SITE FIDELITY AND SEX RATIOS OF EASTERN PIPISTRELLES (*PIPISTRELLUS SUBFLAVUS*) HIBERNATING IN A CENTRAL TEXAS CAVE

THESIS

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ABSTRACT

SITE FIDELITY AND SEX RATIOS OF EASTERN PIPISTRELLES (*PIPISTRELLUS SUBFLAVUS*) HIBERNATING IN A CENTRAL TEXAS CAVE

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Site fidelity and sex ratios of hibernating eastern pipistrelles (*Pipistrellus subflavus*) were studied in Gorman Cave at Colorado Bend State Park, Texas, from 2001-2002, with one visit in January 2003. Bats were tagged with Passive Integrated Transponders and information about each individual was recorded including gender, weight, and location in the cave. The sex ratio of eastern pipistrelles in Gorman Cave remained equal for the entirety of the study most likely due to the mild winter climate in central Texas. A large percentage of bats were captured only one time (41.6%). Of 149-tagged individuals, 18.7% were captured five or more times. Size of area used was calculated for these bats. Males ($\bar{x} = 4.41$ m^2) and females ($\bar{x} = 10.12$ m^2) had similar

size use areas. Females moved farther than males on each successive recapture ($\bar{x}$ = 12.66 m versus $\bar{x}$ = 8.66 m), however, this was not statistically different. Females, in general, had stronger site fidelity, although several males did demonstrate strong site fidelity. Microclimatic variables influenced the location of eastern pipistrelles in the cave; and a second order curvilinear relationship between abundance of bats and temperature ($r^2 = 0.26$, $F = 6.21$, $p < 0.01$) and humidity ($r^2 = 0.16$, $F = 3.93$, $p < 0.05$) was detected. Female body mass averaged 5.8 g, which was significantly more than males which averaged 5.6 g ($p < 0.05$).

INTRODUCTION

During hibernation, animals lower their body temperature to near ambient temperature and become inactive for periods of time ranging from several days to months. Hibernation may occur seasonally as a response to cold temperatures or the unavailability of food. Under these environmental conditions, maintenance of a constant, high body temperature becomes too energetically expensive. Several families of bats have some members, especially in northern temperate areas, capable of hibernation for energy conservation (Vaughan et al., 2000). The large, mostly hairless, wing membranes of bats increase their surface area to volume ratio resulting in a higher metabolic rate than other mammals of similar size (Twente, 1955b). Therefore, many temperate bat species that capture seasonally available insect prey, including the eastern pipistrelle (*Pipistrellus subflavus*), must rely upon long winter hibernation for their survival. Various physical structures, including mines, tunnels, buildings, and culverts provide suitable hibernacula for eastern pipistrelles (Sandel et al., 2001). My study concentrated on bats hibernating in Gorman Cave in central Texas.

The choice of appropriate hibernacula is of utmost importance to the survival of a hibernating bat (Raesly and Gates, 1987). Unsuitable conditions, for example hibernating in an environment that is too warm or too cold, can lead to frequent arousal and the over-use of fat reserves before the end of winter (Speakman et al., 1991; Twente, 1955b).

Since there is a spectrum of microclimatic conditions available within a hibernaculum and bats must choose a site based on their energetic needs (Twente, 1955a), one strategy for surviving winter would be to develop fidelity to a site with a stable microclimate that allows conservation of energy. Lewis (1995), in a review of literature on site fidelity, found bats remained faithful to permanent roosts in buildings and caves and frequently moved between abundant roost sites. Strong site fidelity and survival value may cause some eastern pipistrelles to use the same site within Gorman Cave throughout winter.

Arousal from hibernation and movement of bats occur throughout winter because of physiological needs of the bat or disturbance (Whitaker and Rissler, 1992; Hassell, 1969). Moffat (1904) observed pipistrelle bats (*Pipistrellus pipistrellus*) active most nights in the winter when temperatures at dusk exceeded 6.1° C, and occasionally observed them at temperatures as low as 3.9° C. Avery (1985) suggested that pipistrelles aroused from hibernation on warmer nights to forage on more abundant insect prey, which maximized the energetic cost of awakening. Speakman and Racey (1989) concluded arousal and winter emergence of the pipistrelle bat corresponded with the need to drink water, not feed on insects. They found that non-cavemiculous pipistrelle bats detected the temperature outside the hibernacula and aroused to find water and drink every nine to 12 days; whereas, bats hibernating in caves, like the eastern pipistrelle, may remain in torpor for a longer time because of the availability of water in the cave (Speakman and Racey, 1989). Hassell (1969) reported that male and female eastern pipistrelles moved an average of three to four times during the hibernation period, females remained inactive for shorter periods of time (13.6 days versus 16.9 days for males), and moved shorter distances when active (20.0 m versus 23.6 m). Occasionally, after a move, individuals returned to a previously occupied site in the cave, and on nine occasions, individual bats returned to the exact site within a cave on two successive winters (Hassell, 1969).

Four species of bats, the big brown bat (*Eptesicus fuscus*), cave myotis (*Myotis velifer*), big-eared bat (*Corynorhinus rafinesquei*), and Bunker's pallid bat (*Antrozous pallidus bunkeri*), frequently moved, either from the disturbance of being banded or natural arousal, and settled at different sites (Twente, 1955a). These species apparently did not have strong site fidelity within a cavern (Twente, 1955a). In central Texas, all recaptures of eastern pipistrelles occurred in the same highway culvert occupied the previous winter, but because of low recapture rates and the availability of alternate hibernacula, Sandel et al. (2001) concluded the species did not evidence a strong site fidelity.

The sex ratio of hibernating eastern pipistrelles can be skewed from one to one (Sandel et al., 2001; Fujita and Kunz, 1984; Jones and Suttkus, 1973; Jones and Pagels, 1968). In Louisiana, the sex ratio for populations of eastern pipistrelles varied seasonally with females outnumbering males in winter (November through March) and males outnumbering females in summer (April to October) (Jones and Suttkus, 1973; Jones and Pagels, 1968). The dispersal of more females than males in spring, as females moved from roosts to maternal colonies and greater female assembly in fall caused the disparate ratios (Jones and Pagels, 1968). In Texas, however, the sex ratio favored males in winter (Sandel et al., 2001).

The eastern pipistrelle is a small bat in the family Vespertilionidae with a distribution throughout most of the eastern United States and much of eastern Central

America (Hall, 1981). The westernmost border of its range occurs in central Texas (Davis and Schmidly, 1994; Fujita and Kunz, 1984). The species is an obligate hibernator, roosting singly or in small clusters. *Pipistrellus subflavus* has demonstrated fidelity to winter hibernacula and a disproportionate sex ratio during hibernation (Fujita and Kunz, 1984). I focused my study on eastern pipistrelles in a natural winter hibernacula, Gorman Cave. I investigated site fidelity over winter, the influence of microclimate parameters on site selection, and the sex ratio.

MATERIALS AND METHODS

The Study Site

Colorado Bend State Park is located 48 km west of Lampasas in San Saba and Lampasas counties. The park encompasses distinctive features including waterfalls, the Colorado River, and several caves. Many caves on the property are open to the public for guided tours, the most popular of which is Gorman Cave (Fig. 1). Gorman Cave is 914 m (3,000 ft) in length and about 8 m (25 ft) tall at its greatest height (Elliott, 2000). The main and secondary entrances to the cave open near the Colorado River. The walls of the cave are marked by large calcite crystals and a small stream runs through the cave contributing to the formation of several travertine pools (Elliott, 2000). A bat gate, installed to protect maternal colonies of cave myotis (*Myotis velifer*), divides the cave into two sections. It is at this spot, the bat gate, where witness point 1 occurs. Seventeen witness points (hereafter, WP) extend from the bat gate toward the entrance (Fig. 2). A screw drilled into the wall identifies each WP. The study area only included the section of the cave from the entrance to the bat gate; about 215 m linear distance. Eastern pipistrelles use this cave as a hibernaculum in winter.

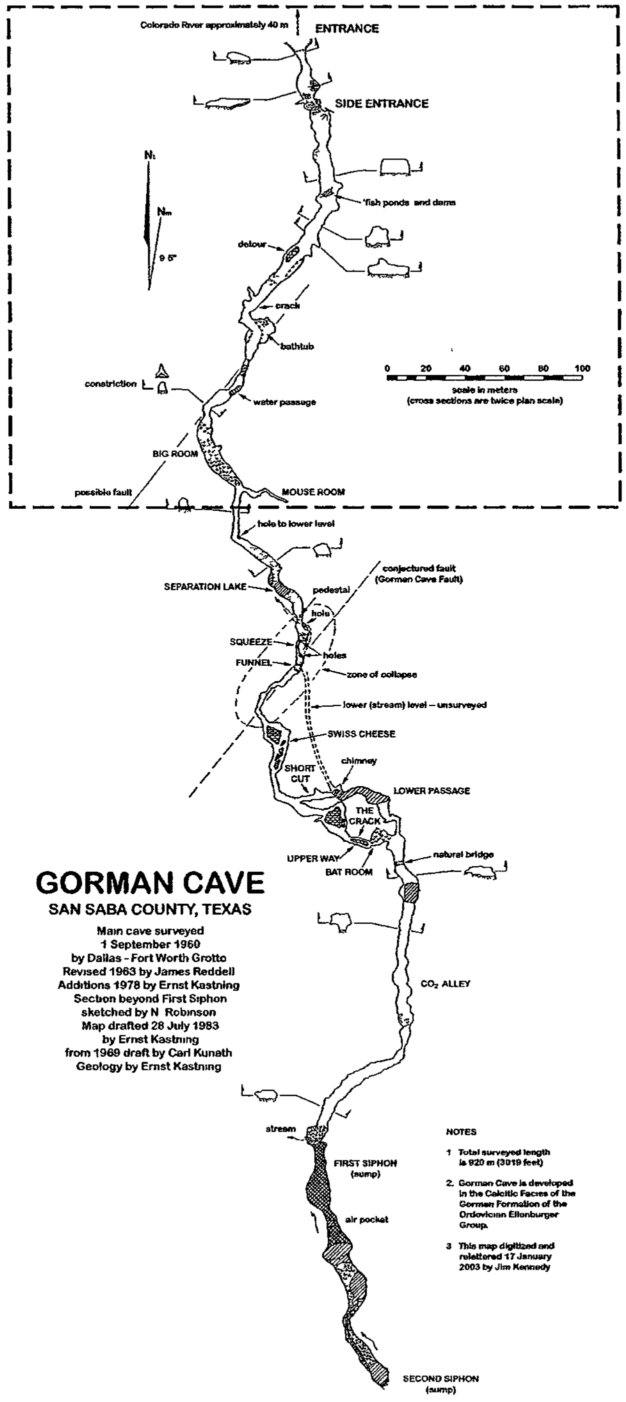

Figure 1. Map of Gorman Cave, Colorado Bend State Park from the Texas Speleological Survey. The dashed box depicts the portion of the cave used for this project, and is enlarged in Figure 2.

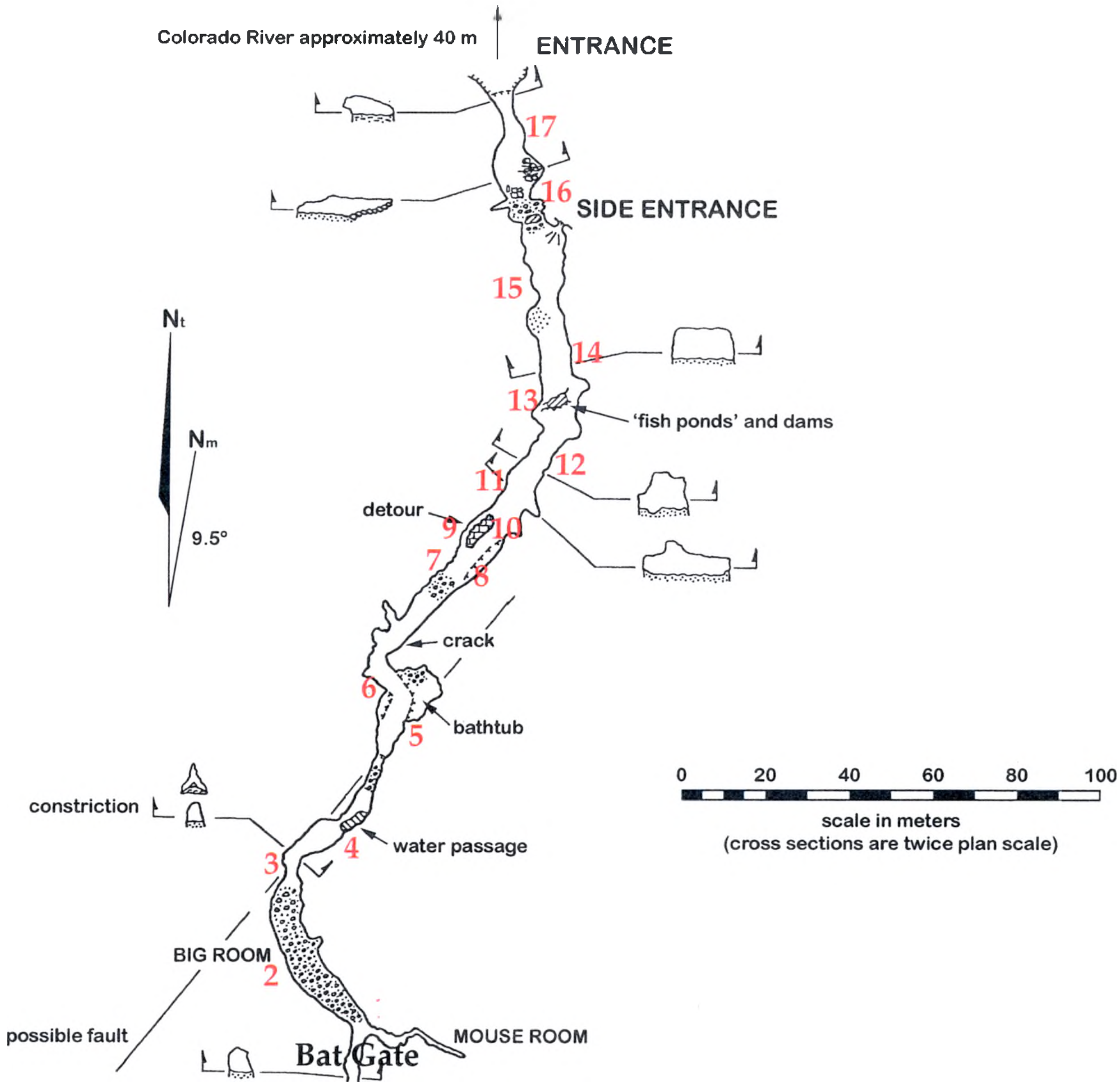

Figure 2. Enlarged map of Gorman Cave from the bat gate to the entrance showing the approximate locations of Witness Points. Witness Points are marked by their number in red.

Mapping Locations within the Cave

A borehole into Gorman Cave from the strata above enters the cave near the bat gate. I used a Global Positioning System (GPS) (Trimble, Sunnyvale, CA) to locate the borehole and Trimble Pathfinder Office v. 2.8 software (Trimble, Sunnyvale, CA) to differentially correct the point improving the accuracy to within 1 m. A telescoping pole extended from the floor of the cave up through the borehole provided a fixed point with known GPS coordinates. I used a tape measure strung tightly between the telescoping pole and WP 1 to measure the distance in centimeters along a taut line. I used a Suunto compass (Model KB-14, Suunto USA, Carlsbad, CA) to determine the angle bearing between the pole and WP 1. This located the WP in time and space. I repeated this process for each of the 17 WPs in sequential order by measuring the distance between the two WPs and determining the angle bearing.

Collecting Methods and Tagging

I observed bats in Gorman Cave twice monthly from February 2001 to April 2001 and November 2001 to April 2002. I made a final visit to the cave on 20 January 2003. Data collection began at WP 1 near the bat gate and continued in sequence of WPs toward the entrance of the cave. I recorded temperature and humidity at each WP using a digitized Thermohygrometer (Forestry Suppliers, Jackson, MS). I searched surfaces of the cave including the ceiling, walls, ledges, and crevices for eastern pipistrelles.

I collected untagged, torpid bats from the surfaces in the cave by hand, with the aid of a padded tong if bats were inside narrow cave formations, or by dislodging them from high locations with the telescoping pole. Bats were individually collected, tagged, and released before the capture of the next bat to minimize handling time. I used a 3 cc syringe with a 12-gauge needle to subcutaneously implant a 12 mm Passive Integrated Transponder (PIT tag) (AVID, Norco, CA) in the lumbar region of each eastern pipistrelle. PIT tags allowed me to quickly give each bat a unique number and to easily identify the bat. This technique has been used on various taxa including snakes, birds and mammals, including the big brown bat, with no adverse physiological or behavioral response (Elbin and Burger, 1994). I scanned each tag before implantation to insure proper function. I sterilized the needle with a drop of Betadine Solution (povidone-iodine, 10%) between implants to prevent possible transmission of infection. Once the tag was implanted in the bat, a second scan confirmed the proper function of the tag.

At this time, I recorded the unique nine-digit identification number of the individual along with its sex and weight. I also determined whether the substrate type occupied by the bat occurred over water or rock. Bats inhabited either exposed rock surfaces or in arrays of soda straws or other cave formations. I determined the location of a bat by measuring the distance in centimeters from the bat to the nearest WP. I obtained a direction from a WP to the bat using a compass. I noted the height of the bat from the floor in centimeters, and any additional comments on cave conditions or the condition of the bat at this time. After tagging, I allowed each bat to recover from the implantation process for approximately five minutes, and then placed the bat on a ledge or rock for final recovery and flight.

I scanned all eastern pipistrelles encountered in the cave with the AVID Mini TracKer PIT tag reader (AVID, Norco, CA) to verify their identity. I attached the PIT tag reader to a telescoping pole to scan bats that were above my reach. I did not disturb previously tagged hibernating bats. I determined their location within the cave as described previously, and recorded other information about the bat and ambient conditions.

I imported data on WP locations and information on locations of eastern pipistrelles from Excel spreadsheets into ArcView GIS version 3.3 for analysis. I created minimum convex polygons (MCP) for each bat with more than five captures using the Animal Movement Program version 2.0 Beta (Hooge et al., 1999). I used the MCP to determine an area of use for each bat to estimate their site fidelity.

For the duration of this project I operated under permits from the Texas Parks and Wildlife Department (SPR-0890-234) and the Institutional Animal Care and Use Committee (5Q6DDW).

Statistical Analysis

I used chi-square goodness of fit tests to analyze gender data and the substrate type each bat roosted over. I used the Kolmogorov-Smirnov goodness of fit test to test the hypothesis of horizontal (discrete data) and vertical (grouped data) random assortment of bats within the cave. A simple regression analysis performed on temperature and humidity data from each WP estimated probable temperature and humidity at the location of the bat. Another regression analysis tested for a correlation between temperature, humidity and the abundance of bats at a location. T-tests were used to distinguished differences in weights of male and female bats as well as differences in the size of areas occupied. An alpha value of 0.05 determined significance for all statistical tests.

RESULTS

Sex Ratio and Recaptures

During the winter 2001-2002, the number of eastern pipistrelles gradually increased from a low of six torpid bats on 2 November 2001 to a high of 58 bats on 21 January 2002. Eastern pipistrelle numbers dwindled by late March, and by early April in both 2001 and 2002 few bats remained (Table 1). Five of the eastern pipistrelles hibernating in Gorman Cave on 20 January 2003 were previously tagged.

A total of 146 eastern pipistrelles were tagged during 10 collection periods, there were six trips when PIT tags were not available to tag new individuals. Three bats, PIT tagged during a previous study, were recaptured for a total of 149-tagged individuals. Of the 149 individuals, two males, one female and one bat of unknown gender were tagged, never recaptured, and their location as recorded was insufficient for analysis. I did not import information for these bats into ArcView for analysis but they were used to calculate the sex ratio and recapture rates.

The sex ratio of eastern pipistrelles in Gorman Cave (Table 1) did not differ from 1:1 ($\chi^2 = 0.062$, $p > 0.05$) over the course of this study. There were 74 males (49.6%), 71 females (47.7%), and 4 bats of unknown sex (2.7%).

Sixty-two bats, accounting for 41.6% of the tagged eastern pipistrelles, were captured one time, 59 bats (39.7%) were observed two to four times, and 28 bats (18.7%) were observed five or more times (Table 2).

Table 1. Sex ratio of tagged eastern pipistrelles for each visit to Gorman Cave, Colorado Bend State Park, Texas in 2001-2003.

Date	Males	Females	Total Bats[a]	Sex Ratio	χ^2
02/21/2001	2	2	4	1:1	[c]
03/16/2001	15	9	24	1.7:1	1.5, $p > 0.05$
04/02/2001	1	0	1	1:0	[c]
11/02/2001	4	0	6	4:0	[c]
11/13/2001	9	12	22	0.8:1	0.46, $p > 0.05$
12/11/2001	16	15	32	1.1:1	0.03, $p > 0.05$
12/18/2001	23	21	45	1.1:1	0.09, $p > 0.05$
12/30/2001	27	18	46	1.5:1	1.8, $p > 0.05$
01/21/2002	28	27	58	1:1	0.02, $p > 0.05$
02/04/2002	22	23	47	1:1	0.02, $p > 0.05$
[b] **02/10/2002**	21	23	45	0.9:1	0.09, $p > 0.05$
[b] **03/04/2002**	18	14	33	1.3:1	0.5, $p > 0.05$
[b] **03/15/2002**	9	10	19	0.9:1	[c]
[b] **03/24/2002**	7	10	17	0.7:1	[c]
[b] **04/08/2002**	5	4	9	1.3:1	[c]
[b] **01/20/2003**	4	1	5	4:1	[c]

[a] Includes bats of unknown gender.

[b] No new bats tagged on this date.

[c] Unable to calculate chi-square values due to small sample size.

Table 2. Recapture rates for eastern pipistrelles in Gorman Cave, Colorado Bend State Park, Texas in 2001-2003. Total includes bats of unknown gender.

Number of Captures	**Males**	**% Males**	**Females**	**% Females**	**Total**	**% of Total**
1	27	36.5	33	46.5	62	41.6
2	14	18.8	14	19.7	29	19.5
3	12	16.2	6	8.5	18	12.1
4	9	12.1	3	4.2	12	8.1
5	4	5.4	4	5.6	8	5.4
6	1	1.4	6	8.5	7	4.7
7	4	5.4	2	2.8	6	4.0
8	1	1.4	1	1.4	2	1.3
9	1	1.4	0	0.0	2	1.3
10	0	0.0	2	2.8	2	1.3
11	0	0.0	0	0.0	0	0.0
12	1	1.4	0	0.0	1	0.7
Totals	74	100.0	71	100.0	149	100.0

Areas of Use

The size of area used by eastern pipistrelles in Gorman Cave during my study ranged from a low of 0.04 m^2 to 47.21 m^2 (Fig. 3). The size of areas used by males ranged from 0.49 m^2 to 12.33 m^2 ($\bar{x}$ = 4.41 m^2, SE = 1.06). Overall, females had a larger mean area ($\bar{x}$ =10.12 m^2, SE = 4.08) with a range from 0.04 m^2 to 47.21 m^2. The size of male and female areas of use did not differ from one another ($t = 1.22$, $p > 0.05$). Two females had unusually large areas of use compared to all others. After dropping these two female bats from the analysis, the mean area of use dropped dramatically ($\bar{x}$ = 4.42 m^2, SE = 1.47), but the difference in the size of male and female use areas remained non-significant ($t = 0.01$, $p > 0.05$). I generated maps showing minimum convex polygons for areas of use for bats in Gorman Cave with more than five recaptures. Representative female and male areas of use are presented in Figures 4 and 5. Areas of use for all other bats are shown in Appendix A.

Females moved greater distances than males between successive recaptures during winter 2001-2002 ($\bar{x}$ = 12.66 m, SE = 2.7; $\bar{x}$ = 8.66 m, SE = 1.69), respectively. This difference in movements was not statistically significant ($t = 1.26$, $p > 0.05$). Three of 28 bats captured more than five times were caught in successive seasons. Male 1 was located on 13 November 2001; 23.6 m from the first site I located him on 21 February 2001. This bat moved back up 23.6 m and remained in that area for the rest of winter. Male 4 was captured on 20 January 2003, 0.34 m from his last capture site on 4 March 2002. Finally, Female 12 was recaptured on 20 January 2003, 13.85 m from her capture site on 24 March, 2002. The average distances moved for all bats are presented in Appendix B.

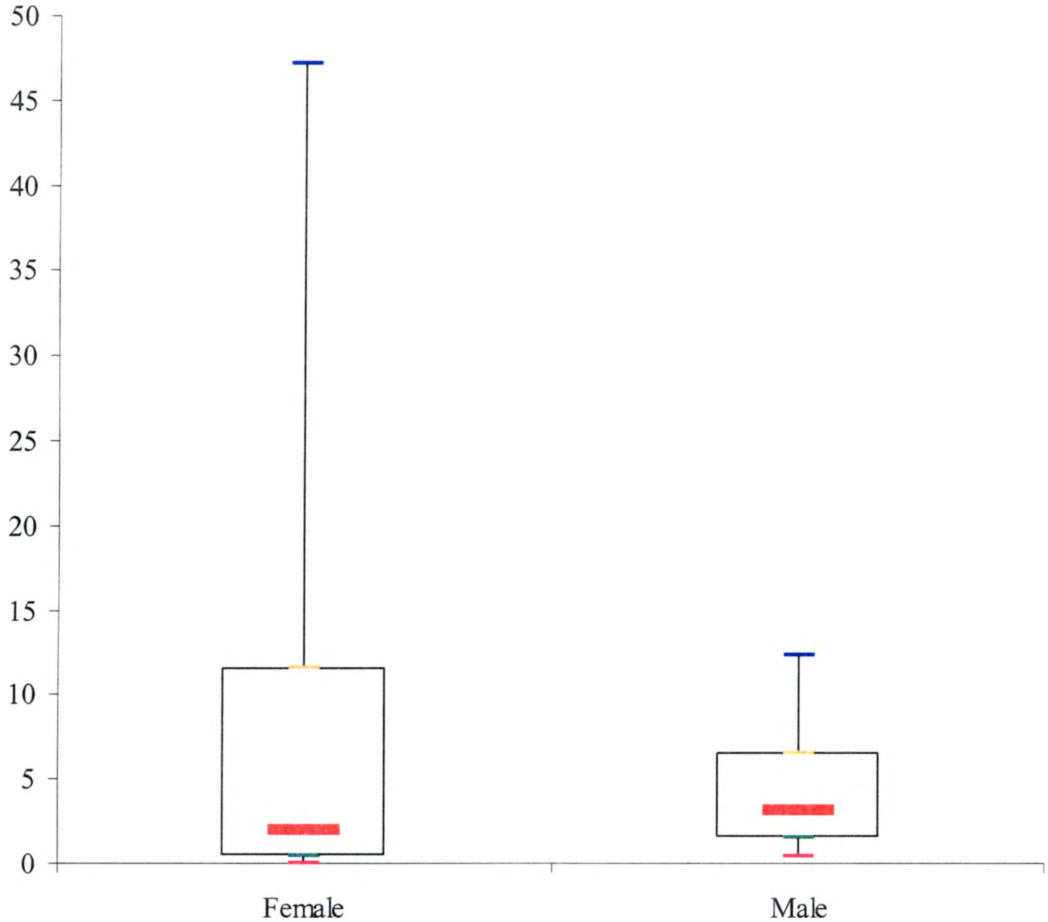

Figure 3. Box and Whisker diagram showing female and male area of use (m^2) for eastern pipistrelles in Gorman Cave, Colorado Bend State Park, Texas in 2001-2003. The median (red), range, and percentiles (25 and 75, green and orange respectively) are illustrated in the diagram.

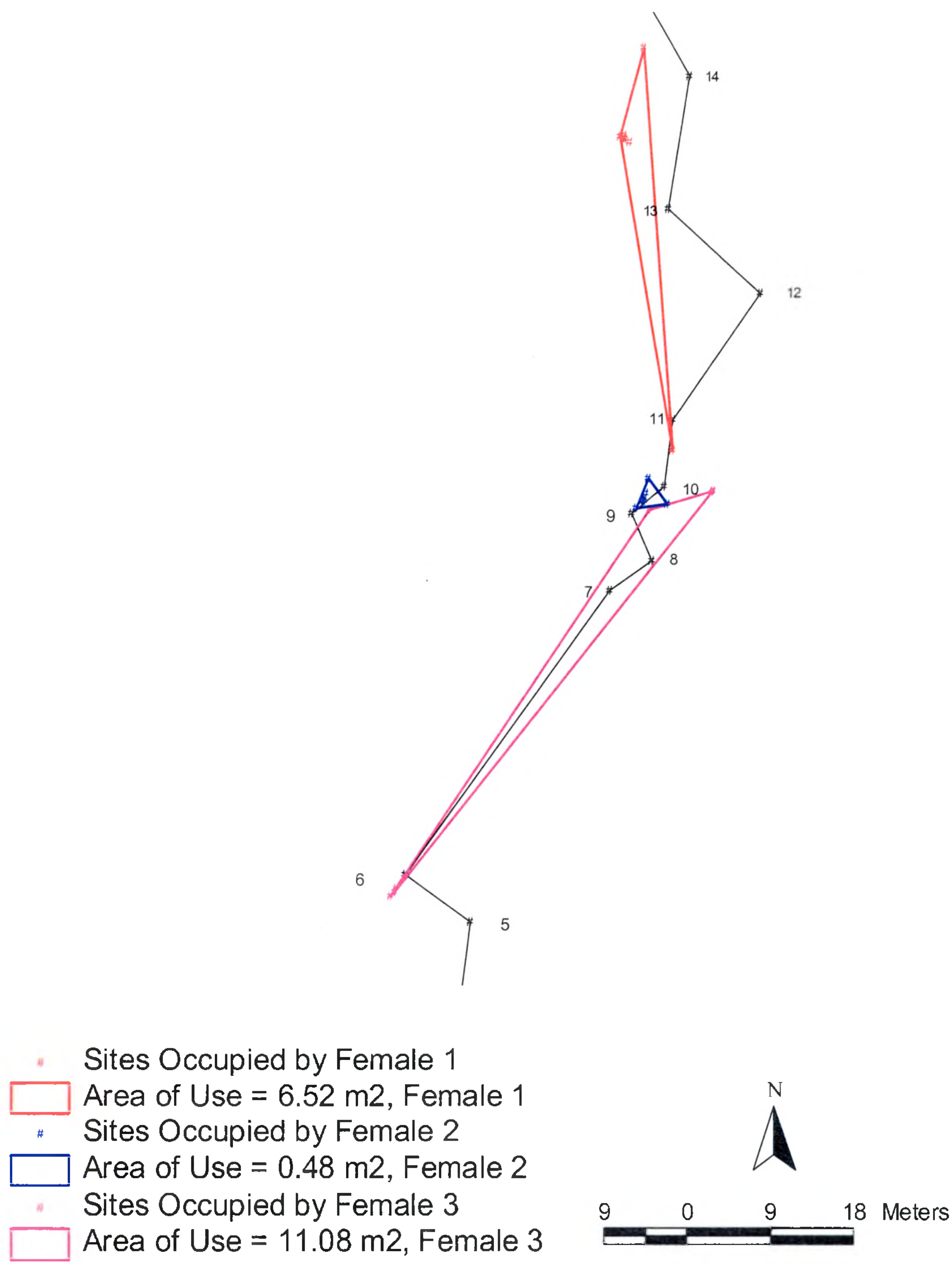

Figure 4. Minimum convex polygons representing areas of use (m^2) by female eastern pipistrelles in Gorman Cave, Colorado Bend State Park, Texas in winter 2001-2002.

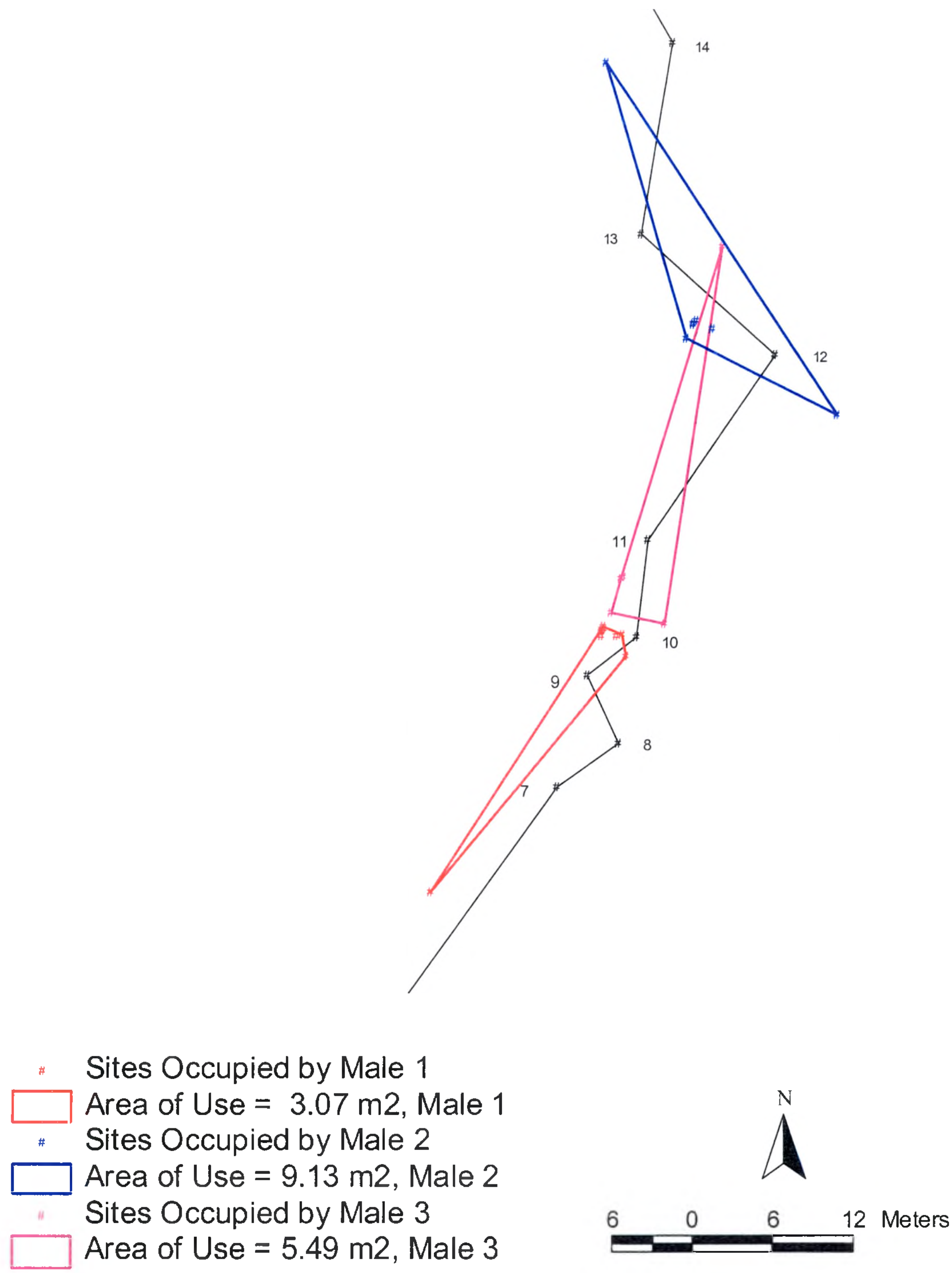

Figure 5. Minimum convex polygons representing areas of use (m^2) by male eastern pipistrelles in Gorman Cave, Colorado Bend State Park, Texas in winter 2001-2002. Male 1 captured once during winter 2000-2001.

Spatial Distribution and Site Selection of Bats

The vertical distribution of eastern pipistrelles was not random (D = 57, $p < 0.05$). Bats positioned themselves at heights ranging from 0.28 m to 5.0 m with the majority of observations occurring between 1.0 – 1.99 m (Table 3).

Table 3. Number of observations of hibernating eastern pipistrelles at 1 m height intervals in Gorman Cave, Colorado Bend State Park, Texas in 2001-2003.

Height from Floor (m)	Number of Observations	Percent of Observations
0.0 – 0.99	24	17.4
1.0 – 1.99	82	59.4
2.0 – 2.99	26	18.8
3.0 – 3.99	5	3.6
4.0 – 4.99	0	0.0
5.0 – 5.99	1	0.7

Eastern pipistrelles were not randomly distributed throughout the cave (D = 43.24, $p < 0.05$). The majority of observations, 86.6%, occurred between WP 7 and WP 14. Only 6.1% of observations occurred between WP 1 and WP 6 with the remaining 7.4% between WP 15 and WP 17 (Table 4).

Average temperature and humidity values for each WP in Gorman Cave are summarized in Table 4. The microclimate varied considerably between points, possibly accounting for the skewed distribution of bats among the WPs. The best-fit line describing the temperature gradient in Gorman Cave is $\hat{Y} = 21.39 + (-0.05)\,x$ (see Fig. 6) and the best-fit line describing the humidity gradient is $\hat{Y} = 98.08 + (-0.06)\,x$ (see Fig. 7).

Table 4. Mean temperature and humidity measurements at each witness point in Gorman Cave, Colorado Bend State Park, Texas in 2001-2002. The number and percentage of eastern pipistrelles occurring at each witness point are included.

Witness point	Temperature (C°)	Humidity (%)	Number of bats	Percentage
1	19.1; SE = 0.25	95.3; SE = 1.85	0	0.0
2	19.9; SE = 0.48	96.0; SE = 0.87	0	0.0
3	19.7; SE = 0.41	95.5; SE = 1.54	4	2.7
4	19.7; SE = 0.53	95.8; SE = 0.88	1	0.7
5	19.0; SE = 0.55	95.0; SE = 1.20	1	0.7
6	18.6; SE = 0.44	93.8; SE = 1.66	3	2.0
7	15.8; SE = 0.64	88.0; SE = 2.66	43	29.1
8	15.8; SE = 0.84	89.0; SE = 3.15	5	3.4
9	15.5; SE = 0.70	92.0; SE = 2.53	15	10.1
10	14.3; SE = 0.51	89.0; SE = 2.94	16	10.8
11	14.8; SE = 0.77	92.5; SE = 1.97	10	6.8
12	14.3; SE = 0.92	90.3; SE = 2.74	14	9.5
13	13.4; SE = 0.80	91.3; SE = 3.49	6	4.1
14	12.8; SE = 1.01	85.0; SE = 4.02	19	12.8
15	12.9; SE = 1.29	83.0; SE = 4.33	3	2.0
16	12.0; SE = 1.12	80.5; SE = 4.97	8	5.4
17	10.8; SE = 1.41	86.6; SE = 4.54	0	0.0

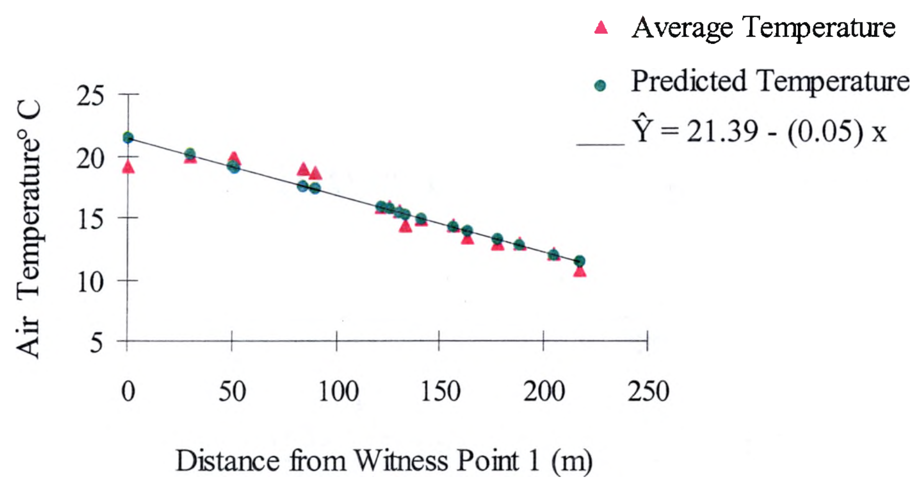

Figure 6. Best fit regression line, temperature (°C), for Gorman Cave, Colorado Bend State Park, Texas in winter 2001-2002.

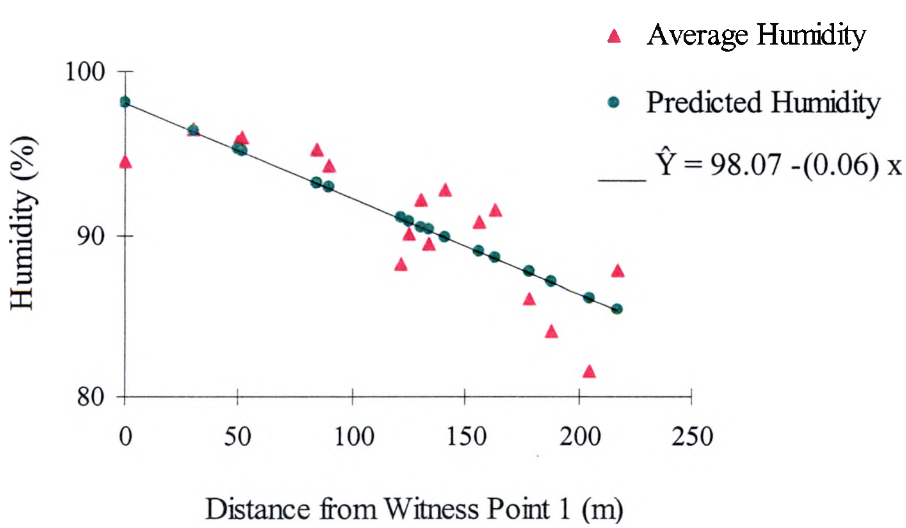

Figure 7. Best fit regression line, percent humidity, for Gorman Cave, Colorado Bend State Park, Texas in winter 2001-2002.

Tagged bats were found resting, torpid or hibernating in Gorman Cave at temperatures ranging from 11.8 ° C to 20.3 ° C. There was a second order curvilinear relationship between air temperature and the abundance of eastern pipistrelles $\hat{Y} = -0.32 x^2 + 10.26 x - 76.69$ ($r^2 = 0.26$, $F = 6.21$, $p < 0.01$) (see Fig. 8). Percent humidity at sites selected by eastern pipistrelles ranged from 86.5% to 96.8%. The data suggests a second order curvilinear relationship between humidity and abundance of bats $\hat{Y} = -0.16 x2 + 28.84 x - 1316.1$ ($r^2 = 0.16$, $F = 3.93$, $p < 0.05$) (see Fig. 9).

Eastern pipistrelles preferentially selected sites where they were roosting over solid substrate (χ^2=10.2, $p < 0.01$). Out of 149 bat observations, 94 bats (63%) selected substrate types that were positioned over rock or gravel, and 55 (37%) positioned themselves over water.

Weight and Longevity

Weight of individuals ranged from a low of 4.0 g for both sexes, to a high of 7.5 g for males and 8.5 g for females. There was a statistically significant difference in male and female weights (male: $\bar{x} = 5.60$ g, SE = 0.09; female: $\bar{x} = 5.83$ g, SE = 0.10), respectively ($t = 1.73$, $p < 0.05$).

Three individuals tagged during a previous study were PIT #023-302-793, a female first tagged 1 January 1997; PIT #023-794-268, a female first tagged 13 December 1996; and a male, PIT #025-589-862, tagged first on 8 November 1997. I recaptured both females in spring 2002, 5 years and 4 months after initial tagging. I recaptured the male 11 times during the study, once in spring of 2001 and 10 times during the winter 2001-2002 season. At time of last capture this bat had been tagged for 4 years 5 months.

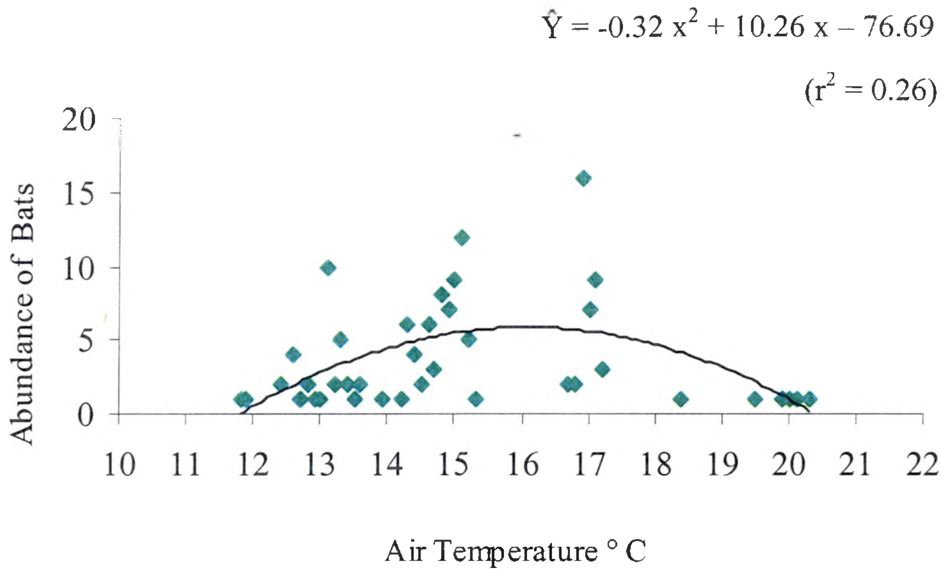

Figure 8. Graph showing the second order curvilinear relationship between temperatures (° C) and abundance of eastern pipistrelles in Gorman Cave, Colorado Bend State Park, Texas in 2001-2003.

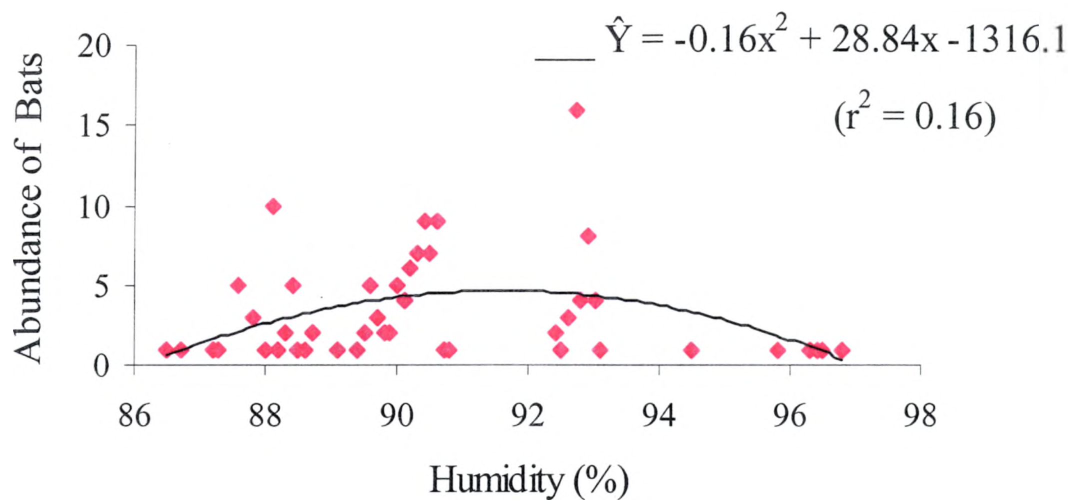

Figure 9. Graph showing the second order curvilinear relationship between percent humidity and abundance of eastern pipistrelles in Gorman Cave, Colorado Bend State Park, Texas in 2001-2003.

DISCUSSION

Dates and Patterns

Eastern pipistrelles were present in Gorman Cave from early November until the first weeks of April 2001-2002. They are primarily solitary during hibernation (Raesly and Gates, 1987; Fujita and Kunz, 1984) but several times groups of two to four individuals were observed clustered together, and occasionally, an eastern pipistrelle was roosting with a single cave myotis.

Throughout winter a flux of new individuals arrived at the cave and other tagged bats were not found, presumably moving to alternate hibernacula. During summer, eastern pipistrelles frequently switch or leave roosts presumably for alternate roosts nearby (Whitaker, 1998). Many other caves occur in the vicinity of Gorman Cave, making locating to a new site after disturbance possible. Gorman Cave also may provide a stopping place for bats in route to other hibernacula in the area. For 21 individuals, 15 males and six females, of 87 bats captured more than one time, there was a gap in time between successive captures. Eleven of these bats, eight males and three females, were not recaptured the visit following their initial tagging. These bats may have left due to the disturbance of tagging. In her review on site fidelity, Lewis (1995) found having more than one winter roost advantageous in several ways, particularly as a way to avoid disturbances such as visitors to the cave, predation, or unfavorable changes to the microclimate. When bats returned or were relocated in the cave, females were in the same location 66.7% of the time, whereas, males were in the same location only 26.7% of the time. Often bats were present and tagged in late fall or early winter, absent all or part of December, January, or February, and returned to Gorman Cave in early spring. The disappearance of tagged bats from Gorman Cave and their subsequent recapture makes the use of alternate hibernacula appear plausible. Raesly and Gates (1987) reported finding solitary species, like the eastern pipistrelle, present in a greater number of hibernacula than gregarious species.

Of 28 bats captured more than five times in Gorman Cave, the majority entered the cave on 11 November 2001, 11 December 2001, or 18 December 2001, with the remaining bats entering either 30 December 2001 or 21 January 2002 (Appendix B). For this same group of eastern pipistrelles, males remained in Gorman Cave longer than females; only 33.3% of males had left the cave by 24 March 2002, whereas 46.7% of females had left by the same date. Whitaker (1998) reported that summer colonies of eastern pipistrelles in Indiana began forming in mid to late April, about the time bats were leaving their hibernacula, the same is probably occurring in central Texas caves.

Sex Ratios

I expected to find skewed sex ratios in Gorman Cave based on other reports for wintering eastern pipistrelles in Texas and Louisiana (Sandel et al., 2001; Jones and Suttkus, 1973; Jones and Pagels, 1968). Our data, however, showed equal ratios of males and females in Gorman Cave. Davis (1959), reported sex ratios highly skewed towards males in caves in Ontario, Missouri, and West Virginia with an increasing percentage of females hibernating in caves further south in the United States. A cave in southwest

Georgia contained an equal number of male and female eastern pipistrelles, the larger percentages of hibernating females in a cave corresponded with a milder winter climate (Davis, 1959). The climate in central Texas, where Gorman Cave is located, is mild. This possibly explains the equal ratios we observed. Tinkle and Milstead (1960) described an increase in the percentage of female cave myotis hibernating in Texas as the winter progressed. The sex ratio of eastern pipistrelles in Gorman Cave remained constant throughout the study period.

Recaptures

About 42% of eastern pipistrelles were only captured one time, of these females outnumbered males, 46.5% to 36.5%. Jones and Suttkus (1973) observed similar percentages of bats not recaptured, but they found males more likely than females to permanently leave the colony after the initial disturbance. Almost 40% of the bats in Gorman Cave were captured between two to four times with males outnumbering females, 47.3% to 32.4%, respectively. In my study, 18.7% of bats were captured five or more times with females slightly outnumbering males, 21.1% versus 16.2%. Females appear to exhibit slightly greater fidelity to Gorman Cave and were recaptured there with greater frequency than males.

Site Fidelity

The overall area of use for eastern pipistrelles in Gorman Cave was 7.27 m^2. Bats moved on average 10.6 m between successive recaptures. The area of use for males averaged 4.41 m^2, which was smaller than the average of 10.12 m^2 for females. Two female bats (numbers 14 and 15) showed signs of apparent random movements and lack of site fidelity, increasing the average area of use size for females. When these bats were excluded from data analysis, the average area of use for females decreased to 4.42 m^2. Females on average moved farther between successive captures than males, 12.66 m versus 8.66 m. This conflicts with information reported by Hassell (1969). He found males moved farther between successive captures. Hassell (1969) also reported movements of 20.0 m for females and 23.6 m for males, much larger distances than our average movement, but the difference between males and females was still insignificant. There was much more variance in female data, but female bats appeared more strongly associated to their site and had higher site fidelity than males.

Four female bats (numbers 2, 6, 7, and 11) exhibited strong fidelity to their sites; they all used an area of less than 0.49 m^2. Females 1, 4, 5, and 8 evidenced site fidelity for the majority of winter; all four of these bats traveled many meters from initial tagging location to the spot of their next several captures. Female 1 and Female 8 both moved again and their final capture location in March was 34.4 m and 58.7 m respectively, from their main wintering site. Female 10 also selected a site in Gorman Cave and returned to it although she was not found in the cave during the winter between 18 December 2001 and 4 March 2002. A number of females apparently lacked fidelity to a specific site within Gorman Cave, these included Females 3, 9, 12, 14, and 15. Female 13 may have been searching for appropriate microclimatic conditions or left the cave to feed, she settled in a new location on 4 March 2002, then returning to near her former positions for two final captures.

Males 1, 2, 3, 4, 8, and 11 were faithful to one location except for the initial capture date in Fall of 2001, and Male 7 remained near one site except for first and last capture. Males 5, 6, 9, 10, and 12 apparently lacked strong fidelity to a site.

Of 15 female bats with more than five captures, 66.7% exhibit fidelity to a site, whereas only 58.3% of 12 male bats captured more than five times, demonstrated fidelity to a site in Gorman Cave. Females in general exhibited strong fidelity to their sites in Gorman Cave. Not only did a larger percentage of them appear to have a very small area of use for winter, but females also were more likely to return to the same location within Gorman Cave after a prolonged absence. Jones and Suttkus (1973) reported that female eastern pipistrelles appear more closely associated with a particular site, but found strong site fidelity for some males as was the case in Gorman Cave.

Many bats captured initially and tagged in fall located to a new area after first disturbance. Two possibilities may explain this pattern, either the bats relocated to avoid future disturbance or they choose different sites in fall when outside temperatures ensure successful feeding, settling later in the season in sites that are energetically more favorable for hibernation. Male 1, a bat tagged in 1997, provides evidence pointing to the later possibility. He was located on 10 occasions near WP 10, but his first capture site in Fall 2001 was 23.6 m from all previous and subsequent captures. Several studies have shown increased activity of bats during hibernation when outside temperatures were warmer, but intercave movements of bats also are common (Whitaker and Rissler, 1992; Speakman and Racey, 1989; Avery, 1985; Hassell, 1969; Moffat, 1904).

Positioning in Gorman Cave

Raesly and Gates (1987) offered several criteria bats use in choosing a cave; these include cave type and size, proximity to a river and winter-feeding grounds, temperature and humidity variation inside the hibernacula, and tendency to use the same cave year after year. Once the cave is selected, a bat still has many microclimatic options to choose from inside the hibernacula (Twente, 1955b).

The largest aggregations of eastern pipistrelles in Gorman Cave hibernated between WP 7 and WP 14. The temperature dropped between WP 6 and WP 7 from a mean of 18.6° C to a mean of 15.8° C. A corresponding drop in average humidity from 93.8% to 88.0% also occurred between the WPs (Table 4). The physiognomy of Gorman Cave near WP 7 is also conducive to hibernating eastern pipistrelles. At this point, there are many cave formations including soda straws, ledges and crevices that offer a break in air currents. This provides more stable temperature and humidity regimes than in more open areas of the cave (Twente, 1955b). Eastern pipistrelles were often found taking advantage of the constant microclimatic conditions by hibernating inside soda straws, crevices, and side pockets of the cave and under short ledges that offered more protection from airflow. Racey (1973) never found the pipistrelle bat in Britain hanging in exposed areas; they always roosted in crevices and between church beams away from drafts.

Low numbers of eastern pipistrelles were found near WP 15 and WP 17, the locations nearest the entrances of the cave. Climatic fluctuations are greatest at these locations because they are strongly influenced by the weather outside the cave. Fluctuating temperatures increase irritability of bats, which may increase the waste of winter reserves by forcing bats to undergo the expensive process of arousal from hibernation; arousal can use up to 90% of a bat's winter reserves (Whitaker and Rissler, 1992; Twente, 1955b). Low numbers of bats also were seen at WP 8, which is located just 5.7 m from WP 7 and only 5.6 m from WP 9. The close proximity of these points probably influenced the number of bats measured from WP 8. The lack of cave features and exposed nature of the walls near WP 13 possibly influenced the number of bats hibernating in the area, accounting for the low numbers of bats at the WP.

Bats in Gorman Cave were concentrated at heights between 1 – 1.99 m from the ground surface. Often this corresponded with cave formations offering more protection from varying microclimatic conditions at these heights. There are many sections of Gorman Cave with soda straws, tunnels, low-lying ledges and dead end passages that have a low ceiling the bats seemed to prefer.

Raesly and Gates (1987) reported that eastern pipistrelles chose to hibernate in areas of caves that were significantly warmer and more humid than those chosen by other species, around 10.9 ° C and 84.8% humidity. In Gorman Cave, hibernating cave myotis were found in crevices located near WP 17 where the temperature was much lower than in areas occupied by eastern pipistrelles. Eastern pipistrelles, due to their solitary nature and their small size, are the only cave bats that can enter hibernation at temperatures above 14 ° C (McNab, 1974). McNab (1974) further noted that there was a thermal barrier between active and torpid bats that occurred at 18 ° C. In Gorman Cave, the majority of eastern pipistrelles hibernated at sites with temperatures between 13 ° C and 17 ° C and percent humidity ranging between 88% and 93%. There was a significant curvilinear relationship between abundance of bats and temperature and humidity. Based on the curvilinear relationships for temperature and humidity shown in Figures 8 and 9, the largest abundance of eastern pipistrelles in Gorman Cave should occur at about 16 ° C and 91% humidity. These values are close to the temperature and humidity measured at WP 7, which had the largest number of bats (43).

Bats were seen more frequently hibernating at sites located above rock or gravel. Several bats throughout winter were seen with condensation covering their fur. The presence of condensation did not depend on whether the bat was hanging over water or dry ground. It is known that bats periodically awaken and groom, and by lapping water from their fur may satiate their need for water during hibernation (Speakman and Racey, 1989).

Weight

Female eastern pipistrelles in Gorman Cave weighed about 3.5% more on average than the males, 5.8 g versus 5.6 g, respectively. Eastern pipistrelles normally produce two young whose combined weight equals about one-third of the maternal weight (Fujita and Kunz, 1984; Myers, 1978). Myers (1978) suggested that the larger size of female bats helps them to carry the extra weight of young while flying and also lowers the cost of lactation per unit mass. Williams and Findley (1979) also reported that females of many species of vespertilionids are larger than males. In addition to allowing bats to carry an increased load during pregnancy, Williams and Findley (1979) suggested that larger female size makes thermoregulation required for embryo development easier and allows females to select a wider variety of prey items making feeding more productive.

Longevity

During my study I recaptured one bat tagged in 1996 and two bats tagged in 1997. Two of these individuals, both females, were tagged 5 years 4 months before their last capture. Parturition in eastern pipistrelles usually occurs in June showing the life span of these individuals is at least 5 years 10 months in the wild (Fujita and Kunz, 1984). These bats were most likely adults at the time of tagging increasing their age to 6 years 10 months. Reported longevity records for eastern pipistrelles extend from 6 years to a single account of a bat recaptured 14.8 years after it was banded (Fujita and Kunz, 1984). Bats have a remarkably long life span. Austad and Fischer (1991) found that bats generally lived three times as long as a similarly sized eutherian mammal. They attributed this extraordinary difference in longevity to the reduced risk of hazards, like predation, that bats encounter by flying, a pattern that is also seen in birds and other arboreal or gliding animals (Austad and Fischer, 1991). Male eastern pipistrelles benefit from increased survivability when compared with females (Davis, 1966). Some males remained torpid in caves much longer than females accounting for their decreased vulnerability to predation (Davis, 1959). This was seen in Gorman Cave with a larger percentage of males than females torpid in April. There are probably more males still alive than females tagged during this earlier period. They were not recaptured during my study but Jones and Suttkus (1973) found that after five years the number of females recaptured outnumbers the number of males recaptured.

Tagging with Passive Integrated Transponders

Various problems were encountered with the PIT tagging of individual eastern pipistrelles. A single needle frequently tagged over 20 bats resulting in dull tips that were occasionally difficult to get through the skin. The small size of the bat caused an instance where the PIT tag was pushed all the way through the skin and outside the body; this was seen also with the tagging of big brown bats (Elbin and Burger, 1994). Over the course of this study, six bats appeared to have infections at or near the PIT tag insertion point on the dorsum. One individual had a "bite mark on back of head" at the time of initial tagging 18 December 2001 and on 4 February 2002 an infection near the insertion point was recorded in the notes. On 24 March 2002, two bats tagged in mid-December 2001 were observed with open wounds on their backs; in one case the PIT tag was protruding from the back, suggesting that the immune system of the bat was fighting to remove the foreign object. The rate of infection due to tagging is unknown and the cost of fighting off infection during hibernation is apt to be high, these instances account for 4% of the bats tagged during this study. Sterile single use disposable syringes were used for a short while, but for the remainder of the study one needle tagged several bats increasing the possibility of infection.

Improvements and Further Investigations

Numerous improvements could be made on this type of project. More frequent visits to Gorman Cave, on a weekly basis from early November through mid to late April would have allowed one to better document a pattern of bat abundance and movement throughout winter. More visits also would increase the chances of capturing bats tagged in previous years and yield more data on longevity and site fidelity of eastern pipistrelles during hibernation. Surveying the cave in this manner for several years would yield more information about population demographics and the numbers of new individuals entering the cave versus those who are returning.

The lack of PIT tags during the last few visits to the cave hindered this project. Information on new bats entering the cave after 10 February 2002, and their gender, weight and location were not recorded. There may have been a difference in numbers of males or females entering or hibernating in the cave that we were unable to detect with our limited data.

In the future, an expedition beyond the bat gate to look for eastern pipistrelles, especially in the late fall may yield some results. I suggest continuing this study to encompass several consecutive years to accurately determine the winter site fidelity of the eastern pipistrelle in Gorman Cave and to see if locations occupied are random or non-random. Mapping Gorman Cave in a three-dimensional format would reflect the true and intricate shapes of the cave and allow height to be taken into consideration as part of the location of the bat.

A future project may include mist netting in the vicinity of Gorman Cave during spring and summer searching for tagged eastern pipistrelles to determine if the population that resides in the cave is non-migratory.

LITERATURE CITED

Austad, S. N., and K. E. Fischer. 1991. Mammalian aging, metabolism, and ecology: evidence from the bats and marsupials. Journal of Gerontology: Biological Sciences 46:B47-53.

Avery, M. I. 1985. Winter activity of pipistrelle bats. Journal of Animal Ecology 54:721-738.

Davis, W. H. 1959. Disproportionate sex ratios in hibernating bats. Journal of Mammalogy 40:16-19.

Davis, W. H. 1966. Population dynamics of the bat *Pipistrellus subflavus*. Journal of Mammalogy, 47:383-396.

Davis, W. B., and D. J. Schmidly. 1994. The mammals of Texas. Texas Parks and Wildlife Press, Austin, Texas.

Elbin, S. B., and J. Burger. 1994. Implantable microchips for individual identification in wild and captive populations. Wildlife Society Bulletin 22;677-683.

Elliott, W. R. Wild caving tours. Texas speleological survey. http://www.utexas.edu/depts/tnhc/.www/tss/wildtours.htm (15 Dec. 2000).

Fujita, M. S., and T. H. Kunz. 1984. *Pipistrellus subflavus*. Mammalian Species 228: 1-6.

Hall, E. R. 1981. The mammals of North America. John Wiley & Sons, New York, second ed., 1: xv + 1-600 + *90*.

Hassell, M. D. 1969. Intra-cave activity of four species of bats hibernating in Kentucky. University Microfilms, Inc, Ann Arbor, Michigan, 69-15, 448 pp.

Hooge, P. N., W. Eichenlaub, and E. Solomon. 1999. The animal movement program. USGS, Alaska Biological Science Center. [computer program]

Jones, C., and J. Pagels. 1968. Notes on a population of *Pipistrellus subflavus* in southern Louisiana. Journal of Mammalogy 49:134-139.

Jones, C., and R.D. Suttkus. 1973. Colony structure and organization of *Pipistrellus subflavus* in southern Louisiana. Journal of Mammalogy 54: 962-968.

Lewis, S. E. 1995. Roost fidelity of bats: a review. Journal of Mammalogy 76: 481-496.

McNab, B. K. 1974. The behavior of temperate cave bats in a subtropical environment. Ecology 55: 943-958.

Moffat, C. B. 1904. Bats, hedgehogs, and frogs in winter. The Irish Naturalist 13:81-87.

Myers, P. 1978. Sexual dimorphism in size of vespertilionid bats. American Naturalist 112:701-711.

Racey, P. A. 1973. The time of onset of hibernation in pipistrelle bats, *Pipistrellus pipistrellus*. Journal of Zoology, Proceeding of Zoological Society of London 171:465-467.

Raesly, R. L., and J. E. Gates. 1987. Winter habitat selection by north temperate cave bats. American Midland Naturalist 118:15-31.

Sandel, J. K., G. R. Benatar, K. M. Burke, C. W. Walker, T. E. Lacher, Jr., and R. L. Honeycutt. 2001. Use and selection of winter hibernacula by the eastern pipistrelle (*Pipistrellus subflavus*) in Texas. Journal of Mammalogy 82:173-178.

Speakman, J. R, and P. A. Racey. 1989. Hibernal ecology of the pipistrelle bat: energy expenditure, water requirements and mass loss, implications for survival and the function of winter emergence flights. Journal of Animal Ecology 58:797-813.

Speakman, J. R., P. I. Webb, and P. A. Racey. 1991. Effects of disturbance on the energy expenditure of hibernating bats. Journal of Applied Ecology 28:1087-1104.

Tinkle, D. W., and W. W. Milstead. 1960. Sex ratios and population density in hibernating myotis. American Midland Naturalist 63:327-334.

Twente, J. W., Jr. 1955a. Aspects of a population study of cavern-dwelling bats. Journal of Mammalogy 36:379-390.

Twente, J. W., Jr. 1955b. Some aspects of habitat selection and other behavior of cavern-dwelling bats. Ecology 36: 706-732.

Vaughan, T. A., J. M. Ryan, and N. J. Czaplewski. 2000. Mammalogy, Fourth Edition. Saunders College Publishing, Orlando, Florida: ix + 1-565.

Whitaker, J. O., Jr. 1998. Life history and roost switching in six summer colonies of eastern pipistrelles in buildings. Journal of Mammalogy 79:651-659.

Whitaker, J. O., Jr., and L. J. Rissler. 1992. Winter activity of bats at a mine entrance in Vermillion County, Indiana. American Midland Naturalist 127:52-29.

Williams, D. F. and J. S. Findley. 1979. Sexual size dimorphism in vespertilionid bats. American Midland Naturalist 102:113-126.

Appendix A.

Area use maps for female and male eastern pipistrelles in Gorman Cave, Colorado Bend State Park, San Saba and Lampasas Counties in 2001-2003.

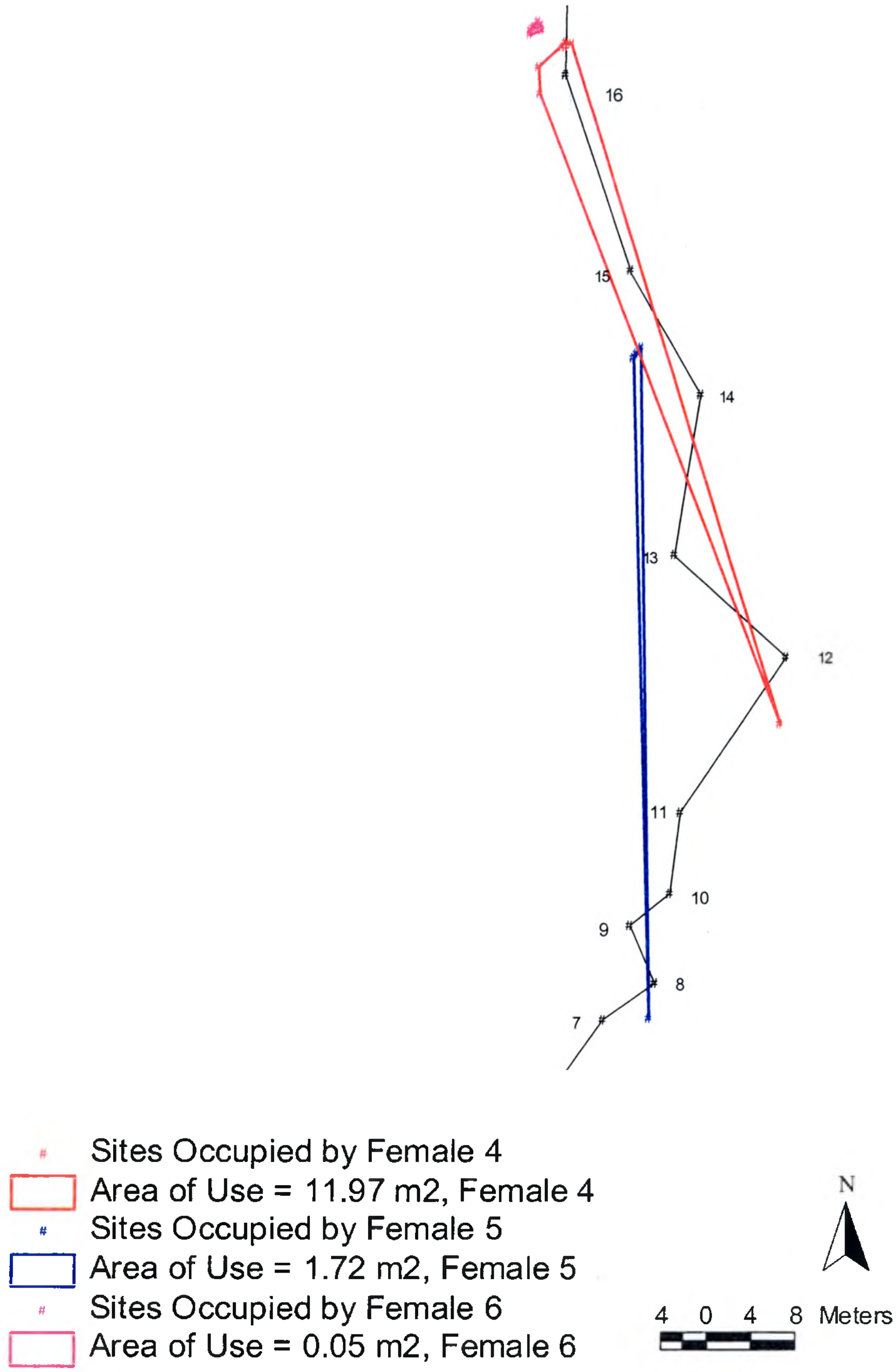

Figure 10. Minimum convex polygons representing areas of use (m^2) by female eastern pipistrelles in Gorman Cave, Colorado Bend State Park, Texas in winter 2001-2002.

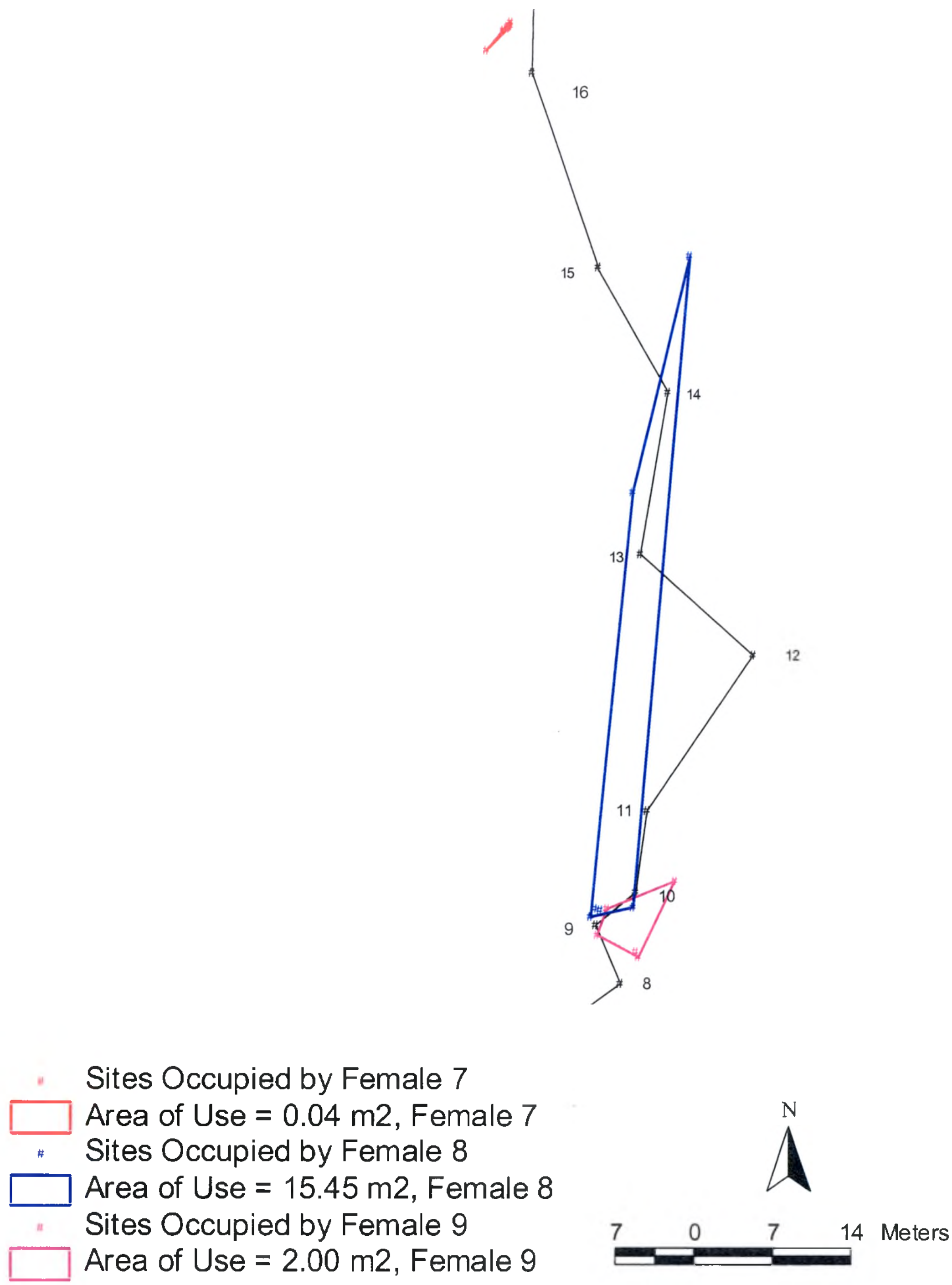

Figure 11. Minimum convex polygons representing areas of use (m^2) by female eastern pipistrelles in Gorman Cave, Colorado Bend State Park, Texas in winter 2001-2002.

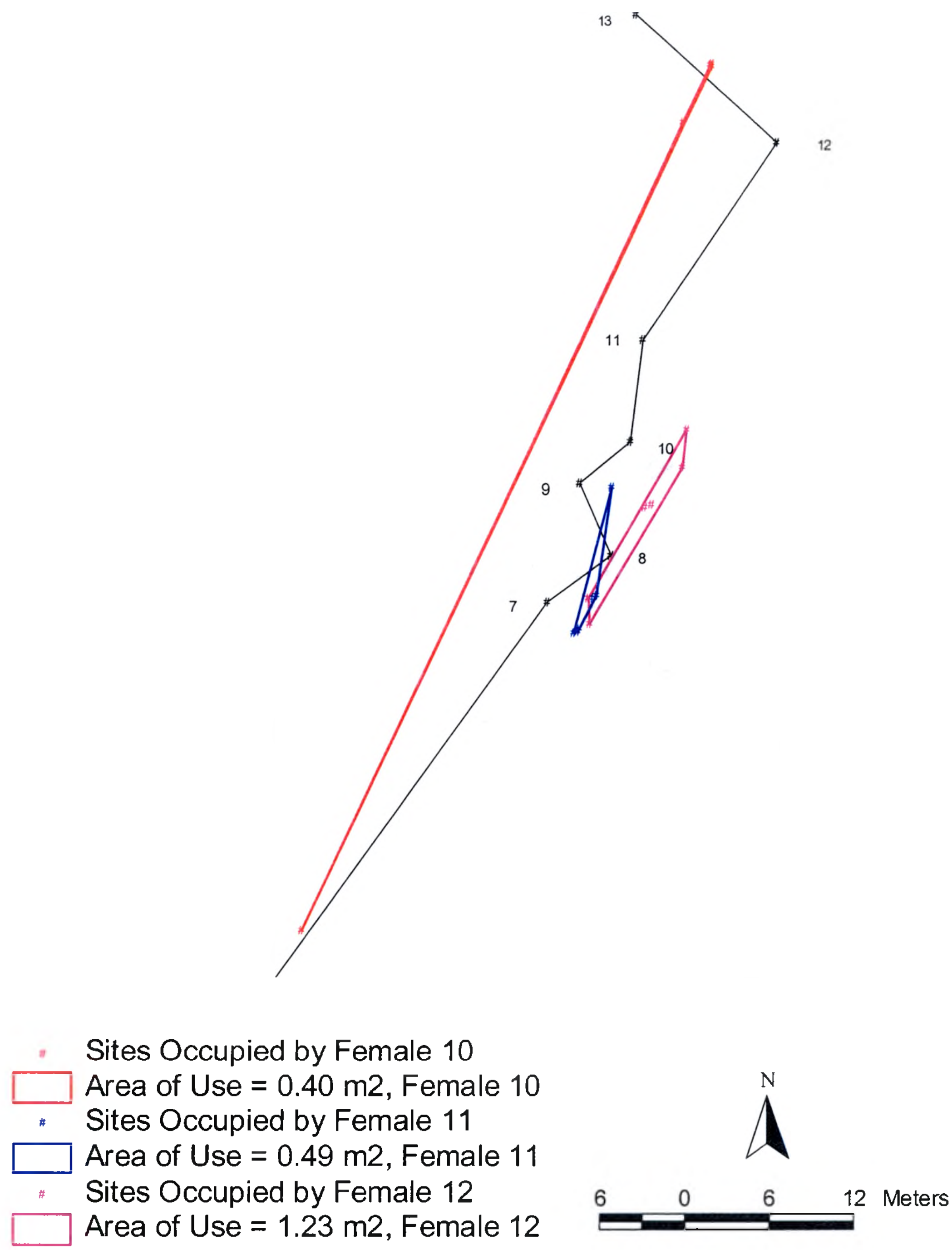

Figure 12. Minimum convex polygons representing areas of use (m^2) by female eastern pipistrelles in Gorman Cave, Colorado Bend State Park, Texas in winter 2001-2002. Female 12 was also captured once during 2003.

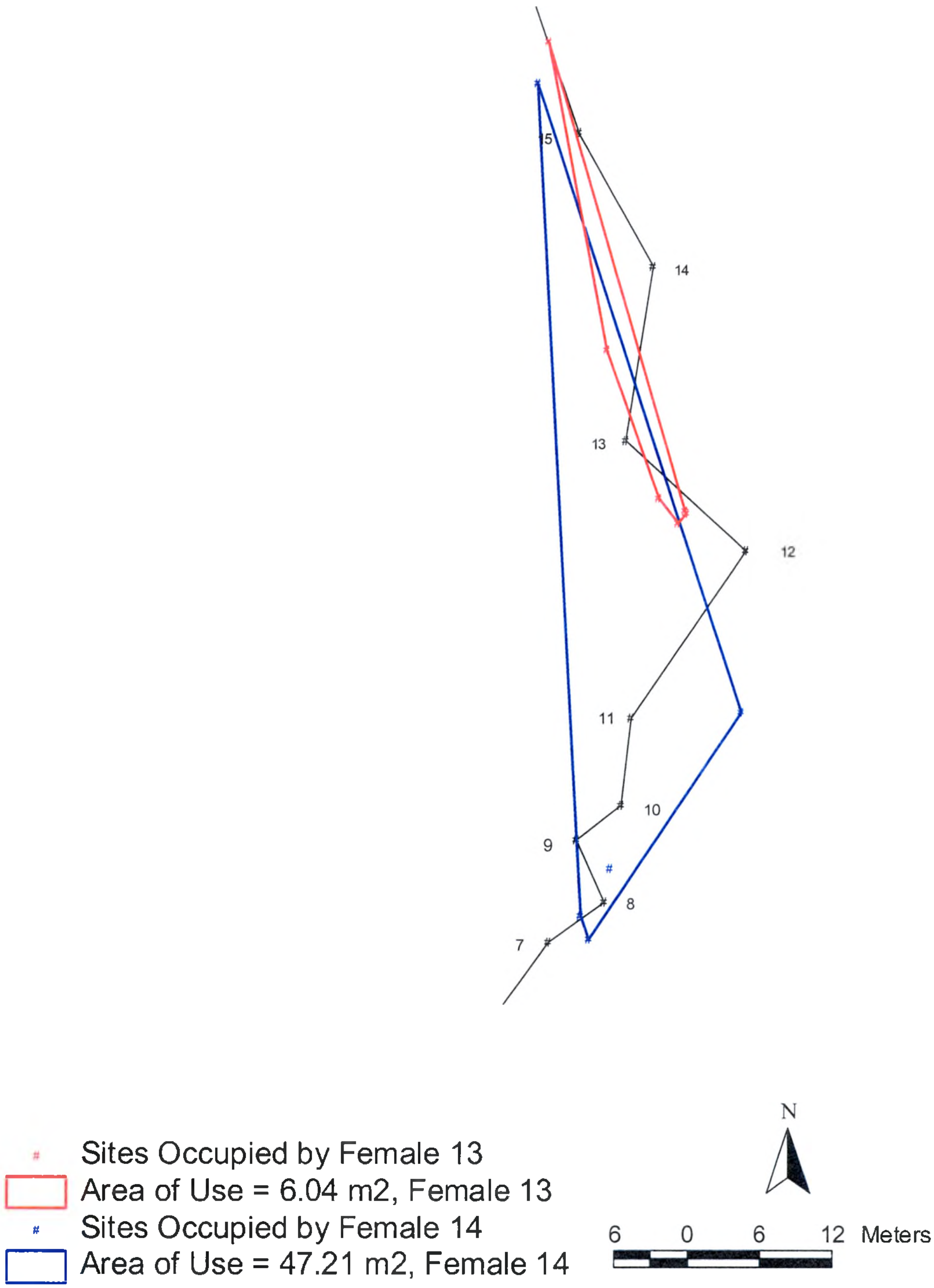

Figure13. Minimum convex polygons representing areas of use (m^2) by female eastern pipistrelles in Gorman Cave, Colorado Bend State Park, Texas in winter 2001-2002.

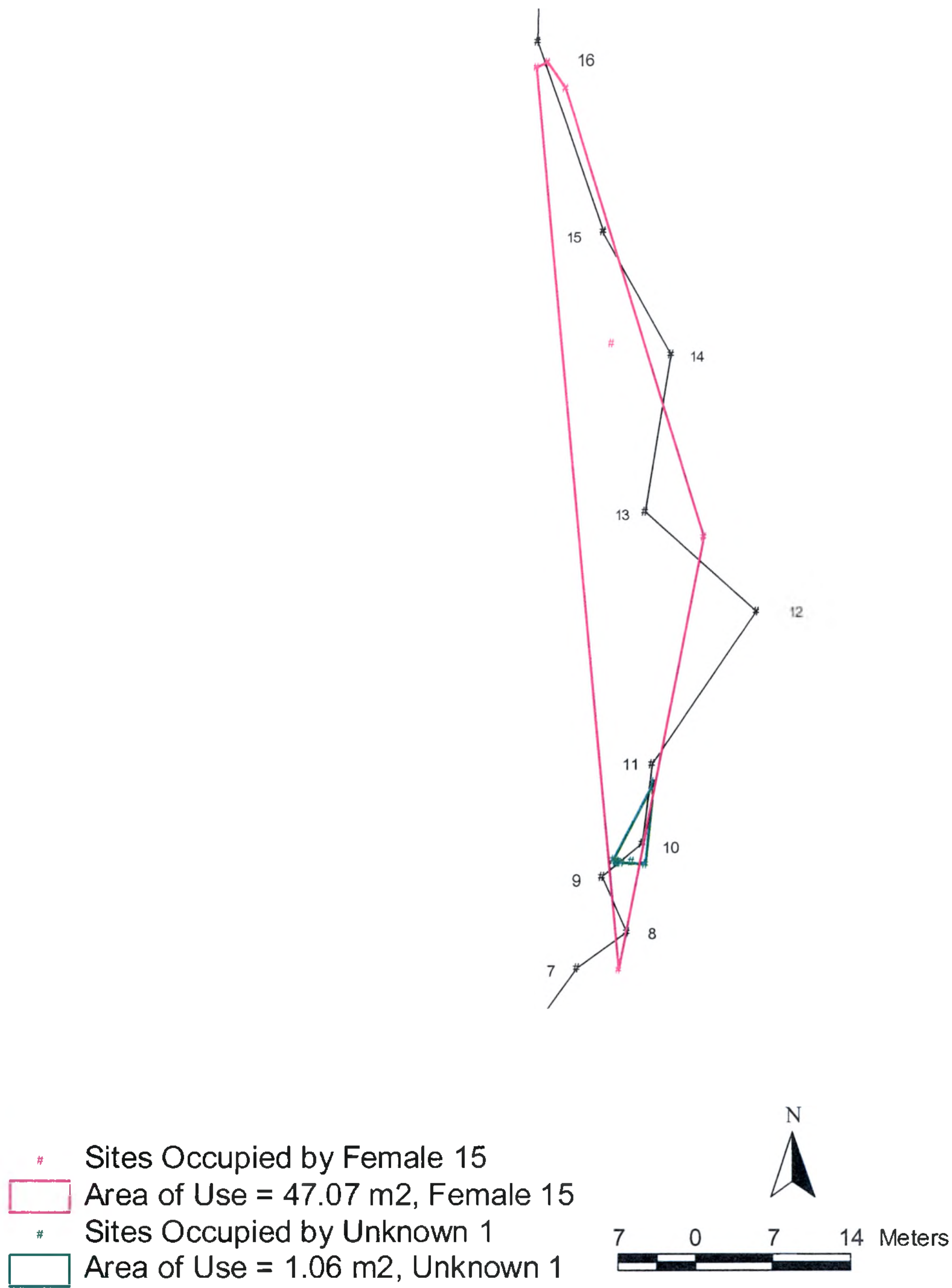

Figure 14. Minimum convex polygons representing areas of use (m^2) by one female eastern pipistrelle and one eastern pipistrelle of unknown gender in Gorman Cave, Colorado Bend State Park, Texas in winter 2001-2002.

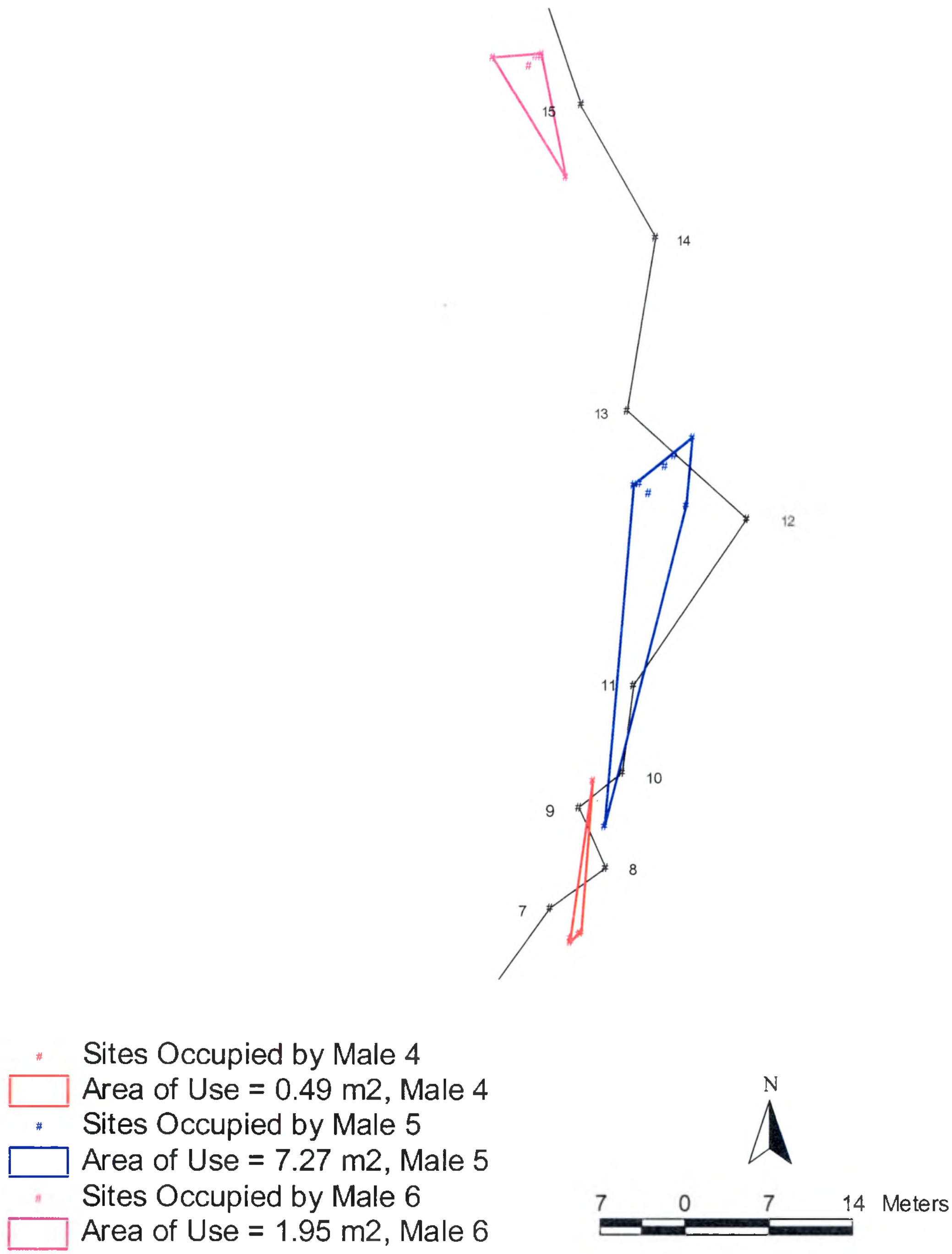

Figure 15. Minimum convex polygons representing areas of use (m^2) by male eastern pipistrelles in Gorman Cave, Colorado Bend State Park, Texas in winter 2001-2002. Male 4 was also captured once during 2003.

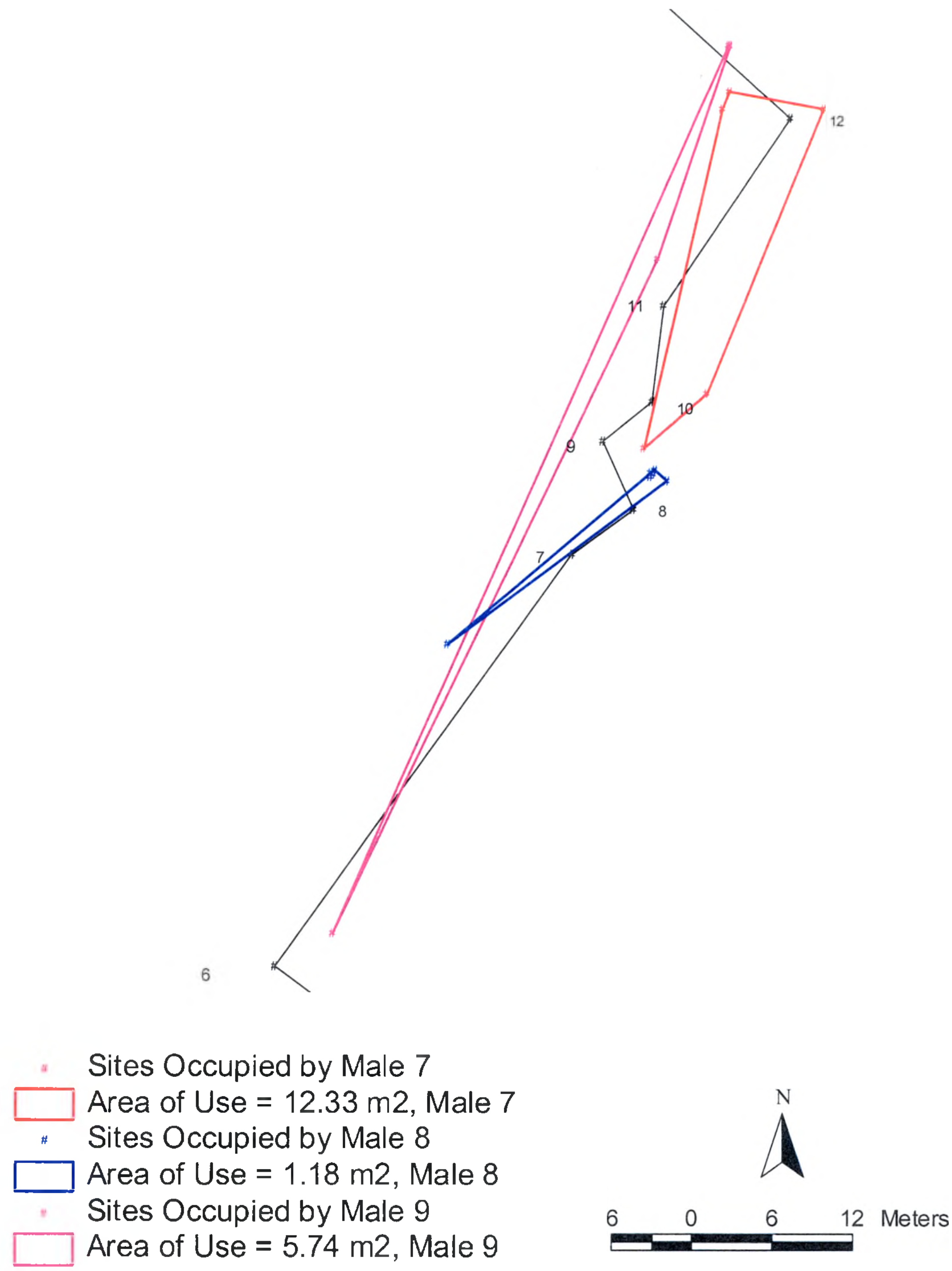

Figure 16. Minimum convex polygons representing areas of use (m^2) by male eastern pipistrelles in Gorman Cave, Colorado Bend State Park, Texas in winter 2001-2002.

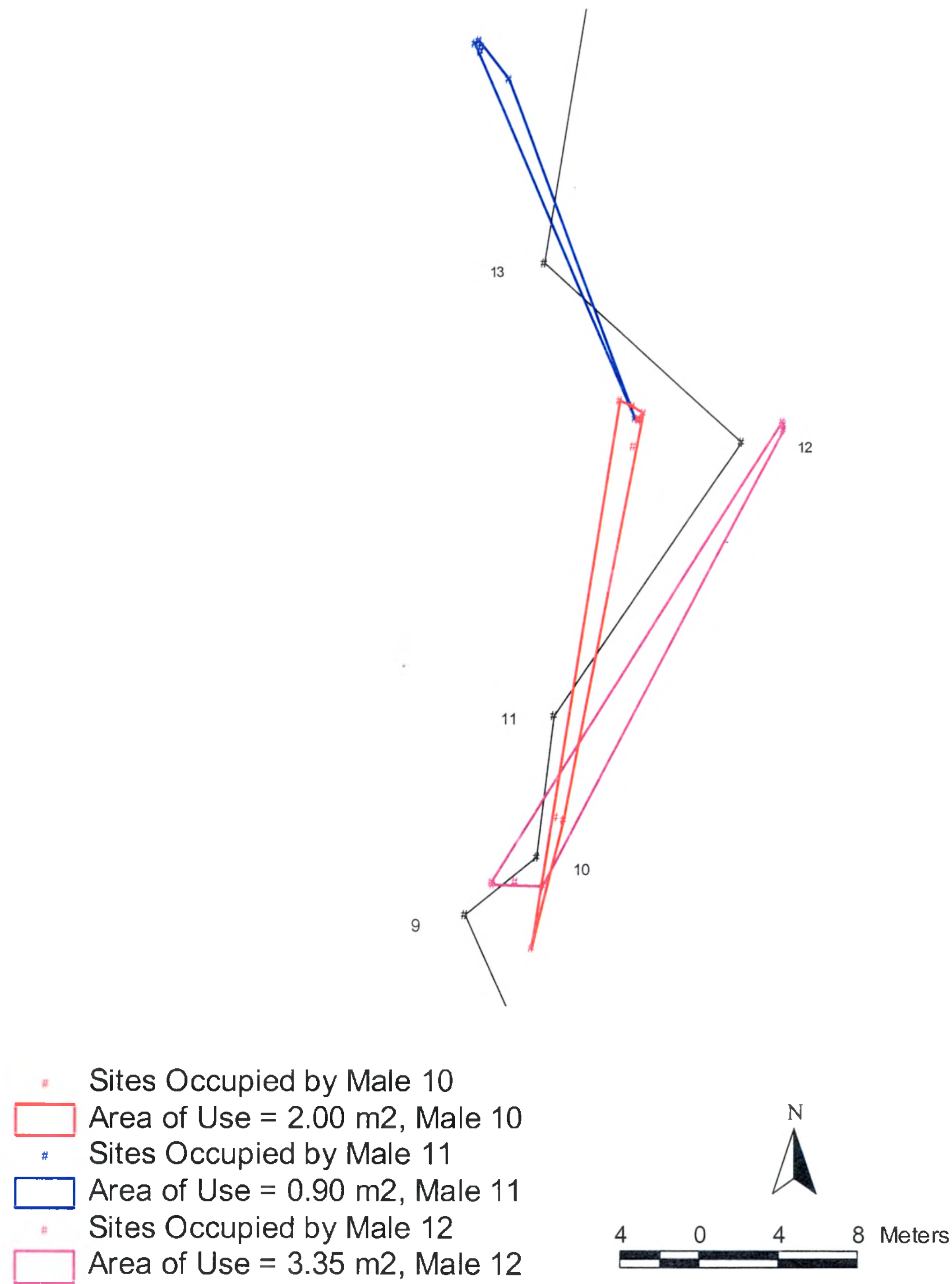

Figure 17. Minimum convex polygons representing areas of use (m^2) by male eastern pipistrelles in Gorman Cave, Colorado Bend State Park, Texas in winter 2001-2002.

Appendix B. MCP size and mean distance between successive sites occupied by eastern pipistrelles in Gorman Cave, Colorado Bend State Park, Texas, winters 2001-2003.

Identification	MCP Area (m2)	Distance	Number of Captures	Date Entered 2001-2002	Date Left 2002
Female 1	6.52	7.74; SE = 5.54	8	12/18/2001	03/15/2002
Female 2	0.48	1.81; SE = 0.38	6	12/30/2001	03/24/2002
Female 3	11.08	32.45; SE = 13.17	6	12/11/2001	03/04/2002
Female 4	11.96	12.67; SE = 9.96	7	12/11/2001	03/24/2002
Female 5	1.72	15.03; SE = 14.66	5	12/18/2001	02/10/2002
Female 6	0.05	0.51; SE = 0.10	9	12/18/2001	04/08/2002
Female 7	0.04	0.66; SE = 0.33	10	12/11/2001	04/08/2002
Female 8	15.45	20.84; SE = 11.7	6	12/11/2001	03/04/2002
Female 9	2.00	3.92; SE = 1.24	5	11/13/2001	02/04/2002
Female 10	0.40	16.93; SE = 15.39	5	11/13/2001	03/24/2002
Female 11	0.48	2.38; SE = 1.50	6	11/13/2001	02/10/2002
Female 12	1.23	5.85; SE = 2.60	6	01/21/2001	03/24/2002
Female 13	6.04	19.46; SE = 8.64	6	12/30/2001	03/24/2002
Female 14	47.21	19.96; SE = 12.01	5	12/18/2001	03/04/2002
Female 15	47.07	29.73; SE = 11.18	6	12/11/2001	04/08/2002
Male 1	3.07	3.63; SE = 2.52	11	11/13/2001	04/08/2002
Male 2	9.13	8.04; SE = 3.52	7	12/11/2001	03/04/2002
Male 3	5.49	14.40; SE = 7.47	5	12/11/2001	02/10/2002
Male 4	0.49	4.75; SE = 4.08	5	12/18/2001	03/04/2002
Male 5	7.27	6.22; SE = 3.60	8	12/18/2001	03/24/2002
Male 6	1.95	3.23; SE = 1.56	7	11/13/2001	04/08/2002
Male 7	12.33	14.77; SE = 6.13	5	11/13/2001	03/24/2002
Male 8	1.18	4.52; SE = 3.93	6	11/13/2001	02/04/2002
Male 9	5.74	22.44; SE = 17.22	5	11/13/2001	04/08/2002
Male 10	2.00	7.34; SE = 3.64	9	11/13/2001	03/24/2002
Male 11	0.90	4.40; SE = 3.30	7	12/30/2001	04/08/2002
Male 12	3.35	10.17; SE = 5.38	7	12/30/2001	03/24/2002
Unknown 1	1.06	2.26; SE = 1.03	8	11/13/2001	03/04/2002

VITA

Sara Diane Moren was born in La Mesa, California, on November 17, 1974, the daughter of Augustine Ricardo Herrera and Theodora Dell Herrera. Sara received her Bachelor of Science degree from the University of California, Santa Barbara, in June, 1996. The following year she was an Americorps volunteer at Uvalde National Fish Hatchery, in Uvalde, Texas. She was then employed by the SPCA of Monterey County, in Monterey, California. Sara moved to Texas in 1998 and was employed as the wildlife permits assistant with Texas Parks and Wildlife until May of 2000. In August of 1999, she began graduate school at Southwest Texas State University, San Marcos, Texas, and has been an Instructional Assistant for Modern Biology, Ecology, Anatomy and Physiology, and Mammalogy. Sara interned in the Wildlife Diversity program and the Upland Game Bird program at Texas Parks and Wildlife during the summers of 2000 and 2001, respectively.

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