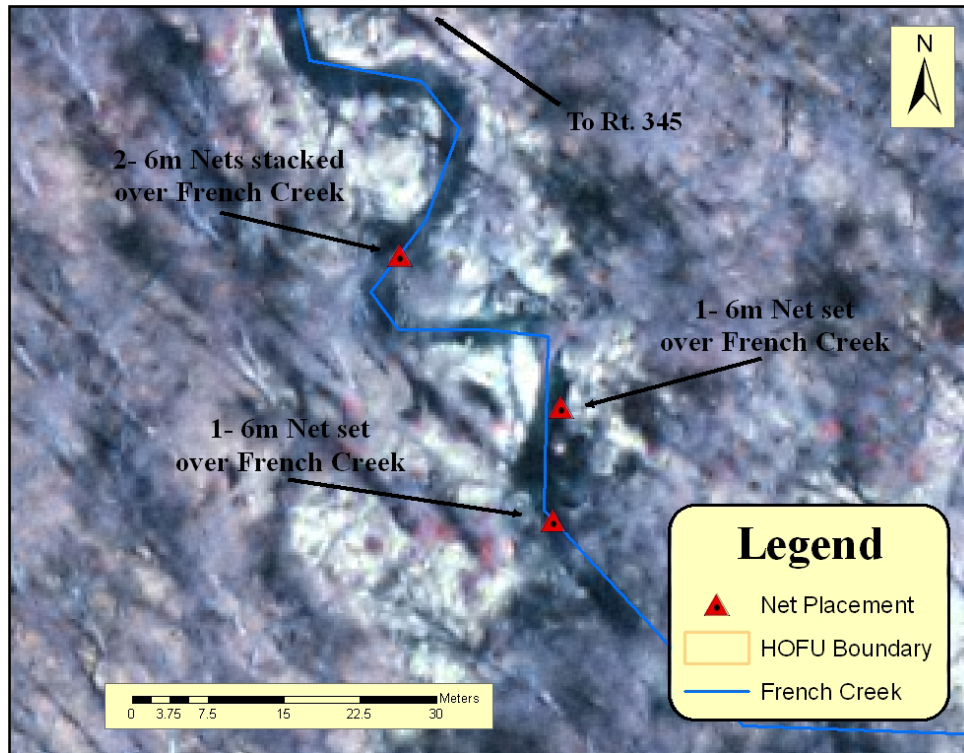
Appendix B. Placement of mist nets at the five survey sites in HOFU.



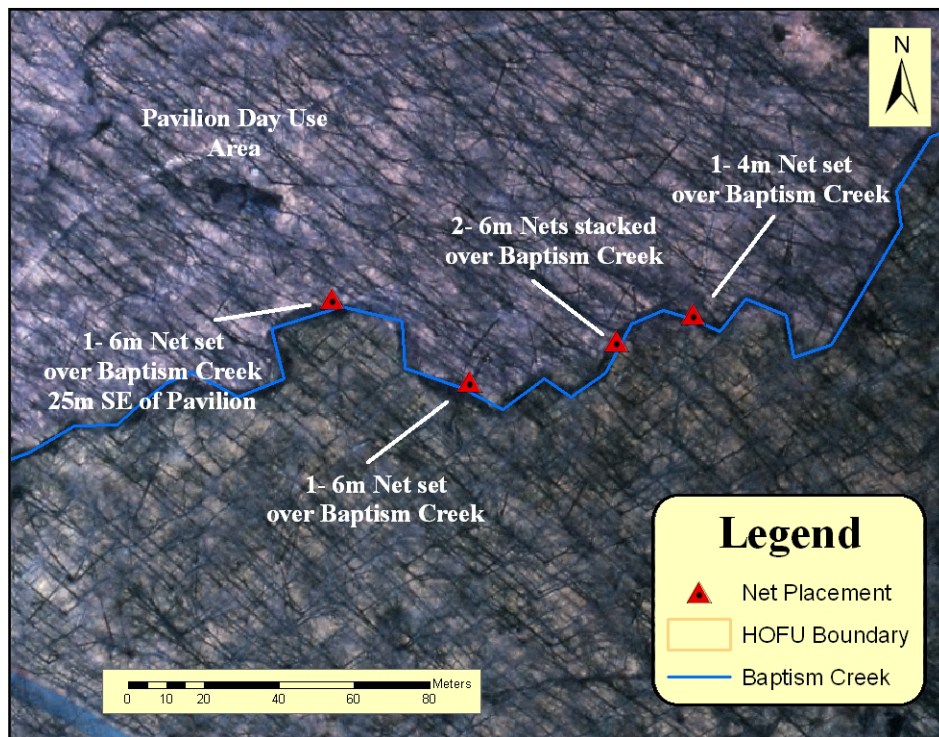
French Creek, Hopewell Furnace NHS, at site HOFU_BATS_HOFU01.



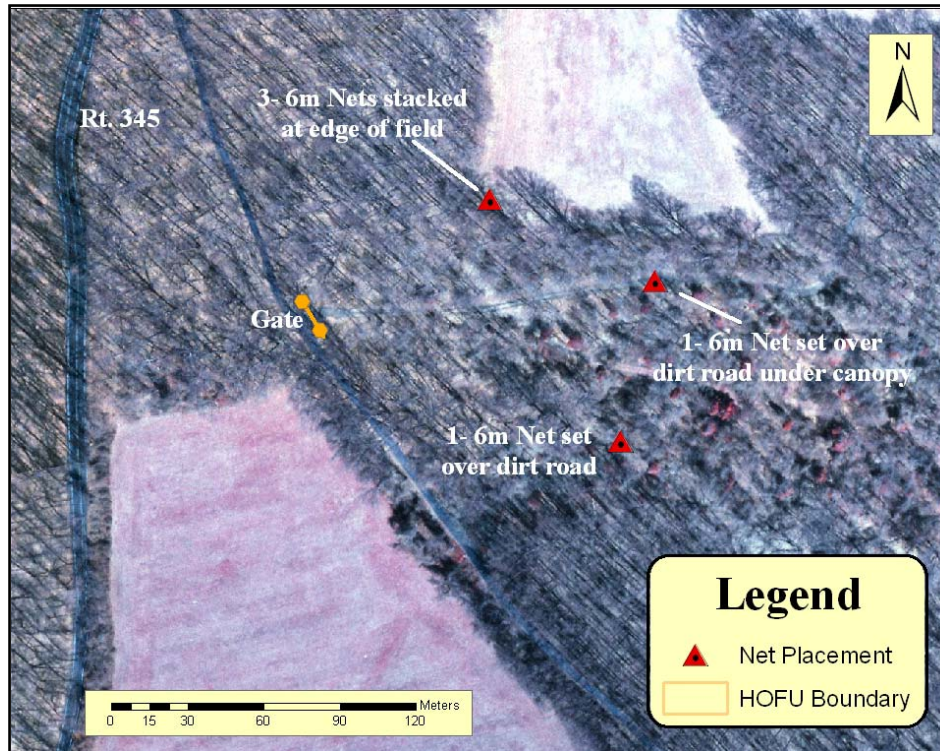
Baptism Creek, Hopewell Furnace NHS, at site HOFU_BATS_HOFU02.



French Creek, Hopewell Furnace NHS, at site HOFU_BATS_HOFU03.



Baptism Creek, Hopewell Furnace NHS, at site HOFU_BATS_HOFU04.



Harrison Loyd site, Hopewell Furnace NHS, HOFU_BATS_HOFU05.

Appendix C. A photo of a “Bat Condo” built by the Pennsylvania Game Commission at Canoe Creek State Park, Blair County.



Appendix D. List of photographs of bats and habitats surveyed at Hopewell Furnace NHS
accompanying Technical Report

Folder- HOFU_Bats Captured

HOFU01

- HOFU01-03_Myotis-lucifugus.jpg - Photo of a little brown bat, *Myotis lucifugus*
- HOFU01-04_Myotis-lucifugus.jpg - Photo of a little brown bat, *Myotis lucifugus*

HOFU02

- HOFU02-01_Myotis-septentrionalis.jpg - Photo of northern long-eared bat, *M. septentrionalis*
- HOFU02-02_Myotis-lucifugus.jpg - Photo of a little brown bat, *Myotis lucifugus*

HOFU03

- HOFU04-02_Lasiurus-borealis.jpg - Photo of red bat, *Lasiurus borealis*
- HOFU04-03_Myotis-septentrionalis.jpg - Photo of northern long-eared bat, *M. septentrionalis*
- HOFU04-04_Myotis-septentrionalis.jpg - Photo of northern long-eared bat, *M. septentrionalis*
- HOFU04-05_Myotis-septentrionalis.jpg - Photo of northern long-eared bat, *M. septentrionalis*
- HOFU04-06_Myotis-lucifugus.jpg - Photo of a little brown bat, *Myotis lucifugus*

HOFU04

- HOFU05-01_Eptesicus-fuscus.jpg - Photo of a big brown bat, *Eptesicus fuscus*
- HOFU05-02_Myotis-septentrionalis.jpg - Photo of northern long-eared bat, *M. septentrionalis*

Folder- HOFU_Habitat Photos

Site HOFU_BATS_HOFU01

- Hofu1A01.bmp - Photo of French Creek looking east
- Hofu1A04.jpg - Photo of French Creek just below Hopewell Dam
- Hofu1E02.jpg - Photo below dam looking east

Site HOFU_BATS_HOFU02

- HOFU Site 02 017.bmp - Baptism Creek #1 looking west
- HOFU Site 02 034.bmp - Baptism Creek #1 looking along the old Mill Race
- HOFU Site 02 039.jpg - Baptism Creek #1 looking east

Site HOFU_BATS_HOFU03

- HOFU03 006.bmp - French Creek #2 looking east along floodplain forest
- HOFU03 020.bmp - French Creek #2 looking east within forest

Site HOFU_BATS_HOFU03 (continued)

- HOFU03 026.jpg - French Creek #2 looking west
- HOFU03_TulipPolar_forest_1.bmp - Floodplain forest along French Creek #2

Site HOFU_BATS_HOFU04

- HOFU04 010.jpg - Baptism Creek #2 facing northeast
- HOFU04 019.bmp - Baptism Creek #2 facing southwest
- HOFU04 033.bmp - Baptism Creek #2 facing southwest

Site HOFU_BATS_HOFU05

- hofu05 014.bmp - Harrison Lloyd site facing north toward agricultural field
- hofu05 020.bmp - Harrison Lloyd site facing east along dirt road
- hofu_05 024.jpg - Harrison Lloyd site facing east along dirt road

As the nation's primary conservation agency, the Department of the Interior has responsibility for most of our nationally owned public land and natural resources. This includes fostering sound use of our land and water resources; protecting our fish, wildlife, and biological diversity; preserving the environmental and cultural values of our national parks and historical places; and providing for the enjoyment of life through outdoor recreation. The department assesses our energy and mineral resources and works to ensure that their development is in the best interests of all our people by encouraging stewardship and citizen participation in their care. The department also has a major responsibility for American Indian reservation communities and for people who live in island territories under U.S. administration.

National Park Service
U.S. Department of the Interior



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