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Seasonal Use Of An Abandoned Mine And Summer Maternity Roost By Northern Bats (Myotis Septentrionalis)

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SEASONAL USE OF AN ABANDONED MINE AND SUMMER MATERNITY ROOST BY NORTHERN BATS (*Myotis septentrionalis*)

(TITLE)

BY

HEATHER RAE FRASER

THESIS

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SEASONAL USE OF AN ABANDONED MINE AND SUMMER MATERNITY ROOST BY NORTHERN BATS (*MYOTIS SEPTENTRIONALIS*)

A Thesis Presented

by

HEATHER RAE FRASER

Submitted to the Graduate School of
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SUMMARY

Northern bats (*Myotis septentrionalis*) are relatively common in the eastern U.S. and southern Canada, but only a few studies have been conducted on this species and little information is available on the species' current population status, natural history, or behavior. Northern bats inhabit Copperhead Cave, an abandoned mine in west-central Indiana, year-round and this site serves as a hibernaculum for this species. In addition, a maternity colony of northern bats is located in a warehouse on the Newport Chemical Depot (NECD), approximately 8 km northwest of Copperhead Cave. The purpose of this study was to investigate aspects of the behavior and natural history of this species by intensively trapping, marking, and observing individuals occupying these roosts. Specifically, my objectives were to: (1) assess the seasonal abundance of northern bats at Copperhead Cave, (2) investigate whether the installation of gates at Copperhead Cave coincided with fewer bats using the mine, (3) test whether swarming activity at Copperhead Cave is associated with mating and copulation, (4) quantify seasonal changes in body mass, (5) investigate whether northern bats drink and/or move among roosts during winter flights, and (6) describe characteristics of the maternity roost at NECD and the duration of occupancy of this roost by female northern bats and their offspring.

A total of 507 bats of 4 species, including 271 northern bats, were trapped on 28 nights at Copperhead Cave from January to November 2002 using harp traps. Sex ratios were skewed towards males in all species. The male:female ratio of northern bats was 2.2:1, which differed significantly from the expected 1:1

ratio. The number of bats using the cave appears to have declined in the period following gate construction. The capture rate for bats during 1998 and 1999 (13.6 bats/h) before the gates were added was significantly higher than that in 2002 (7.8 bats/h) after the gates were installed ($P = 0.003$). However, the species composition of captures was similar before and after gate construction.

I performed vaginal swabs on 23 female northern bats, 6 little brown bats and 3 eastern pipistrelles during the peak of swarming behavior between 15 September and 7 November to determine whether mating occurs during swarming. After examining swabs with a scanning microscope, I could find no evidence of semen in any of the swabs, nor did I observe semen around the vulva or any other signs of copulation.

Female northern bats tended to be heavier than males in all seasons. Both sexes showed similar seasonal patterns of change in body mass, gaining mass from late-winter through summer and into fall. Females averaged 5.77 g in late-winter, increased to 5.99 g by summer, and peaked at 7.82 g in fall prior to entering hibernation. Males averaged 5.63 g in late winter, increasing to 5.90 g in summer and 7.31 g in fall. Winter and summer weights did not differ ($P = 0.45$), but fall masses were significantly heavier than either winter ($P < 0.01$) or summer ($P < 0.01$) masses.

A total of 53 northern bats were captured as they exited Copperhead Cave during January and February. Some individuals of both sexes engaged in winter flights outside the mine on every night that I sampled, although males predominated. Only one bat was recaptured re-entering the cave on the same night. This individual had gained 0.52 g (8.2% of body mass) in the period between exiting and re-entering the mine. Light tags were attached to 12 bats during their winter flights. None of these were seen approaching or drinking from the nearby stream, nor entering any mine entrance other than the one they exited. Most of these winter flights occurred along the forested hillsides near the cave, the preferred foraging habitat for northern bats.

At least 76 adult bats occupied a summer roost in a warehouse at NECD. This was a mixed-sex colony consisting of 42 female and 24 male northern bats, 7 male little brown bats, and 3 male big brown bats. Pregnant northern bats occupied the roost from mid-May to mid-August. Eight females had been banded previously at the roost, suggesting that northern bats exhibit site fidelity at this maternity roost. Parturition appeared to be synchronized in the colony. The first pup was observed on 18 June, but at least 20 pups were present in the colony by 20 June. Females lost 1.5-2.5 g of body mass during the perinatal period. Juveniles gained weight quickly, weighing approximately 5 g by mid-July. Recaptures of bats marked during my study and previous studies suggest that there is some movement of individuals between Copperhead Cave and the NECD maternity roost.

Although I was not able to identify the purposes of swarming behavior or winter flights by northern bats, my study contributes new information on seasonal use of a hibernaculum and the possible detrimental effects of gate construction at the site. This research also contributes to our understanding of seasonal changes in body mass and the characteristics and use of maternity roosts.

Copperhead Cave and NECD's Building 121C provide critical habitat for northern bats. Monitoring should continue at these sites and they should be considered conservation priorities for protecting northern bat populations in Indiana.

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INTRODUCTION

The northern bat (*Myotis septentrionalis)* is found from southern Canada through the central and eastern United States to northern Florida (Barbour and Davis 1969, Harvey et al. 1999). It is a widespread and relatively common species throughout most of its geographic range (Harvey et al. 1999). Prior to 1980, this small, insectivorous bat was classified as an eastern subspecies of the Keen's bat *(Myotis keenii septentrionalis)*, but more recently all populations outside of the Pacific Northwest have been recognized as a unique species based on differences in both distribution and morphology (van Zyll de Jong 1979, Caceres and Pybus 1997, Lacki and Schwierjohann 2001).

Because few studies have been conducted on northern bats, little information is available regarding the species' current status, natural history, and behavior (Lacki and Schwierjohann 2001). Furthermore, inconsistencies in reports of roost site selection by northern bats suggest that additional research is needed to explain their habitat use and roost requirements (Lacki and Schwierjohann 2001, Menzel et al. 2002). Bat Conservation International (BCI) reported recently that the greatest impediment to conserving northern bats is the lack of information regarding their natural history (BCI Inc. 2001). Because a population of this species occupied a hibernaculum and summer roost site at Copperhead Cave, an abandoned mine in west-central Indiana, and a maternity roost at the Newport Chemical Depot (NECD) nearby, my study was designed to investigate several questions regarding the natural history and behavior of this species.

Use of caves and mines by bats

Caves and abandoned underground mines provide important roost sites for 10 species of bats in the eastern U.S. Of these species, 3 are endangered (Indiana bats (*Myotis sodalis),* gray bats (*M. grisescens*), and Townsend's big-eared bats *(Corynorhinus townsendii*), 3 more are species "of special concern" considered prospects for listing (southeastern bats (*M. austroriparius*), small-footed bats (*M. leibii*), and Rafinesque's big-eared bat (*C. rafinesquii*), and 4 others are thought to be declining in portions of their geographic range (big brown bats (*Eptesicus fuscus*), eastern pipistrelles (*Pipistrellus subflavus*), little brown bats (*M. lucifugus*), and northern bats (*M. septentrionalis*) (Harvey et al. 1999, Harvey 2000). Besides providing protection from the elements and predators, many caves and mines provide above-freezing temperatures needed for hibernation in winter and act as cold-sinks in summer protecting roosting bats from hot summer temperatures. Meier (2000) estimated that up to 70% of the underground mines in the northern and eastern U.S. are occupied by bats.

Northern bats are one of 5 species that regularly hibernate in caves in Indiana, frequently roosting with little brown bats, Indiana bats, eastern pipistrelles and big brown bats. Northern bats hibernate in sections of caves and mines that are cool, moist, and still, preferring sites with 60-70% relative humidity and 6.5-7.4°C air temperature (Raesly and Gates 1987, Caceres and Pybus 1997). They tend to be more solitary than other bats, often preferring to roost in tight crevices and holes (Harvey et al. 1999). Some sources have reported that few (10-100) northern bats occupy any one site (BCI Inc. 2001, Brack et al. 2003), but this may be an underestimate as they can be easily overlooked due to their roosting preferences (Raesly and Gates 1987, Whitaker et al. 2002, Brack et al. 2003). For example, Whitaker and Rissler (1992a) estimated approximately 900 northern bats occupying Copperhead Cave based on captures during spring emergence. In addition, large numbers of this species have been seen entering caves in March, leading some biologists to suspect that many hibernate in cliff-face crevices outside caves (BCI Inc. 2001).

Although northern bats are caught frequently in mist nets during the summer in Indiana, they are not usually found in caves or mines during this time of year (Brack and Whitaker 2001, 2004; Brack et al. 2003). Movement into hibernacula begins in August and extends through October. Hibernation begins when there are insufficient flying insects to warrant foraging, usually after 1-2 killing frosts (Caceres and Pybus 1997). The species emerges from hibernation after approximately 6 months in late-March and early-April, generally before the emergence of little brown bats (LaVal et al. 1977, Whitaker and Rissler 1992b).

Response of bats to gates at cave entrances

Although caves and mines provide crucial habitat for northern bats, vandals, recreational spelunkers, scientists, and commercialization of caves may disturb these sites (Speakman et al. 1991, Johnson et al. 1998, Fenton 2001). Disturbance during hibernation and the maternity season can reduce survival and reproductive success, cause roost abandonment, and is an important contributor in the decline of cave and mine-dependent bats (Tuttle 1977, Currie 2000). Therefore, protection of these sites is a high priority in all bat recovery plans.

In an effort to protect cave-roosting bats, early conservation strategies called for erecting educational signs and gates at entrances to inform the public or limit access (Currie 2000). During the past 30 years, gating caves has become the primary technique used to protect hibernacula and gates have been installed on well over 1,600 abandoned mine sites alone (Sherwin et al. 2002). Some gates have proven to be very successful, while others have failed to protect bats adequately, and some have been counter-productive.

Unfortunately, gates that restrict people may also restrict the use of caves and mines by bats if they restrict flight patterns, increase predation risks (Ludlow and Gore 2000), or cause microclimatic changes in temperature or air flow within the roost (Tuttle 1977). Further, different species of bats respond differently to gates (White and Seginak 1987). Some species tolerate full gates, whereas others require partial gates with an open flight space above the top bar (Currie 2000, Sherwin et al. 2002). In some cases, gates may reduce the abundance or diversity of bats using caves, alter emergence patterns, or cause complete abandonment of the roost site (Ludlow and Gore 2000). In turn, gate removal may reverse these trends. For example, Richter et al. (1993) found an increase in the number of Indiana bats occupying Wyandotte Cave in Indiana, after gates were removed in 1977 and the cave entrance was restored. By 1991, the population of Indiana bats was estimated to be nearly 13,000, a dramatic increase from the 1,000-3,000 individuals using the cave from the mid-1950's through the 1970's.

Gates can be expensive to install, aesthetically unappealing, and difficult to construct (Tuttle and Taylor 1994). The style currently used at most sites, including

Copperhead Cave, is a steel-bar gate constructed of 4-inch angle iron with a minimum spacing of 5.75 inches between horizontal bars and 48 inches between vertical supports (Currie 2000). Where gates prove to be counter-productive, they may be replaced by perimeter fences erected outside of cave entrances. These are less likely to impact roosts and bats, but are less secure against human trespassers, unsightly, and may be difficult to erect at entrances on steep slopes or cliff-faces (Ludlow and Gore 2000). The potential impacts of gate construction on hibernacula used by northern bats have not been assessed.

Swarming activity of bats

Little is known about the timing of courtship and mating in northern bats, but mating is thought to occur in the fall prior to hibernation (Harvey et al. 1999), coinciding with swarming activity (Whitaker and Rissler 1992a, Wilson 1997). Swarming, which is most prevalent among *Myotis* bats (Parsons et al. 2003), has been defined by Fenton (1969) as flights through the hibernaculum by large numbers of bats during late-summer and early-fall. These swarms are created when bats congregate around cave or mine entrances prior to hibernation in autumn (Whitaker and Rissler 1992a, Fenton 2001). Mixed-species swarms are common at caves used for hibernation, but many caves that attract swarming bats appear to be used solely as gathering sites (BCI Inc. 2001). At Copperhead Cave, swarming begins in August and declines in October, with females tending to decrease in numbers earlier than males (Whitaker and Rissler 1992a).

Although swarming has been studied in Europe (Parsons et al. 2002) and North America (Schowalter 1980, Whitaker and Rissler 1992a), its function is still unclear.

Some have speculated that this behavior is associated with courtship and mating (Parsons et al. 2003), or it may involve the exploration of potential hibernacula (Fenton, 1969, 2001). Whitaker (1998) suggested that swarming sites might serve also as migration stop-offs between hibernacula or between winter and summer ranges. Northern bats probably do not migrate, but make shorter seasonal movements between summer and winter habitats (BCI Inc. 2001). To date, no evidence has been provided to give strong support to one hypothesis or another. However, because swarming activity coincides with the mating season of most temperate bats, the predominant notion is that swarming is associated with mating. Since hundreds of bats swarm at Copperhead Cave during the fall when I trapped bats, it provided the opportunity to test females for evidence of mating.

Winter arousal and activity of bats

Bats are metabolically challenged during winter when food supplies are limited, so they hibernate in order to reduce body temperature and metabolic rate (Thomas and Geiser 1997). This allows bats in temperate zones to decrease energy use in times of sparse food and low ambient temperatures (Park et al. 2000). Several researchers have reported that northern bats periodically arouse and become active during winter months while hibernating (Whitaker and Rissler 1992a, 1992b, 1993; Richter et al. 1993). Winter activity appears to be most common on warmer days and males may be more active than females (Avery 1985, Speakman 1990, Whitaker and Rissler 1992b). While arousal from hibernation is not uncommon, it is energetically costly as it requires metabolizing limited stores of brown fat (Johnson et al. 1998, Trayhurn 1993).

Little is known about the function of winter arousals (Whitaker and Rissler 1993, Thomas and Geiser 1997), but it has been suggested that this activity may be associated with feeding, drinking, and/or changing roost sites (Whitaker and Rissler 1992b, Johnson et al. 1998). Brigham (1987) found that active bats had significantly less body mass and fat reserves than inactive individuals and noted that this was consistent with the hypothesis that activity was associated with foraging to meet critically low energy reserves. In addition, some bats appear to time their flights to coincide with good feeding conditions (Speakman 1990). However, Whitaker and Rissler (1993) suggested that feeding is not the reason for winter arousals because they found no evidence of fresh food in the digestive tracts of active northern bats and little brown bats collected between 30 October 1990 and 5 April 1991 at a cave in Indiana. Consequently, my hypotheses were that winter arousals are triggered either by water loss and the need to drink periodically during hibernation or by the need to periodically move from one hibernaculum to another.

Summer roosting ecology

Although limited information is available regarding the summer ecology of northern bats (Foster and Kurta 1999), some data suggest that males are largely solitary and nomadic, whereas breeding females inhabit maternity roosts during summer. Summer roost sites usually are in tree cavities or under loose tree bark (Sasse and Pekins 1996, Foster and Kurta 1999, Lacki and Schwierjohann 2001, Menzel et al. 2002), but caves and man-made structures such as mines, barns or park shelters also may be used (Brandon 1961, Cope and Humphrey 1972, Caceres and Pybus 1997, Harvey et al. 1999).

Adult female northern bats and their single pups form small nursery colonies of 3-60 individuals in the early summer months. These maternity roosts constitute critical habitat for bats. Females seek warm roosts where they can maintain a constant body temperature and avoid torpor, thereby speeding fetal development (Caceres and Pybus 1997). Gestation lasts approximately 60 days with births occurring in late-June and July. Juveniles are born naked and need high temperatures to accelerate their development and maximize growth during their first few weeks (Racey 1982, Fenton 2001).

In June 1993, an active maternity colony was found in a warehouse at the NECD near Newport, Indiana (Veilleux et al. 1999). At the time of its discovery, the colony was believed to contain approximately 100 individuals. Subsequently, the site was surveyed 7 times during the summer of 1997 and a maximum of 46 individuals was counted. I investigated the use of this building by northern bats during the perinatal period in 2002. By carefully observing the bats occupying this maternity site, quantifying temperatures and physical characteristics, and capturing and banding residents, I hoped to provide new information on the seasonal use and characteristics of this site.

Specifically, my objectives were to: (1) assess the seasonal abundance of northern bats and other species using Copperhead Cave, (2) investigate whether the installation of protective gates at Copperhead Cave coincided with a reduction in the use of this site by northern bats, (3) test whether swarming activity at Copperhead Cave is associated with mating and copulation, (4) quantify seasonal changes in the body mass of northern bats, (5) investigate whether this species drinks and/or moves among hibernacula during winter flights, and (6) describe characteristics of the maternity roost at the NECD site and the duration of occupancy of this roost by female northern bats and their offspring.

METHODS

Study areas

This study was conducted at 2 roost sites in west-central Indiana: an abandoned mine used year-round by bats and a warehouse used in summer by a maternity colony of northern bats. Copperhead Cave, in Vermilion County, is an abandoned mine in a limestone bluff 400 m west of the Wabash River and 1.5 km west of the town of Montezuma (Fig. 1). Due to glaciations, natural caves do not exist in this area and Copperhead Cave serves as a hibernaculum and summer roost for northern bats, little brown bats, and eastern pipistrelles (Whitaker and Rissler 1992a).

There are 3 south-facing entrances that bats use to access this mine (Fig. 2). The two largest entrances are approximately 2.5-3.0 m wide and 1.5 m in height. The third and smallest entrance is a plastic ventilation tube that was excavated through the limestone and into the mine. This tube is 6.4 m long and has a diameter of 73 cm (Fig. 2). In order to decrease vandalism and protect roosting bats, each of these entrances was equipped with a security gate in 2001. Gates installed at the two larger entrances consist of horizontal steel bars that are each 10 cm wide and spaced 14 cm apart. A smaller, circular gate was placed at the opening of the ventilation tube. This gate has 2-cm diameter round bars spaced 14 cm apart supported by a central 1-cm diameter bar positioned vertically down the center of the gate. The mean temperature at 4 ceiling roost locations inside the mine during September was 14°C.

A summer roost and maternity colony was located at the Newport Chemical Depot (NECD) approximately 8 km northwest of Copperhead Cave. NECD is a government-owned, military installation supervised by the U.S. Army Soldier and Biological Chemical Command. The depot was built in the 1940s in a largely agricultural area south of the town of Newport, Indiana. The roost and maternity colony are located in an empty warehouse, Building 121C, on the depot. Veilleux et al (1999) reported that the colony was discovered on 1 June 1993. On that date, approximately 100 bats were present. When the site was surveyed again in 1998, the number of bats using the building varied from 2 to 46, suggesting that the colony may use multiple roosts during the summer. No other roosts have been found on NECD.

Capturing, banding and weighing bats

I captured bats from dusk until approximately 2400 h once a week at either Copperhead Cave or the Newport Chemical Depot beginning on 28 January 2002 and continuing through 7 November 2002. Bats were live-trapped at the 2 large entrances to Copperhead Cave using a double-frame harp trap. The harp trap was placed approximately 1 m outside the gated entry and any gaps between the perimeter of the trap and the entrance walls were blocked with netting. At the smaller circular entrance, I trapped bats by draping a mist net over the opening of the ventilation tube. Trapped bats were immediately removed from harp traps or mist nets, identified to species, sexed, and tagged with individually numbered, flanged metal wing bands (Barclay and

Bell 1988). Each individual was weighed to the nearest 0.1 g using a quadruple beam balance. Individuals could be sexed by inspection of external genitalia. Sex ratios of each species were tested to determine whether they differed from 1:1 using the non-parametric binomial test.

Relative abundance of bats before and after gate construction

I compared the number of bats exiting the cave before and after installation of gates to investigate whether gate installation may have influenced the number of bats using the mine. The number of bats captured per hour between dusk and 2400 h at each cave entrance was calculated and compared to similar data collected by Dr. John O. Whitaker, Jr. (unpublished data, Indiana State University) in 1998 and 1999, prior to installation of the gates. I used paired t-tests to test for differences in the mean number of bats captured per hour during bi-weekly periods from August through November 1998 versus 2002.

Winter observations and light-tagging of bats

To investigate the purpose of winter flights, I captured bats weekly from mid-January to mid-March at Copperhead Cave and weighed them as they exited and re-entered the cave. In addition, I attached chemi-luminescent light tags (Chemical Light, Inc., Vernon Hills, IL) on randomly-selected bats, so that their flight paths could be observed after they exited the hibernaculum. Light tags were secured between the scapulae with non-toxic surgical glue (Skinbond, Pfizer Hospital Products Group, Inc., Largo, FL). Light tags weighed 0.25 g and do not interfere with flight or mobility

(Barclay and Bell 1988). After releasing tagged bats, I visually monitored their movements to see if they flew low over water sources that were in close proximity (~150 m) to the mine entrances, particularly the stream at the base of the bluff. I also monitored these flights to see if individuals re-entered the cave at the same entrance from which they exited or whether they switched exit and entry points. Observers were placed along the ridge line above Copperhead Cave and the valley below to better observe the flight paths and activities of light-tagged bats.

<u>Swarming behavior and evidence for mating</u>

Whitaker and Rissler (1992a) found that swarming activity of northern bats and little brown bats began in late-July and ceased by the end of October. Therefore, I captured and examined females of these 2 species at Copperhead Cave from mid-September through early-November 2002 to test the hypothesis that swarming behavior is associated with mating. I examined each female for the presence of semen around the vulva and swabbed the vaginas of most females to look for the presence of spermatozoa (Racey 1988). Swabbing was conducted using sterile cotton swabs. These were stored in 10 ml microfuge tubes filled with 5 ml of sterile saline solution and transported to the lab where the solution was transferred immediately to microscope slides and examined for the presence of spermatozoa using a scanning microscope at 100X magnification. Furthermore, since male *Myotis* bats are known to bite the fur at the nape of the female's neck during copulation (Racey 1988, Fenton 2001), I carefully examined this region on each female to check for disturbed pelage, an indirect sign of sexual activity.

Characteristics of the maternity roost

Bats were captured at the NECD maternity roost using mist nets suspended between the floor and ceiling of the warehouse, as well as in the doorways. These nets were secured to poles and could be raised and lowered using a pulley system. Captured bats were immediately removed from the nets, weighed, sexed, and banded. Nets were furled, lowered to the floor and covered, to avoid accidentally entangling bats when I was not present.

During the perinatal period, I monitored pregnant and post-partum females and their pups to better characterize the use of maternity sites by northern bats. At least twice weekly from late-April through August, I systematically counted the number of adult females and pups present in the warehouse. Almost all of the resident females and some of their offspring were captured, weighed, and tagged during this period. I measured the heights and identified substrates where females roosted. I also measured the daily July temperature ranges at typical roost sites in the warehouse and compared them to air temperatures outside the warehouse using HOBO temperature loggers (Onset Computer Corp., Pocasett, MA) attached to the ceiling near roosting bats.

To determine whether the females that use the maternity roost at NECD also roost or hibernate at Copperhead Cave, I searched my capture records and those of Dr. Whitaker for individuals that had been observed at both sites. I was interested to know if proximity of NECD to the hibernaculum at Copperhead Cave might be important in the bats' selection of this maternity site.

RESULTS

Composition of the bat community at Copperhead Cave

I captured 507 bats of 4 species while trapping on 28 nights at Copperhead Cave. Species captured included northern bats, little brown bats, eastern pipistrelles and big brown bats (Table 1). Of this sample, 494 individuals (97.4%) were first-time captures, whereas 13 were recaptured bats that I had marked previously. Most bats (N = 450) were captured at gate #1; 39 were captured at gate #2 and 5 at gate #3 (Table 2). The mean capture rate was 6.5 bats/h (SD = 4.2). Capture rate was highest at the main entrance (gate #1), averaging 7.0 bats/h, while rates were lower at gates #2 and #3, averaging 4.4 and 2.5 bats/h, respectively. First-time captures included 271 (54.9%) northern bats, 173 (35.0%) little brown bats, 46 (9.3%) eastern pipistrelles, and 4 big brown bats (0.8%). Species composition did not differ among the 3 gates (X^2 = 5.64; df = 8; P = 0.688). Northern bats composed 54%-80% of the bats captured at each gate. Little brown bats were also common at each gate, composing 20-35% of each sample.

Sex ratios were skewed heavily towards males in all species (Table 1). The male:female ratio of northern bats was 2.2:1, which differed significantly from the expected 1:1 ratio (P < 0.001). The sex ratio of little brown bats (5.9:1) also differed from unity (P < 0.001). Males predominated in the sample of eastern pipistrelles (1.7:1), but this ratio did not reach statistical significance (P = 0.105). Male northern bats generally outnumbered females throughout the year, but were particularly abundant in late-October and early-November when bats were entering hibernation, in March when they emerged from hibernation, and in June and July when females were in summer maternity roosts (Fig. 3).

Capture rates and species composition of bats before and after gate construction

The total number of bats captured during September-November 1998 was 1,343 in 107.3 hours of trapping, a capture rate of 12.5 bats/h. In 1999, 995 bats were captured in 64.3 hours of trapping during these months, a rate of 15.5 bats/h. During the same months in 2002, I trapped 330 bats in 42.5 hours, a rate of 7.8 bats/h. The capture rate for bats during the 1998 and 1999 trapping periods (13.6 bats/h) before the gates were added differed significantly from that in 2002 (7.8 bats/h) after the gates were installed ($t = 3.12$; $DF = 52$; $P = 0.003$). The species composition of captured bats was similar between the pre- and post-gate samples. The 1998-99 sample was composed of 59.2% northern bats, 32.7% little brown bats, and 6.5% eastern pipistrelles. The percentages for these species in 2002 were 54.9%, 35.0, and 9.3%. Although the post-gate species composition differed significantly statistically from pre-gate species composition, there is no ecological significance ($\chi^2 = 11.5$; $DF = 5$; $P = 0.04$).

The sex ratios of species captured during the pre-gate period (1998-99) were heavily skewed towards males, as were the post-gate samples. Male:female ratios for northern, little brown and eastern pipistrelle bats before gates were installed were 6.4:1, 1.7:1 and 2.3:1, respectively.

Reproductive condition of swarming females at Copperhead Cave

Swarming behavior was observed at Copperhead Cave from late-July through October. Three species predominated in these swarms: northern bats, little brown bats, and eastern pipistrelles. While trapping individuals swarming outside the cave from 15 September through 7 November, I performed vaginal swabs on 23 female northern bats, 6 little brown bats and 3 eastern pipistrelles to determine whether they had copulated during the swarming activity. After examining these swabs with a scanning microscope, I could find no evidence of spermatozoa in any of the swabs. Furthermore, I did not observe semen around the vulva of any female, nor did I detect any indirect signs of copulation such as disturbed pelage.

Seasonal changes in body mass of northern bats

Female northern bats tended to be heavier than males in all seasons, but this difference was not significant ($F = 2.08$; $df = 1$; $P = 0.15$; Table 3). Seasonal increases in the body mass of both sexes were significant ($F = 67.36$; $df = 2$; $P < 0.01$) with both sexes gaining mass from late-winter (January-March) through summer (April-July) and into fall (September-November; Table 3). Females averaged 5.77 g in late-winter, increased to 5.99 g by summer, and peaked at 7.82 g in fall prior to entering hibernation. Males averaged 5.63 g in late winter, increasing to 5.90 g in summer and 7.31 g in fall. There was no interaction between sex and season ($F = 0.86$; $df = 2$; $P = 0.423$). A Tukey post hoc test of body masses for both sexes suggested that winter and summer masses did not differ ($P = 0.45$), but fall masses were significantly heavier than either winter ($P < 0.01$) or summer ($P < 0.01$) masses.

Winter flights

During January and February 2002, 53 northern bats exiting gate #1 were captured during 5 nights of trapping (Table 4). This sample included individuals of both sexes, although males predominated. The mean mass of bats leaving the cave was 5.63 g. Only one of these bats was captured re-entering the cave on the same night. On 8 February 2002, an adult male exited the cave at 2110 h and re-entered at 2142 h. The bat weighed 6.35 g when it left the cave and 6.87 g when it re-entered, a gain of 0.52 g (8.2% of body mass). It was not possible to tell by examination whether this individual had been eating, drinking, or both.

In addition, I affixed light tags to 12 northern bats as they exited the cave during this winter period in order to observe their activities while outside of the cave. None were seen approaching or drinking from the nearby stream even though open water was available. The only individual recaptured after a winter flight was caught re-entering the entrance from which he had departed. No light-tagged individuals were observed re-entering or attempting to re-enter another entrance during these trapping periods.

Characteristics of the maternity colony

Building 121C, the warehouse that served as a maternity roost for northern bats at NECD is predominately a single large room (36.5 m x 58.5 m) with graduated, beamed ceilings that are 3.7-4.5 m in height. A second small room occupies the northwest corner of the building, measuring 2.5 m x 2.5 m x 3.7 m. Although bats were sometimes found roosting from the beams and electrical wires on the ceiling of the larger room, the greatest numbers were found roosting on the ceiling of the small room. Of the 113 total captures at this site, 104 occurred in the smaller room (Table 3). Daily roost temperatures were at or above 100° F during the day and were approximately 10° F warmer than the ambient temperatures outside the warehouse (Fig. 4).

During 2002, 76 individual bats were captured using mist nets inside the warehouse. This was a mixed-sex colony consisting of 42 female and 24 male northern bats, 7 male little brown bats, and 3 male big brown bats (Table 5; Appendix A, B, C). Female northern bats used this site as a maternity roost, arriving in early- to mid-May, and leaving abruptly in mid-August. Eight of these females had been banded in the warehouse by previous researchers, suggesting that they exhibit some fidelity to this maternity roost.

Parturition among female northern bats began in mid-June. The first sighting of a pup occurred on 18 June 2002 and a palpably pregnant female was captured the same day. Twenty pups were observed in the colony on 20 June and others could be heard vocalizing. Four pregnant females captured in early-June then recaptured in late-June or July (after parturition) had lost 1.5-2.5 g of body mass (Fig. 5). The mean body mass of all adult female northern bats dropped from 7.5 g in early-June when pregnant individuals were being captured to a postnatal mean of 5.9 g in July ($t = 6.73$; $df = 34$; $P < 0.001$). I banded seven juvenile northern bats between 20 June and 18 July. The mean mass of these individuals was 4.7 g ($SD = 0.5$; Appendix B). Only one juvenile was recaptured during this period. This individual increased in mass from 4.75 g on June 27 to 5.25 g on July 18, a gain of 0.5 g (11%) in 21 days.

Of the 34 adult male bats known to share this warehouse with the maternity colony, 24 were northern bats, 7 little brown bats and 3 big brown bats (Appendix C). Male northern bats occupied the building from 13 June to 12 August 2002 coinciding closely with the arrival and departure of females. However, the first male observed at the warehouse was a little brown bat, arriving on 4 June. Similarly, the last male to occupy the roost was a little brown bat caught on 1 September.

Although Copperhead Cave is in close proximity to the NECD warehouse maternity site (Fig. 1), I did not recapture any of the females banded at the cave at the warehouse or vice versa. However, one male northern bat that was initially banded on 13 July at the NECD was recaptured at the cave on 22 September 2002.

DISCUSSION

Composition of the bat community at Copperhead Cave

The composition and relative abundance of species inhabiting Copperhead Cave in 2002 were similar to those reported during 1989-1991 (Whitaker and Rissler 1992a). This previous survey found that the mine served as a hibernaculum for approximately 900 northern bats, 300 little brown bats, 200 eastern pipistrelles, and small numbers of big brown bats and Indiana bats. I did not catch any Indiana bats in 2002, but trapped less intensively than the previous study. However, the mine continues to be an important roost for little brown bats and pipistrelles, and it contains more northern bats than any hibernaculum reported in the literature.

Although northern bats are common in caves and mines throughout their geographic range during winter, few usually are found at any one site (BCI Inc 2001, Brack et al. 2003). However, most surveys of hibernacula count visible bats hanging from the ceilings and walls. The northern bat's habit of roosting in tight cracks and crevices probably leads to under-estimates of their abundance. I saw relatively few northern bats on the 4 occasions when I entered the cave and yet they were the most abundant species exiting the cave in all seasons. Whitaker et al. (2002) observed that northern bats are rarely found in large numbers in Indiana's caves although they are the 4^{th} or 5^{th} most abundant bat in the state.

It is interesting to note that only a small percentage of bats (2.6%) were recaptured in my study. Whitaker and Rissler (1992a) also recaptured relatively few bats (14.0%) in their previous surveys at Copperhead Cave. This might be expected if tags are lost and individuals are not recognized as recaptures. But the flanged metal tags that I used appear to be retained well and I found no loose tags on those individuals that were recaptured. It seems more likely that Copperhead Cave is inhabited primarily by transients that use the mine sporadically either while moving through the area or in conjunction with alternative local roosts.

I found no evidence that bats exiting one entrance enter at another, or that different species use different mine entrances. The species composition of captures at the 3 entrances was similar. Although I recaptured few bats, individuals initially captured at an entrance were always recaptured at the same entrance, suggesting that individuals use particular entrances to access their roost sites. Most bats entered and exited the mine through the largest entrance (gate #1) and the fewest bats exited through the smallest entrance (gate #3). This pattern is consistent with speculation that bats prefer to exit from less crowded openings (Ludlow and Gore 2000).

It is not clear why male bats predominate at Copperhead Cave. Balanced sex ratios appear to be normal in most hibernacula. For example, Tinkle and Milstead (1960) found colonies of *Myotis velifer incautous* in Texas at ratios near unity in late-fall and early-winter. In Missouri, male and female northern bats were caught in similar numbers during most of the year. Exceptions were in spring when males predominated because females were moving to maternity roosts, and in June when there was a spike in the number of males captured apparently due to an influx of transients moving through the area (Caire et al. 1979). Whitaker and Rissler (1992a) reported an overall male:female ratio of 1.57:1 among northern bats captured at Copperhead Cave between 1989 and 1991. As in my study, they found a predominance of males entering and leaving the cave in October and March, respectively. The sex ratio also was skewed in part because they caught large numbers of males at the cave in June and July, when females were in maternity colonies. In 2002, female northern bats were most frequently caught in fall and spring, coinciding with entrance and emergence from hibernation. But, smaller numbers of females appear to use the mine in summer, too. These may be non-reproducing individuals. My results do not support Whitaker and Rissler's (1992a) observation that females enter hibernation earlier than males. Although females declined from September through October, peak numbers were caught in November coinciding with the capture of large numbers of males.

<u>Capture rates before and after gate construction</u>

Steel gates are frequently installed at the entrances to caves and mines used by bats to prevent people from entering and disturbing roosting bats. However, some

Myotis species, including the federally-endangered Indiana bat respond negatively to gates (Richter et al. 1993). My results suggest that the numbers of bats using Copperhead Cave have declined since gates were added to the 3 mine entrances in 2001. Capture rates were significantly lower in 2002 than in 1998-99 prior to gate construction (7.8 bats/h versus 13.6 bats/h). These results should be interpreted cautiously however because the abundance of bats using any hibernaculum tend to fluctuate naturally from year-to- year, so apparent declines were not necessarily caused by the construction of gates.

Population levels of individual bat species also may be changing. Whitaker et al. (2002) provided data suggesting that little brown bats may be declining in Indiana, whereas northern bat populations appear stable, and pipistrelles may be increasing. At Copperhead Cave however, all 3 species were captured at much lower rates in 2002 than in 1998-99 and declines were consist among species and sexes suggesting that the use of this mine by all bats has declined since the addition of the gates.

Gates can cause bats to abandon roosts, presumably by interfering with flight paths, altering microclimates in roosts, and increasing predation by providing perches for predators or crowding bats at entrances (Kallen 1964, Tuttle 1977, Ludlow and Gore 2000). For example, a *Myotis* population inhabiting Hundred Dome Cave in Kentucky, declined from 100,000 individuals in the 1960's when entrances were modified to 4,500 by 1975, then to 50 individuals by 1991 (Richter et al. 2003). Bats hibernating in Wyandotte Cave in Crawford County, Indiana, which has an artificially-modified entrance, experienced a 42% greater loss of winter body mass than those using the unaltered Twin Domes Cave in Harrison County, Indiana. This loss in body mass was a result of warmer cave temperature and its effect on metabolism of winter fat stores (Richter et al. 1993).

The impacts of gates are difficult to assess in part because the little is known about how various species respond to gate installation and each cave or mine is unique. Further, although the gray literature contains many anecdotes regarding the positive and negative effects of gates on roosting bats, very few well-designed, systematic studies have been conducted to quantify these effects (Sherwin et al. 2002). My study was designed to investigate possible changes in bat abundance before and after gate construction by comparing capture rates using the same methods, sites, and time periods. Additional surveys will help clarify whether the declines seen in 2002 continue in subsequent years. However, the causal relationship between gates and bat numbers would be stronger if the numbers of bats using the mine increase again after gates are removed. Because many bats continue to use Copperhead Cave since gate construction, and the mine poses a clear safety hazard to people, careful consideration is warranted before the gates are removed.

Reproductive condition of swarming female northern bats

Pre-roosting aggregations interest researchers studying a wide variety of animal taxa because the function of these groupings is not understood. For example, avian pre-roosting aggregations may serve multiple purposes such as lowering predation risks or helping to locate foraging sites (Moore and Switzer 1998). Aggregating bats create swarms at hibernacula. Some researchers have characterized chiropteran swarming as having two distinct phases, the swarming phase and the arrival phase. During the swarming phase, bats stay at the swarming site for only a few hours each night. Later, during the arrival phase, they begin to hibernate and stay at the site throughout the day. Bats tend to be less active during the latter phase (Fenton 1969; Degn et al. 1995). Unfortunately, it is often difficult to detect the differences in these phases (Parsons et al. 2003) further complicating our understanding of this behavior.

Swarming behavior in bats is poorly understood, but researchers have suggested various purposes for this behavior. For example, Thomas et al. (1979) observed chasing, copulating, and calling among swarming bats, which support the hypothesis that swarms function to aid in mating. In contrast, Humphrey and Cope (1965) proposed that adult females may be introducing their young to new hibernacula and Whitaker (1998) suggested that bats swarm at sites that serve as stop-offs and orientation points between hibernacula along migration routes. It is possible that swarming serves any or all of these purposes.

Copperhead Cave swarms included predominantly northern bats and little brown bats, with fewer pipistrelles. Although I trapped, carefully inspected, and swabbed 32 adult females throughout the period of swarming, I did not find any evidence of copulation in this sample. Other researchers have observed mating behavior in swarming bats, so I cannot rule out the hypothesis that swarming is associated with mating. Furthermore, my observations did not support or refute the suggestion that swarming helps adult females introduce their juvenile offspring to new hibernacula. Although I caught both adult females and juveniles entering the mine during swarming, it was not possible to associate mothers with their offspring. Future mark-recapture studies may help determine whether the bats that swarm at Copperhead Cave tend to stay at the site or use it only temporarily, but the large number of bats marked at this site, and the low number of marked bats recaptured, suggest that turnover at the mine may be high.

Seasonal changes in body mass of northern bats

Temperate-zone bats exhibit seasonal changes in body mass associated with hibernation in the winter (Harvey et al. 1999). Caceres and Pybus (1997) reported that *Myotis* species in Canada generally add 30-40% of their summer mass in fat during late-summer and fall to use as energy reserves during hibernation. This build-up of fat is necessary to sustain the bats through winter and may be equally important for successful reproduction (Kunz et al. 1998).

My results indicate that female northern bats tend to be heavier than males in all seasons. The bigger body mass of females may be necessary to ensure that pregnant females have adequate nutritional reserves to support fetal development and lactation after emergence from hibernation in the spring. Females averaged 5.8 g, 6.0 g, and 7.8 g in late-winter, summer, and fall, respectively, a gain of approximately 34% by hibernation. During these seasons, males increased from 5.6 g to 5.9 g to 7.3 g, a gain of 30%. For comparison, LaVal et al. (1977) found that female *Myotis* are significantly heavier than males throughout most of the year in Missouri. These bats increase in mass from 5.8 g in August to 8.4 g in October, a 45% increase. Females increased from 6.1 to 8.6 g, a 41% gain.

In Michigan, both sexes of little brown bat showed maximum gains in mass from mid-August to mid-September (Kunz et al. 1998). The average gain for males was 2.3

(32.9%) g and 2.1 g for females (29.6%). It may be particularly difficult for juvenile bats to gain enough mass during this period to sustain themselves through hibernation. These authors speculated that relatively low survival and fecundity in female little brown bats at northern latitudes occur because juvenile females deposit relatively little fat in their first fall. Juvenile males also weigh less than adults when they enter hibernation (Schowalter et al. 1979).

I found that northern bats in Indiana show seasonal changes in body mass similar to those of other *Myotis* bats in the eastern U.S. Fat deposition occurs primarily during a 2-month period prior to hibernation. These individuals then metabolize 1.5–2.0 g of fat during their 6-month hibernation. Females enter and emerge from hibernation heavier than males and this extra mass may be necessary for gestation and lactation during the summer, a period when gains in body mass are minimal.

<u>Winter flights</u>

At Copperhead Cave, some bats exited the mine every winter night that I trapped. Flights appeared to be most common on relatively warm nights and became more common in February, after the coldest period of winter had passed. I was not able to identify the purpose of these flights. The only bat that was re-captured and weighed after a 30-minute flight had gained 0.52 g (8.2%) of body mass suggesting that it had consumed food or water while outside the cave. It seems unlikely that the bat found active insects to consume on this cold night, but open water was available, so the individual may have consumed water. However, I did not see other light-tagged bats flying low over open water during winter, so I cannot confirm that bats are drinking during these flights. Furthermore, I did not observe tagged bats moving among cave entrances during this period which might be expected if the purpose was to move from one roost site to another. Most tagged individuals were seen flying along the wooded slopes in the valley. Forested hillsides and ridges are the preferred foraging habitats for northern bats, but also are the predominant habitat-type in the landscape surrounding the mine (Caire et al. 1979, Harvey et al. 1999). Consequently, my observations did not support or refute any of the 3 hypotheses for why bats engage in winter flights.

Maternity colony and summer roost

Adult female northern bats gather in small groups to give birth and raise their young during the spring and summer (Foster and Kurta 1999). Prior to my study, few published papers have described summer roost selection by this species, which has resulted in inconsistencies in reports of their natural history (Lacki and Schwierjohann, 2001). Cope and Humphrey (1972) found 34 adult northern bats occupying a barn in Indiana during the summer, while another summer colony occupied a park shelter (Brandon 1961). Foster and Kurta (1999) and Lacki and Schwierjohann (2001) also found summer roosts in live trees and snags. In intensively-managed forests, maternity colonies usually were found in roost trees that were generally shorter than canopy trees. Although taller, more exposed trees would allow for more solar radiation and higher roost temperatures, some researchers suggest that northern bats may use these shorter trees to avoid predators (Menzel et al. 2002) or to have increased roost visibility and access (Vonhof and Barclay 1996).

During the summer of 2002, a maternity colony of at least 42 female northern bats occupied warehouse 121C at NECD. The use of this site was first observed in June 1993, when about 100 individual bats were present (Veilleux et al. 1999). A series of subsequent surveys in 1998 reported that about 46 individuals occupied the site that summer. This warehouse is an unusual maternity site because female northern bats are known to use trees primarily as maternity roosts (Sasse and Pekins 1996, Foster and Kurta 1999, Lacki and Schwierjohann 2001, Menzel et al. 2002). It also was unusual to find male northern bats, as well as males of other species, sharing this site with the females. Lacki and Schwierjohann (2001) concluded that female northern bats in Kentucky formed colonies in snags during the summer, but males roosted alone in cavities of living hardwoods. They did not observe any adult males sharing maternity roosts. However, Elder and Gunier (1972) found mixed-sex colonies of gray bats during the summer roosting period. Approximately 1/3 of the bats in the roost were males, suggesting that isolation of the sexes does not occur in this *Myotis* species.

Northern bats have a 60-day gestation, followed by up to 34 days of nursing (BCI Inc. 2001). The NECD maternity site appeared to provide excellent environmental conditions for parturition and the early development of young bats. Daily temperatures were hot (about 10^{o}F warmer than outside) which would help pregnant females to maintain a constant body temperature and avoid torpor, maximizing fetal development (Caceres and Pybus 1997). The sheet metal roof and steel exterior walls of the building may be important factors contributing to the suitability of this site because they would effectively trap and radiate heat to the interior.

In 2002, all female northern bats had moved into the maternity roost by mid-May and had left by mid-August, a minimum occupancy of 90 days. Eight females that had been banded at the maternity roost during previous studies were recaptured at the roost in 2002, suggesting that northern bats show fidelity to maternity roosts. Births started in mid-June and appeared to be highly synchronized, with most occurring between 18 and 20 June. This is contrary to the previous idea that births are not closely synchronized in northern bats, unlike other colonial species (BCI Inc. 2001). The general timing of arrival and departure of females at the NECD maternity site is similar to that found among female little brown bats in a large maternity colony near Brazil Indiana. These females begin arriving in late-March and complete formation of the maternity colony by early May, then begin to disperse in late-summer coincidental with their movement to winter roosts (Davis and Whitaker 2002).

By comparing body mass of adult females before and after parturition, I found that these individuals lost 1.5-2.5 g of mass during the birthing period. Juveniles grew quickly and most weighed approximately 5 g by mid-July, approximately 1 month after birth. Few data are available regarding female mass at parturition or growth rates of their offspring. However, adult female little brown bats gained mass during pregnancy, lost body mass at parturition and during lactation in July, then gained mass in late-summer (Schowalter et al. 1979). In Missouri, LaVal et al. (1977) reported that 5 *Myotis* females near term averaged 7.3 g, indicating a 23% increase in mass during pregnancy.

Although I did not recapture any females banded at the maternity roost at Copperhead Cave or vice versa, I did recapture one male banded at the NECD site at the cave indicating that some movement between sites occurs. Little is know about the selection of hibernacula by female northern bats. However, suitable winter roosts are likely to be rare in this region because very specific environmental conditions are needed for hibernation (Raesly and Gates 1987). Furthermore, central Indiana contains no natural caves and my study sites are approximately 120 km northwest of the unglaciated cave country in southern Indiana and Kentucky (Whitaker and Rissler 1992a).

Banded female little brown bats in Alberta Canada sometimes travel long distances to hibernate (Schowalter 1980). Bats in central Indiana could move south to find suitable hibernacula in the caves of southern Indiana, Kentucky, and Tennessee. Therefore, it is possible that Copperhead Cave is not the primary hibernaculum used by females occupying the NECD maternity roost. However, current information suggests that northern bats are not migratory and make only local seasonal movements (BCI Inc. 2001). Futhermore.hundreds of other adult female northern bats were captured at Copperhead Cave in the winter, so this site is a suitable hibernaculum for females of this species. Once suitable hibernation sites are located, males and females of the *Myotis* genus usually demonstrate roost fidelity, returning to the same hibernaculum year-after-year (Caceres and Pybus 1997). Given the small number of bats that I was able to recapture at both study sites, it seems likely that the NECD females use Copperhead Cave, but that they entered and exited the mine on nights that I did not sample or they used alternate entrances and avoided my harp traps. The close proximity of Copperhead Cave to the NECD maternity site seems to be an important factor contributing to the value of both sites for northern bats.

CONCLUSIONS

Although the northern bat is relatively common throughout its geographic range, many aspects of its natural history and behavior are poorly understood. This is due in part to the fact that it is a nocturnal, volant species that prefers to roost in cracks and crevices making it difficult to study. In addition, the species has not declined sufficiently to warrant listing as a threatened or endangered species thereby triggering the intensive study that often comes with this status. The current status and trends of northern bat populations are difficult to assess because so little is known about the species habits and habitats. Harvey (2000) reported that this species appears to be declining in parts of its range, but populations in Indiana are thought to be stable (Whitaker et al. 2002). The future status of northern bats is likely to depend on how well we can identify and protect critical habitat and the resources needed by this species. Priorities for conservation must include protection of hibernacula and maternity roosts.

Copperhead Cave has provided important winter roosts for northern bats, as well as little brown bats and eastern pipistrelles, for at least 30 years. Recognition of the importance of this site for conserving bats resulted in the construction of gates to prevent disturbance by humans. My study suggests that gate construction coincided with a decline in use of the mine by all three species of resident bats. However, additional monitoring will be necessary to determine whether these species are abandoning the site or are experiencing a normal population fluctuation.

Similarly, Building 121C at NECD provides important habitat as a maternity roost for female northern bats and a summer roost for smaller numbers of males. However, current plans to decommission the chemical depot leave the status of this warehouse and roost in doubt. The warehouse has been used only sporadically for storage in recent years and this lack of disturbance may be an important factor in its use by bats. Since we know so little about the environmental requirements of maternity colonies, it is difficult to know whether other suitable summer roosts are available if this building is destroyed or used more intensively by people. Some studies suggest that small groups of females use loose bark and tree cavities as maternity roosts. But, it is clear from the number of females marked and recaptured at Building 121C that the resident females have shown a preference for the site through their fidelity over the years. Efforts should be made to continue monitoring the fall bat populations at Copperhead Cave and summer populations at the NECD maternity site. In addition, these sites should be considered high priorities for protection if northern bats are to be conserved in Indiana.

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Table 1. Numbers, species composition, and sex ratios of bats captured at Copperhead Cave, Vermillion County, Indiana, from January to November 2002.

Species	Males	Females	Total	Sex Ratio
Northern bats *(Myotis septentrionalis)*	185	86	271	2.2: 1
Little brown bats *(Myotis lucifugus)*	148	25	173	5.9: 1
Eastern pipistrelles *(Pipistrellus subflavus)*	29	17	46	1.7: 1
Big brown bats *(Eptesicus fuscus)*	4	0	4	--
Total	366	128	494	2.9: 1

Table 2. Numbers, species, and sex of bats captured at the 3 entrances to Copperhead Cave, Vermillion County, Indiana, from January to November 2002.

	Gate #1		Gate #2		Gate #3		
Species	M	F	M	F	M	F	Total
Northern bats *(Myotis septentrionalis)*	162	81	20	4	3	1	271
Little brown bats *(Myotis lucifugus)*	139	20	8	5	1	0	173
Eastern pipistrelles *(Pipistrellus subflavus)*	28	16	1	1	0	0	46
Big brown bats *(Eptesicus fuscus)*	4	0	0	0	0	0	4
Total	333	117	29	10	4	1	494

Table 3. Body mass (g) of 267 male and female northern bats (*Myotis septentrionalis*) captured during winter (January-March), summer (April-July), and fall (September-November) at Copperhead Cave, Vermillion County, Indiana in 2002.

	Winter			Summer			Fall		
Sex	N	Mean*	SD	N	Mean*	SD	N	Mean*	SD
Female	18	5.77	0.54	15	5.99	0.64	51	7.82	1.29
Male	47	5.63	0.87	32	5.90	0.75	104	7.31	1.42

*Mean mass did not differ between sexes ($F = 2.08$; $df = 1$; $P = 0.15$), but did differ among seasons ($F = 67.36$; $df = 2$; $P < 0.01$). There was not a significant interaction between sex and season ($F = 0.86$; $df = 2$; $P = 0.423$).

Table 4. Total number of northern bats (*Myotis septentrionalis*) exiting Copperhead Cave, Vermillion County, Indiana, by date during winter 2002.

Date	No. males	No. Females	Total
28 January	3	1	4
8 February	7	3	11
11 February	4	0	4
19 February	25	8	33
22 February	0	1	1
Total	39	13	53

Table 5. Species composition, sex, and age (adult or juvenile) of bats captured at the Newport Chemical Plant warehouse during June-September, 2002.

Species	No. males	No. Females	Total
Northern bats (*Myotis septentrionalis*)	24[a]	42[b]	66
Little brown bats (*Myotis lucifugus*)	7	0	7
Big brown bats (*Eptesicus fuscus*)	3	0	3
Total	34	42	76

[a] Includes 3 juvenile males.
[b] Includes 4 juvenile females.

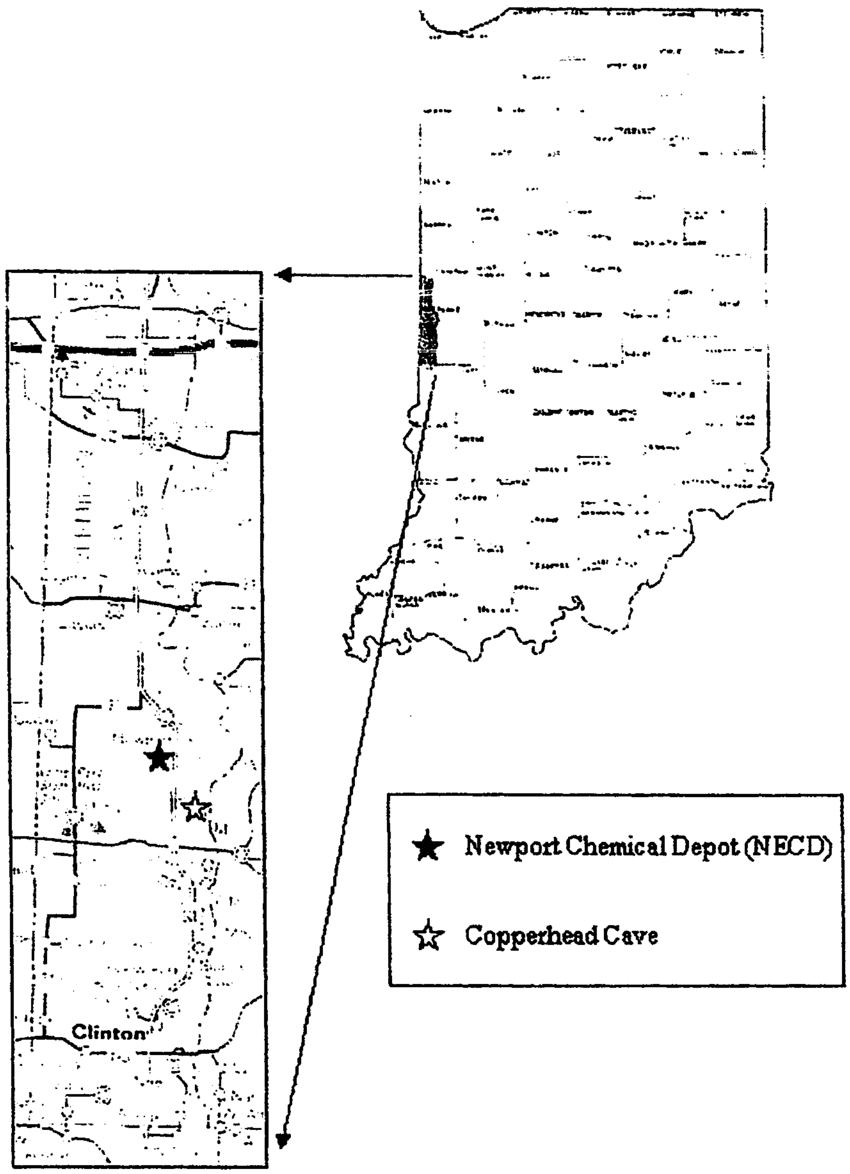

Figure 1. Locations of Copperhead Cave and Newport Chemical Depot (NECD) in west-central Indiana.

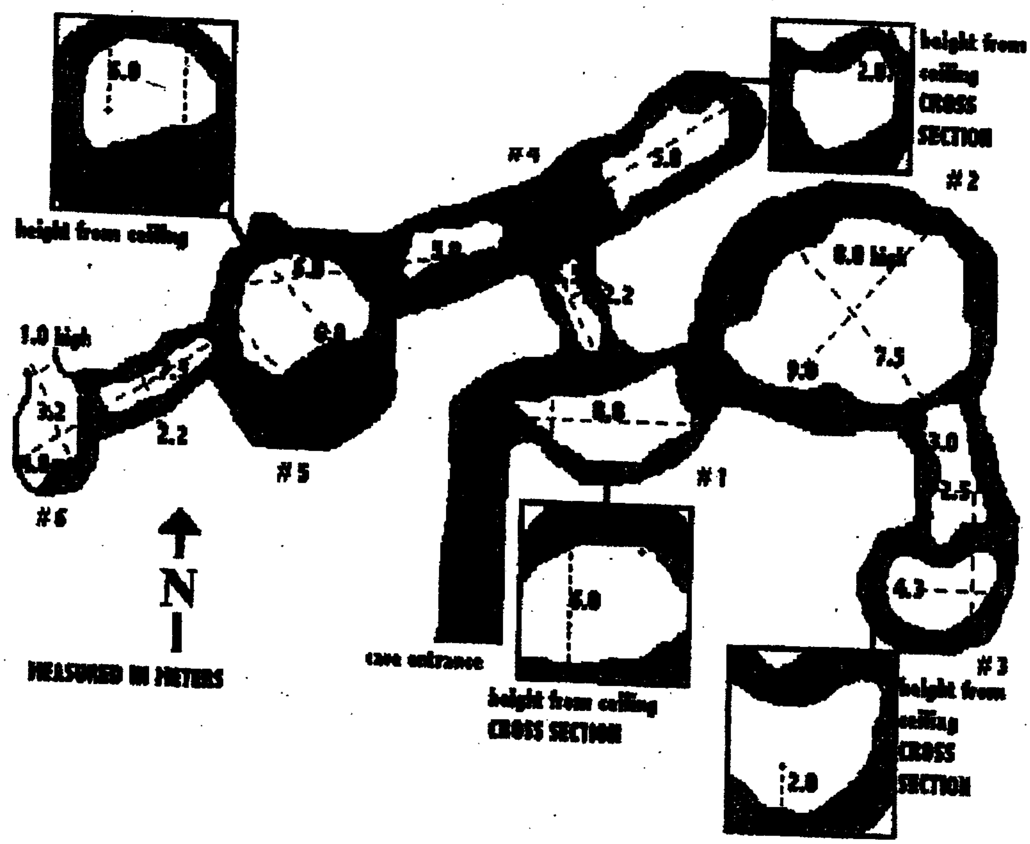

Figure 2. Cross-sectional diagram of Copperhead Cave in Vermillion County, Indiana.

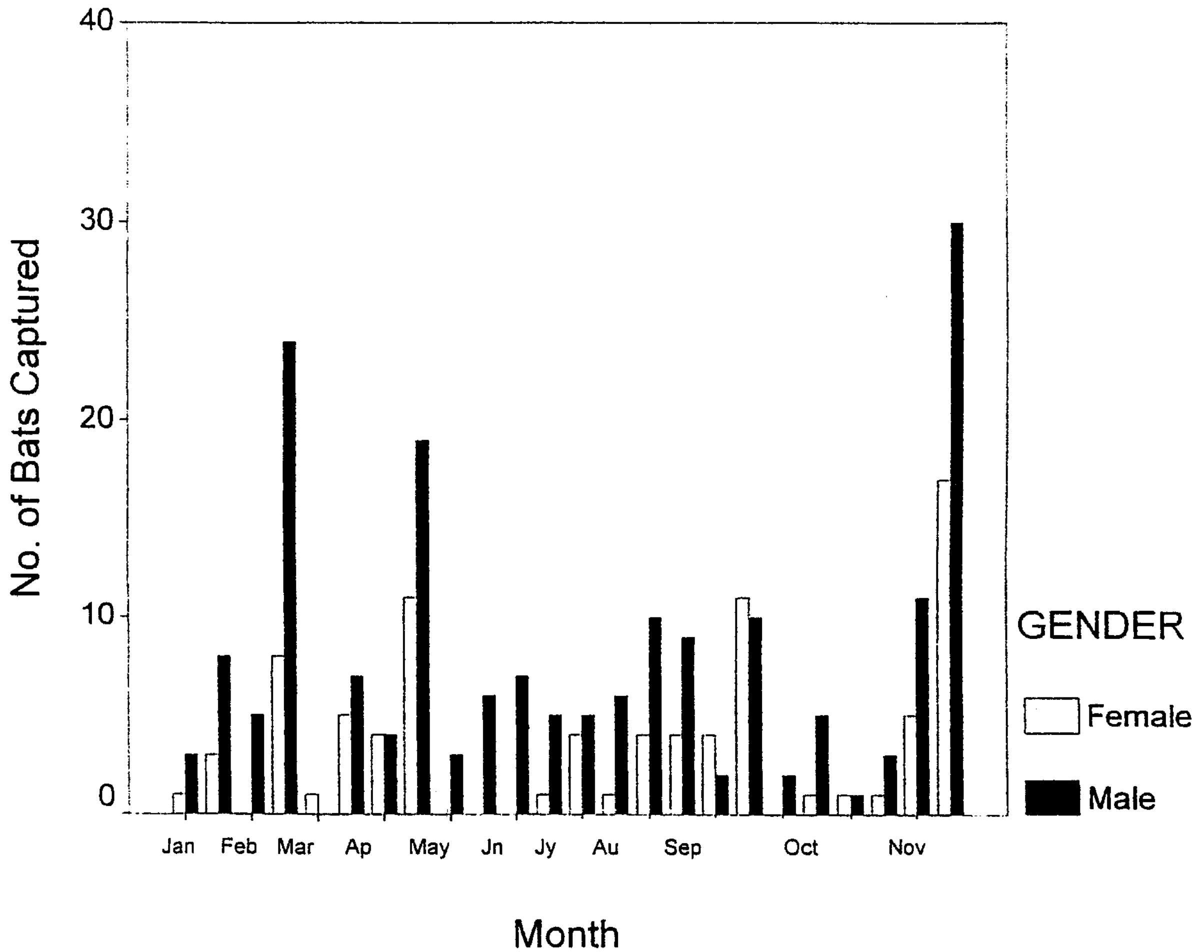

Figure 3. Number of male and female northern bats (*Myotis septentrionalis*) captured at the entrances to Copperhead Cave each month, January-November, 2002.

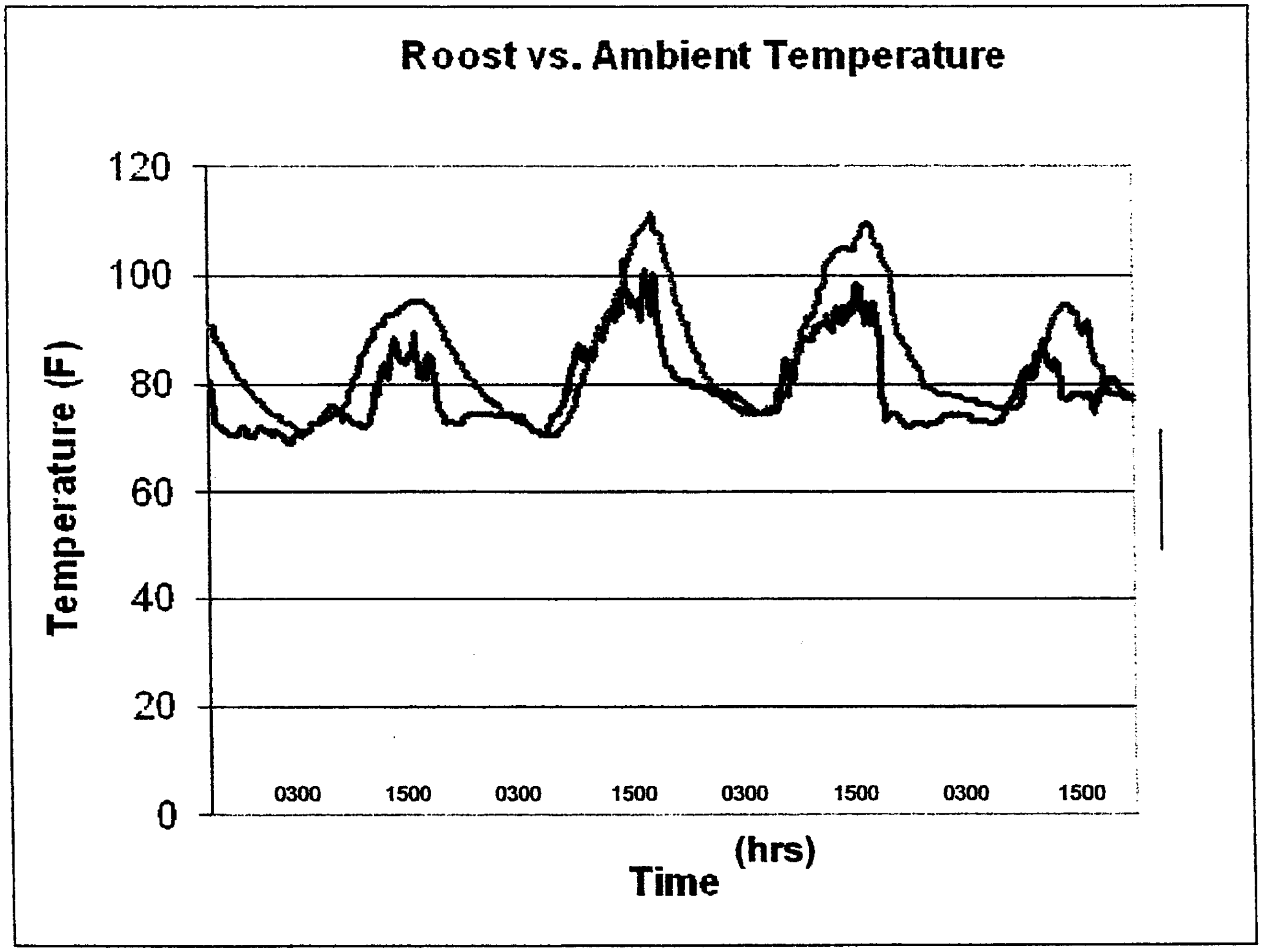

Figure 4. Temperature profile for the summer roost and maternity colony in Building 121C at NECD recorded over a 4-day period in July. Roost temperature is shown by gray line; outside ambient temperature is shown by black line. Temperatures were recorded with HOBO temperature loggers. Temperatures at the roost were about 10^{o}F warmer than outside temperatures during the day.

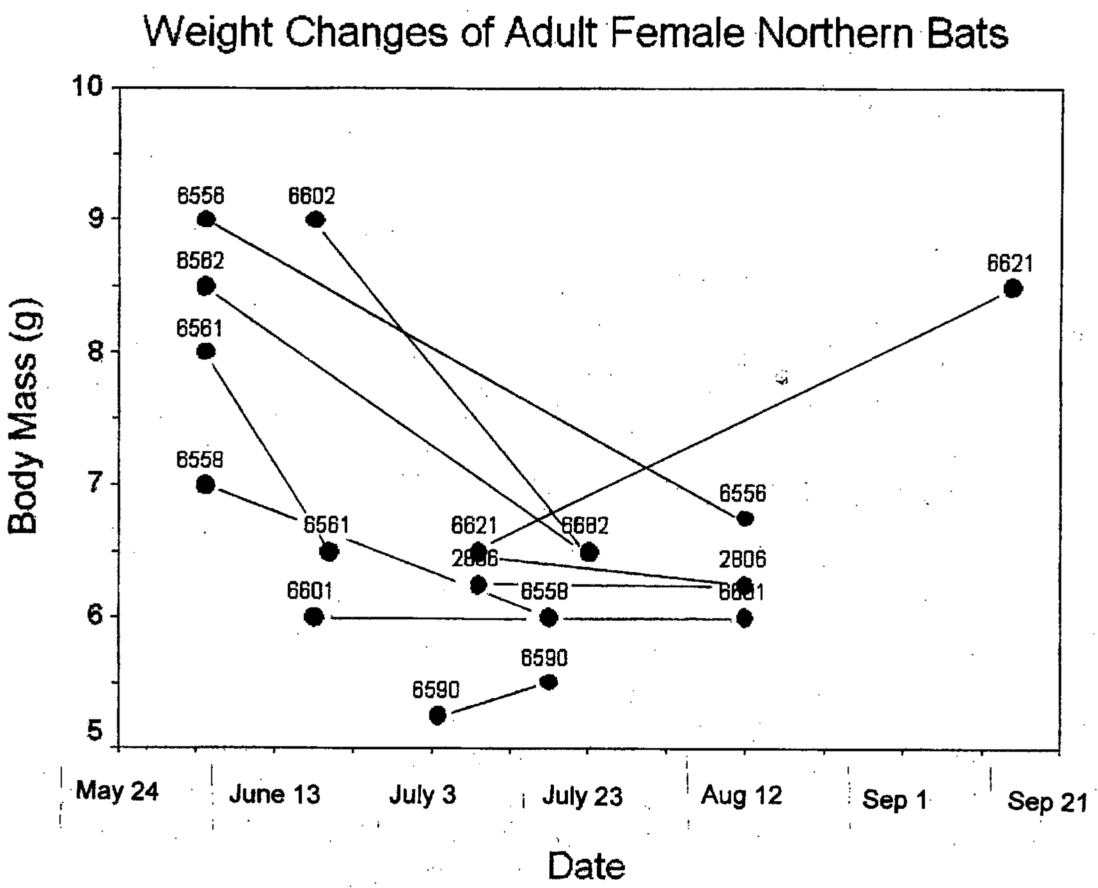

Figure 5. Changes in body mass (g) of 8 female northern bats (*Myotis septentrionalis*) captured and re-captured at the maternity roost at NECD warehouse near Newport, Indiana.

Appendix A. Adult northern bats (*Myotis septentrionalis*) females caught in mist nets at the Newport Chemical Depot (NECD) Building 121C in Vermillion County, Indiana during 2002.

DATE	SPECIES	SEX	BAND #	BAND COLOR	WEIGHT (g)	CAPTURE STATUS
5/29/2002	*Myotis septentrionalis*	f	AO6555	aluminum	6.75	1
6/4/2002	*Myotis septentrionalis*	f	1869	white	6.75	1
6/4/2002	*Myotis septentrionalis*	f	2807	red	8	1
6/4/2002	*Myotis septentrionalis*	f	AO6556	aluminum	9	1
6/4/2002	*Myotis septentrionalis*	f	AO6558	aluminum	7	1
6/4/2002	*Myotis septentrionalis*	f	AO6560	aluminum	7	1
6/4/2002	*Myotis septentrionalis*	f	AO6561	aluminum	8	1
6/4/2002	*Myotis septentrionalis*	f	AO6562	aluminum	8.5	1
6/4/2002	*Myotis septentrionalis*	f	AO6563	aluminum	7.5	1
6/4/2002	*Myotis septentrionalis*	f	AO6564	aluminum	7	1
6/14/2002	*Myotis septentrionalis*	f	AO1337	aluminum	6.5	1
6/14/2002	*Myotis septentrionalis*	f	AO6584	aluminum	7.5	1
6/18/2002	*Myotis septentrionalis*	f	AO6601	aluminum	6	1
6/18/2002	*Myotis septentrionalis*	f	AO6602	aluminum	9	1
6/20/2002	*Myotis septentrionalis*	f	1864	white	6.5	1
6/20/2002	*Myotis septentrionalis*	f	1871	white		1
6/20/2002	*Myotis septentrionalis*	f	AO6561	aluminum	6.5	2
6/20/2002	*Myotis septentrionalis*	f	AO6618	aluminum	6.5	1
6/20/2002	*Myotis septentrionalis*	f				1
7/4/2002	*Myotis septentrionalis*	f	AO6590	aluminum	5.25	1
7/4/2002	*Myotis septentrionalis*	f	AO6591	aluminum	6	1
7/4/2002	*Myotis septentrionalis*	f	AO6592	aluminum	6	1
7/4/2002	*Myotis septentrionalis*	f	AO6593	aluminum	6	1
7/4/2002	*Myotis septentrionalis*	f	AO6594	aluminum	6	1
7/4/2002	*Myotis septentrionalis*	f	AO6601	aluminum		2
7/9/2002	*Myotis septentrionalis*	f	2806	red	6.25	1
7/9/2002	*Myotis septentrionalis*	f	AO6616	aluminum	6	1
7/9/2002	*Myotis septentrionalis*	f	AO6621	aluminum	6.5	1
7/9/2002	*Myotis septentrionalis*	f	AO6623	aluminum	6.5	1
7/18/2002	*Myotis septentrionalis*	f	AO6558	aluminum	6	2
7/18/2002	*Myotis septentrionalis*	f	AO6590	aluminum	5.5	2
7/18/2002	*Myotis septentrionalis*	f	AO6592	aluminum	5.5	2
7/18/2002	*Myotis septentrionalis*	f	AO6634	aluminum	5.75	1
7/18/2002	*Myotis septentrionalis*	f	AO6638	aluminum	5.25	1
7/23/2002	*Myotis septentrionalis*	f	1869	yellow	6	1
7/23/2002	*Myotis septentrionalis*	f	AO6562	aluminum	6.5	2
7/23/2002	*Myotis septentrionalis*	f	AO6577	aluminum	5.75	1
7/23/2002	*Myotis septentrionalis*	f	AO6601	aluminum	6	2
7/23/2002	*Myotis septentrionalis*	f	AO6602	aluminum	6.5	2
7/23/2002	*Myotis septentrionalis*	f	AO6649	aluminum	6.25	1
7/25/2002	*Myotis septentrionalis*	f	AO1327	aluminum	6.25	1

Appendix A. continued.

DATE	SPECIES	SEX	BAND #	BAND COLOR	WEIGHT (g)	CAPTURE STATUS
7/25/2002	*Myotis septentrionalis*	f	AO6555	aluminum		2
7/25/2002	*Myotis septentrionalis*	f	AO6585	aluminum		1
8/1/2002	*Myotis septentrionalis*	f	AO6581	aluminum	6	1
8/5/2002	*Myotis septentrionalis*	f	2806	red	6	2
8/5/2002	*Myotis septentrionalis*	f	AO6631	aluminum	5.5	1
8/5/2002	*Myotis septentrionalis*	f	AO6642	aluminum	7	1
8/5/2002	*Myotis septentrionalis*	f	AO6643	aluminum	5.75	1
8/5/2002	*Myotis septentrionalis*	f	AO6646	aluminum	6	1
8/12/2002	*Myotis septentrionalis*	f	2806	red	6.25	2
8/12/2002	*Myotis septentrionalis*	f	AO6556	aluminum	6.75	2
8/12/2002	*Myotis septentrionalis*	f	AO6583	aluminum	6.25	1
8/12/2002	*Myotis septentrionalis*	f	AO6601	aluminum	6	2
8/12/2002	*Myotis septentrionalis*	f	AO6631	aluminum		2
8/12/2002	*Myotis septentrionalis*	f	AO6979	aluminum	6.5	1
8/12/2002	*Myotis septentrionalis*	f	AO6986	aluminum	7	1
8/12/2002	*Myotis septentrionalis*	f	AO6996	aluminum	6	1
9/15/2002	*Myotis septentrionalis*	f	AO6621	aluminum	8.5	2

Capture status 1 = 1st time capture; capture status 2 = recapture.

Appendix B. Juvenile northern bats (*Myotis septentrionalis*) banded at the Newport Chemical Depot (NECD) Building 121C, Vermillion County, Indiana, during 2002.

DATE	SPECIES	SEX	BAND #	BAND COLOR	WEIGHT	CAPTURE STATUS
6/20/2002	*Myotis septentrionalis*	f	AO6636	aluminum		1
6/27/2002	*Myotis septentrionalis*	f	AO6568	aluminum	4.25	1
6/27/2002	*Myotis septentrionalis*	f	AO6569	aluminum	4.75	1
6/27/2002	*Myotis septentrionalis*	m	AO6572	aluminum	4.5	1
6/27/2002	*Myotis septentrionalis*	m	AO6576	aluminum	4	1
6/27/2002	*Myotis septentrionalis*	m	AO6598	aluminum	5	1
7/18/2002	*Myotis septentrionalis*	f	AO6569	aluminum	5.25	2
7/18/2002	*Myotis septentrionalis*	f	AO6632	aluminum	5.25	1

Capture status 1 = 1st time capture; capture status 2 = recapture.

Appendix C. Adult male northern bats (*Myotis septentrionalis*), little brown bats (*Myotis lucifugus*), and big brown bats (*Eptesicus fuscus*) occupying the Newport Chemical Depot maternity site during summer 2002.

DATE	SPECIES	SEX	BAND #	BAND COLOR	WEIGHT	CAPTURE STATUS
6/4/2002	*Myotis lucifugus*	m	AO6559	aluminum	6.5	1
6/13/2002	*Myotis septentrionalis*	m	AO6565	aluminum	6.5	1
6/13/2002	*Myotis septentrionalis*	m	AO6566	aluminum	6	1
6/18/2002	*Myotis septentrionalis*	m	AO6565	aluminum	6	2
6/18/2002	*Myotis septentrionalis*	m	AO6603	aluminum	5.25	1
6/27/2002	*Myotis septentrionalis*	m	AO6571	aluminum	6.75	1
6/27/2002	*Myotis septentrionalis*	m	AO6588	aluminum	6.75	1
7/4/2002	*Myotis septentrionalis*	m	1861	yellow	ESCAPE	1
7/9/2002	*Myotis septentrionalis*	m	1861	yellow	6	2
7/9/2002	*Myotis septentrionalis*	m	AO6611	aluminum	6	1
7/9/2002	*Myotis septentrionalis*	m	AO6612	aluminum	7.5	1
7/9/2002	*Myotis septentrionalis*	m	AO6613	aluminum	7.25	1
7/9/2002	*Myotis septentrionalis*	m	AO6615	aluminum	5.75	1
7/9/2002	*Myotis septentrionalis*	m	AO6617	aluminum	6.25	1
7/9/2002	*Myotis septentrionalis*	m	AO6624	aluminum	7.5	1
7/13/2002	*Myotis lucifugus*	m	AO6622	aluminum	7	1
7/13/2002	*Myotis lucifugus*	m	AO6625	aluminum	6.5	1
7/13/2002	*Myotis septentrionalis*	m	AO6626	aluminum	6.5	1
7/13/2002	*Myotis lucifugus*	m	AO6627	aluminum	7	1
7/13/2002	*Myotis septentrionalis*	m	AO6628	aluminum	6	1
7/13/2002	*Myotis septentrionalis*	m	AO6629	aluminum	6	1
7/13/2002	*Myotis lucifugus*	m	AO6630	aluminum	6.25	1
7/18/2002	*Myotis septentrionalis*	m	AO6588	aluminum	6	2
7/18/2002	*Myotis septentrionalis*	m	AO6612	aluminum	7.5	2
7/18/2002	*Myotis septentrionalis*	m	AO6620	aluminum	5.5	1

Appendix C. continued.

DATE	SPECIES	SEX	BAND #	BAND COLOR	WEIGHT	STATUS
7/18/2002	*Myotis lucifugus*	m	AO6633	aluminum	6.25	1
7/18/2002	*Myotis septentrionalis*	m	AO6635	aluminum	5.25	1
7/23/2002	*Myotis septentrionalis*	m	AO6565	aluminum	5.75	2
7/23/2002	*Myotis septentrionalis*	m	AO6578	aluminum	5.5	1
7/23/2002	*Eptesicus fuscus*	m	AO6579	aluminum	13	1
7/23/2002	*Myotis septentrionalis*	m	AO6580	aluminum	5.5	1
7/23/2002	*Myotis septentrionalis*	m	AO6586	aluminum	5	1
7/23/2002	*Myotis septentrionalis*	m	AO6587	aluminum	5.75	1
7/23/2002	*Myotis septentrionalis*	m	AO6603	aluminum	5.5	2
7/23/2002	*Myotis septentrionalis*	m	AO6647	aluminum	5.75	1
7/25/2002	*Myotis septentrionalis*	m	1861	yellow	ESCAPE	2
7/25/2002	*Myotis septentrionalis*	m	AO6588	aluminum	6	2
8/1/2002	*Myotis septentrionalis*	m	1861	yellow	5.75	2
8/12/2002	*Myotis septentrionalis*	m	1861	yellow	6.25	2
8/12/2002	*Myotis septentrionalis*	m	AO6565	aluminum	6.5	2
8/12/2002	*Myotis septentrionalis*	m	AO6565	aluminum	ESCAPE	2
8/12/2002	*Myotis septentrionalis*	m	AO6588	aluminum	6	2
8/12/2002	*Myotis septentrionalis*	m	AO6597	aluminum	6	1
8/12/2002	*Myotis septentrionalis*	m	AO6644	aluminum	6	1
9/1/2002	*Myotis lucifugus*	m	AO6907	aluminum	7.75	1

Capture status 1 = 1st time capture; capture status 2 = recapture.