FINAL REPORT

SECTION 6

ENDANGERED SPECIES ACT

FEDERAL AID PROJECT E-3

BIOLOGY OF THREATENED AND ENDANGERED SPECIES IN OKLAHOMA

STUDY 4 - MANAGEMENT OF THE ENDANGERED OZARK BIG-EARED BAT: TELEMETRY INVESTIGATIONS

APRIL 1, 1991 - MARCH 31, 1994

FINAL REPORT

STATE:	**Oklahoma**	PROJECT NUMBER: **E-3**
PROJECT TITLE:	Biology of Threatened and Endangered Species in Oklahoma	
JOB NUMBER:	**4**	
JOB TITLE:	**Management of the endangered Ozark big-eared bat: telemetry investigations**	
JOB OBJECTIVE:	To identify use of critical surface habitats by adult female Ozark big-eared bats in fall, winter, and spring and adult males (possibly juveniles) throughout the year through radio telemetry of 20 bats.	
PERIOD COVERED:	1 April 1991-31 March 1994	

REPORT OVERVIEW

The attached appendix represents a M.S. Thesis by Traci A. Wethington entitled "*Foraging activity, habitat use, and cave selection by the endangered Ozark big-eared bat.*" The thesis was prepared in three chapters to satisfy both Ms. Wethington's degree requirements and contractual obligations under Endangered Species Project E-3-4 between the Oklahoma Department of Wildlife Conservation and Oklahoma State University. Chapters II and III provide the substantive research results and were prepared in the format of the *Journal of Mammalogy*. Chapter II is entitled "Geographic information system and radiotelemetry to determine foraging activity and habitat use of Ozark big-eared bats" and constitutes our primary response to the Job Objective listed above. Chapter III is entitled "Vegetational structure and land-use evaluation to assess cave selection by Ozark big-eared bats" and represents additional information on habitat characteristics and cave selection within the range of the subspecies. Implications to management, particularly recovery objectives, are discussed at the end of each chapter. Additional research needs to be conducted on habitat use and movements of the Ozark big-eared bat during parts of year that we have been unable to investigate.

SIGNIFICANT DEPARTURES

During this project, we radio-marked 20 Ozark big-eared bats. We originally proposed to mark a few bats of both sexes during various seasons until we had marked a total of 20 bats during the 3-year study. Because of the high risk of losing bats after they were marked and the possibility of poor radio reception due to topography and the inherent low battery strength of miniature radio transmitters, it was judged best to mark greater numbers of bats at one time to maximize data acquisition. Therefore, 3 groups of 5 (Oct 1991), 8 (Aug 1992), and 7 (Sep 1992) female and male Ozark big-eared bats were radio-marked and tracked during and after maternity colony break-up to complement Clark's (1991) telemetry work during the maternity season (Clark, B. S., Activity patterns, habitat use, and prey selection by the Ozark big-eared bat [*Plecotus townsendii ingens*], Ph.D. Diss., Okla. State Univ., Stillwater: Clark, B.S., D. M. Leslie, Jr., and T. S. Carter, 1993, Foraging activity of adult female Ozark big-eared bats in summer, J. Mammal. 74:422-427).

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APPENDIX

FORAGING ACTIVITY, HABITAT USE, AND CAVE SELECTION BY THE ENDANGERED OZARK BIG-EARED BAT (<u>PLECOTUS TOWNSENDII</u> <u>INGENS</u>)

By

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the requirements for
the Degree of
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May, 1994

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Title of Study: FORAGING ACTIVITY, HABITAT USE, AND CAVE SELECTION BY THE ENDANGERED OZARK BIG-EARED BAT (PLECOTUS TOWNSENDII INGENS).

Pages in Study: 53 Candidate for the Degree of Master of Science

Major Field: Wildlife and Fisheries Ecology

Scope and Method of Study: Foraging activity and habitat use of the Ozark big-eared bat (Plecotus townsendii ingens) was studied during October 1991 and August and September 1992. Fourteen females and six males were marked with radiotransmitters for this study. Locations for each bat were plotted on topographic maps and digitized for analysis. Emergence times, number of foraging areas per bat, distance traveled to foraging areas, and size of foraging areas were evaluated. Habitat and land-use within the study area were determined by interpretation of color infrared aerial photography and subsequent digitization of cover types into a geographic information system (GIS) for analysis. Chi-square analysis was used to determine if bats used habitat types in proportion to their availability. Habitat was evaluated surrounding used and unused caves within the range of the subspecies to evaluate cave selection. Vegetational structure of the habitat immediately surrounding caves was assessed within 0.04-ha circular plots. The percentage of each land-use category within 3 km of caves was determined by using GIS.

Findings and Conclusions: Intra- and intersexual comparisons showed no differences in number of foraging sites per bat, median distances to foraging sites, and median size of foraging areas. Late emergence times and frequent periods of inactivity during October 1991 may have been due to cold weather. Females used smaller foraging areas and traveled shorter distances than females previously studied during the maternity season. Females used habitats in proportion to their availability throughout this study; males used forest habitat more than expected in September. I concluded that habitat use likely was determined by prey distribution because P. t. ingens has high flight maneuverability and thus would not be restricted in its use of habitat types. For the habitat analysis, few differences were documented for the vegetative parameters measured. Land-use patterns surrounding used (maternity and hibernacula) and unused caves did not differ. Based on these and previous findings, surface habitat surrounding caves does not appear to be significant in cave selection by this subspecies.

ADVISER'S APPROVAL ______________________

FORAGING ACTIVITY, HABITAT USE, AND CAVE

SELECTION BY THE ENDANGERED OZARK

BIG-EARED BAT (PLECOTUS

TOWNSENDII INGENS)

Thesis Approved:

Thesis Advisor

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CHAPTER I

INTRODUCTION

This thesis is composed of two manuscripts written for submission to the Journal of Mammalogy. Each manuscript is complete, not requiring additional support material. Chapter II is entitled "Geographic information system and radiotelemetry to determine foraging activity and habitat use of Ozark big-eared bats (*Plecotus townsendii ingens*)." Chapter III is entitled "Vegetational structure and land-use evaluation to assess cave selection by Ozark big-eared bats (*Plecotus townsendii ingens*)."

CHAPTER II

GEOGRAPHIC INFORMATION SYSTEM AND RADIOTELEMETRY TO DETERMINE FORAGING ACTIVITY AND HABITAT USE OF OZARK BIG-EARED BATS (PLECOTUS TOWNSENDII INGENS)

ABSTRACT.--Foraging activity and habitat use of the endangered Ozark big-eared bat (*Plecotus townsendii ingens*) were studied during October 1991 and August and September 1992. Fourteen females and six males were marked with radiotransmitters. Intra- and intersexual comparisons showed no differences in median distances to foraging areas, median size of foraging areas, and number of foraging sites per bat. Late emergence times and frequent periods of inactivity during October 1991 may have been due to cold weather. Females traveled shorter distances to foraging sites, and used smaller foraging areas than females previously studied during maternity season. Females used habitats in proportion to their availability throughout this study; males used forest habitat more than expected in September. I concluded that habitat use likely was determined by prey distribution because *P. t. ingens* has high flight maneuverability and thus would not be restricted in its use of habitat types.

The Ozark big-eared bat (Plecotus townsendii ingens) has been listed as an endangered species since 1979 (Bagley 1984). The highest estimate of the population in Oklahoma obtained since federal listing was 1,700 in 1990 (Clark, 1991). The historical range of this subspecies included southwestern Missouri, northwestern and north-central Arkansas, and eastern Oklahoma (Harvey, 1992). Currently, only one hibernaculum and one maternity colony are known to exist in north-central Arkansas (Harvey, 1992), and three hibernacula and four maternity colonies (represented by five caves) are known to exist in eastern Oklahoma (Clark, 1991). The Missouri colonies appear to have been extirpated (Figg, 1987).

Little is known of the specific habitat requirements of P. t. ingens. However, recent telemetry studies of foraging adult females from one of the Oklahoma maternity colonies characterized some aspects of foraging ecology (Clark et al., 1993). During the maternity season, females used edge habitat more than expected and traveled further to forage as the season progressed (Clark et al., 1993).

This study was designed to further evaluate foraging activity and habitat requirements of the subspecies by focusing on the period after maternity colony breakup and prior to hibernation. I quantified the following parameters: emergence times, number of foraging sites per bat, distance traveled to foraging sites, and size of foraging areas. I expected no change among study periods or between this study and that of Clark et al. (1993) in emergence times, number of foraging sites per bat, and size of foraging areas. I hypothesized that distance traveled to foraging sites would increase after the maternity season when females no longer needed to return to maternity caves to nurse young. I also reevaluated habitat use and expected a continued preference for edge (Clark et al., 1993) by *P. t. ingens*.

STUDY AREA AND METHODS

Research was conducted in Adair County, Oklahoma, in the Boston Mountain Plateau subdivision of the Ozark Plateaus Province physiographic region (Madole et al., 1991). Faulting throughout this region has created a series of prominent, steep-faced fault blocks separated by narrow stream valleys; maximum relief is 300 m and valleys 100-150 m deep are common (Huffman, 1958; Madole et al., 1991). Ridge tops are capped by resistant sandstone that overlays fossiliferous limestone interbedded with shale (Huffman, 1958). Climate is classified as humid subtropical, characterized by hot, humid summers and relatively mild winters punctuated by sporadic periods of severe cold. Mean annual temperature is 13-17°C, and mean annual precipitation is 100 cm (Madole et al., 1991). Vegetation in this area is dominated by eastern deciduous oak-hickory forest with elm (*Ulmus* spp.), cedar (*Juniperus virginiana*), and pine (*Pinus* spp.) being locally abundant (Küchler, 1964).

Bats were trapped at a maternity cave (used by Clark, 1991) and a transient cave that were within approximately 1 km of each other. Focus was intended to be at the maternity site, but low bat numbers made a second night of trapping at the transient cave necessary. Bats were captured by draping a mist-net over cave entrances. For each bat captured, age, sex, weight, forearm length, and reproductive condition were determined. Skin Bond® cement was used to attach 0.65-0.75 g transmitters (Model BD-2B, Holohil Systems Ltd., Ontario, Canada), with frequencies of 150.8-151.8 MHz, between scapulae of bats. Bats were tracked during 11-22 October 1991, 23 August-3 September 1992, and 10-23 September 1992 with TRX-1000s receivers and 3-element Yagi antennae (Wildlife Materials, Inc., Carbondale, IL). Directional fixes were determined by the loudest signal method (Springer, 1979) at 2-min intervals.

Efforts were made to reduce or at least account for telemetry error by locating a known transmitter to build radio-tracking skills and to become familiar with effects of topography on radio signals (Macdonald and Amlaner, 1980). Trackers also communicated by hand-held radios to permit simultaneous readings and reduce error due to movement when tracking an animal (Schmutz and White, 1990). Data involving non-intersecting bearings or outlying points recorded during localized sequential bearings were discarded (Clark, 1991). An estimate of sampling error was obtained by taking repeated bearings to known transmitter sites and calculating a pooled standard deviation (Saltz and Alkon, 1985).

Locations for each bat were plotted on 7.5-min United States Geological Survey (USGS) topographic maps. Locations were then digitized using an automated mapping software package, ATLAS DRAW (3.0) (Strategic Locations Planning, Inc.) and later converted to ASCII format and imported into a geographic information system (GIS) software package for analysis. Sizes of foraging areas for each bat were estimated by creating minimum convex polygons (Mohr, 1947) as determined by peripheral fixes. Distances were calculated from the geometric center of activity (Hayne, 1949) for each foraging area to the cave that each bat used most frequently.

First emergence times, distance from utilized caves to foraging sites, number of foraging sites, and size of foraging areas for each bat were evaluated among the three study periods by Kruskal-Wallis one-way analysis of variance (SAS Institute, 1985). Median values for each bat (except for number of foraging sites) were used in analyses (Clark et al., 1993). Comparisons between females in this study and Clark et al. (1993) were made by an unbalanced design analysis of variance on ranked values for each parameter, which is essentially the same as performing a Kruskal-Wallis test (Conover and Iman, 1981). This test identified if there were differences among the six study periods. Because such differences could be explained by either within or between study variation, post-hoc linear comparisons (Wilkinson, 1989) contrasting the three maternity season study periods (Clark et al., 1993) with the three post-maternity season study periods were conducted.

Because of potential differences in foraging behavior due to sex, data for males and females were treated separately. Because of the small sample size, juveniles were grouped with adults for analysis; this grouping was justified because by late August when radio-tracking began, juveniles likely would be foraging like adults (Kunz, 1974).

Available habitat was determined by taking the midpoint between the two caves used for trapping and extending a radius from it that encompassed all foraging points. This area was classified into seven land-use categories: development, cropland, orchard, pasture, rangeland, forest, and water. Areal coverage of each land-use category was ascertained by interpreting 1:58,000 color infrared aerial photographs taken in 1984-85 by the Soil Conservation Service (SCS). Land-use cover maps made from the aerial photography were converted to a scale of 1:24,000 with a Bausch and Lomb zoom transfer scope and USGS topographic maps. Cover maps were digitized creating vector files georeferenced to a Universal Transverse Mercator projection using GRASS (4.0) software (Geographical Resources Analysis Support System, U.S. Army Corps of Engineers, Construction Engineering Research Laboratory, Champaign, IL). These files were combined with previously digitized vector files

(SCS, Stillwater, OK) to form a single file encompassing the entire study area.

The resulting habitat data vector file was then rasterized into a matrix of 25- by 25-m grid cells. The habitat data vector file was used to create an eighth habitat category, forest edge. Edge was defined as any area where forest bordered another land-use category. The forest edge file was rasterized and combined with the previous raster file to form a new habitat data raster file with eight habitat and land-use classes.

The original habitat data vector file was reclassified into only two classes, forest and open (all other classes). To permit direct quantitative comparison with Clark et al. (1993), a second habitat data raster file containing three classes (forest, open, and edge) using a 76- by 76-m grid cell size was created using the same methods described above.

Habitat use was evaluated by combining the bat (point) location file and the 25-m resolution or 76-m resolution habitat data raster files with GRASS software. Chi-square analysis was used to determine if bats used habitat types in proportion to their availability. If use was disproportionate, Bonferroni confidence intervals were calculated around the proportion of use for each habitat type to determine selection or avoidance (Byers et al., 1984; Neu et al., 1974). Significance was set at $\underline{P} < 0.05$ for all statistical tests.

RESULTS

During the study, 22 bats were captured, measured, and released (Appendix I). Fourteen females and six males were marked with radiotransmitters. No males were marked during the October study period. Telemetry data were collected for only 17 individuals (Fig. 1; Appendix II) due to immediate loss of three bats after marking.

Repeated bearings ($\underline{n}$ = 159) to a known transmitter location resulted in a small standard error (0.64°). Calculation of 95% confidence intervals indicated bearings would be off by only ±1.25°. More than 95% of the bearings on mobile bats crossed within 1.0 km of the receivers. At this distance, point locations from intersecting bearings could have been off by as much as 22 m, which was considered acceptable without evaluation of error polygons (Heezen and Tester, 1967). I assumed that the probability of misclassifying habitat use was equal among all habitat types and thus did not bias the analysis.

Foraging activity.--Median times of emergence for females differed among the three study periods ($\underline{H}$ = 7.90, $\underline{d.f.}$ = 2, $\underline{P}$ = 0.02; Table 1). However, median times of emergence for males did not differ between periods ($\underline{H}$ = 0.33, $\underline{d.f.}$ = 1, $\underline{P}$ = 0.56; Table 2). Median distances traveled by females from used caves to the geometric center of activity of each foraging area were similar among periods ($\underline{H}$ = 4.00, $\underline{d.f.}$ = 2, $\underline{P}$ = 0.14; Table 1). Median distances traveled by males decreased, although not significantly, between study periods (H = 3.00, $d.f.$ = 1, P = 0.08; Table 2).

The number of foraging sites for each female bat was the same among the three study periods (H = 2.60, $d.f.$ = 2, P = 0.27; Table 1). Similarly, the number of foraging sites for each male bat did not differ between periods (H = 0.11, $d.f.$ = 1, P = 0.74; Table 2). Median size of foraging areas for female bats decreased temporally throughout the study, but they were not significantly different (H = 2.20, $d.f.$ = 2, P = 0.33; Table 1). Median size of foraging areas for males did not differ (H = 0.60, $d.f.$ = 1, P = 0.44; Table 2).

No differences ($d.f.$ = 1) were found between males and females for emergence times during August (H = 3.16, P = 0.14) or September (H = 0.21, P = 0.64), distance to foraging sites during August (H = 3.0, P = 0.08) or September (H = 2.4, P = 0.12), number of foraging sites during August (H = 0.11, P = 0.74) or September (H = 0.06, P = 0.80), size of foraging areas during August (H = 0, P = 1.0) or September (H = 1.35, P = 0.25).

Comparing over all maternity (Clark et al., 1993) and post-maternity season study periods, analysis of variance showed significant differences for distance traveled to the geometric center of activity of foraging areas (F = 4.91, $d.f.$ = 5, P = 0.01) and size of foraging areas (F = 3.42, $d.f.$ = 5, P = 0.03). No differences were found for emergence times ($\underline{F}$ = 1.48, $\underline{d}.\underline{f}.$ = 5, $\underline{P}$ = 0.24) or number of foraging sites per bat ($\underline{F}$ = 0.69, $\underline{d}.\underline{f}.$ = 5, $\underline{P}$ = 0.64). Post-hoc linear comparisons identified differences between the three maternity season study periods and the three post-maternity season study periods for distances traveled to foraging sites ($\underline{F}$ = 9.76, $\underline{d}.\underline{f}.$ = 1, $\underline{P}$ = 0.01) and size of foraging areas ($\underline{F}$ = 7.05, $\underline{d}.\underline{f}.$ = 1, $\underline{P}$ = 0.02). Both distances traveled and size of foraging areas were smallest after the maternity season (Fig. 2).

Habitat use.--With 25-m resolution data, available habitat was composed of 41.7% pasture, 46.4% forest, 8.4% edge, and 3.5% all other land-use categories combined. Bats were never observed in development, cropland, orchard, or water, and rarely in rangeland. Rangeland and pasture categories were grouped to form a single range category. To avoid having >20% of expected values <5 and no values equal to zero (Cochran, 1954; Zar, 1974), chi-square analyses were conducted on range, edge, and forest only. Female bats used habitats in proportion to their availability during all three study periods (χ^2 = 0.004, χ^2 = 0.55, and χ^2 = 5.51, $\underline{d}.\underline{f}.$ = 2, $\underline{P}$ > 0.05; Fig. 3). Male bats showed no habitat preference in August (χ^2 = 4.51, $\underline{d}.\underline{f}.$ = 2, $\underline{P}$ < 0.05; Fig. 4); however, they used forest more than expected in September (χ^2 = 8.34, $\underline{d}.\underline{f}.$ = 2, $\underline{P}$ < 0.05; Fig. 4).

Female bats used habitats equally between August and September (χ^2 = 0.18), August and October, (χ^2 = 4.10), and September and October (χ^2 = 3.76) ($\underline{d}.\underline{f}.$ = 2, $\underline{P}$ > 0.05).

Male bats used habitats equally between August and September ($\chi^2 = 2.41$, *d.f.* = 2, $P > 0.05$). Intersexual comparisons of habitat use among study periods showed no difference between males and females in August ($\chi^2 = 2.69$, *d.f.* = 2, $P > 0.05$). However, females foraged differently than males in September ($\chi^2 =$ [illegible]49, *d.f.* = 2, $P < 0.05$); males showed a preference for forested habitat during this time period (Fig. 4).

With 76-m resolution data (following Clark et al., 1993), available habitat was composed of 36.2% open, 26.0% edge, and 37.8% forest. As with the 25-m resolution data, female bats used habitats in proportion to their availability during all three study periods ($\chi^2 = 4.83$, $\chi^2 = 2.21$, $\chi^2 = 3.10$, *d.f.* = 2, $P > 0.05$; Fig. 5). However, with this coarser resolution, females foraged differently in August compared to September ($\chi^2 = 7.03$, *d.f.* = 2, $P < 0.05$); they used edge habitat more in August than September. Females used habitats similarly between August and October and between September and October ($\chi^2 = 2.64$, and $\chi^2 = 2.86$, respectively, *d.f.* = 2, $P > 0.05$).

DISCUSSION

Smaller transmitters have allowed researchers to use radiotelemetry to assess aspects of foraging behavior for insectivorous bats. However, the recommendation of 5% animal body mass for transmitter weight (Cochran, 1980) is often exceeded (Brigham, 1991; Clark, 1991, Hickey and Fenton, 1990; Tidemann et al., 1985); in this study, transmitters ranged from 4.3-7.3% of body mass.

Transmitter weight could cause a decrease in maneuverability due to increased wing loading (weight/wing area) and potentially could decrease foraging efficiency (Aldridge and Brigham, 1988). However, by observing behavior of bats with and without transmitters, researchers have shown radio-tagging does not affect emergence times (Wai-Ping and Fenton, 1989), foraging times (Hickey and Fenton, 1990), and foraging success (Hickey, 1992). Although these studies all involved transmitters within the guideline of 5% of body mass and this study exceeded this limit slightly, I assumed that the behavior of radio-tagged bats did not differ from untagged bats.

Foraging activity.--Late emergence times and frequent periods of inactivity during October 1991 may have been due to the cold weather occurring during this time. Temperatures dropped as low as 7°C. This cold weather could have affected prey availability (Barclay, 1985; Rydell, 1989). Bats may have spent less time foraging and more time night-roosting to minimize energetic losses due to cooler temperatures and lower prey densities (Anthony et al., 1981; Rydell, 1989). Bats previously should have built up fat reserves for hibernation; therefore, energy demands would be minimal.

Because Clark et al. (1993) found that as maternity season progressed, female *P. t. ingens* traveled farther to forage, I expected females during this study to travel further because they would no longer need to return to nurse young. However, during the autumn study, females traveled shorter distances to forage (Fig. 2). Perhaps during late lactation, females were traveling further to avoid direct competition with young as suggested by Clark et al. (1993) and others (Humphrey et al., 1977; Kunz, 1974). Young cave myotis (Myotis velifer) begin to forage as efficiently as adults at 6-8 weeks of age (Kunz, 1974). Assuming a similar pattern for young P. t. ingens, adult females could travel shorter distances, as I observed, without adversely affecting juvenile foraging success.

Size of foraging area can be highly correlated with energy requirements (McNab, 1963). Kurta et al. (1989) found that daily energy requirements for female little brown bats (Myotis lucifugus) nearly doubled during peak lactation. A similar phenomenon may explain the peak in size of foraging areas for female P. t. ingens during mid-lactation (Clark et al., 1993; Fig. 2). Energy expenditures of lactating females would be expected to decrease after volant young begin to supplement their diet with insects (Kunz, 1987; Kurta et al., 1989). This decrease in energy expenditures of lactating females may explain the decrease in size of foraging areas for female P. t. ingens during late lactation (Clark et al., 1993; Fig. 2).

The decrease in size of foraging areas after the maternity season (Fig. 2) also may reflect lower energy demands. Ultimately, prey availability and density could affect size of foraging areas and distances traveled to foraging areas.

Habitat use.--Differences in methods between this study and that of Clark et al. (1993) potentially could explain differences in habitat selection. With 25-m resolution data, the percentage of edge available (8.5%) was smaller than that of Clark et al. (1993) who defined edge as 32.3% of the available habitat. This difference in the amount of edge available reflects the grid cell size used for analysis; the number of cells with both forest and other habitat types increases with cell size. For that reason, I also conducted analyses on 76-m resolution data to make results comparable to Clark et al. (1993). With that resolution more edge was defined as available (26.0%); however, analysis of both data sets failed to show habitat preference by females. This substantiates the occurrence of a change in habitat selection between studies rather than an apparent change as a result of different methods.

Wing loading is defined as the ratio of weight to wing area; maneuverability decreases as the ratio increases. Because of the low wing loading of P. townsendii (Farney and Fleharty, 1969), it is highly maneuverable in flight (Aldridge, 1986; Aldridge and Brigham, 1988). Such maneuverability would allow this species to forage in cluttered habitats (Aldridge and Rautenbach, 1987). Also, such a species would be able to catch more elusive prey such as moths, which agrees with Clark's (1991) determination that P. t. ingens is a moth specialist.

As suggested by Fenton (1990), species with low wing loading and aspect ratio, such as P. townsendii, may not be as restricted to particular habitats as species with high wing loading and aspect ratio. Maneuverability of species with high values for these ratios would not be great enough to allow them to forage in highly cluttered habitats; whereas, a species like P. townsendii could forage in both cluttered and open habitats. Therefore, habitat use by "clutter-adapted" species may be more highly correlated with prey distribution (Brigham et al., 1992; Saunders and Barclay, 1992) than with habitat type. Aldridge (1986) further suggested that differences in habitat use may be more related to a species' ability to catch prey.

Lack of habitat selection during most of this study agrees with the conclusion that species with greater maneuverability can use different habitat types in which they find optimal prey. Male preference for forested areas during September may have resulted from use of a forest patch with high prey concentration. Clark et al. (1993) determined that females preferred edge and avoided forested habitat in postpartum periods; this preference may have been attributable to insect availability in different habitat types. Insect densities were high during that study (Clark, 1991), which would allow females to forage more selectively. Edge may have been selected over open or forested habitat because there was less clutter making it less costly to forage in relative to forest and more cover providing protection from predation relative to open areas (Clark et al., 1993). Only limited conclusions can be made on habitat use without incorporating data on prey availability and distribution.

Implications for recovery efforts.--*Plecotus townsendii* is essentially a sedentary cave-dwelling species. The longest recorded movement for the species is 64.4 km in Kentucky and Virginia (Barbour and Davis, 1969); however, the largest recorded movements for *P. t. ingens* is only about 8 km in Arkansas (Harvey, 1992) and 7.3 km in Oklahoma (Clark et al., 1993). Therefore, recovery efforts for *P. t. ingens*, such as habitat conservation, should focus on areas within 8-km radii from all used caves. Protection of surface habitat may require land acquisition and management, but more likely cooperative agreements with landowners will be necessary (S. Hensley, pers. comm.). Cooperation with landowners would allow immediate knowledge of land-use changes and any potential threats to critical habitats. In addition, studies that focus on population dynamics and distribution of prey would permit a better understanding of habitat use by *P. t. ingens* and aid in the recovery of this endangered species.

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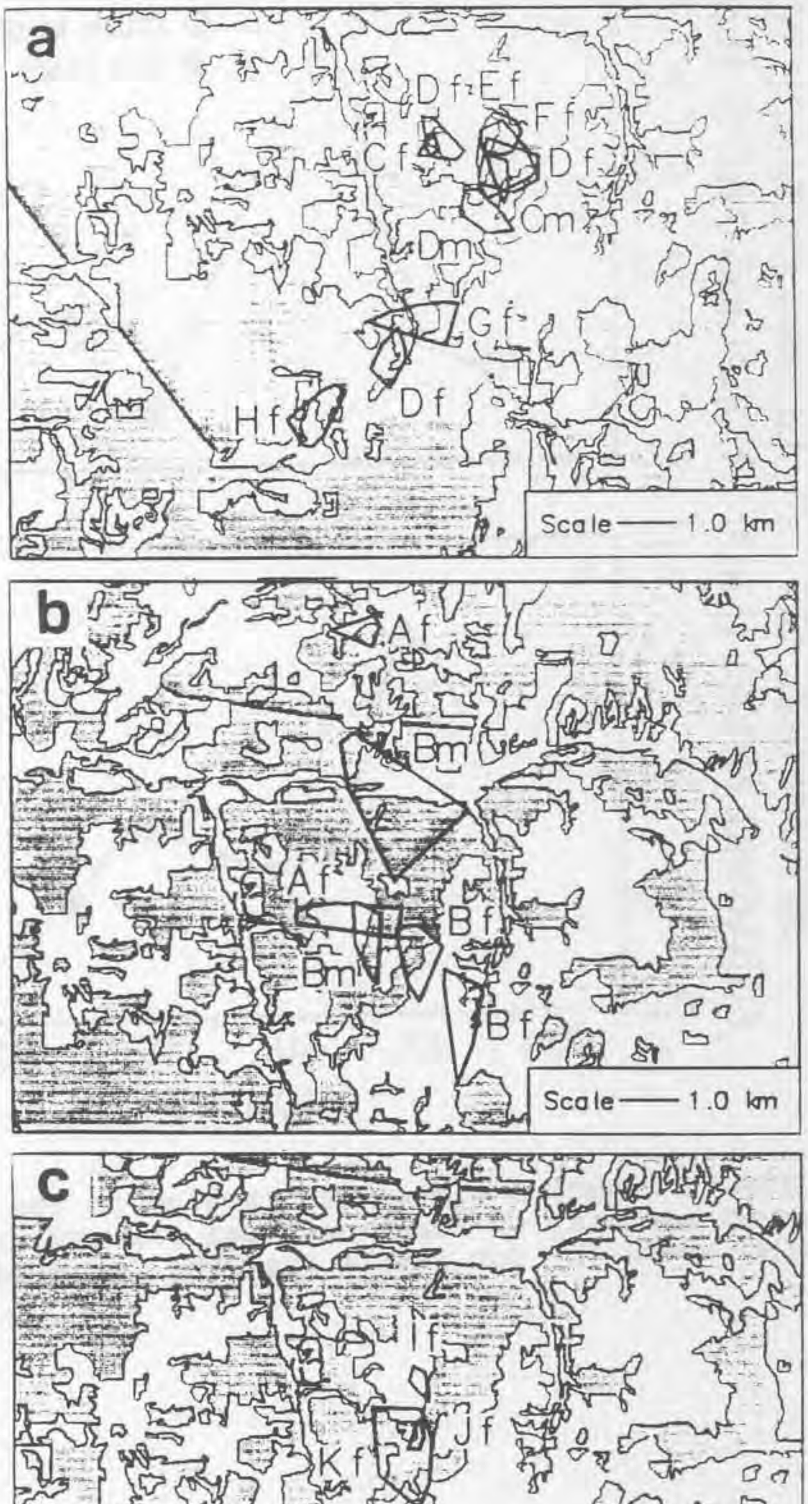
TABLE 1.--Emergence times and foraging site parameters of female *Plecotus townsendii ingens* during October 1991 and August and September 1992.

Parameter	August			September			October		
	Median	Range	n	Median	Range	n	Median	Range	n
Time of emergence (min after sunset)	47.5	47.5-47.5	2	38.8	35.0-41.0	4	56.3	55.[illegible].0	4
Distance to foraging sites (km)	0.6	0.4-0.8	2	1.6	0.5-5.0	5	0.5	0.3-0.5	3
Number of foraging sites	1.5	1.0-2.0	2	2.0	1.0-3.0	5	1.0	1.0-1.0	3
Size of foraging areas (km^2)	0.8	0.7-0.8	2	0.5	0.4-0.7	5	0.1	0.1-1.4	3

TABLE 2.--Emergence times and foraging site parameters of male Plecotus townsendii ingens during August and September 1992.

	August			September		
Parameter	Median	Range	n	Median	Range	n
Time of emergence (min after sunset)	39.0	32.0-40.0	3	36.8	33.0-40.5	2
Distance to foraging sites (km)	2.4	1.9-5.5	3	0.8	0.3-1.3	2
Number of foraging sites	1.0	1.0-2.0	3	1.5	1.0-2.0	2
Size of foraging areas (km^2)	0.9	0.2-1.6	2	0.3	0.2-0.4	2

Fig. 1.--Foraging sites of female (f) and male (m) Plecotus townsendii ingens during August 1992 (a), September 1992 (b), and October 1991 (c). Forest habitats are stippled; capital letters represent individual bats.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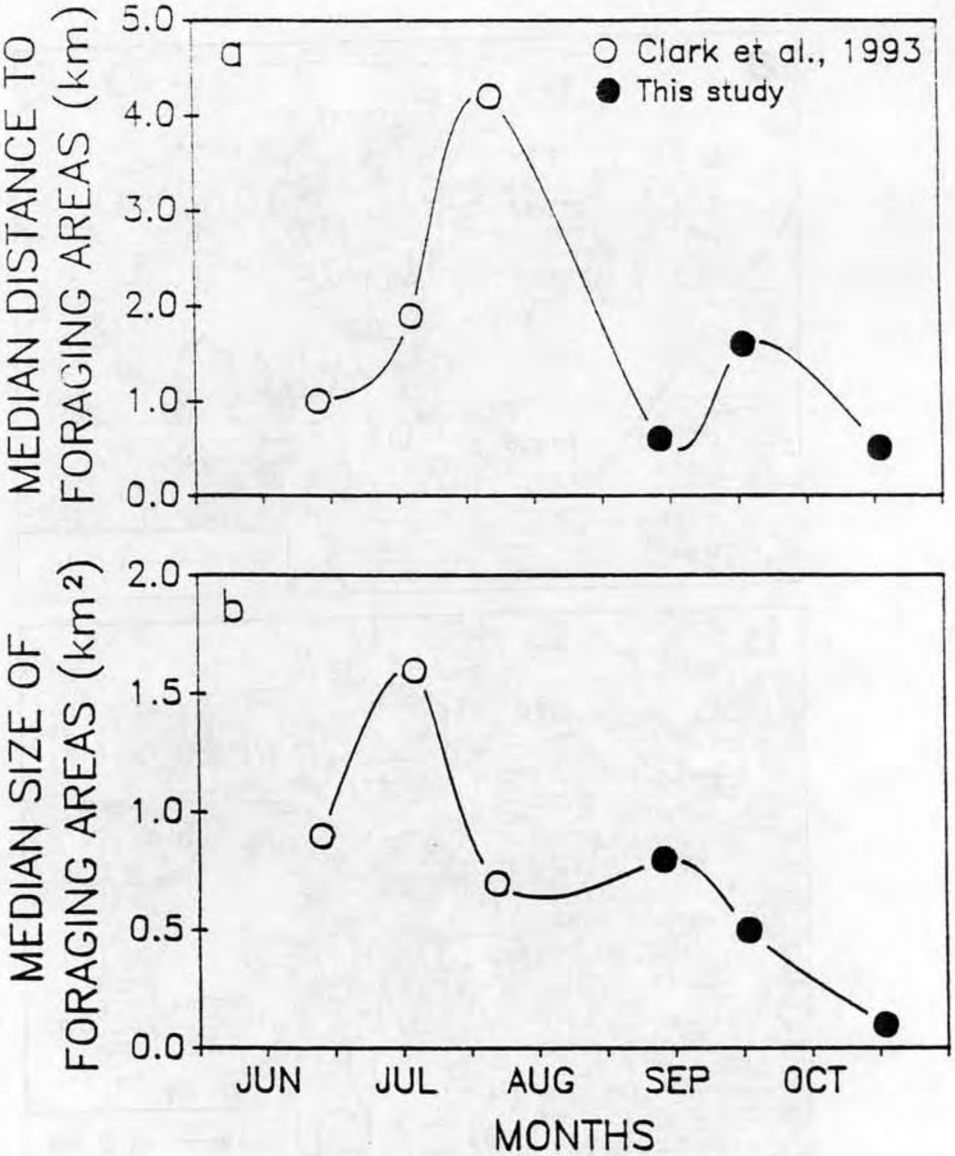

Fig. 2.--Median distances traveled to the geometric center of activity of foraging areas (a) and median size of foraging areas (b) for female <u>Plecotus townsendii ingens</u>.

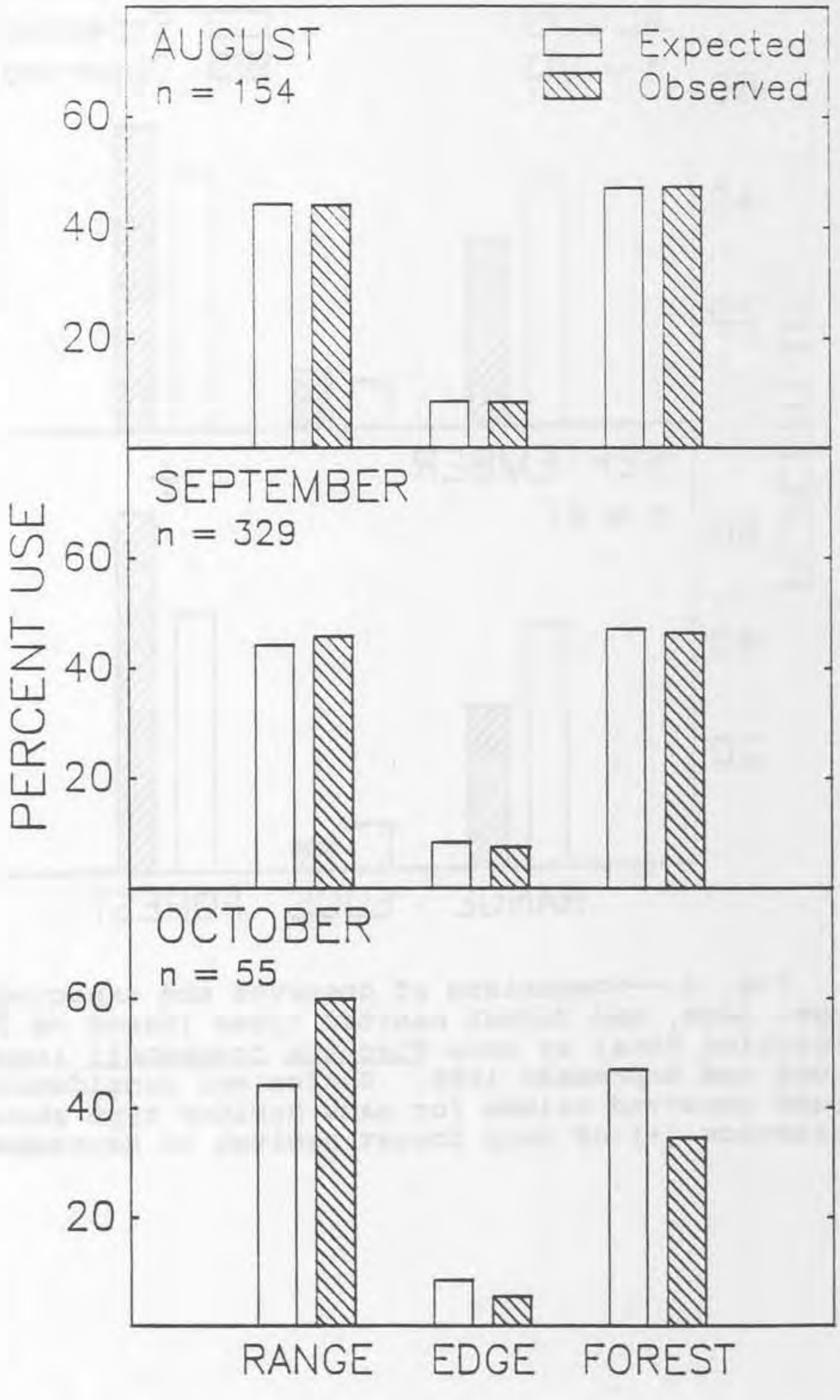

Fig. 3.--Comparison of observed and expected use of range, edge, and forest habitat types (based on 25-m resolution data) by female <u>Plecotus</u> <u>townsendii</u> <u>ingens</u> during October 1991 and August and September 1992. All habitat types were used in proportion to their availability.

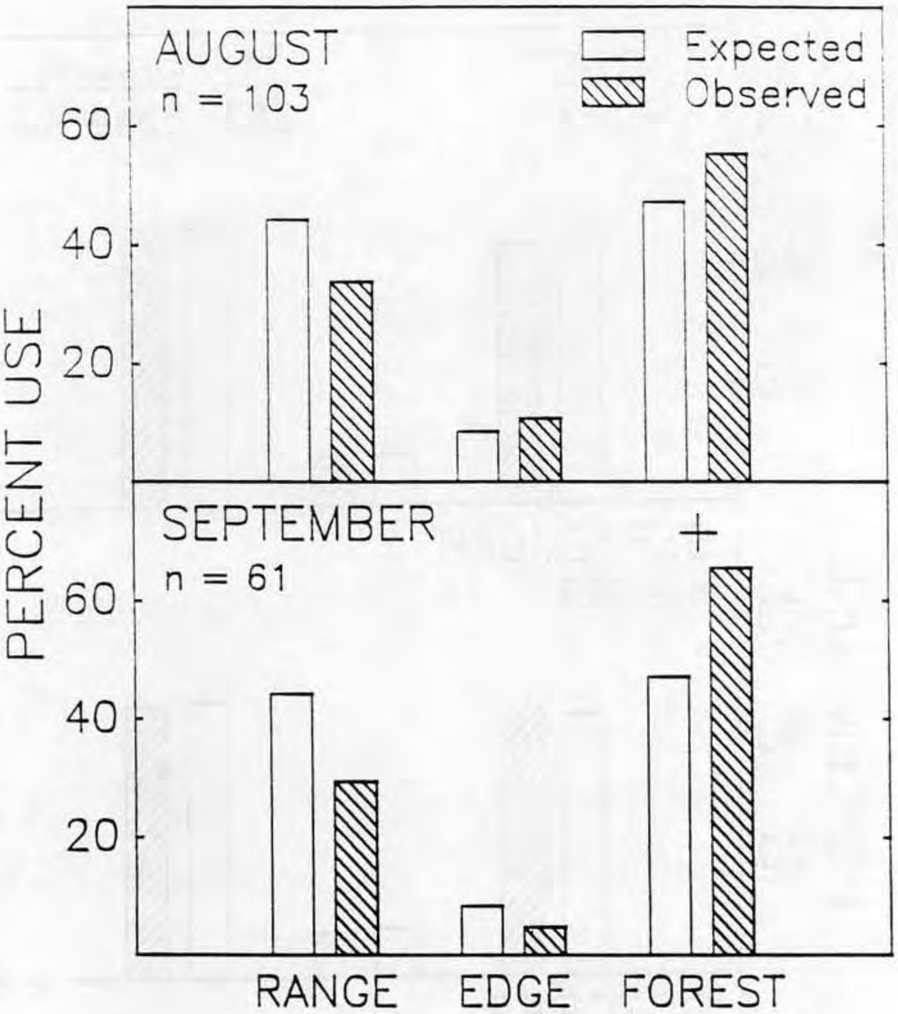

Fig. 4.--Comparison of observed and expected use of range, edge, and forest habitat types (based on 25-m resolution data) by male Plecotus townsendii ingens during August and September 1992. Bonferroni confidence intervals around observed values for each habitat type showed preference (+) of only forest habitat in September.

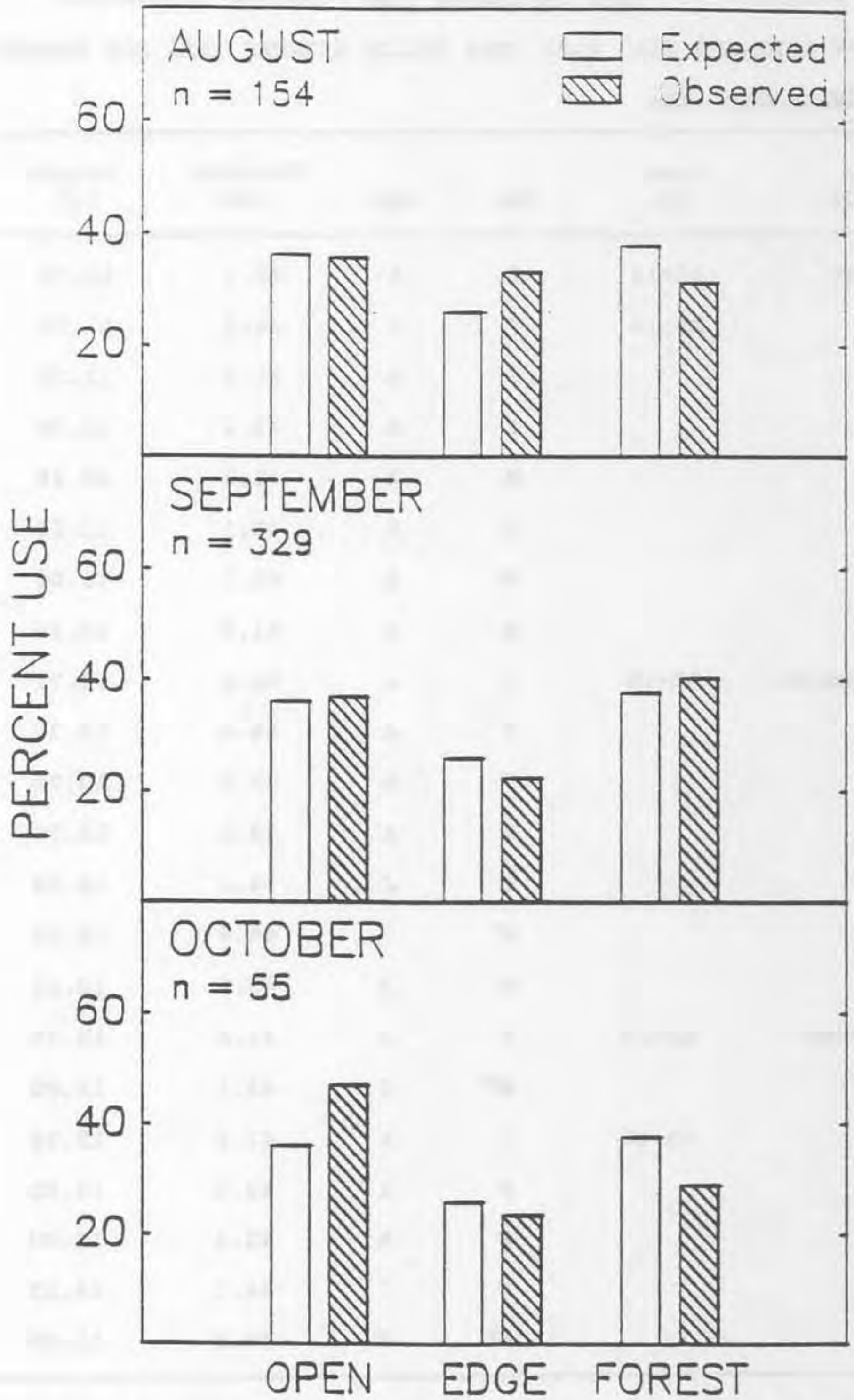

Fig. 5.--Comparison of observed and expected use of open, edge, and forest habitat types (based on 76-m resolution data following Clark et al., 1993) by female Plecotus townsendii ingens during October 1991 and August and September 1992. All habitat types were used in proportion to their availability.

APPENDIX I.--Data collected from Plecotus townsendii ingens captured with mist nets during October 1991 and August and September 1992.

Study Period	Cave No.	Sex	Age	Forearm (mm)	Weight (g)
August	AD-13	F	A	42.4	12.75
	AD-16	F	A	44.6	11.25
		F	A	41.8	11.25
		F	A	43.4	10.50
		M	A	42.9	10.25
		M	A	40.1	11.25
		M[a]	A	42.2	12.00
		M	A	41.9	10.25
September	AD-16	F	A	45.2	10.75
		F	A	46.4	12.75
		F	A	43.5	10.75
		F	A	43.5	12.25
		F	J	44.3	13.25
		M[a]	J	44.4	12.25
		M	J	43.7	10.25
October	AD-13	F	J	41.4	13.75
		M[a,b]	J	43.1	13.00
	AD-16	F	A	43.5	15.25
		F	A	43.5	13.00
		F	A	43.5	12.00
		F	J	44.1	14.25
		M[b]	J	44.3	11.50

[a] Bat in reproductive condition (i.e., testes descended).

[b] Bat not marked with transmitter.

APPENDIX II.--Data collected on individual *Plecotus townsendii ingens* monitored with radiotelemetry. Note: Some bats had more than one foraging site.

Study Period	Bat	Sex	Age	No. of point locations determined	Size of Foraging site (km^2)	Distance to Foraging site (km)	Cave used most often
August	581	F	A	74	0.82	0.39	AD-145
	997	F	A	70	0.62	0.10	AD-13
				10	0.76	1.53	AD-13
	027	M	A	4	--[a]	2.35	AD-13
	157	M	A	11	0.24	5.52	AD-13
	321	M	A	13	0.46	0.68	AD-16
				75	2.70	3.14	AD-16
September	058	F	A	8	0.08	1.70	AD-16
				61	0.93	0.86	AD-16
	107	F	A	35	0.69	3.09	AD-13
	188	F	A	17	0.33	1.59	AD-16
				57	0.71	0.70	AD-16
				32	0.35	2.97	AD-16

APPENDIX II.--Continued.

Study Period	Bat	Sex	Age	No. of point locations determined	Size of Foraging site (km^2)	Distance to Foraging site (km)	Cave used most often
September	228	F	A	57	0.57	5.01	AD-16
	749	F	J	55	0.39	0.93	AD-13
				7	--[a]	0.08	AD-13
	641	M	J	42	0.40	0.25	AD-16
	562	M	J	16	0.17	0.14	AD-16[b]
				3	--[a]	2.35	AD-16[b]
October	522	F	J	2	--[a]	--[c]	AD-13
	542	F	A	13	0.08	0.33	AD-16
	622	F	J	22	1.37	0.54	AD-19
	731	F	A	22	0.11	0.53	AD-150

[a]Not enough points (<8) to determine extent of foraging area.

[b]This bat appeared to be roosting in a crevice or talus rock. Distances were calculated from this location, north of AD-16.

[c]Distance of 2.9 km determined for this bat, but not included in analysis because no foraging area was determined.

CHAPTER III

VEGETATIONAL STRUCTURE AND LAND-USE EVALUATION TO ASSESS CAVE SELECTION BY OZARK BIG-EARED BATS (PLECOTUS TOWNSENDII INGENS)

ABSTRACT.--Habitat was evaluated surrounding used and unused caves within the range of the endangered Ozark big-eared bat (*Plecotus townsendii ingens*). Vegetational structure of the habitat immediately surrounding caves was assessed within 0.04-ha circular plots. Land-use within 3 km of caves was determined by interpretation of color infrared aerial photography and subsequent digitization of cover types into a geographic information system for analysis. Few differences were documented for the vegetative parameters measured. Land-use patterns surrounding used (maternity and hibernacula) and unused caves did not differ. Based on these and previous findings, surface habitat surrounding caves does not appear to be significant in cave selection by this subspecies.

Numerous limestone caves exist in eastern Oklahoma that could be potentially used by Ozark big-eared bats (*Plecotus townsendii ingens*). However, only five caves are currently used as maternity and/or hibernacula sites (Clark, 1991; Clark et al., 1991) This restricted use of caves during critical life history periods suggests that some cave selection criteria exist.

Clark et al. (1991) found that bats had certain microhabitat requirements within used caves; both hibernating and maternity clusters were found at cooler locations compared to solitary individuals or random points. Land-use surrounding used and unused caves was assessed and no distinct differences were found (Clark et al., 1991); however, data resolution through remote sensing may have been too coarse (4-ha cells) to detect differences. It was suggested that other parameters, such as the structure of the vegetation immediately surrounding caves, could affect cave selection (Clark et al., 1991).

I evaluated vegetational structure of habitat in the immediate vicinity of used, sporadically used, and unused caves to better understand cave selection by *P. t. ingens*. In addition, I reassessed land-use patterns surrounding used (maternity and hibernacula) and unused caves at a finer resolution than that used by Clark et al. (1991) to determine if differences existed.

STUDY AREA AND METHODS

Research was conducted in Adair and Delaware counties, Oklahoma, in the Boston Mountain Plateau subdivision of the Ozark Plateaus Province physiographic region (Madole et al., 1991). Faulting throughout this region has created a series of prominent, steep-faced fault blocks separated by narrow stream valleys; maximum relief is 300 m and valleys 100-150 m deep are common (Huffman, 1958; Madole et al., 1991). Ridge tops are capped by resistant sandstone that overlays fossiliferous limestone interbedded with shale (Huffman, 1958). Climate has a Köppen classification of humid subtropical being characterized by hot, humid summers and relatively mild winters punctuated by sporadic periods of severe cold; mean annual temperature is 13-17°C and mean annual precipitation is 100 cm (Madole et al., 1991). Vegetation in this area is dominated by eastern deciduous oak-hickory forest with elm (Ulmus spp.), cedar (Juniperus virginiana), and pine (Pinus spp.) being locally abundant (Küchler, 1964).

Data were collected on vegetational structure in the immediate vicinity of used (n = 7), sporadically used (n = 6), and unused (n = 5) caves. Based on counts completed by Clark et al. (1991), caves with ≥15, 2-15, or ≤1 bat(s) at any given time were classified as used, sporadically used, or unused, respectively (Appendix I). I collected data on diameter at breast height (dbh), height, overstory cover, and foliage density within 0.04-ha circular plots centered on each cave (Fig. 1).

Circular plots were divided into four quadrants, one of which was centered on the directional orientation of the cave opening. Overstory cover and foliage density were measured at 11.3 m from the center of the plot on bearings through the center of each quadrant. Overstory cover also was measured over the cave entrance and at 22.6 m from the plot center on bearings through the center of each quadrant. All data collected were analyzed with Kruskal-Wallis one-way analysis of variance tests to assess differences between cave classes.

Trees were classified into dbh classes (<2.5 cm, 2.5-5.0 cm, 5.0-7.5 cm, 7.5-15.0 cm, 15.0-22.5 cm, 22.5-37.5 cm, >37.5 cm) and height classes (1-3 m, 3-6 m, 6-9 m, 9-12 m, >12 m). Overstory cover (%) was measured with a densiometer (Lemmon, 1957). An estimate of foliage density was obtained by using a density board (Noon, 1980). The density board was divided into the following height classes: <0.3 m, 0.3-1 m, 1-2 m, and 2-3 m in which the number of squares at least 50% obscured by vegetation were recorded (Noon, 1980). Foliage density readings were made from the center of each plot.

Locations of 16 caves (Appendix I) were digitized from 7.5-minute United States Geological Survey (USGS) topographic maps. The area encompassed by a 3-km radius from each cave was classified into seven habitat and land-use categories: development, cropland, orchard, pasture, rangeland, forest, and water. These categories are essentially the same as those identified by Clark et al. (1991), but that study included two categories of rangeland and distinguished between bottomland forest and mixed forest. Areal coverage of each land-use category was ascertained by interpreting 1:58,000 color infrared aerial photographs taken in 1984-85 by the Soil Conservation Service (SCS). Land-use cover maps made from the aerial photographs were converted to a scale of 1:24,000 by use of a Bausch and Lomb zoom transfer scope and USGS topographic maps. Cover maps were digitized creating vector files georeferenced to a Universal Transverse Mercator projection using GRASS (4.0) software (Geographical Resources Analysis Support System, U.S. Army Corps of Engineers, Construction Engineering Research Lab, Champaign, IL). These files were combined with previously digitized vector files (SCS, Stillwater, OK) to form a single file encompassing the entire study area.

The resulting habitat data vector file was then rasterized into a matrix of 25- by 25-m grid cells. The habitat data vector file was used to create an eighth habitat category, forest edge. Edge was included because Clark et al. (1993) found that during the maternity season, female P. t. ingens preferred to forage in edge habitat. Edge was defined as any area where forest bordered any other land-use category. The forest edge file was rasterized and combined with the previous raster file to form a new habitat data raster file with eight habitat and land-use classes.

Three buffer zones of 1-km, 2-km, and 3-km radii were created around each cave site (Fig. 1). Percent habitat cover within each buffer zone was determined by combining the buffer zones for each cave with the habitat data raster file. One-way unbalanced design analyses of variance (PROC

GLM; SAS Institute, 1985) were used to determine differences in the percentage of each habitat and land-use category by zone between maternity and nonmaternity caves, hibernacula and nonhibernacula caves, and all caves and an equal number of random locations (n = 16). Arcsine square root transformed percentages were used for analysis. Statistical significance was set at $P < 0.05$ for all tests.

RESULTS

Four of seven dbh categories were significantly different between cave types (Fig. 2). Only one of five height classes were significantly different (Fig. 2). No significant differences were found in overstory cover and foliage density among cave types (Table 1).

No differences were found for any land-use category between maternity (n = 4) or nonmaternity (n = 12) caves (P > 0.05; Table 2) using transformed percentages. Similarly, no differences were found for any land-use category between hibernacula (n = 3) and nonhibernacula caves (n = 13) (P > 0.05; Table 2). However, when all caves (n = 16) were compared to random locations, caves had significantly more forest and less pasture in all zones and less edge in zones 2 and 3 compared to random locations (P < 0.05; Table 3).

DISCUSSION

In both height and dbh categories, I counted lower numbers of stems at sporadically used caves. These caves seemed to be the most disturbed sites; for example, three sporadically used caves had plots that included mowed or logged areas. I tentatively conclude that there is little difference in the vegetational structure surrounding used and unused caves. Sporadically used caves may have received more use by _P. t. ingens_ in the past, but disturbance of the vegetation may have caused use to decline.

The importance of vegetational structure surrounding caves is unclear. Few studies have addressed how vegetational structure influences cave selection by bats. Important parameters could have been overlooked in this study. Lacki et al. (1993) studied different vegetative parameters surrounding rock shelters that were used and unused as roosts by the endangered Virginia big-eared bats (_P. t. virginianus_); however, they found no difference in these parameters between sites.

Clark et al. (1991) used a data resolution of 4 ha to evaluate land-use patterns surrounding caves and found no difference between used (maternity and hibernacula) and unused caves. I used a data resolution of 25 m (0.06 ha) but was unable to demonstrate differences between used and unused caves with finer resolution of land-use data. The differences found between all caves and random locations may be attributable to the fact that limestone caves in the study area are found on forested mountain slopes.

Clark et al. (1991) pointed out several possible reasons for their inability to demonstrate differences between used and unused caves. Two of these possibilities, scale of habitat analysis and vegetative parameters (exclusive of species composition), were evaluated in this study and could not be used to differentiate between used and unused caves. Proximity to habitat required for foraging would not seem to be a factor based on the ability of P. t. ingens to forage in a variety of habitats (Chapter II). Because the Ozark big-eared bat population is extremely small, a few caves may be all that are needed as suggested by Clark et al. (1991). It is important, however, not to overlook the impact of disturbance in the form of human visitation to caves. Some caves may appear suitable and even have evidence of past use; however, human disturbance may keep bat numbers down or eliminate them altogether (Barbour and Davis, 1969; Hill and Smith, 1984; Humphrey and Kunz, 1976; Pearson et al., 1952; Sheffield et al., 1992; Tuttle, 1979).

Implications for recovery efforts.--Based on macrohabitat analyses, there appear to be numerous potential cave sites for P. t. ingens within eastern Oklahoma. Microhabitat requirements may not be limiting; however, further research is needed to determine if microhabitat requirements are met within unused caves. Raesly and Gates (1987) found many caves unused in winter, which had suitable microhabitats for common species such as Eptesicus fuscus, Pipistrellus subflavus, and Myotis lucifugus.

The tendency of cave-dwelling bats to concentrate in large numbers is of concern to biologists working on recovery efforts. Given the low productivity of bats (McCracken, 1989), disturbance, whether natural or human, can be very detrimental to bats during critical times in their life history. For example, bats awakened during hibernation may use 2-3 weeks of the energy reserves needed to sustain them until spring when insect availability increases (Harvey, 1992). The California subspecies of the Townsend's big-eared bat (P. t. townsendii), which is not a cave obligate, has shown large enough population declines because of human disturbance of roost sites (Pierson, 1988) to warrant its status as a candidate species for federal listing.

Caves that are important to P. t. ingens need continued protection, as is currently afforded through the Oklahoma Bat Caves National Wildlife Refuge. Currently, a maternity cave of P. t. ingens in Arkansas is gated (Harvey and Barkley, 1990), and its success can serve as a partial model for gating caves in Oklahoma. Gating is planned for at least two caves in Oklahoma to restrict human visitation (C. Heflebower, pers. comm.), but effects of gating on microhabitat within caves must be carefully evaluated. Numerous researchers recognize the importance of cave microhabitats and that natural or artificial alterations can cause abandonment and/or population decline (Hill and Smith, 1984; Humphrey, 1978; Twente, 1955). Gating can even obstruct flight patterns and increase the risk of predation

(Tuttle, 1977). The need for public education concerning bats cannot be over-emphasized, especially on a local level. The need for gating could be eliminated if people were aware of the important ecological role of bats and their sensitivity to disturbance during critical times in their life history.

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TABLE 1.--Mean percent foliage density (±SE) by height class (Noon, 1980) and mean percent overstory cover (±SE) by distance from cave entrance for vegetation surrounding used, sporadically used, and unused caves within the range of Plecotus townsendii ingens.

Parameter	Class	Cave class: Used ($\underline{n}$ = 7)	Sporadically used ($\underline{n}$ = 6)	Unused ($\underline{n}$ = 7)
Foliage density	<0.3 m	78.6 ± 5.4	67.5 ± 16.2	61.0 ± 13.7
	0.3-1 m	67.5 ± 16.2	52.6 ± 16.4	53.0 ± 11.8
	1-2 m	57.5 ± 9.1	45.1 ± 14.2	28.9 ± 6.9
	2-3 m	43.1 ± 10.4	48.1 ± 13.4	33.9 ± 4.1
Overstory cover	Above cave	88.3 ± 3.1	73.6 ± 11.3	86.8 ± 4.1
	11.3 m	85.6 ± 6.2	79.4 ± 6.9	78.4 ± 6.5
	22.6 m	84.1 ± 8.1	76.8 ± 6.1	82.8 ± 2.4

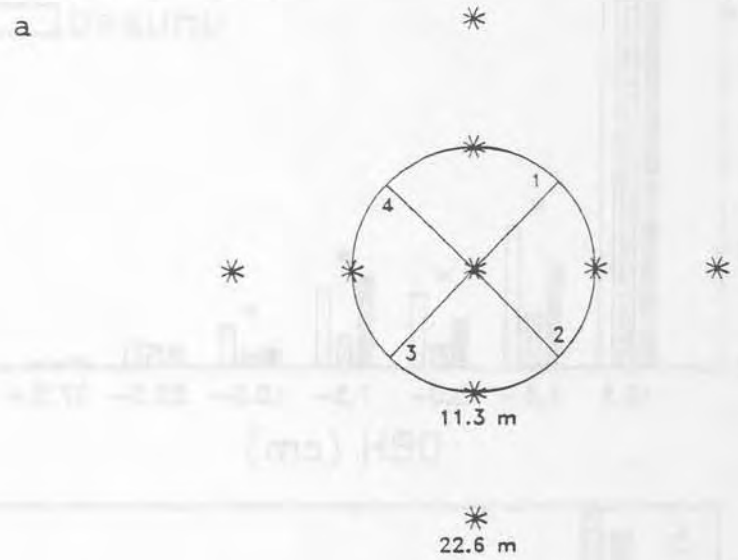
TABLE 2.--Mean percent land-use surrounding maternity (n = 4) and nonmaternity (n = 12) caves and hibernacula (n = 3) and nonhibernacula (n = 13) caves in eastern Oklahoma.

	Development		Cropfields		Orchards		Pasture		Rangeland		Forest		Water		Edge	
Cave type	$\bar{X}$	SE	$\bar{X}$	SE	$\bar{X}$	SE	$\bar{X}$	SE	$\bar{X}$	SE	$\bar{X}$	SE	$\bar{X}$	SE	$\bar{X}$	SE
Within 1 km of cave																
Maternity	0.0	--	0.2	0.2	0.0	--	17.7	10.6	0.1	0.1	78.2	11.8	0.2	0.2	3.6	1.5
Nonmaternity	0.3	0.2	0.0	--	0.0	--	16.8	3.9	0.8	0.3	76.9	4.6	0.1	0.1	5.0	0.8
Hibernacula	0.1	0.1	0.0	--	0.0	--	16.3	8.2	0.0	--	79.9	10.1	0.0	--	3.8	1.9
Nonhibernacula	0.3	0.2	0.0	--	0.0	--	17.2	4.4	0.8	0.3	76.7	5.0	0.2	0.1	4.9	0.8
Within 2 km of cave																
Maternity	0.0	--	0.3	0.3	0.0	--	22.0	10.4	0.7	0.5	71.1	11.8	0.1	0.0	5.7	1.7
Nonmaternity	1.4	1.0	0.4	0.2	0.0	--	23.8	5.7	1.0	0.3	67.8	6.7	0.3	0.1	5.3	0.7
Hibernacula	0.4	0.4	0.1	0.1	0.0	--	13.9	6.6	1.0	0.6	79.0	9.6	0.5	0.5	5.1	2.1
Nonhibernacula	1.2	0.9	0.5	0.2	0.0	--	25.6	5.7	0.9	0.3	66.3	6.6	0.2	0.1	5.4	0.7
Within 3 km of cave																
Maternity	0.1	0.0	0.7	0.4	0.0	--	27.9	8.7	1.0	0.4	63.5	9.7	0.5	0.5	6.3	1.0
Nonmaternity	1.6	1.0	0.6	0.2	0.3	0.3	25.4	5.5	1.5	0.5	64.2	6.6	0.4	0.2	6.1	0.6
Hibernacula	0.2	0.2	0.9	0.5	0.0	--	19.0	5.5	1.2	0.5	71.4	8.4	1.0	0.9	6.3	1.5
Nonhibernacula	1.4	1.0	0.6	0.2	0.3	0.3	27.7	5.4	1.4	0.5	62.3	6.3	0.3	0.1	6.1	0.5

TABLE 3.--Mean percent land-use surrounding caves (n = 16) and random locations (n = 16) in eastern Oklahoma.

	Development		Cropfields		Orchards		Pasture		Rangeland		Forest		Water		Edge	
Cave type	$\bar{X}$	SE	$\bar{X}$	SE	$\bar{X}$	SE	$\bar{X}$	SE	$\bar{X}$	SE	$\bar{X}$	SE	$\bar{X}$	SE	$\bar{X}$	SE
Within 1 km of cave																
Caves	0.2	0.2	0.0	--	0.0	--	17.0[a]	3.8	0.6	0.3	77.3[a]	4.3	0.1	0.1	4.7	0.7
Random points	0.6	0.3	0.7	--	0.0	--	38.9	5.9	1.1	0.9	51.6	6.9	0.0	--	7.1	0.9
Within 2 km of cave																
Caves	1.0	0.8	0.4	0.1	0.0	--	23.4[a]	4.8	0.9	0.3	68.6[a]	5.7	0.3	0.1	5.4[a]	0.6
Random points	0.9	0.5	0.8	0.3	0.0	--	39.6	4.9	0.7	0.2	50.0	5.6	0.4	0.2	7.6	0.6
Within 3 km of cave																
Caves	1.2	0.8	0.6	0.2	0.2	0.2	26.1[a]	4.5	1.4	0.4	64.0[a]	5.4	0.4	0.2	6.1[a]	0.5
Random points	1.3	0.7	0.6	0.2	0.6	0.4	39.5	3.8	0.7	0.2	49.1	4.6	0.3	0.2	7.9	0.4

[a]Significantly more or less than random points; analysis of variance ($P < 0.05$).



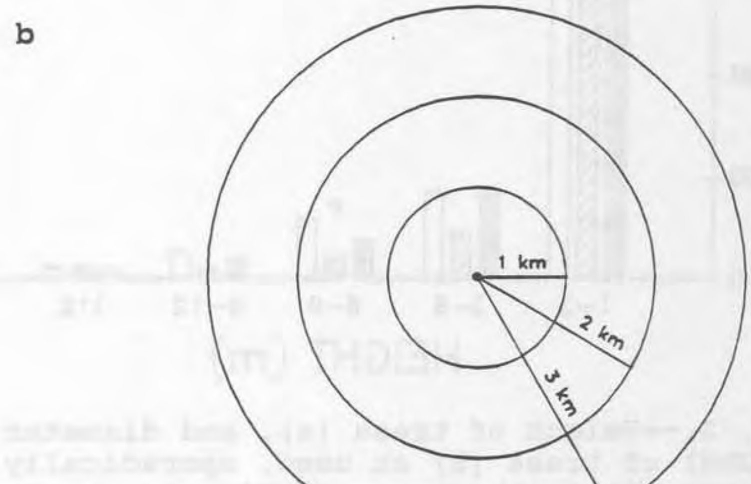


Fig. 1. Plot designs for vegetational structure analyses (a) and land-use analyses (b). Each plot is centered around the cave. Asterisks denote where measurements were taken for the vegetational structure study.

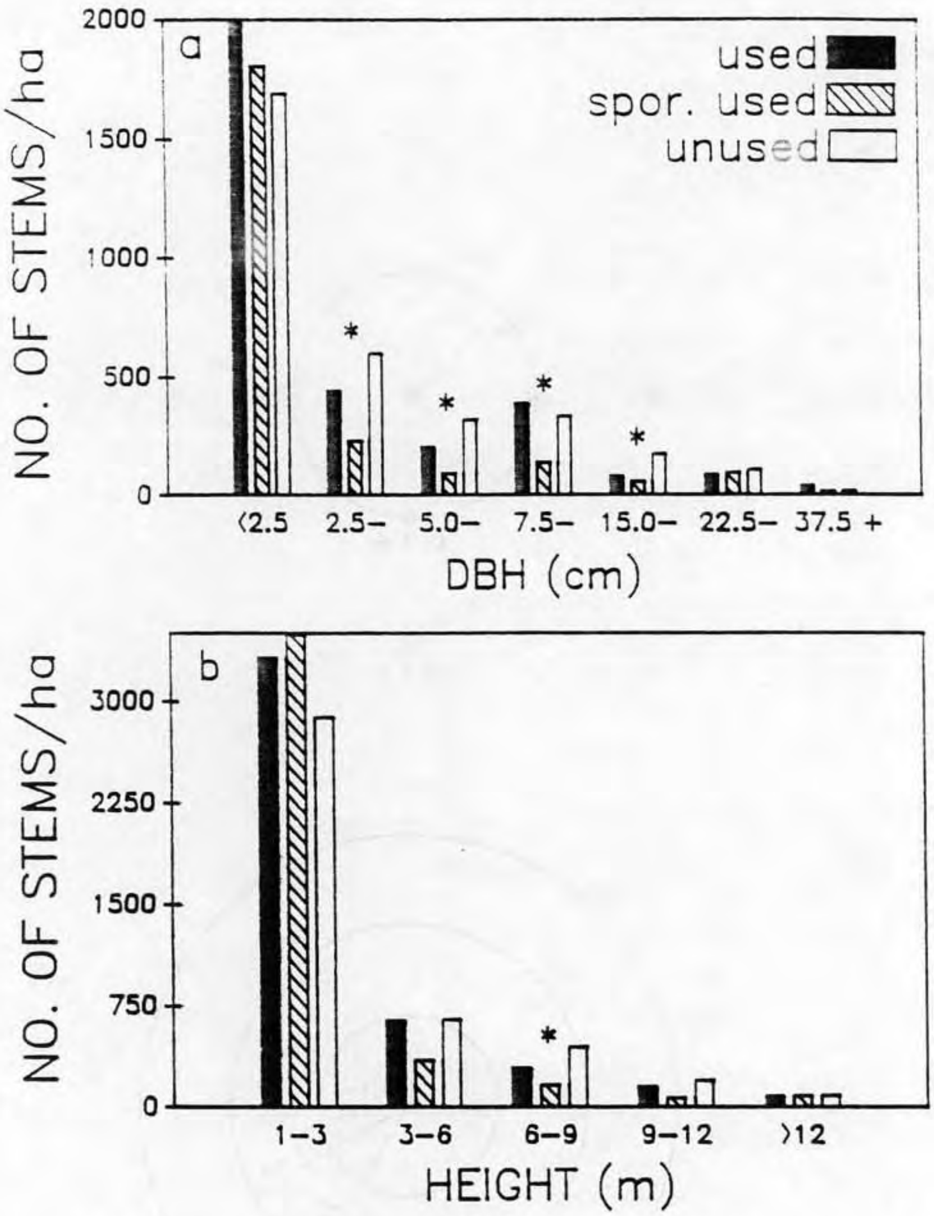


Fig. 2.--Height of trees (a), and diameter at breast height (DBH) of trees (b) at used, sporadically used, and unused caves within the range of Plecotus townsendii ingens in eastern Oklahoma (*P < 0.05).

APPENDIX I.--Cave classification for the vegetational structure and land-use habitat analyses.

Cave ID	Cave classification	
	Vegetational structure	Land-use
AD-003	Used	Nonmaternity, Hibernacula
AD-010	Used	Maternity, Hibernacula
AD-012	Sporadically Used	--[a]
AD-013	Used	Maternity, Nonhibernacula
AD-015	Sporadically Used	Nonmaternity, Nonhibernacula
AD-016	Used	Nonmaternity, Nonhibernacula
AD-017	Used	Maternity, Nonhibernacula
AD-018	Used	--[a]
AD-025	Sporadically Used	--[a]
AD-029	Sporadically Used	Nonmaternity, Nonhibernacula
AD-041	--[b]	Nonmaternity, Nonhibernacula
AD-051	Unused	Nonmaternity, Nonhibernacula

APPENDIX I.--<u>Continued</u>.

	Cave classification	
Cave ID	Vegetational structure	land-use
AD-118	--[c]	Nonmaternity, Nonhibernacula
AD-125	Used	Maternity, Hibernacula
AD-127	Unused	Nonmaternity, Nonhibernacula
AD-134	Unused	--[a]
AD-142	Unused	Nonmaternity, Nonhibernacula
AD-167	Sporadically Used	Nonmaternity, Nonhibernacula
AD-186	Unused	Nonmaternity, Nonhibernacula
DL-21	Sporadically Used	Nonmaternity, Nonhibernacula

[a]Cave not included in study to reduce land-use overlap of adjacent caves (Clark et al., 1991).

[b]Cave not included in this study.

[c]Access denied by landowner.