1997

Bat House Use in Central Florida, With Emphasis on Nycticeius humeralis and Tadarida brasiliensis cynocephala

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BAT HOUSE USE IN CENTRAL FLORIDA, WITH EMPHASIS ON *Nycticeius humeralis* AND *Tadarida brasiliensis cynocephala*

by

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B.S. University of Central Florida, 1989

A thesis submitted in partial fulfillment of the requirements
for the degree of Master of Science
in the Department of Biology
in the College of Arts and Sciences
at the University of Central Florida
Orlando, Florida

Spring Term
1997

ABSTRACT

Bat houses and roost sites utilized by *Tadarida brasiliensis* and *Nycticeius humeralis* were studied in four central Florida counties. Temperatures were monitored in occupied roosts and in bat houses. It was determined that the presence of bats affects roost temperature. The mean temperature in the bat house that was preferred at the Seminole Community College (SCC) site was above ambient temperature a significantly greater amount of time than mean temperature in the other style houses located at that site. A colony of bats roosting in buildings on the property of SCC was successfully relocated into bat houses located .4 kilometers from the main roost. At another Sanford site (Aikins), a bat house occupied by both species, was moved to a site located 5 miles to the north. During the bat house move, *Tadarida* did not relocate successfully and left prevolant pups behind. *Nycticeius* remained at the new site for two months. Bats appear to prefer bat houses and roosts with west or northwest orientations, but have occupied all other orientations.

This work is dedicated to my husband Thomas Finn, my parents Janet and Sim Seckbach, and to the bats.

ACKNOWLEDGMENTS

My sincerest thanks to all those who made this project possible. My graduate committee: I. Jack Stout, Lew Ehrhart, and Walter K. Taylor, proved indispensable. I am especially grateful for support from Dr. Merlin Tuttle and a grant from Bat Conservation International. Thanks to Seminole Community College (SCC), University of Central Florida (UCF), Rollins College, Oviedo High School, Central Florida Research and Education Center (CFREC), my parents Jan and Sim Seckbach, Ernie Stevens, Sheila Hill, Aikins Printing, and the Central Florida Zoological Park for allowing me to place bat houses on their property and monitor them on a continual basis. I appreciate the donation of power poles from Florida Power, and materials from Builders Square, Home Depot, and Reflectix Corp. I thank the following organizations and individuals who donated manpower and skill to build and mount the houses: Florida Power Corporation, SCC physical plant, Rollins College physical plant, UCF physical plant, CFREC farm crew, Ernie Stevens and Tom Laputka. I am grateful to Dr. Gary Leibee and Kenneth Savage at CFREC for allowing me to take so much time off to work on this project, and also at CFREC thanks goes to Dr. Richard Beeson for sharing his knowledge about the Campbell datalogger system. Thanks also goes to Dave Nickerson, in the UCF Department of Statistics for all his time and patience. Especially, I thank my husband, Thomas Finn, who built and mounted more than 1/2 of the bat houses.

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CHAPTER 1
BACKGROUND AND JUSTIFICATION

Introduction

Two-thirds of bat species in the United States roost in man-made structures such as buildings and bridges (Barbour and Davis, 1969). Bat colonies in caves, mines, trees, and man-made structures, range in size from tens, to thousands or even millions of individuals. Bats are vulnerable to loss of roost habitat from natural (e.g., floods and wind damage) and human related causes. This loss often leads to high mortality and may threaten some populations with extirpation (Tuttle, 1988; Harvey, 1992; Gore and Hovis, 1992).

Eighteen chiropteran species occur in Florida (Table 1). Thirteen of the 18 species have confirmed breeding populations here (Jennings, 1958; Brown, 1985,1986,1987; Finn, unpublished). In the time period since Jennings did his research (1958), bat populations have declined dramatically. He wrote: "The number of roosts located during the study make it obvious that almost every town with abandoned buildings may shelter a *Tadarida* colony". More recent data compiled by Bain (1981) and Hermanson and Wilkins (1986) suggest a decline of *Tadarida* has occurred in Florida. Bain (1981) attributes much of this to a decline in suitable roosting structures. This decline is often due to a public fear of chiropteran rabies, that typically results in the extermination of colonies.

Hermanson and Wilkins (1986) found only three maternity colonies of *Tadarida* in north Florida from 1976 -1983 and noted all of these colonies were exterminated or scheduled for extermination.

Since the 1950's, cave roosting bats such as *Myotis austroriparius* have also declined in Florida. Gore and Hovis (1992) found only five of the 15 caves known to have housed a *M. austroriparius* colony in the past, still contained bats in 1991. In recent years, mines and caves that house bat colonies have gained some protection, but little has been done to secure roosts that occur in buildings and other man-made structures. Roost destruction and colony eviction may be increasing faster than alternate roosts become available. Conservation measures must be undertaken to protect the roosts of these animals. For urban bats these measures might include protection of active building roosts and/ or erection of alternate man-made structures (i.e., bat houses) to provide potential roost sites.

Bird houses, for example, have been popular for years in the United States and Europe and are important in the conservation of many bird species (i.e., Zeleny, 1976). In Europe, bat houses are popular and are moderately successful in attracting bats (Stebbins and Walsh, 1991; Hutson, 1987). Bat houses are gaining popularity in North America, but research is needed to increase their effectiveness as a conservation tool.

Loss of even a small colony of bats can have a significant environmental impact. Most North American bats are insectivorous and are important predators

of nocturnal insects. Each bat can consume half its body weight, or more, in insects nightly (Kunz et al., 1995; Whitaker and Clem, 1991). Moths and beetles (Lepidoptera and Coleoptera), which are often significant crop pests, mosquitoes and other flies (Diptera), and Hemipterans (i.e., cicadas, leafhoppers & planthoppers) are regularly eaten by bats (Barbour and Davis, 1969).

The significance of bat houses to local bat populations was evaluated by Bat Conservation International (BCI, 1993). Their data suggested bat house occupancy was at 52%. Bat houses occupied by bats have several factors in common. One of these is a favorable range of internal temperatures. However, most research occurred in northern regions where the chief concern was keeping bat houses warm enough to be acceptable maternity sites. In the South, where bats are active year-round, a dual problem occurs where houses should remain warm, but provide protection from temperature extremes both in the summer and winter months.

The focus of my study was to determine bat house needs in a subtropical region (central Florida). I collected data on the temperature ranges tolerated by bats that roost in central Florida buildings. Furthermore, I modified existing bat house designs to mimic these requirements. Tuttle and Hensley (1993) suggested height above ground, distance to nearest water source, etc., would influence occupancy of bat houses. However, no data existed to show how temperatures in bat houses might affect occupancy rate or how different species respond to bat house temperatures in a subtropical region.

Can bats be expected to occupy a bat house? Bat houses erected near a site prior to an exclusion seem to have a slightly higher success rate than bat houses erected in an area where bats have not been recently excluded from a known roost (BCI, 1987). The question remains: what attracts bats to a roost, or in particular, to a bat house? And, what keeps a bat returning to a roost on a regular basis; or, what makes a roost home?

Several theories have been discussed by bat house researchers as to various means of attracting bats to bat houses (Tuttle and Hensley, 1993; Cope, 1959; Fenton, 1985). These include, but are not limited to, scenting the bat house with guano, playback of recorded vocalizations, and seeding houses with live bats. I utilized scent and seeding in my experiments; however, the cost and logistics of recording and playback of high frequency vocalizations prevented experimentation with that technique during my project.

Bats In Central Florida

Nine bat species occur in central Florida. Five roost in man-made structures. Two families are represented here. Vespertillionidae includes *Myotis austroriparius*, the Southeastern Myotis; *Nycticeius humeralis*, the Evening bat; *Eptesicus fuscus*, the Big brown bat; and *Plecotus rafinesquii*, Rafinesque's big-eared bat. Molossidae is represented by *Tadarida brasiliensis*, the Brazilian free-tailed bat (Jennings, 1958; Zinn, 1977; Bain, 1981). The Big brown bat, *Eptesicus fuscus fuscus* and *E. f. osceolus*, (Vespertillionidae) is

considered rare in central Florida (Zinn, 1977), but is known to roost with *Tadarida* in buildings (Jennings, 1958). Colonies of *Myotis austroriparius* were not found roosting in buildings during my study, (but they were confirmed in 3 bridges in the area, and on two occasions I found single individuals in buildings with *Tadarida* and *Nycticeius*). *Plecotus rafinesquii* is classified as rare (FCREPA, 1992). Although this species roosts in buildings in central Florida, these structures are usually abandoned and the bats are not causing any conflict with humans (Clark, 1995; Finn, 1996).

Main Study Species

I studied two of the five central Florida bat species that roost in man-made structures.

Tadarida brasiliensis

Tadarida brasiliensis is the most conspicuous local chiropteran species and is usually found in large colonies. This species consists of nine subspecies, that differ not only in geographic range, but also in ecological and behavioral traits (Wilkins, 1989). Two subspecies are found in the United States. *Tadarida brasiliensis mexicana* (the Mexican or Brazilian free-tailed bat), is found in the Southwestern U.S. where it is migratory and generally roosts in caves. This subspecies is found in large maternity groups (often numbering in the millions) in caves (i.e., Bracken, Carlsbad) and in some bridges (i.e., Congress Ave. bridge,

Austin, Texas) and buildings. The Southeastern subspecies, *T. b. cynocephala* (LeConte's free-tailed bat), is not migratory, has not been documented to roost in caves, and seems to prefer man-made structures (Wilkins, 1989). This subspecies is not found in large concentrations like *T. b. mexicana*, but can still be found in groups of hundreds or thousands. *Tadarida b. cynocephala,* in central Florida, give birth to a single pup in early June (Finn, unpublished).

Bats in the family Molossidae possess a gland on the neck that produces an oily secretion that has a distinctive odor (Herreid, 1960). Colonies of these bats can often be identified by this odor and staining on and around the roost entrances.

Nycticeius humeralis

In Florida, *Nycticeius humeralis* consists of two subspecies. *Nycticeius h. subtropicalis* is confined to the southern part of the state, with *N. h. humeralis* found throughout the remainder of Florida (Jennings, 1958). *Nycticeius* occurs in much smaller groups and does not possess the distinct odor associated with *Tadarida*. Breeding habits of *Nycticeius* in Florida were studied intensively by Bain (1981). This species is non-migratory in the southern part of its range and usually gives birth to twins (occasionally triplets) in late spring (mid-May in central Florida). *Tadarida* and *Nycticeius* can be found roosting together through most months of the year.

Importance of Roost Temperature

Roost thermo-conditions and the energy budgets of bats are intimately related. Bats spend more than half their lives in their roost and it is important that they select roosts and roost sites that promote an efficient energy budget. Although the physiology of bat thermoregulation and energy budgets will not be discussed in detail here (see Kunz, 1982 and McNab, 1982 for excellent reviews on the subject), it should be understood this is probably the most important selective pressure for roost site choice.

Tuttle and Stevenson (1982), and Kunz (1995) summarize that bats generally require warm maternity roosts to insure efficient metabolism of food by pre-volant pups. Rapid development and early volancy (usually in 3 - 4 weeks) are needed for pups and adults to accumulate sufficient fat reserves to supply energy during the winter while food supplies are low. Roosts that are too cool during the maternity season may not allow pups to grow quickly enough to achieve this state and can increase post weaning mortality. This is particularly important in temperate regions where low fall temperatures make it necessary for juvenile and adult bats to either migrate or hibernate. Bats (particularly Vespertillionids) may choose non-maternity roosts with temperatures that allow them to remain torpid during cool days to conserve energy (Vaughan and O'Shea, 1976; Kunz, 1982). Bachelor colonies of several species are found in these cooler roosts (Tuttle, 1988).

As discussed by McNab (1982), temperate Vespertillionids (*Nycticeius humeralis* could be classified as such) are more physiologically temperature labile than the tropical and subtropical Molossids. For instance, *Nycticeius* may enter torpor during low temperatures in the fall and winter (Baker et al., 1968; Genoud, 1990). Molossids, on the other hand, become torpid for only short periods of time and there is no evidence that they enter torpor for longer periods or actually hibernate. Most in fact, prefer to migrate to warmer regions for the winter months. However, *T.b. cynocephala* is non migratory. Temperatures below freezing can be lethal for *Tadarida* (pers. obs.).

Molossids endure extreme high temperatures better than Vespertillionids and are often found in areas where temperatures exceed that of most Vespertillionid roost areas. Licht and Leitner (1967) recorded the behavior of *Tadarida* and two Vespertillionid species in a hot roost in California. They noted that, in general, *Tadarida* was most tolerant of high temperature and that both Vespertillionids moved to cooler roost areas at ambient (roost) temperatures of 40^0C. *Tadarida* would frequently remain in these areas until temperatures climbed to 41^0-42^0C. This behavioral adjustment to roost temperature has been recorded in other species as well (i.e., Dwyer and Harris, 1972). The thermoneutral zone for *Nycticèius* is 32^0-36^0C (Genoud, 1990); however, I could find no data pertaining specifically to thermoneutral zones for *Tadarida*, but several authors reported a similar temperature zone preference by this species (Licht and Leitner, 1967; Herreid, 1963, 1967).

Bat House History

The first known attempt to provide bats with an artificial roost was in 1909 when Dr. Charles Campbell erected a bat tower to attract bats for mosquito control in San Antonio, Texas. This house was not successful, but the next one he built two years later was occupied by *T. b. mexicana* and Dr. Campbell sold their guano as fertilizer (Campbell, 1925; Storer, 1926).

Bat house occupation in North America is presently around 52% (BCI, 1993). Research on bat houses in North America has met with varying success. Houses erected in Chautauqua, N.Y. (Neilson, 1991) were not occupied. A study in Pennsylvania (Williams-Whitmer, 1994) reported a 90% occupancy rate. Striking differences in the methods used in these experiments may explain the results. The houses in Chautauqua were not intentionally placed near any known colonies. Those in the Pennsylvania experiment were placed directly on the exterior wall of buildings occupied by bats. Bat houses on buildings where bats were later evicted were soon occupied. In contrast, bat houses on buildings where bats were allowed to stay remained empty.

Exclusion and Relocation

Bats that roost in human-occupied buildings are often considered a nuisance. Although they are not destructive, as are rodents, large numbers of bats can create an aesthetic problem when their guano accumulates on objects near the roost opening (i.e., cars, sidewalks, and the external walls of buildings), and a

significant odor can often develop (Herreid, 1960). A considerable level of misunderstanding still surrounds these animals in the general public and bat colonies in human dwellings can create unfounded fear in the minds of the human occupants.

In many states it is legal to use poisons, sticky traps, etc., to eradicate bats from buildings. In Florida, no poisons or fumigants are registered for use against bats (see Belwood, 1992). In areas where poisons are illegal, or conservation is desired, the inhabitants are often evicted via an exclusion method (Greenhall, 1982; Constantine, 1982; Corrigan, 1984). A local example of exclusion is the colony that was evicted from the Education building, at the University of Central Florida, in the winter of 1988.

Properly designed bat houses have potential as a management tool if a colony is slated for eviction. The goal of using bat houses for management is to provide a roost site where bats will not be a nuisance and will not be harassed or evicted. If bat houses are available prior to eviction of a nuisance colony, these houses provide the animals with a potential roost site when their main roost is no longer available.

Can bats be expected to occupy a bat house when their present roost is slated for eviction or destruction? Bat houses erected before bats are excluded seem to have a slightly higher occupancy rate than bat houses erected in areas where bats have not been recently excluded from a known roost site (BCI, 1987). The results of a relocation experiment performed in New York state (Frantz,

1989) were positive (three of five houses occupied), while similar experiments at the University of Florida (UF) and Auburn University (Kiser, 1996) were less successful. Bats moved into the UF house after it had been up for almost 4 years, but not due to the relocation attempt (Anonymous, 1995; Marks, 1996). In Chapter 2, I describe three types of relocation experiments I performed during this study and the exclusion that occurred at my main study site.

Objectives

During my study I wanted to determine the importance of temperature and substrate in bat house occupation. Although bat houses erected in areas where bats have been excluded are most successful, more often the bats simply move into another building similar to the original roost (Tuttle, 1988). The need exists to develop a bat house that will be attractive to bats and adopted as 'home'. A house that is small and simple enough for the average homeowner to build would also be desirable. Important factors to consider in the construction and placement of bat houses are: (1) location -- proximity to original roost, proximity to water, and height above ground; and (2) design -- roosting substrate, opening unobstructed, and temperature profile.

My study objectives were to: (1) determine the roost temperature tolerated by bats roosting in central Florida buildings; (2) build and erect bat houses at eight central Florida sites; (3) confirm the importance of a rough roosting substrate; (4) attempt relocation of a bat colony at Seminole Community College, and; (5)

determine the importance of temperature in bat house occupation and how the presence of bats modifies the bat house or roost temperature. The main objective of this project was to increase the likelihood of bat house occupation, which could have important implications for bat conservation and management.

Methods and Materials

Study Sites

Eight sites were originally chosen as bat house sites (Table 2, Figure 1, and Appendix A). By the end of the study I was monitoring thirteen sites. Some sites were chosen for study due to the proximity to active or recently excluded bat colonies, whereas others were selected due to the interest of the property owners. Tables 3 and 4, and Appendix A, give details of bat house placement at each site.

Three primary bat house designs were used in my study. These originated with Bat Conservation International (BCI) (see Tuttle and Hensley, 1993). The BCI beginners bat house (single chamber, 40.6 x 60.9 cm) is referred to here as the simple style house, and the BCI small (three chambers, 55.8 x 76.2 cm) and large (four chambers, 60.9 x 88.9 cm) nursery houses are referred to as small and large maternity style houses. At three sites an additional, larger house (ten chambers, 55.8 x 121.9 cm) was also placed (BCI, Texas Style house). Officials of Seminole Community College (SCC) chose to also erect two larger houses. One of these was a larger modification similar to BCI's Texas Style

house (20 chambers, 76.2 x 101.6 cm), the other was a square design (40 chambers, 60.9 x 76.2 cm) that resulted in chambers facing four different directions (Figure 2).

Five sites had the series of three BCI designs. All of these bat houses were mounted in pairs, back to back on poles (donated by Florida Power Corporation) so they were facing southeast and northwest. Seven other sites had varying styles and placements of houses. Bat houses were mounted on poles, 4" x 4" (10.2 x 10.2 cm) timbers, tree trunks (palms and pines) and buildings. All houses were mounted 15-20 feet (3.96-5.28 m) above ground and all bat houses had the surface of the roosting chambers roughened through the addition of hardware cloth, fiberglass window screen, polypropylene netting, or by manually scraping the boards.

Temperature Monitoring

Copper-constantin thermocouple wire (Omega, PP-T-24) was used in combination with a Campbell CR10 datalogger configured with an AM416 multiplexer (Campbell Scientific, Inc.) to monitor temperature profiles of the bat houses. Thermocouples were also placed inside occupied roosts at four sites. At each site an additional thermocouple was placed at a height comparable to the bat houses or roosts to monitor ambient temperature. The ambient thermocouple was mounted in a white, three sided box, and was shaded with fiberglass screen in an attempt to prevent ambient temperature readings being

affected by direct solar radiation on the thermocouple tip. A Li-Cor, LI-200SA Pyranometer was used in conjunction with the datalogger to monitor solar radiation ($kW/m^2/mV$). Due to vandalism and equipment failure solar radiation was not collected at all sites on all dates.

Bat houses were treated with insulation, white and dark paint, and insulative paint (Astec Ceramic Coating) in an effort to determine which treatment would most closely approximate the temperatures of the occupied roosts and allow for temperature gradients within each house. Some modification of the bat houses continued throughout the project.

Once the bat houses were in place, they were monitored closely for bat activity and occupation. Temperatures were monitored in both occupied and unoccupied bat houses and preferred roosting area(s) within the occupied houses were noted. When comparisons between the houses resulted is significant temperature differences, modifications to unoccupied houses were made in an attempt to improve the temperature profile.

Temperature Analysis

All temperature data were reduced using Lotus 123 (version 5) spreadsheets. Data were then analyzed with Statgraphics Plus (Manugistics, Inc., 1995). Temperature profiles among bat house styles and bat house sites were examined. Attempts were made to compare temperatures between occupied roosts and bat houses. Due to the non-normality of the data, non-parametric

p-values (Kruskal-Wallis, test of medians) are reported. Several attempts were made using Taylor's Power Law (Fry, 1993) to transform the temperature data, but none were successful at normalization. Multiple regression analysis was performed in an attempt to learn the importance of ambient temperature, solar radiation, and time in determining the variability of mean temperatures recorded in the bat houses and roost sites. The inability to collect data simultaneously at two different sites made direct comparisons problematic and results should be viewed with these difficulties in mind.

Summary

Loss of suitable roosts is one of the biggest threats facing bat populations worldwide. The final outcome of this study should be the confirmation of a bat house design that has the optimal temperature profile for a successful bat colony in central Florida. Implications of a successful bat house design are multiple. The primary outcome being a practical management tool to provide alternate roost sites when needed.

Literature Cited

ANONYMOUS, 1995. Same bat channel? Online, 10(7):2.

BAIN, J. R. 1981. Roosting ecology of three Florida bats: *Nycticeius humeralis, Myotis austroriparius* and *Tadarida brasiliensis*. M.S. thesis, University of Florida, Gainesville, Florida, 130pp.

BAKER, W. W., S. G. MARSHALL, AND V. B. BAKER. 1968. Autumn fat deposition in the Evening bat (*Nycticeius humeralis*). Journal of Mammalogy, 49:314-317.

BARBOUR, R. W., AND W. H. DAVIS. 1969. Bats of America. University Press of Kentucky, Lexington, 286 pp.

[BCI] BAT CONSERVATION INTERNATIONAL. 1987. About your bat house. Bat Conservation International, Austin, Texas, 4pp.

[BCI] BAT CONSERVATION INTERNATIONAL. 1993. The bat house study. Bats, 11(1):4-11.

BELWOOD, J. J. 1992. Brazilian free-tailed bat, *Tadarida brasiliensis cynocephala*. Pp. 357-368 *in* Rare and Endangered Biota of Florida (S.R. Humphrey, ed.). University Press of Florida, Gainesville, Florida, 1:1-392.

BROWN, L. N. 1985. First record of the Little brown bat, *Myotis lucifugus*, in Florida. Florida Scientist, 48(4):200-201.

BROWN, L. N. 1986. First record of the Silver-haired bat, *Lasionycteris noctivagans*, in Florida. Florida Scientist, 49(3):167-168.

BROWN, L. N. 1987. A checklist of Florida's mammals. Florida Game and Freshwater Fish Commission, Nongame Wildlife Program, Tallahassee, Florida, 8 pp.

CAMPBELL, C. 1925. Bats, mosquitoes and dollars. The Stratford Co. Boston, Massachusetts, 262 pp.

CLARK, M. K. 1995. Survey for Rafinesque's big-eared bat (*Plecotus rafinesquii*) in Florida. Final Report. Florida Game and Fresh Water Fish Commission, Nongame Wildlife Program. 8 December, 1995. 14pp.

CONSTANTINE, D. G. 1982. Batproofing buildings by installation of valve-like devises in entryways. Journal of Wildlife Management, 46(2):507-512.

COPE, J. B. 1959. Build bats out. Pest Control, 27:28-29.

CORRIGAN, R. M. 1984. Nuisance bats: current technology in their management and control. Pp 174-179 *in* Proceedings Eleventh Vertebrate Pest Conference (D. O. Clark, ed.). University of California, Davis, California.

DAVIS, W.H. 1959. Taxonomy of the Eastern Pipistrel. Journal of Mammalogy, 40:521-531.

DWYER, P. D., AND J. A. HARRIS. 1972. Behavioral acclimatization to temperature by pregnant *Miniopterus* (Chiroptera). Physiological Zoology, 45:14-21.

[FCREPA] FLORIDA COMMITTEE ON RARE AND ENDANGERED PLANTS AND Animals, 1992. Rare and endangered biota of Florida, Volume 1. Mammals. Humphrey, S.R., editor. University Press of Florida, Gainesville, Florida, 392 pp.

FENTON, M. B. 1985. Communication in the chiroptera. Indiana University Press, Bloomington, Indiana, 161 pp.

FINN, L. S. 1996. Roosting and foraging ecology of a Southeastern big-eared bat, *Corynorhinus rafinesquii macrotis*, maternity colony in central Florida. Final Report. Florida Chapter of The Nature Conservancy. 1 January, 1996. 18pp.

FRANTZ, S. C. 1989. Bat houses in state parks: An experiment in New York. Bats, 7(2):14.

FRY, J. C. 1993. One-way analysis of variance. pp 1-40 *in* Biological data analysis (J.C. Fry, ed.). Oxford University Press Inc., New York, 418 pp.

GENOUD, M. 1990. Seasonal variations in the basal rate of metabolism of subtropical insectivorous bats (*Nycticeius humeralis* and *Lasiurus seminolis*): A comparison with other mammals. Revue Suisse Zoologic, 97(1):77-90.

GORE, J. A., AND J. A. HOVIS. 1992. The Southeastern brown bat, another cave roosting species in peril. Bats, 10(2):10-12.

GREENHALL, A. M. 1982. House bat management. Unites States Fish and Wildlife Service, Resource publication 143, Washington, D.C., 33 pp.

HARVEY, M. J. 1992. Bats of the Eastern United States. Arkansas Game and Fish Commission, 46 pp.

HERMANSON, J. W., AND K. T. WILKINS. 1986. Pre-weaning mortality in a Florida maternity roost of *Myotis austroriparius* and *Tadarida brasiliensis*. Journal of Mammalogy, 67:751-754.

HERREID, C. F., II. 1960. Comments on the odors of bats. Journal of Mammalogy, 41:396.

HERREID, C. F., II. 1963. Temperature regulation in Mexican free-tailed bats in cave habitats. Journal of Mammalogy, 44:560-573.

HERREID, C. F. II. 1967. Temperature regulation, temperature preference and tolerance, and metabolism of young and adult free-tailed bats. Physiological Zoology, 40(1):1-23.

HUTSON, A. M. 1987. Bats in houses. The Bat Conservation Trust, London, 32 pp.

JENNINGS, W. L. 1958. The ecological distribution of bats in Florida. Ph.D. dissert., University of Florida, Gainesville, Florida, 125pp.

KISER, W. M. 1996. Conservation of Le Conte's free-tailed bats (*Tadarida brasiliensis cynocephala*): Environmental parameters of a natural and an artificial roost. M.S. thesis, Auburn University, Auburn, Alabama, 245 pp.

KUNZ, T. H., 1982. Roosting Ecology. Pp 1-55 *in* Ecology of Bats (T. H. Kunz ed.). Plenum Publishing Co., New York, 425 pp.

KUNZ, T. H., 1995. Postnatal growth and development in the Mexican free-tailed bat (*Tadarida brasiliensis mexicana*). Birth size, growth rate and age estimation. Journal of Mammalogy, 76:769-783.

KUNZ, T. H., WHITAKER, J. O., AND M. D. WADANOLI. 1995. Dietary energetics of the insectivorous Mexican free-tailed bat (*Tadarida brasiliensis*) during pregnancy and lactation. Oecologia, 101:407-415.

LICHT, P., AND P. LEITNER. 1967. Behavioral responses to high temperatures in three species of California bats. Journal of Mammalogy, 48:51-61.

MANUGUSTICS, INC. 1995. Statgraphics plus version 2. Rockville, Maryland.

MARKS,G. 1996. The University of Florida bat house. The Night Flyer, 1(3):2-4.

MCNAB, B. K. 1982. Evolutionary alternatives in the physiological ecology of bats. Pp 151-200 *in* Ecology of Bats (T. H. Kunz ed.). Plenum Publishing Co., New York, 425 pp.

NEILSON, A. L., 1991. Population ecology of the Little-brown bat, *Myotis lucifugus*, at the Chautauqua Institution, Chautauqua, New York. M.S. thesis, York University, York, Ontario, 57 pp.

STEBBINS R. E., AND S. T. WALSH. 1991. Bat boxes. The Bat Conservation Trust, London, 24pp.

STORER, T. I. 1926. Bats, bat towers and mosquitoes. Journal of Mammalogy, 7:85-91.

TUTTLE, M. D. 1988. Americas neighborhood bats. University of Texas Press, Austin, Texas, 95pp.

TUTTLE M. D., AND D. L. HENSLEY, 1993. The bat house builders handbook. University of Texas Press, Austin, Texas, 34pp.

TUTTLE, M. D., AND D. STEVENSON. 1982. Growth and survival of bats. Pp 105-150, *in* Ecology of Bats (T. H. Kunz ed.). Plenum Publishing Co., New York, 425pp.

VAUGHAN, T. A.., AND T. J. O'SHEA. 1976. Roosting ecology of the Pallid bat, *Antrozous pallidus*. Journal of Mammalogy, 57:19-22.

WHITAKER, J. O., AND P. CLEM. 1991. Food of the Evening bat, *Nycticeius humeralis*, from Indiana. American Midland Naturalist, 127:211-214.

WILKINS, K. T. 1989. *Tadarida brasiliensis*. Mammalian Species, 331:1-10.

WILLIAMS-WHITMER, L. M. 1994. Maternity roost selection and the use of bat boxes by displaced colonies of Big brown and Little brown bats. M.S. thesis. Pennsylvania State University, State College, Pennsylvania, 147 pp.

ZELENY, L. 1976. The Bluebird: How you can help its fight for survival. Indiana University Press, Bloomington, 170 pp.

ZINN, T. L. 1977. Community ecology of Florida bats with emphasis on *Myotis austroriparius*. M.S. thesis, University of Florida, Gainesville, Florida, 88 pp.

CHAPTER 2
EXCLUSION AND RELOCATION

Bats that roost in human-occupied buildings are often considered a nuisance. Although they are not destructive, as are rodents, large numbers of bats can create an aesthetic problem when their guano accumulates on objects near the roost opening (e.g., cars, sidewalks, and the external walls of buildings) and a significant odor can often develop (Herreid, 1960). A considerable level of misunderstanding still surrounds these animals, in the general public, and bat colonies in human dwellings can create unfounded fear in the minds of the human occupants. In many states, it is legal to use poisons, sticky traps, etc., to eradicate bats from buildings. In Florida, no poisons or fumigants are registered for use against bats (see Belwood, 1992). In areas where poisons are illegal, or conservation is desired, the inhabitants are often evicted via exclusion (Greenhall, 1982; Constantine, 1982; Corrigan, 1984). A local example of exclusion was a colony evicted from the Education building at the University of Central Florida (UCF) in the winter of 1988.

Properly designed bat houses have potential as a management tool in situations that require exclusion. The goal of using bat houses for management is to provide a roost site where bats will not be a nuisance and where they will not be harassed or evicted. If bat houses are available prior to eviction of a

nuisance colony, these houses provide the animals with a potential roost site when their main roost is no longer available.

Can bats be expected to occupy a bat house when their present roost is slated for eviction or destruction? Bat houses erected before bats are excluded seem to have a slightly higher occupancy rate than bat houses erected in areas where bats have not been recently excluded from a known roost site (Bat Conservation International, 1987). In a bat house project conducted in Pennsylvania (Williams-Whitmer, 1994), bat houses placed on buildings where bats were excluded soon became occupied, while those on buildings where the bats were not excluded remained empty. The results of a relocation experiment performed in New York state (Frantz, 1989) were positive (three of five houses occupied), while similar experiments at the University of Florida (UF) and Auburn University (Kiser, 1996) were less successful. Bats moved into the UF house, but not due to any relocation attempt. They did not use this house until it had been up for almost 4 years (Anonymous, 1995; Marks, 1996).

In an attempt to populate local bat houses, I conducted relocation experiments over a period of two years (1994-1996). During my study three types of relocation experiments were attempted: (1) seeding, (2) relocation of bats, and (3) relocation of an occupied bat house.

Materials and Methods

All bats captured for use in my experiments were caught using fish nets (Cummings, landing net) and insect nets (Bioquip) with three foot handles. The design of the buildings the bats were using at Seminole Community College (SCC) made capturing animals as they attempted to re-enter the building relatively easy from either the breezeway or the flat roof. Capture of bats began 1-2 hours before sunrise as they were returning to the roost. This method insured the capture of bats with full stomachs to prevent hunger and water stress. However, bats used in the seeding experiments, which were also used in the controlled experiments (Chapter 3), were captured at night and maintained until the following morning. Placing bats in bat houses in the morning rather than at night provides a method to introduce bats to the bat house without confining them. It is my experience that bats will not leave bat houses during daylight hours.

Seeding

Seeding consisted of catching bats from a local colony and placing them into an unoccupied bat house. Close attention is not paid to locations of the bat colony source or target bat house. I hypothesized that even if the bats left, they would scent the house with their guano, and hopefully would return at a later date. Table 5 provides details on seeding experiments performed during my study.

Bats were collected from a source colony, in groups of 14-113 ($\overline{x}$=24.2), and were placed into bat houses at the target site. The target in all experiments was 8-40 km east or northeast of the source colony. Bats were placed in bat houses as soon after capture as possible, usually in the morning or early afternoon, and were not caged.

Relocation

Relocation consisted of a focused attempt to relocate a specific bat colony to a specific bat house or bat house site. Generally the colony to be relocated was a nuisance colony and was slated for eviction Relocation in my study consisted of two types: (1) relocating bats, and (2) relocating an occupied bat house.

Relocating Bats

I am aware of at least three earlier bat relocation experiments (Cope, 1959; Anonymous, 1995; Franz, 1989) in the United States. In these experiments bats were captured in the evening as they left the main roost and were transported to the bat houses. Some of the animals were caged up to 24 hours. The experiment I performed was very different in its protocol and extreme care was taken to stress the animals as little as possible.

A mixed colony of *Nycticeius humeralis humeralis* and *Tadarida brasiliensis cynocephala* was in residence in the Science/Library building at SCC, Sanford, Florida, for at least the past 10 years. The colony consisted of over 1000 bats.

Build-up of guano was significant in the attic, below the areas where the bats were roosting. Twenty-five 10 gallon bags of guano were removed from the Science building at a later date, evidence of the length of time the bats had occupied this building. Due to this build-up of guano, the distinctive odor of *Tadarida* permeated the buildings. Bats were causing aesthetic problems and on at least one occasion caused secondary student injury (upon seeing a bat, a college co-ed ran out of the women's rest room, and hit a wall knocking herself unconscious). Finding dead or grounded bats in and around the campus buildings was an almost weekly occurrence. A decision was made to exclude the bats from the buildings. In preparation for the exclusion eight bat houses were erected on SCC property (Chapter 1, and Appendix B), .4 km from the main roost. An attempt was made to relocate bats from the campus buildings into the bat houses, while the exclusion was being performed.

Entryways used by bats at SCC were small expansion areas between two concrete slabs (Figure 4). The bats entered through this space and traveled under the metal flashing attached around the perimeter of the building. Bats were never found roosting in the open attic spaces. They remained localized on the extreme edge of the building in the concrete expansion joints and under the metal flashing. The west and south sides of the building seemed to be preferred, but some activity also occurred on the east side. The north side was occupied on only one occasion. Due to the design of this building, it was impossible to make

observations concerning behavior in the roost (e.g., exact location, clustering, species composition).

The exclusion was begun in April 1995. All buildings that did not contain bats had all small openings sealed with .55 cm metal hardware cloth or polypropylene mesh (Tensar, heavy duty hardware net) secured with siliconized latex caulk (Red Devil, Lifetime) to prevent bats from later entering. After the potential alternate roosts were preventively sealed, exclusion on the main buildings began (4 May 1995). This late exclusion date was made necessary by the class schedule at the college. All efforts were made to monitor the reproductive condition of the colony to prevent the possibility of sealing nonvolant pups inside buildings.

For bat occupied buildings, the exclusion occurred systematically by first sealing inactive holes as described above. Then active holes were covered with excluders made of fiberglass window screen, and secured to the building on the top and sides with duct tape. As the exclusion progressed, bats were eventually localized to a few key areas that were logistically difficult to exclude and were left open until late summer.

While the exclusion was taking place, I captured bats in the early morning as they attempted to return to the building. Captured bats were placed into clean, empty, 5 gallon buckets lined on the lower half with fiberglass screen or cotton rags. This lining allowed bats to hang in a normal fashion. Cloth rags were placed on the bottom of the bucket to absorb urine and guano, in an attempt to

keep the animals as clean as possible. A 53 cm piece of cotton sleeving (Bioquip, stockinette sleeve) was attached with duct tape to the mouth of the bucket. This material enabled easy closure of the bucket (without increasing humidity), with a clip or knot.

Once bats no longer attempted to return to the building (usually 20-30 minutes after sunrise), captives were transported to the bat house site, .4 km away (see Appendix B). Bats were identified to species, reproductive condition was determined, and interesting markings or injuries were noted. To minimize stress to the animals, additional detail (weight, wing measurements, etc.) was not collected. Bats were not banded at this time, but I did make note of several bats of both species that had been banded on an earlier date and released at another bat house site during the seeding experiments.

After processing, bats were injected into bat houses in groups of not less than five bats per house. Over a period of eight days an average of 58.23 bats per day (range 13-127) were injected into all bat houses on this site (Table 6). No attempt was made to confine the bats to the bat houses once night-fall came. The relocation and exclusion were discontinued when a lactating *Nycticeius* was captured on 12 May 1995.

Bats were captured from the last remaining areas of the building on several dates in July to determine reproductive status. On 22 July, volant *Tadarida* pups were captured. At the request of the college administrators the relocation and exclusion was continued on this date (I probably should have waited until

mid- to late-August to be positive of volancy and weaning of all pups). Bats were again captured while returning to the roost in the early morning and injected into the bat houses on two dates in late July. The exclusion of the main roost was then finalized and bats could no longer enter the campus buildings.

Relocating an Occupied Bat House

In August of 1993, I became aware of an old, two-story brick building located in downtown Sanford (roughly 3.13 km north of SCC), which was the site of a moderate-sized colony (200-500) of *Tadarida* and *Nycticeius*. The bats inhabited the first story awning that was badly deteriorated and weathered (see Appendix A: Aikins, for more detail). In June 1994, a BCI large maternity bat house (natural stain, no insulation) was mounted on the east side of the building, 1.3 meters above the main colony entrance. At this time I began to monitoring the thermal profile of both the roost and bat house. Bats did not occupy the bat house until late winter 1995/6.

In December 1994, the building was sold to a local realty company and in June 1995, the lower half of the building was leased to a local minister and became 'Lion of Judah House of Worship.' The new tenant was not open-minded about the bats and wanted them exterminated.

Florida Game and Fresh Water Fish Commission (FGFC) guidelines (FGFC, 1995) on eviction of bats from buildings recommend exclusions not be performed during maternity season (1 May - 1 September, in Florida). The new tenant was

made aware of these guidelines, but was not respectful of them. On 11 June the awning that housed the main colony was torn down under his direction. The adult bats (primarily *Nycticeius*) flew into the nearby bat house, that was already populated by a colony consisting primarily of *Tadarida*. However, the pre-volant juveniles fell to the sidewalk in front of the building. After receiving a phone call from the building owner, I arrived to find fifty to 75 *Nycticeius* pups and four adults with young had been swept against the wall, and behind a sheet of plywood, with a push broom. I collected the animals and placed them into a holding bucket. They were injected into the populated bat house in hopes they would be reunited with their mothers. The tenant continued to be uncooperative and now wanted the bat house removed from the property.

The occupied bat house was removed from the building the morning of 15 June 1996. Polypropylene mesh was attached to the bottom of the house to prevent bats from exiting during the move. A site 8 km northeast was chosen as the new location and the house was mounted on the east side of a one-story residence.

Results and Discussion

Relocation experiments must be designed with the homing instincts of bats as a consideration (Cope, 1959). Both *Tadarida* and *Nycticeius* home well (Davis, 1966; Cope and Humphrey, 1967) and I observed behavior during and after the SCC exclusion that suggested strong site fidelity by these animals.

Seeding

At least one local nuisance wildlife control operator advocates seeding bat houses to his clients. I am aware of several occasions when this was attempted unsuccessfully. In order to test the hypothesis that seeding bat houses is useful, I performed thirteen seeding experiments. In an attempt to optimize the possibility of bats returning to the bat houses I did not confine them. I believe that stressing bats by caging them in an unfamiliar location will result in the animals leaving the area immediately upon release in a defensive-escape response. However, most of the bats used in the seeding experiments were used in the controlled experiments of bat house preferences (see Chapter 3). Those animals were captured in the evening and used in the controlled experiments that night, before being placed in the bat houses in the morning. They surely underwent some stress due to the length of time they were held, and to handling for banding and measuring purposes.

When the bats left the bat houses in the evening, it was usually early enough for me to make visual observations. Invariably the bats behaved the same way. They would exit the house, then fly around the property and circle the bat houses three or four times. After a minute or two of 'orienting' they generally flew in the direction of 'home'. In none of the 13 seeding experiments I conducted did bats return to the target bat house after the evening exodus. Bats used in the flight cage experiments (Chapter 3), which were also used in the seeding experiments,

were banded, and many were later recaptured back at the source colony 10.3 km to the southeast.

Seeding bat houses does nothing more than stress the animals involved and likely increases the risk of mortality due to predation or exposure in unfamiliar territory. Due to the homing ability of bats these animals probably attempted to return to their 'home' roost or to an alternate roost in the familiar area (Leffler et al., 1979). I can not recommend seeding as a means to populate a bat house under any circumstances, and I would be skeptical of anyone who made a claim that this practice would result in successful occupation

Relocation

Relocating Bats

Bats were captured during their return to the roost in the morning and injected into the bat houses; however, these bats were free to leave. It was expected they would attempt to return to the original roost (Davis, 1966; Cope, 1959; Cope and Humphrey, 1967) after leaving the bat houses in the evening. Upon return to the excluded roost, the bats would either go to alternate roosts in the area (Leffler et al., 1979; Clem, 1993) or accept the bat houses as a new roost site.

After the bats in the SCC buildings were excluded, they were tenacious in their attempt to re-enter the roost in the morning and many continued until after sunrise indicating strong site fidelity. Bats were seen roosting in exposed areas

immediately after the exclusion. At this time I witnessed the taking of bats by fish crows (*Corvis ossifragus*) on several occasions.

Table 6 details the activities that took place during the relocation attempt. One week prior to this, a single *Tadarida* was noted in the NW small maternity house. This was the first time a bat had been seen in any of the eight houses on this site since their placement one year earlier. A single *Nycticeius* was noted in the same bat house on the second and third morning of the relocation. The morning prior to this two pregnant *Nycticeius* were placed into a nearby bat house. It is not known if this was one of those bats or if it was the same animal both mornings.

Bats first began to return to the bat houses on the fourth morning of injecting bats into bat houses at the SCC site. The northwest (NW) small maternity house had an even mix of *Nycticeius* and *Tadarida* consisting of a minimum of 20 animals. The relocation continued for another four mornings and bats were injected into bat houses. At the end of the eighth morning the NW small maternity house contained 75 -100 bats of both species. These bats had returned to the bat house on their own. Although a single bat was noted in the SE small maternity house and in each of the large maternity houses on the fifth morning, these were slow to gain occupancy. Within two weeks, bats using the NW small maternity house were too numerous to count. Four days later, bats were found in the SE small maternity, most were in the middle chamber.

Three weeks after the relocation attempt and successful occupation of the bat houses, I began to notice the fiberglass window screen, which was used as a liner in the roosting chambers, was beginning to deteriorate and was hanging out of the bat houses. At this time I also noted that *Nycticeius* pups were present in the SE small maternity house. Both small maternity houses were occupied.

By 1 July, nearly two months later, very few bats were in any houses, and by 9 July all bat houses were again empty. *Tadarida* pups would not have been volant by this date and it was never confirmed that *Tadarida* used the bat houses as a maternity site during this occupation. *Nycticeius* pups, however, would have been volant by this date and probably flew away with the adults. The failed fiberglass screen was theorized to be the main cause of the abandonment. It was removed as well as possible from all bat houses.

A maternity group of *Tadarida* remained in the two roost areas left open on the SCC campus. After the pups were confirmed to be volant, the relocation was resumed. On two dates in late July, bats were captured at the building as they returned in the morning and the exclusion was completed. Bats were injected into all of the maternity houses. They again began to return to the small maternity houses.

In December 1995, bats began to occupy the large maternity houses. In November, some modifications were made to them. Polypropylene mesh was added to the landing pad in an attempt to make it easier for the bats to enter the houses, and the Reflectix insulation was removed. The small maternity houses,

which the bats seem to prefer, still had insulation and did not have a landing pad.

At the time of this writing (April 1997) bats are still present in the SCC bat houses. Bats are now utilizing all four of the maternity style houses. The simple style houses remain empty and although small numbers of bats have been seen in the two larger houses on several occasions, they remain largely unoccupied.

Exclusion of a bat colony can lead to an increased mortality rate. Lack of suitable alternate roosts can result in increased predation. Although excluded bats probably move into alternate roosts in the area on most occasions (if they are available), provision of bat houses prior to an exclusion can be successful and beneficial to the bats. If the persons or company performing the exclusion have the time necessary for a thorough relocation effort, it should be attempted. As illustrated in this relocation experiment, it can be a success if the following factors are taken into consideration: (1) the bat houses used should be a style that is known to be acceptable by the target species; (2) the bat houses should be located as close to the original roost as possible; (3) repeat the relocation attempt at least five mornings; (4) if possible begin the relocation prior to the exclusion in order to introduce the bats to the potential alternate roost site; and (5) limit stress to the animals as much as possible.

Bats often have alternate roost sites in the area, and are loyal to these sites. If adequate alternate roosts are available, the bats will generally opt to utilize these familiar areas rather than unfamiliar bat houses (see Appendix A: Sea World, for details of another, not as successful, relocation experiment). A

successful relocation will not only utilize proper eviction and exclusion techniques on the building used by the bat colony, but will also attempt to preventively seal and exclude potential alternate roosts in the immediate area.

Relocating an Occupied Bat House

I witnessed *Tadarida* and *Nycticeius* roosting side by side like 'spoons in a drawer,' in the awning roost at this site (Aikins) on earlier dates. They had apparently segregated during pupping season. Although there was still some mixing, the majority of the bats in the awning were *Nycticeius* while most of those in the bat house were *Tadarida*. *Nycticeius* adults utilized the bat house after their awning roost was destroyed and I placed their nonvolant pups into the house. Within two days, most of the *Nycticeius* abandoned the bat house, presumably carrying their pups with them (see Davis, 1970).

The occupied bat house was moved the evening of 15 June and mounted at the new site. I counted a minimum of 126 bats leaving the bat house. My inspection revealed many bats, primarily *Tadarida*, (>50) remained inside. The following evening only 13 bats were seen to exit, while a large number remained. The bats remaining in the bat house were *Tadarida* pups, pinkish in coloration and with no fur. On 20 June, the pups began to hang close to the bottom of the bat house and on 21 June, six days after the move, I recovered the first starved pup. At that time I attempted to remove the *Tadarida* pups from the bat house

in an effort to hand-raise them. A total of 39 starving and emaciated *Tadarida* pups were eventually removed from the bat house.

During the time the *Tadarida* pups were starving, a small population of adult *Nycticeius* remained within the bat house and with the *Tadarida* pups. These bats had not vacated the bat house after the move. I witnessed *Tadarida* pups crawling on *Nycticeius* adults and attempting to nurse. On several occasions *Tadarida* pups were 'nursing' on the faces and shoulders of *Nycticeius* adults. I never observed a *Nycticeius* adult allowing a *Tadarida* pup to nurse. They, however, did not react adversely to the presence or activity of the pups; the *Tadarida* pups were simply ignored.

Conditions were suitable in the relocated bat house for *Nycticeius* and these bats remained on site, often moving between other bat houses on the property for 2 months after the bat house relocation. Literature accounts of *Nycticeius* abandoning a roost that was disturbed (i.e., Watkins, 1970) led me to believe it would not be appropriate to determine age or sex of these *Nycticeius* adults (all animals were volant, but it is possible some of the animals were juvenile). After the *Nycticeius* colony disappeared on 19 August 1996, I was glad I had not disturbed them and would have blamed the exit on my intrusion. That these bats left in mid-August was not surprising. I am aware of at least two other central Florida *Nycticeius* colonies that showed this behavior (See Appendix A: Paisley, and Stevens). Although this species is present year-round in central Florida, some aspect of its summer roost requirements changes and the animals often

leave maternity roosts for other fall and winter quarters. Bain and Humphrey (1986) reported *Nycticeius* to be predictably absent from a north Florida roost only in mid-April. They hypothesized that perhaps the bats were using a tree hollow or other similarly enclosed roost site that would be more thermally stable to endure the late winter months.

Although this small group of *Nycticeius* remained with the bat house after it was moved, the *Tadarida* adults were highly stressed, and left soon after, resulting in high mortality of the pups. It is not known why the *Tadarida* adults did not attempt to move their pups to a new site. I hypothesized that the presence of young in the bat house relocation would play a factor in the bats activity and that either (1) all the bats would leave with their pups, or (2) that the bats would return to this bat house to care for their flightless pups. I did not anticipate that adults would leave nonvolant pups to starve.

Four days after the bat house was mounted at the new site, another set of bat houses was added that may have been more acceptable to *Tadarida*. I suspect the relocated bat house was placed in an area that was suboptimal for this species. The bottom of the bat house was only 2.6 m above ground and a small aluminum shed was within 1.05 m of it. When bats were exiting the first night, I witnessed several bats (presumably *Tadarida*) hit the tool shed and saw one fall to the ground. Given the lack of maneuverability (in cluttered spaces) in the Molossid family (Norberg and Rayner, 1987), I believe these bats may have

remained if the bat house had been mounted higher and in a more open area or if other houses of that fashion were already in place as alternate roost sites.

The relocation of an occupied bat house should be performed only as a last resort and never during maternity season. In areas where bats are absent during the colder months of the year, moving a bat house to a new site can be done while the bats are absent. However, in Florida these conditions may not occur. Careful planning should accompany any bat house relocation and should include the following: (1) the bat house should remain as close as possible to the original site; (2) bat houses should not be moved during maternity season; (3) if a maternity season move is unavoidable, care should be taken to monitor the bat house for the potential of abandoned pups; if present, pups should be immediately removed and turned over to a qualified wildlife rehabilitator; and (4) the bat house should be placed in an optimal site (greater than 3.96 m above ground, with the opening and surrounding area unobstructed).

It is unfortunate that FGFC recommendations not to disturb bat colonies during maternity season are only recommendations and can not be enforced. Although Florida bats are protected by a loophole because no poisons or fumigants are registered for use against bats in the state, little is done to protect bats from exclusion during maternity season. Although exclusion is legal, it leads to increased mortality, and if alternate roosts are not available where bats will not be harassed or excluded in the future, they will continue to undergo decreases in population numbers. If, however, bat houses are available and

used by bats, and the land owner later decides the bat house is no longer wanted, the problem has not been solved. Any homeowner accepting the placement of a bat house on his/her property should be certain the animals will be allowed to remain should they colonize the bat house.

Literature Cited

ANONYMOUS, 1995. Same bat channel? Online, 10(7).

BAIN, J. R., AND S. R. HUMPHREY. 1986. Social organization and biased primary sex ratio of the Evening bat , *Nycticeius humeralis*. Florida Scientist, 49(1):22-31.

[BCI] BAT CONSERVATION INTERNATIONAL. 1987. About Your Bat House, Bat Conservation International, Austin, Texas, 4 pp.

BELWOOD, J. J. 1992. Brazilian free-tailed bat, *Tadarida brasiliensis cynocephala*. Pp. 357-368 *in* Rare and Endangered Biota of Florida, (S.R. Humphrey ed.). University Press of Florida, Gainesville, Florida, 1:1-392.

CLEM, P. D., 1993. Foraging patterns and the use of temporary roosts in female Evening bats, *Nycticeius humeralis*, at an Indiana maternity colony. Proceedings of the Indiana Academy of Sciences, 102:201-206.

CONSTANTINE, D. G. 1982. Batproofing buildings by installation of valvelike devises in entryways. Journal of Wildlife Management, 46(2):507-512.

COPE, J. B. 1959. Build bats out. Pest Control, 27:28-29.

COPE, J. B., AND S. R. HUMPHREY. 1967. Homing experiments with the Evening bat, *Nycticeius humeralis*. Journal of Mammalogy, 48(1):136.

CORRIGAN, R. M. 1984. Nuisance bats: Current technology in their management and control. *in* Proceedings Eleventh Vertebrate Pest Conference, (D.O. Clark ed.). University California, Davis.

DAVIS, R. 1966. Homing performance and homing ability in bats. Ecological Monographs, 36:201-237.

DAVIS, R. 1970. Carrying of young by flying female North American bats. American Midland Naturalist, 83:186-196.

[FGFC] FLORIDA GAME AND FRESH WATER FISH COMMISSION, 1995. Florida wildlife resources handbook. University of Florida, Institute of Food and Agricultural Sciences, Gainesville, Florida.

FRANTZ, S. C. 1989. Bat houses in state parks: An experiment in New York. Bats, 7(2):14.

Greenhall, A. M. 1982. House bat management. United States Fish and Wildlife Service, Resource publication 143, Washington, D.C., 33 pp.

Herreid, C. F., II. 1960. Comments on the odors of bats. Journal of Mammalogy, 41:396.

Kiser, W.M. 1996. Conservation of LeConte's Free-tailed bats (*Tadarida brasiliensis*): Environmental parameters of a natural and an artificial roost. M.S. thesis, Auburn University, Auburn, Alabama, 245 pp.

Leffler, J. W., L. T. Leffler, and J. S. Hall. 1979. Effects of familiar area on the homing ability of the Little brown bat, *Myotis lucifugus*. Journal of Mammalogy, 60(1):201-204.

Marks, G. 1996. The University of Florida bat house. The Night Flyer, 1(3):2-4.

Norberg, U. M., and J. M. V. Rayner. 1987. Ecological morphology and flight in bats (Mammalia: Chiroptera): Wing adaptations, flight performance, foraging strategy and echolocation. Philosophical Transactions of the Royal Society of London, B 316:335-427.

Watkins, L. C. 1970. Observations on the distribution and natural history of the Evening bat (*Nycticeius humeralis*) in Northwestern Missouri and adjacent Iowa. Transactions of the Kansas Academy of Science, 72(3):330-336.

Williams-Whitmer, L. M. 1994. Maternity roost selection and the use of bat boxes by displaced colonies of Big brown and Little brown bats. M.S. thesis, Pennsylvania State University, State College, Pennsylvania, 147 pp.

CHAPTER 3

TEMPERATURE and SUBSTRATE

Data published by Bat Conservation International (BCI, 1993), reports bat house occupancy at 52%. Bat houses that become occupied have several features in common. Temperature and substrate are two of the most important ones. The importance of roost temperature and the thermoregulation of bats in roost choice has been reviewed by several authors (i.e., Kunz, 1982; McNab, 1982; Hill and Smith, 1984). Most bat house research has taken place in northern regions where the concern is in keeping bat houses warm enough to be acceptable maternity sites in the summer. During the winter months, bats in these regions generally hibernate in locations other than bat houses (caves, trees, and attics). In the South, where bats are active year-round, a dual problem occurs: roosts should remain warm, but not get too hot in summer months, or too cold in winter months.

Central Florida has a humid, subtropical climate (Chen and Gerber, 1990). The focus of my study was to determine the physical characteristics of successful (occupied) bat houses in this warm southern region. Data available at the start of my study suggested parameters such as height above ground, distance to nearest water source, etc., would influence use of bat houses (Tuttle and Hensley, 1993). However, no data existed to show how the temperatures in

southern bat houses can influence occupancy rate or how different species respond to temperatures in these houses.

My objectives were: (1) to determine the roost temperature in four central Florida buildings occupied by bats, (2) to verify the importance of a rough roosting substrate and attempt to determine the preferred substrate for *Tadarida brasiliensis cynocephala* and *Nycticeius humeralis humeralis*, (3) to build and erect bat houses at eight central Florida sites, and (4) to determine the importance of roost temperature in bat house occupation in central Florida. My main objective was to increase the likelihood of bat house occupation in the central Florida area, which could have important management implications through the creation of alternate roosts.

Materials and Methods

Flight Cage Experiments

To examine the importance of various substrates in roost choice by bats, a series of controlled experiments was performed in a flight cage. Figure 5 illustrates the flight cage and the position of roost choices within the cage. Bats used in the experiments were captured with hand nets as they were exiting a local colony to forage. Both *Tadarida* and *Nycticeius* were tested in groups of 14-16 (mean=14.9). Bats were transported to the test site in clean, empty, 5 gallon buckets (see Chapter 2 for more detail on capture and holding methods).

Upon arrival at the test site, bats were identified to species, measured, sexed, and banded with size XCL plastic split-ring bat bands (Avinet, Dryden, NY). Bats were then released into the flight cage and left for the night. The following morning the flight cage was checked and the roosting location of each bat was noted. The bats were given a set of eight roost choices for each test. Bat house roost choices were similar to BCI's single chamber design. The front of these houses was hinged to ease the removal of bats after tests were completed. Additional roost choices were also supplied and are described below.

The first experiment was designed to determine if bats preferred different roost substrates (e.g., plywood, pine bark, and brick). Four plywood houses were offered, two were lined with metal hardware cloth or fiberglass screen, the other two unlined. Two large pieces of pine bark were secured together with cotton string to form a cavity, and a set of three, three-hole-cored bricks were used to form a brick structure where the holes provided potential roost areas.

Two additional choices provided during this test were to determine the importance of scent in bat house occupation. A cotton rag that had been in a cage with a small captive colony of *Nycticeius* was used as a roost choice item. This rag was scented with urine and guano. A nylon stocking filled with guano collected from the Seminole Community College (SCC) attic was also provided. This test was replicated 6 times.

The second experiment was designed to determine if bats preferred bat houses with or without landing pads. Eight plywood houses were provided.

Four had landing pads, four did not. Here again the bat houses were both lined and unlined. In this second series of tests, modifications were made to the flight enclosure to prevent bats from roosting in other areas of the enclosure and force them to choose among the roost choices provided. This was done by lining the ceiling and top half of the flight cage with a clear plastic drop cloth. This test was replicated four times.

Bat Houses

Three basic bat house designs were used in my study (see Tuttle and Hensley, 1993; and Chapter 1 for more detail). These were Bat Conservation International (BCI) designs. Some modifications of the houses continued throughout the project.

At three sites an additional larger house was also placed (BCI, Texas Style house). Officials at SCC, chose to also erect two larger style houses. One was simply a larger modification of the BCI Texas style house, the other was a large square house with four quadrants that enabled partitions to face four directions (see Figure 2). At all sites the bat houses were mounted 15-20 feet (5.5-7.3 meters) above ground. All original bat houses faced either southeast and northwest or east and west. Some bat houses were later placed at two sites oriented north and south. Bat houses were either mounted in pairs, back to back, on poles (donated by Florida Power Corporation), 4"x4" (10.2 x 10.2 cm) timbers, tree trunks (palms and pines); or mounted singly on buildings. All bat

houses had the surface of the roosting chambers roughened in some way (through the addition of hardware cloth, fiberglass window screen, polypropylene netting, or roughened manually by scraping the boards in the roosting chambers).

Temperature

Copper-constantin thermocouple wire (Omega, PP-T-24) was used in combination with a Campbell CR10 datalogger and AM416 Multiplexer (Campbell Scientific, Inc.) to monitor temperature profiles in bat houses and in roost sites. Temperature readings were collected every ten minutes and averaged over each hour. The tip of each thermocouple was shielded by a fiberglass window screen cage, which prevented direct contact with bats.

Roost Temperature

Thermocouples were placed into roosting crevices in four central Florida buildings occupied by both target bat species (see Appendix A for detailed descriptions of each site). Due to logistical constraints it was possible to simultaneously collect roost temperature and bat house temperature at only one of these sites. Two other roost sites were also sites where bat house temperature was monitored, but it was not possible to collect data concurrently at these locations. At the fourth site, unoccupied bat houses were present, but were not included in the temperature study.

At the Aikins and Rollins roosts, building design and other logistical constraints worked together to limit thermocouple placement to areas that were occupied by bats on most occasions. However, it was possible to position thermocouples in both occupied and unoccupied roosting locations at Hill and SCC. This enabled a comparison between areas occupied by bats versus areas not occupied (or occupied infrequently). At the SCC roost, thermocouples were placed to monitor both crevice (air) temperature and wall (surface) temperature (Figure 6B).

Bat House Temperature

Experiments with insulation, paint color, and insulative paint (Astec Ceramic Coating) were performed to determine which treatment would most closely mimic the temperature profile of occupied roosts and allow for temperature gradients within each bat house. Thermocouples were placed in the roosting crevices of bat houses during their construction, as diagrammed in Figure 6A, to permit measurement of temperature variations.

After their placement, bat houses were monitored closely for bat activity and occupation. Temperature profiles of both occupied and unoccupied bat houses were monitored and observations were made of the location of the bats within occupied houses. When needed, modifications were made to improve the temperature profile of unoccupied houses.

Although seven bat house styles were used in my project, I focused most of my time and attention on the set of three BCI styles that could be monitored simultaneously. I focused on the six bat house sites that eventually became occupied by bats. Bat house temperatures were monitored at five of these sites. The sites are listed below.

Bat houses at SCC consisted of all three BCI styles (two of these were occupied), plus two larger houses. Stevens originally had one BCI old style house and later three sets of small maternity houses were added. Finn also originally consisted of one BCI old style house, that was placed to mimic the old style house at Stevens. A large maternity house was later added (see Chapter 2) and two sets of small maternity houses. The Rollins site had a Texas style house and one set of large style houses. The Aikins site is detailed in Chapter 2. Tables 2, 3 and 4, and Appendix A summarize all sites and detail parameters such as color and orientation.

The bat houses located at the SCC and Rollins sites were the only sites where I was able to collect a full year of temperature data prior to occupation. At the SCC site, a comparison between the three BCI styles of houses was performed. Two additional houses, both significantly larger were also at this site. For logistical reasons data could not be collected simultaneously for all bat houses. However, some objective comparisons of the general thermal profiles of these houses could be made.

Due to the massive amount of temperature data collected and limited time available to adequately analyze all data, detailed analyses of the Stevens, Rollins, Finn, and Aikins bat house sites are not included here. Generalizations concerning these sites, however, are included at the end of the Results section.

Statistical Analysis

All temperature data were reduced using Lotus 123 (version 5) spreadsheets. Data were then analyzed with Statgraphics Plus (Manugistics, Inc.). Results of the controlled experiments were tabulated, then analyzed using the CHITEST @ function in Lotus 123 (version 5). Due to the non-normality of the temperature data, non-parametric p-values (Kruskal-Wallis, test of medians) are reported unless otherwise noted. Several attempts were made using Taylor's Power Law (Fry, 1993) to transform the temperature data, but none were successful at normalization. Multiple regression analysis was performed in an attempt to learn the importance of ambient temperature, solar radiation, and time in explaining the variability of the mean temperatures recorded in the bat houses and roost sites. Box and Whisker plots proved to illustrate nicely the comparisons between thermocouple locations. Temperature profiles of bat house styles and bat house sites were examined. The inability to collect data simultaneously, at two different sites, made real-time analysis difficult. Results should be viewed with these difficulties in mind.

Results

Flight Cage Experiments

One hundred and forty-seven bats were used in the flight cage experiments. *Tadarida* made up 92.5% of the test population. A total of eighty-nine bats was used in the first series of six replications. Tables 7 and 8 illustrate the results of each series of two tests, with the corresponding Chi-square probabilities. An additional test on pooled data was performed to determine if roost choice was influenced by the orientation of roost item in the flight cage, rather than roost item alone (Table 9).

Bats did not always choose to roost in one of the roost items provided and sometimes roosted on the side of the screen enclosure. For this reason the Chi-square test was run in three ways. First, all bats that chose to roost in a roost item were tabulated (IN). Second, I added bats that roosted on one or more of the roost items (IN/OUT); and third, I included all bats used in the test whether or not they chose to roost on or in one of the roost items (All). All Chi-square tests discounted the null hypothesis that the probability of a bats roost choice would be equal for each roost item. Chi-square values were also significant ($p=0.000$) for data pooled by location, indicating that location may have influenced roost choice in the controlled experiments.

In test #1, 14.6% of bats chose to roost in an area not considered a roost item (corner of test cage, or on screen behind a roost choice). Bats that roosted on, but not in a roost item made up 21.1% of the total bats tested. A total of 48.7%

of bats that roosted on or in a roost item, chose to use unlined plywood boxes (two were provided) and 14.5% chose to roost in the pine bark cavity. Only 11.9% of bats choosing a roost item chose the lined bat houses. No bats roosted in or on the brick bat house or the guano-soaked rag that came from a cage that housed a captive colony of *Nycticeius*.

Only one male *Nycticeius* was used in Test #1. This bat chose to roost with a male *Tadarida* in the top corner of the flight cage. Of the female *Nycticeius* tested, 77.8% roosted together in the pine bark cavity, while the other 22.2% roosted behind (and on) one of the plywood boxes. None of these bats entered any of the bat house-type roost items.

Of the *Tadarida* tested, 80.1% were male. Male *Tadarida* were found roosting in the fold of the guano bag (5.9%) and the pine bark (5.9%), but females were not. All bat house roost items were chosen at some time. Male and female *Tadarida* used the plywood houses with no liner in approximately equal proportions (56.9% and 50.1%). This was the preferred roost item.

Odor was not particularly attractive with only 3.4% of bats tested roosting in association with it. *Tadarida* did not appear to be attracted to the scent of the *Nycticeius* rag, but on two occasions individual *Tadarida* were found roosting in the fold of the guano bag; all of these animals were male. *Nycticeius* was never found associated with odor.

Problems were encountered in Test #2. Since a total of 14.6% of bats used in Test #1 chose not to roost in or on one of the roost items, a suggestion

was made that 'I was not trying to test *if* the bats would roost on or in one of the items, but which item they would choose' (M. Tuttle, pers. comm.). The decision was made to attempt to force the bats to choose one of the roost items by not allowing them to roost elsewhere. This decision resulted in an increased proportion of bats not choosing roost items. Bats that could not land on the walls of the enclosure roosted on either on the lower wall of the flight cage, below the plastic lining, or between the plastic liner and the screen enclosure. Although these problems made this set of tests inconclusive (50% of bats not using roost items), 44.8% of bats that did chose bat house-type roost items, selected bat houses with landing pads, 24.1% chose bat houses without landing pads and 31% roosted on, but not in, the bat houses.

Chi-square test statistics and resulting p-values presented in Tables 7, 8 and 9 are for all bats. Chi-square analysis was performed for *Tadarida* alone and separated by sex, but Chi-square analysis could not be performed for *Nycticeius* alone due to the low number of test animals.

Roost Temperature

Rollins and Aikins

Table 10 details maximum, minimum, and mean temperatures monitored at each roost site and ambient temperature. Mean roost temperature at Rollins and Aikins was higher than the mean ambient temperature on 75% of the observations. Roost minimum was below ambient minimum only in late summer

(August) at Rollins, but roost minimum at Aikins was below ambient during all observations. Roost maximum at Rollins was below ambient maximum except in August, when roost temperatures got as high as 51.57^{0}C (Figure 7). In contrast, Aikins maximum roost temperatures were always recorded as higher than ambient temperatures (Figure 8). Roost temperature above 35^{0}C occurred only during the August monitoring period at Rollins. At this time temperature >35^{0}C lasted for up to 8 hours.

Roost temperature in at least one of the two roost locations monitored at Rollins was significantly ($p<0.05$) higher than ambient temperature during summer months. Winter months showed a nonsignificant difference between roost and ambient temperatures; however, Box and Whisker plots illustrate that differences between the ranges are evident (Figure 9). At Rollins the difference between roost and ambient temperatures increases as ambient temperature decreases. Plots in some cases show an almost mirror image (Figure 10).

Aikins roost temperature was significantly higher ($p<0.05$) than ambient only in mid-summer, when non-volant pups were present. P-values were non-significant ($p>0.05$) in early fall and late winter. Box and Whisker plots confirm no differences are identifiable in ranges, extremes, or median values (Figure 11).

Temperature differences rise and fall with ambient temperature at the Aikins site (Figure 12). Only in early fall, does the pattern so prominent at the Rollins site, show up at Aikins. Roost temperature was above 35^{0}C on 24% of

observations in mid-summer (up to 10 hours, roost max=43.23^{0}C, ambient max= 36.94^{0}C), when non-volant pups were present. Early fall roost temperatures were above 35^{0}C less than 5% of the time (up to 3 hours, roost max=42.23^{0}C, ambient max=37.16^{0}C) and did not reach 35^{0}C in late winter when roost temperature rose above ambient only 34.6% of the time monitored (Table 10).

The results of multiple regression analysis performed to determine the influence of time, ambient temperature, and solar radiation on the variability of roost temperature at Aikins, Hill, and Rollins are presented in Table 11. At Rollins, solar radiation was the poorest predictor of variability in roost temperature with an R-squared (R^2) value of less than 4.0% for all data sets collected at the site. Ambient temperature gave R^2 values ranging from 40.40%-67.22%. R-squared values for time were the most variable at 0.0%-57:99%. Roost temperature variability was explained as a higher R^2 value when all three parameters were included in the analysis and ranged from 72.46%-90.5%, followed by solar radiation/ambient (69.85%-76.74%) and finally time/ambient (62.3%-73.49%).

Solar radiation was a poor predictor of variability of roost temperature (R^2: 6.41%-33.06%) at Aikins, but overall, time was the poorest predictor of variability at this site (R^2: 0.0%-19.72%). R-squared values point to ambient temperature as a good predictor of roost temperature variability (49.56%-97.73%). Multiple regression analysis that included all three parameters as predictors of roost temperature variability had the highest R^2 values, followed by solar

radiation/ambient combination and time/ambient. The percentage of time that roost temperature was above ambient at Aikins was highest in summer and lowest in winter (81.25% and 34.6%).

Hill

At the Hill and SCC roosts temperatures were recorded both in areas occupied by bats and in areas occupied infrequently or not at all. Hill locations WR and WL were most used by bats. WR was directly beneath the metal ridge cap of the metal roof and WL was between the metal roof and the old roof shingles. As illustrated in Table 10, the mean roost temperatures at these locations were higher than ambient means on all collection dates except in February. At that time WR mean temperature was lower than ambient mean; however, the roost minimum for WR was lower than ambient minimum by 3.6°C (9.15°C and 12.76°C), while roost maximum at this location was higher than ambient maximum by 6.67°C (32.76°C and 26.1°C). On this date, roost temperature range at this location was 10°C greater than the ambient temperature range. The roost maximum for these two locations was always higher than ambient maximum. In February, WR showed temperatures that appeared independent of ambient while the other locations monitored on this date showed close associations with fluctuations in ambient temperature (Figure 13).

Solar radiation was collected at Hill on only one occasion. These data increased the R^2 value an average of 10.76% when used in combination with

time and ambient temperature to predict variability in roost temperature (Table 11). The largest increase was for a location (NC) that the bats did not use (40.76%). At Hill, time was the poorest predictor of variability in roost temperature (0.92%-12.6%). Ambient was the greatest predictor, with high R^2 values (65.98%-95.03%).

The percentage time that roost temperature was greater than ambient temperature varied with location from 19.72%-96.9%. In fall and summer, roost temperature in at least one occupied location was greater than 35^{0}C for 1.2%-17.3% of the time (up to 7 hours, roost max=45.49^{0}C, ambient max=33.46^{0}C). During two of the three monitoring occasions, roost temperature rose above 35^{0}C for as long as six hours. WR had the highest temperatures and peaked at 47.83^{0}C. Ambient was not >35^{0}C during these times. Roost temperature differences in summer (Figure 14) and winter showed a pattern similar to Rollins, but in fall (Figure 15), roost temperature differences rise and drop in close association with ambient temperature.

SCC

SCC was the most studied roost site, with temperature data at this site collected on eleven occasions. Only February and May were not included during monitoring sessions. At SCC ambient temperature was significantly lower than roost temperatures (north, south, and west) on 63.6% of dates monitored (Table 10). Ambient temperature was not significantly different from roost

temperature on the north side of the building for the remaining dates (36.4%). On all dates, roost mean and minimum temperatures were above ambient mean and minimum at all locations.

North wall and crevice temperatures were significantly different from each other in June. This was the only time that a north temperature (NC) was warmer than south temperatures. South crevice was significantly warmer than south wall on all dates. West crevice was warmer than west wall in all months except January in both years of data collection. During January, west crevice and west wall temperature were not significantly different from each other. Crevice temperature was never significantly lower than wall temperature on south, west, or north sides of the building.

Roost temperature rose above 35^{0}C during four monitoring periods (Table 10). On one of these occasions ambient temperature was above 35^{0}C (35.57^{0}C). On two occasions, the west crevice exhibited extreme high temperatures. In August, south and west, crevice and wall temperatures rose above 35^{0}C for as long as eleven hours and reached a maximum of 41.74^{0}C. In December, roost temperature climbed above 35^{0}C for up to 8 hours and reached 56.13^{0}C in the west crevice. During this event, the south wall was >35^{0}C for seven hours (maximum 45.66^{0}C), while the south crevice was >35^{0}C for only three hours and reached 39.41^{0}C. The same location (west crevice) fell below 5^{0}C for seven hours five days later. South wall and south crevice temperatures never fell below 5^{0}C. Ambient maximum and minimum temperatures during this monitoring

period were 34.42°C and 4.056°C. An equipment malfunction prevented the collection of readings from the west wall and north locations on this date.

It was not possible to monitor solar radiation at the SCC roost site. Time and ambient temperature were used in multiple regression analysis to determine their influence on roost temperature variability (Table 12). In most cases, the combination of time and ambient described variability to the greatest degree; however on a few occasions ambient temperature alone accounted for the high variability in temperature at the roost. Time alone was generally a poor predictor of roost temperature variability and usually had R^2 values much lower than either ambient or time/ambient combination. R-squared values were highest in fall and winter months and lowest in summer months.

R-squared values were noticeably higher when bats were absent. Lower R^2 values indicate the parameters of ambient temperature and time are not adequately explaining the variability in roost temperature. The p-values (Table 10) resulting from a comparison of median roost temperature to ambient temperature were similar for all dates tested, and multiple range tests indicated ambient temperature was always cooler than temperature in the monitored roost locations. Only time-series graphs (Figures 16 and 17) indicate any pattern of differentiation between roost temperature and ambient when bats were present versus when they were absent. The areas of SCC that were occupied on a regular basis were the south crevice (SC) and west crevice (WC). The north crevice (NC) was occupied on only one brief occasion.

Bat House Temperature

Due to the immense quantity of temperature data I collected from central Florida bat houses, I chose to limit my in-depth data analysis to the set of three bat house styles placed at SCC. Temperature data were analyzed in several ways. Appendix C lists the results of ANOVA tests of means, Kruskal-Wallis tests of medians, variance tests, and other summary data for the SCC houses. Multiple regression analysis was performed on all data sets to determine how time, ambient temperature, and solar radiation, influenced the variability of mean temperature in the bat houses. The resulting R-squared (R^2) values are reported in Table 13. Durbin-Watson statistics on all data sets were less than 1.4, indicating possible serial correlation. Due to this, several unsuccessful attempts were made to utilize time-series analysis with these data, and will not be reported here. More general approaches were used to examine the data at several other central Florida bat house sites and will be referred to at the end of the Results section.

The set of three bat house styles at SCC was initially painted white. The small style houses had Reflectix insulation in the upper half of both the front and rear chambers. This insulation was also present in the upper half of the second and rear chambers in the large style houses. Data collected from May 1994 through July 1995 was for white bat houses with no bats present. From the second July 1995 period through January 1996, data were collected while the small houses were still white, whereas the simple and large style houses were

modified. Modifications included painting the bat houses dark brown and enclosing the sides between the pairs of bat houses to create a center chamber. A metal roof was then added that covered both houses. In the modified houses ventilation slots were provided both below the metal roof and in the front and back panels of each house. At that time the insulation was removed from the large style houses. Bats were present in some of the bat houses on most of these dates. In February 1996 the small style houses were painted brown, but otherwise left unmodified. Data collected in the period February 1996 - May 1996 were for comparisons between all brown bat houses.

White Houses With No Bats Present

Results of statistical methods used to test for differences between temperatures in and between the bat houses were sometimes confusing. Variance tests were used to determine which statistical test was most valid (ANOVA or Kruskal-Wallis). All p-values for comparisons of mean and median values of temperature between locations in each bat house were $p>0.05$ indicating no significant differences were observed (Appendix C). However, multiple range tests using the least significant differences method (LSD) at a 95% confidence interval (95% CI) illustrated some significant difference did exist (Figure 18).

Temperature summaries provided in Table 14 are for bat houses prior to bat occupancy. The percentage time mean or maximum bat house temperature was

above ambient in the simple style houses was significantly lower than for either the small or large style houses ($p=0.00$). Although ambient temperature climbed above 35^{0}C in July 1994, the simple bat houses remained below 35^{0}C and were above ambient no more than 17.25% of the time monitored during this period. Minimum crevice temperature was below ambient a significantly greater amount of time in the simple houses ($p=0.007$). The small and large style houses were not significantly different from each other in this aspect. During this period, maximum crevice temperature in the small and large houses was above ambient 58.6%-86.67% of the time monitored. The percentage time that mean temperature in the small houses was above ambient was significantly higher than both large and simple style houses ($p=0.00$), while the percentage time that the maximum temperature was above ambient was significantly higher in the large style houses ($p=0.00$).

Multiple regression analysis resulted in R^2 values that were >97.5% for the simple houses, >90.3% for the small houses and >89.9% for the large houses. Time was the least significant in its influence on mean bat house temperature variability and often had T-statistic p-values >0.05. Solar radiation rarely had a p-value >0.05 and ambient temperature was always a significant ($p=0.00$) predictor in the variability of bat house temperature.

No significant difference existed between the total range of temperature (maximum minus minimum for entire monitored period) in any of the bat house styles ($p=0.97$). However, when comparing the range of temperatures within a

bat house (maximum crevice temperature minus minimum crevice temperature), the large style bat houses had a significantly greater range than the small style houses, which in turn had a significantly greater range than the simple style houses (p=0.00). Both the large and small house styles provided twice the range as that seen in the simple houses. At no time was the temperature range within a house at the SCC site greater than 5°C.

Figure 19 illustrates temperature ranges in small and large style houses at SCC and plots temperature differences. The range of temperature between 8:00 and 20:00 was greatest in the SE houses, and the maximum for the NW houses was further below ambient. The NW houses had a more narrow temperature range (ANOVA p=0.0507) within the house, and the maximum house temperature fell further below ambient (ANOVA p=0.0447). No statistical differences, however, were evident between temperature ranges of southeast (SE) compared to northwest (NW) oriented bat houses of a particular design when the entire data set was examined.

The most prominent feature of raw temperature time-series profiles (Figures 20, 21 and 22) and temperature difference (bat house temperature minus ambient) profiles (Figures 19 and 20) within the bat houses is that ambient temperature was higher than the temperatures in the bat houses during the period of afternoon high temperatures. For this reason, the large and simple style bat houses were modified in an attempt to increase temperatures in the bat

house chambers. The small style houses were not modified at this time due to the presence of a single *Tadarida* in the NW small style house.

Unfortunately, extreme low temperatures were not included in data sets for unmodified houses and no comparisons were available for low temperatures.

<u>July 1995 - January 1996: Large and Simple Style Houses Modified</u>

During this period bats were present in the small style houses as a result of the relocation performed in May and July 1995 (see Chapter 2). The large style houses became occupied in December 1995, and the simple style houses remained vacant. Kruskal-Wallis p-values resulting from a comparison of median bat house temperatures showed the same pattern as above for the simple style houses. Multiple range tests (LSD, 95% CI), however, illustrate a small amount of differentiation between thermocouple locations (Figure 23). A significant difference existed between the SE and NW simple houses on most dates. Both the large and small houses had significant differences between the median temperatures, within and between the houses. A distinct range of temperature was now evident in these two bat house styles.

No significant difference existed between the overall temperature range between the bat house styles (p=0.68). A clear difference existed in the temperature ranges within houses and between the orientations. For the simple houses, the SE house range was greater than the NW range on all dates monitored (p=0.00). The large northwest house (LNW) and the large southeast

house (LSE) were significantly different in November and January. In November (no bats present), LSE has a greater range than LNW, but in January (bats present) the opposite occurs. In the small houses, the small northwest (SNW) house shows a greater range than the small southeast house (SSE) in July and October, while SSE is greater than SNW in January. No differences are evident in July (during a period with no bats present) or in November. The simple houses had a lower temperature range than the large houses, which had a lower range than the occupied small houses on all dates monitored.

Tables 15,16 and 17 describe the temperature patterns in the SCC bat houses from July 1995 - May 1996. Data examined from July 1995 through January 1996, comparing the percent time that minimum bat house temperature was below ambient, showed no significant differences between the house types ($p=0.427$). Likewise, there was no significant difference between bat houses when the percent time maximum temperature was above ambient was examined ($p=0.422$). When looking at mean bat house temperature and the percent time above ambient temperature, no difference existed between the large and small houses, but they were both significantly different from the simple houses, with the simple houses being below ambient more often.

The small style houses were above 35^0C a significantly greater amount of time than either the large or simple houses (small 42%: up to 15 hours, max=39.26^0C; large and simple 5%: up to 5 hours, max=39.1^0C and 39.07^0C). All bat houses fell below 5^0C on one or more occasions. During one monitoring period,

ambient fell to -2.2^{0}C. Data were available for only the large and simple houses during this extreme low temperature period. At that time the large style houses fell below 5^{0}C for up to 17 hours, 6 hours of which bat house temperature was below 0^{0}C (min = -2.31^{0}C). The simple houses fell below 5^{0}C up to 16 hours with 7 hours below 0^{0}C (min = -3.53^{0}C). Low temperature data available for the small style houses was for a period when ambient fell to 3.83^{0}C, and bat house temperature fell below 5^{0}C for up to 7 hours (min = 3.17^{0}C). Both small and large style houses were occupied during this period.

Multiple regression analysis (Table 13) resulted in R^2 values >98% for the simple houses. The same analysis performed for the large house resulted in R^2 > 96%, and the R^2 values for the small houses ranged from 50.89% in October to 93.34% in July (a period during relocation when few bats were present).

Time-series profiles for both raw temperature and temperature differences during a period of high ambient temperatures are shown in Figures 24, 25, 26 and 27. Modification of the large and simple style bat houses by painting them brown, etc., increased bat house temperature so that it was now above ambient on a large proportion of readings. Bat house temperatures in the large maternity houses were above ambient during the cooler evening hours. Temperature differences in unoccupied bat houses were not increased greatly, however. The temperatures of simple style houses remained closely correlated with ambient, as do the large maternity houses. Some bats were present in the SNW house and it was warmer than on previous dates, showing more differentiation than noted in

past temperature profiles. The small houses remained painted white and unmodified.

Low weather data for this group of houses (Figures 28, 29, 30 and 31), interestingly showed strong temperature differences in the SE simple style houses that hadn't been seen before. The maximum temperature in the house was significantly warmer during the day, but at night no differences were evident in either orientation of this style. Bats were present in both the large and small style houses. This was best illustrated in the temperature profile of the small style houses that were occupied by greater numbers of bats. The temperatures in most chambers in both styles of houses remained above ambient during the day, but dropped to closely track ambient conditions in the evening hours.

February 1996 - May 1996: Small Houses Painted Brown

The simple style houses continued to show non-significant p-values (Kruskal-Wallis) based on median temperatures. The simple northwest (BNW) and the simple southeast (BSE) houses appeared to be significantly different from each other ($p<0.05$) only in February. Both the large and small style houses showed differences between and within houses at $p<0.05$. Multiple range tests (LSD, 95% CI) illustrated these differences (Figure 32). A range of temperature was evident in all houses except the simple style.

Ambient temperature in February dropped to $-3.11^{0}C$ and temperatures fell below $0^{0}C$ in all houses. The small style houses sustained temperatures below

0^0C for periods up to 14 hours; whereas, this condition lasted 12 hours in the large houses and 13 hours in the simple style houses. The percent time that the bat house temperature was below 5^0C ranged from 15.1% - 19.7% in all houses (large: up to 19 hours, min = -3.24^0C; small up to 18 hours, min = -3.69^0C; simple up to 20 hours, min = -3.53^0C; ambient min = -3.11^0C). The overall percentage was higher (19.7%) in the small house. During this monitoring period ambient rose to 28.87^0C and temperatures above 35^0C were recorded in both the small and simple houses.

In May, temperatures in all houses rose above 35^0C, but did not get above 38.95^0C in the large house, while it rose as high as 45.22^0C in the SNW (up to 11 hours above 35^0C). No significant differences existed between the houses in the percent time mean temperature was above ambient ($p=0.07$) or maximum was above ambient ($p=0.15$). Although the Kruskal-Wallis p-value was not significant ($p=0.21$) with respect to the percent time minimum bat house temperature was below ambient, the multiple range test (LSD, 95% CI) showed the large bat house style minimum was lower than ambient a greater percentage of time than the minimum temperature in the small houses. However, neither relationship was significantly different from the percentage of time the simple style house minimum was below ambient.

The R^2 values resulting from multiple regression analysis were highest for the unoccupied simple houses (R^2>98.39%). R-squared values for the combined large style houses were >96.2%, but when comparing LNW vs LSE, LNW R^2 fell

to 89.6% whereas it was 94.04% for LSE. The small houses had the lowest R^2 value (86.42% and 89.51%) with SSE having lower values (76.58% and 85.12%) when compared to SNW (84.23% and 91.56%).

Figures 33, 34, 35 and 36 illustrate high temperature data after all bat houses were modified. Both the small and large maternity styles contained bats and the profiles were indicative of this condition. All chambers in all occupied houses were above ambient, and great differentials existed in differing locations.

Low temperature profiles are illustrated in Figures 37, 38, 39 and 40. During low temperatures, the SE simple house rose above ambient as much as 15°C during peak highs, but otherwise follows ambient closely. Both of the large maternity houses tracked ambient closely, as did the NW small maternity for most of the time illustrated. Bats were present in the middle chambers of these houses and accounted for the temperature increase noted.

Comparisons

As confirmed by observations of day-time roosting vocalizations during cold periods, bats were present in the large style houses (Figures 30 and 39) in lower numbers and were less active than bats in the small style houses (Figures 29 and 38). It is evident from these temperature graphs that bat activity was lower in the large style houses, while it was greatest in the NW orientation of each house. Winter temperature ranges and differences in the small and large style houses are illustrated in Figures 31 and 40. Greater numbers of bats are present

in the small houses and significantly greater temperature differences and ranges are evident. During high temperature periods no differences were evident when bats were present in both house styles (Figure 36). In Figure 27, temperature profiles for small and large house were not similar, bats were present only in the small houses.

Prior to modifications, the overall temperature range was greatest for the large style and least for the simple style bat houses. It appeared that the simple houses were not getting warm enough. Modifications made to the simple houses in May 1995 (see Appendix A), did not adequately correct the problem. The houses were getting warmer, but a consistent range of temperature was not achieved (Figures 24,28,33,37).

Modifications to the large style bat houses significantly increased the amount of time mean and maximum temperature were above ambient and decreased the time minimum temperatures were below ambient (Table 17). The large bat houses did not reach temperatures above 35^{0}C (Tables 15 and 17) as frequently as the simple style houses. In addition, the large style houses had a greater range of temperature. Modifications made to this bat house style increased the R^2 value attributed to solar radiation from 28.35% in July 1994, to a mean of 47.97% in July 1995. Bats did not begin to occupy the large style houses until December 1995.

At SCC, bats moved into SNW first. Prior to occupation or modifications of any of the bat houses, the mean temperature in the small style houses was above

ambient ($p=0.00$) a greater percentage of time ($\bar{x}=59.5$) than in the large ($\bar{x}=49.9$) or simple style houses ($\bar{x}=1.67$). Only when the 24 hour period was divided into day-time (sunrise-sunset) and night-time (sunset-sunrise) temperatures did any statistical differences between the house styles or orientations appear. Figure 21 illustrates the temperature difference profile for a typical 48 hour period in the small style houses without bats or modifications. The temperature data collected from 8:00 - 20:00 was examined. In the NW houses, a more narrow temperature range (ANOVA, $p=0.0507$) was evident and the maximum house temperature fell further below ambient (ANOVA, $p=0.0447$) than in the SE houses.

Figure 29 illustrates small style bat house temperature during a cold period when the houses were painted white. The presence of bats was indicated by the chamber temperatures remaining above ambient during most periods. It was likely that bats were torpid during the daylight hours when bat house temperature was below ambient. After the houses were painted brown, a severe cold period was recorded (Figure 38). Bats were obviously present in SSE, and absent or torpid in SNW house after the first 12 hours.

Other Occupied Bat Houses:

The two larger size houses at SCC (Florida style and Square) were occupied intermittently and by small numbers of bats. Beginning in January 1996, both species were seen in the Square house (Figure 2), usually during the cooler

months. During one cool period in March, a cluster of 10-15 *Nycticeius* were seen occupying the SE quadrant of this house. And on two cool days in December 1996, 4-5 Tadarida roosted there for two days. This house was originally painted with white insulative paint (Astec coating). The bats preferred the south side (SE or SW), but were found in the NW quadrant on two occasions. The NE quadrant has never been occupied. The mean bat house temperature was above ambient on 69% of time monitored and the maximum was above ambient 87% of monitored time. Even in January during a period when ambient temperature fell to -0.214^{0}C the maximum house temperature was above ambient during 93% of the time monitored, with the house minimum falling below ambient on 49% of the readings. In May 1996, this house was painted dark brown.

The Florida style house was occupied by 1-2 bats on four occasions and usually during cooler periods. This house was painted with clear varnish. No significant differences were evident between the mean crevice temperatures in this house. The mean house temperature was above ambient an average of 64% of the time monitored and the house maximum was above ambient on 95% of readings.

At the Rollins site, the set of large style houses remained empty for almost three years. Since October of 1996, 1-2 *Nycticeius* began using the second crevice in the NW large maternity house. Analysis of temperature data in these houses showed no significant differences existed between crevice temperatures ($p<0.05$), and a time-series temperature profile illustrated very little

differentiation (Figure 41). Bat house temperatures were below ambient during the day and above ambient at night on most dates monitored. The bat(s) at this site consistently roosts in the same location.

At another site (Stevens) where both *Tadarida* and *Nycticeius* were present, the bats appeared to segregate somewhat during maternity season. The population in the west house consisted primarily of *Nycticeius* and the east house consisting primarily of *Tadarida*. Summer temperatures in the bat houses prior to bat occupation are shown in Figure 42. No significant differences exist either between the ranges (p=0.441) or the temperature differences (p=.505) in either house unless I analyzed just day-time temperatures. The temperature range in the west house was then significantly less than the range in the east house (p=0.009). The presence of bats in these houses (Figure 43) reduced the temperature ranges to a nonsignificant level at all times (p=0.264) and temperature differences were not significantly different (p=0.119). However, a multiple sample comparison (LSD, 95% CI) showed west front as having the lowest difference from ambient. When bats were present in these houses the temperature range was low and the time-series profile was unmistakable. This set of houses had a four inch space between the two bat houses that bats sometimes occupied in small numbers. Although a thermocouple was not positioned here, I would expect the temperature to be close to ambient, since it is buffered between the two houses and has a large opening on the bottom that

would increase air flow and ventilation. On cold days this location was never occupied.

Two additional sets of houses were placed at Stevens in February 1996. Both houses were mounted to face north and south. One was painted dark brown (DB) and the other light brown (LB). Bats moved into DB first and have always had higher numbers than bats in LB. The numbers of bats in DB were comparable to bat numbers in the original house that was also painted dark brown, but was positioned east and west (EW). Mechanical problems prevented the collection of temperature data at this time. However, similar houses mounted at a nearby site were monitored prior to occupation and may be used for a comparison between dark brown houses oriented E/W and N/S (see Discussion).

Discussion

Flight Cage Experiments

The controlled flight cage experiments were run with relatively small numbers of animals, and results should be viewed only as indicators of preference for a particular roost item. Bats in the flight cage experiments preferred bat houses with landing pads, but did not prefer bat houses with any type of lining. The choice of landing pads should make it easier for bats to enter a bat house. Bats choosing unlined boxes rather than lined boxes was unexpected because I have

witnessed bats having difficulty crawling into bat houses without the addition of some liner or additional roughening of the wood surface in the roosting crevices.

Despite the results of the above experiment, all bat houses should have an adequate lining or roughening of the roosting crevices. The best approach may be to use a router or hand tool to scar the wood manually. Fiberglass window screen should not be used because it has deteriorated in many of the occupied bat houses (see below and Chapter 2). Polypropylene mesh (1/4 inch) or metal hardware cloth works well. Care must be taken if metal hardware cloth is used to ensure that all sharp corners are smoothed to protect the delicate wings of bats from being cut or torn.

The choice of a pine bark cavity for *Nycticeius* was consistent with the fact that this species is known to roost in tree cavities (Watkins, 1972; Fargo, 1929; Rudolph et al., 1990). *Tadarida* was found roosting in the pine bark cavity in spite of the fact that few colonies of *Tadarida* have been documented in roosts other than buildings or bridges (Wilkins, K.T., 1989; Fargo, 1929; Jennings, 1958). *Tadarida* was more attracted to odor than *Nycticeius*, and in fact the first bat house that became occupied at SCC had a guano filled bag hung on the bat house. Although this may be purely coincidental, more work needs to be done to discover how important scent is in roost occupation.

Bats choosing a roost item located on the south side of the flight enclosure (including SE and SW corners) was 63.75%, while bats choosing a roost item on the north side or north corners was only 36.25%. This suggested another

variable may be involved in roost choice that was not measured or controlled. It would be interesting to repeat this test with animals captured from a roost located north of the test site to discover if a majority of bats will be found on the north side of the enclosure. A more robust test of roost choice should be run to get a better idea of how bats react to choices of differing roost substrates, odors, and orientation.

Roosts, Bat Houses, and Temperature

During periods of high temperature stress, even a small drop in body temperature can be beneficial (Studier, 1981); therefore, a range in roost temperature is advantageous and enables bats to escape temperature extremes. During the warm summer months day-time roost temperature ranges may be critical since bats are obligated to spend all their time in the roost . Most of the night-time hours are spent foraging and away from the roost. During winter months a range in night-time roost temperature may be more important to provide bats an area to escape extreme low temperatures or to provide them with an adequate temperature to successfully remain torpid.

Vertical stratification of roost temperature at the Aikins roost was nonexistent because vertical structure was only eight inches. Bats were not noted to use areas of the roost that were deeper in the awning structure (see Appendix A for roost details). I suspect that during extreme high temperatures (>35^{0}C) the animals may have crowded close to the roost entrance, that consisted of a badly

deteriorated wood face. This deterioration probably allowed significant airflow and aided in evaporative cooling. Conversely, they may have collected at the rear of the roost near the brick face of the building, a location that may have been several degrees cooler than the roost itself (see section on SCC roost, wall versus crevice temperature).

At the Rollins, Hill, and SCC roosts, significantly more area was available to escape extreme temperatures. Both vertical and horizontal thermal stratification were present in the roost areas. When roost temperature at Rollins reached 51.57°C in August, this condition would be lethal (Herreid, 1967) without some thermal stratification in the roosting area to allow bats to escape such severe high temperatures (Licht and Leitner, 1967).

For example, at Hill bats were known to roost directly below the metal roof, both between the metal roof and the old roof tiles and between the metal roof and the metal roof ridge. Although equipment malfunctions precluded monitoring of this site on more than three occasions, on two of these occasions roost temperatures rose above 35°C and even above 40°C. Roost temperature was above 40°C for as long as 5 hours and reached 45.49°C. Bats certainly did not tolerate these extremes well and probably shifted their position to cooler areas (see Figure 44). At this site in September, temperature in WR got as high as 47.83°C and was above 40°C for up to three hours. Temperatures were lower at other monitored locations known to be used by bats (Figure 45). *Tadarida*

was seen at WR when thermocouples were placed in May 1994; the temperature at that time was 41.33°C.

Roosts used by bats in central Florida vary greatly in their thermal profiles. Bats are not restricted to a particular substrate, but do appear to prefer crevices or narrow spaces. They were found in both wood and concrete structures, as well as beneath spanish tile roofs, and below metal roofs and flashing. Although temperature profiles in these roosts vary, one commonality is an adequate temperature range within the roost site that allows bats to escape temperature extremes.

Bats affect the roost or bat house temperature through their metabolic heat production (i.e., Baudinette et al., 1994). During the summer months the small houses at SCC and Stevens were literally packed full of bats. Figure 46 compares small style bat house temperature profiles during a period without bats and during a period with bats on dates with similar ambient temperatures.

In the small style bat houses R^2 values can be used as an indicator of the level of bat activity in the house. While the houses were unoccupied R^2 values > 90.28% occurred ($\bar{x}$=93.50). After occupation, R^2 values dropped as low as 45.84% in the SSE house in October 1995. During the summer months when bat activity was peaking, R^2 values in these houses averaged 69.71%, while in the colder months with lower bat activity, R^2 values averaged 80.63%. The decrease in R^2 values with increased occupation in the small style houses indicate that a parameter other than those measured (time, ambient temperature

and solar radiation) was having an influence on the variation in the mean bat house temperature. That parameter is likely metabolic heat produced by the bats. The bats are in fact influencing and modifying the temperature in their roost area. The importance of this has been discussed by several authors (Baudinette et al. 1994; Kunz 1974,1980,1995).

At the SCC site, I have witnessed *Tadarida* flying at 7.2^{0}C. During the winter months bats occupied the bat houses , but often in decreased numbers. During two cold periods in the winter of 1995/1996, I collected cold stunned *Tadarida* from the ground beneath the small style bat houses at SCC. In an attempt to increase solar heating and prevent the bat houses from getting too cold, this house style was painted dark brown in February 1996. (The large style houses were occupied by smaller numbers of bats and fewer bats appeared to succumb to the cold. This style house was painted brown during the modification in May 1995). Painting the small houses dark brown resulted in an increase in the R^2 values attributed to solar radiation from 50.6% in May 1995 to 65.27% in May 1996. However, no increase was evident during the winter months (December - February) that was the period I had hoped would show an increase in solar warming. Solar radiation values for the large style house were not available for cold months, prior to the modifications. Comparisons of solar radiation values can be misleading, however, due to cloud cover that acted to decrease this parameter. Cloud cover was not monitored during this study.

Although some bat activity was observed during these low temperature periods, on nights of extreme cold I found the bat houses occupied by very low numbers of bats. However, if temperatures were less severe the following night, the bats returned. Apparently a roost site that may not get as cold on these nights was being utilized, but its location has not been identified. The presence of fewer bats during these low periods probably leads to greater low temperature stress on the remaining bats, and increases the chance of them becoming torpid or cold stressed due to decreased cluster size (i.e., Kunz 1980).

During the initial occupation of the SCC bat houses, both *Nycticeius* and *Tadarida* were present in approximately equal numbers. When *Nycticeius* had pups in May 1995 they were evident only in the SE small style house. As discussed below, SSE had a greater temperature range and minimum temperatures remained closer to ambient than in the SNW. During the summer of 1996, *Tadarida* used the bat houses as a maternity site. Although *Nycticeius* was present in the bat houses, they were less evident after the initial occupation and many have chosen to roost elsewhere.

Bat numbers at this site were always greater in the NW side of the houses. Bat preference was best monitored while bat numbers were low. After the houses 'filled up' it became difficult to determine which species preferred which location in which house. Bats were literally on top of each other in the bat houses and the potential existed to make false observations. *Tadarida* at SCC used all

occupied bat houses. *Nycticeius* preferred the small style houses although some were noted in the large houses.

Since the initial eviction and relocation at SCC, *Nycticeius* have been evicted from suboptimal locations on the main campus on several dates. In July 1996, they attempted to colonize an elevator shaft. Bats were entering the main shaft through a small opening under the metal flashing. Once inside the shaft they were unable to exit due to the smooth surface and more than 30 pregnant bats died. Hydraulic oil was in the bottom of the shaft and most bats were found drowned in this oil. Curiously over half of them were found together in a small bucket on the floor of the elevator shaft. Possibly bats that were trapped in the shaft were attracted by the vocalizations of bats that had become trapped in the bucket. The elevator was later sealed to prevent bats from entering. This circumstance illustrates the tenacity of these bats to return to the 'home' roost and probably the lack of adequate alternate roost sites. My observations on the behavior of *Nycticeius* at central Florida roost sites suggests that the tenacity exhibited by this species is more intense than that exhibited by *Tadarida*.

Without some avenue to escape severe high temperatures, even those imposed by the animals own heat production, important problems can arise. These problems may include decreased spermatogenesis (Vaughan 1986), or even death (Herreid 1967). A bat house that has temperatures below ambient prior to the presence of bats might not need as large a temperature range if the temperatures present in the house were sufficiently below ambient to provide

some stress relief. This, however, does not hold true during the winter months (December - February) when roost temperatures above ambient would be required for a bat such as *Tadarida* that does not hibernate. Even *Nycticeius* would require a temperature that did not fall below 5^{0}C for long periods of time. A roost site where temperatures fell below 0^{0}C could be lethal.

Based on the temperature data I can see no clear reasons why the larger houses at SCC were occupied only intermittently. I suspect that as the population in the other bat houses grows, bats will eventually begin to occupy these houses in greater numbers. Due to the large size of these houses, a greater number of bats may be required to modify the temperature profile in a manner acceptable to them; that is a critical number of bats may be needed before these larger houses become viable.

Bats have never occupied the simple style houses at any central Florida site in this study (but see Anonymous, 1997). Apparently the small size (only one chamber) and lack of temperature range does not adequately meet the needs of bats in this area. However, similar, single chamber houses were occupied by *Nycticeius* at a location in Volusia county. The bat houses at that site had a horizontal rather than vertical orientation, and were mounted directly on a house where a *Nycticeius* colony was present. The simple style house may be successful in situations like this, mounted on buildings that already house a colony of bats. In contrast, when mounted on poles or trees this bat house style remains unoccupied, regardless of treatment.

In the summer of 1996 two sets of houses were mounted at Finn . Both were painted dark brown, one faces north and south (FNS) and the other faces east and west (FEW). Figures 47 and 48 illustrates raw temperature profiles of each house prior to bats occupying them. The east facing house was the warmest and remained above ambient during day-time hours. The north house was the coolest with temperatures noticeably below ambient during the afternoon hours and above ambient at night. I consider this configuration of bat houses thermally optimal and it should provide bats with suitable roosting locations during all times of the year.

With the exception of two incidents, bat house occupation at SCC has been constant since the SNW house was first colonized in May 1995. When the fiberglass screen lining deteriorated in July 1995 bats vacated. They returned after the screen was removed. In October 1996, cars were burned within 15 feet of the occupied bat houses by the SCC Fire-Science department, and bats vacated this site for almost two weeks. The fact that the bats returned to this bat house site after such a severe disturbance suggests these bats now consider this site 'home', and that more suitable alternate roost sites are few or unavailable.

Bats in central Florida are evidently not always choosing roost sites that are significantly above ambient temperature prior to occupation, as I had expected. This is probably due to the effect that the bats themselves have on the temperatures in the bat houses. Even the bat house at Stevens that was painted

dark brown remained below ambient on the west side prior to occupation. This orientation (W or NW) is the preferred location for bats at this site, the SCC site, and for the lone bat at the Rollins site.

Bat houses placed on the trunks of trees in my study remained unoccupied, whereas the same house styles on poles were successful. My theory for this pattern of occupation is that bat species that are likely to roost in bat houses do not normally roost in trees, and trees are not in their search image for roost sites. However, *Nycticeius* does roost in trees. The old style bat house at Stevens was occupied by a colony of *Nycticeius*. That house was hanging from the limb of a live oak (*Quercus virginiana*). Mounted in this manner the house was not 'part' of the tree. This may have increased its probability of success. Bat houses mounted on tree trunks at this site were never occupied. Many questions remain unanswered about bat roost preferences in central Florida, particularly for *Nycticeius* that have an interesting pattern of population movement (see Appendix A).

Additional Comments

Other Bat House Inhabitants

Bat houses placed in central Florida have been utilized by species other than bats. These include wasps and mud daubers (Hymenoptera: Vespidae, Vespinae and Sphecidae, Sphecinae), cockroaches (Blattaria, Blattidae), spiders (Arachnida, Heteropodidae), geckoes and anoles (Gekkonidae and Iguanidae).

Although the bat houses are open on the bottom to prevent non-bat vertebrates from using them, gray squirrels *(Sciurus carolinensis)*, have built nests on top of bat houses and on the temperature junction boxes. Temperature wires were chewed at several sites by *Sciurus*, and at one site two unoccupied bat houses were destroyed by chewing squirrels. On several occasions, common flickers (Picidae, *Colaptes auratus*) have roosted between sets of two bat houses.

Banding

During the controlled experiments I banded both *Tadarida* and *Nycticeius*. Both species were recaptured back at the original roost site after release. Although *Nycticeius* did not show any ill effects from the bands, most *Tadarida* that were recaptured exhibited forearm injury and in two cases the bands penetrated the muscle of the forearm. One bat that was recaptured nearly a year after being banded had the skin and muscle tissue grow around the band. Although the animal appeared healthy in all other ways, the wound was not healed. I now have a policy of removing bands from *Tadarida* that are recaptured. Until a better method of identification becomes available, adult Molossids should not be banded unless doing so is absolutely vital to the study; afterwards, attempts should be made to recapture the animals and remove the bands. I have also banded *Tadarida* as pups. Bats banded at this early age tolerate bands much better. I have not recaptured any animals banded in this

manner that showed evidence of injury. Captive *Tadarida* that I banded as pups show no ill effects.

Conclusion

Bat houses with the proper treatment and modifications for central Florida's climate can provide the animals with a sufficient temperature profile to prevent heat stress. A multi-chamber bat house that is painted dark brown, equipped with ventilation slots, and mounted in a west or northwest orientation on a pole is the most likely type of bat house to become occupied in this area (see Appendix D). The real limiting factor in central Florida bat house occupation occurs during low temperature periods. During severe low temperatures, *Nycticeius* roosts elsewhere (they are not in bat houses in large numbers) and *Tadarida* will succumb to cold stress if temperatures drop below 0^{0}C for several hours. Fortunately these events are infrequent and of short duration in central Florida.

If placed prior to an eviction bat houses can be used as a management tool by providing bats with acceptable alternate roost sites. However, properly constructed and placed bat houses will only be occupied if bats need a new roost and suitable alternate roosts are unavailable. After maternity season, juvenile males may be likely to colonize a new roost such as a bat house. My records indicate most new bat houses first become occupied between the months of November and March.

Unlike Hermanson and Wilkins (1986) in their north Florida study, I did not have difficulty finding maternity colonies of *Tadarida* in the central Florida area. Although many of the colonies were considered nuisance colonies, several were tolerated and no plans exist at the present time for their eviction. Animals that are content and not harassed at their present roost site, will continue to be faithful to that site until it is no longer available.

However, many smaller colonies, particularly those in private residences are not tolerated and are usually evicted once the home owner realizes bats are present. Bat houses can be an important tool in bat management and conservation in situations such as this. Without the availability of alternate roost sites, evicted bats will be forced to move into suboptimal areas resulting in increased mortality and decreasing population numbers. For example, the north crevice at SCC was used only for a short time during the eviction at that site. Occupancy at this location was suboptimal. Occupation attempts in such an area proved fatal for three *Nycticeius* (two adult females and 1 juvenile) when their wings were caught on the metal flashing that surrounded the roost entrance. Metal flashing also caused permanent wing injury to at least one female *Tadarida* trying to reenter an excluded area. As noted earlier, over 30 pregnant *Nycticeius* died when they attempted to occupy an elevator shaft on the SCC campus.

Urban bats are not the only bat species in need of adequate alternate roost sites. Bats that roost in trees and abandoned buildings, avoiding human

populations, are also in danger of potential decline through the lack of roost sites. Many tree dwelling bats use hollows in trees located in swamps and mature forests. Areas that support trees that meet these standards are becoming more and more scarce in states such as Florida where the human population has increased by an average of 20,187 people every month from 1990-1995 (Regional Planning Council, pers. comm.).

In general, bats and humans don't mix well and humans are not making it easy for most bat species to exist. More needs to be done to learn the population status and roosting needs of Florida's bats. Bat houses have the potential to provide these animals with roost sites when their natural roosts are no longer common or available. Plans are currently underway to build a new roost structure for a central Florida colony of *Corynorhinus* (FCREPA status: rare). Other bats such as *Eumops* and *Artibeus* in south Florida would certainly benefit from research to learn more about the potential of bat house use in their conservation. This work needs to be done before the human population increases so much that these sensitive species undergo further decline due to lack of adequate roosting sites.

Literature Cited

ANONYMOUS. 1997. Bat house success in North Port. The Night Flyer, 2(1):1-3.

[BCI] BAT CONSERVATION INTERNATIONAL. 1993. The bat house study. Bats, 11(1):4-11.

BAUDINETTE, R.V., R.T. WELLS, K.T. SANDERSON, AND B. CLARK. 1994. Microclimate conditions in maternity caves of the Bent-winged bat, *Miniopterus schreibersii*: An attempted restoration of a former maternity site. Wildlife Research, 21:607-619.

CHEN, E., AND J.F. GERBER. 1990. Climate. Pp 11-34 *in* Ecosystems of Florida (R.L. Myers and J.J. Jewel, eds.). University of Central Florida Press, Orlando, Florida, 764pp.

FARGO, W.G., 1929. Bats of Indian Key, Tampa Bay, Florida. Journal of Mammalogy, 10(3):203-205.

FRY, J. C.1993. One-way analysis of variance. pp 1-40 *in* Biological data analysis (J.C. Fry, ed.). Oxford University Press Inc., New York, 418 pp.

HERMANSON, J. W., AND K. T. WILKINS. 1986. Pre-weaning mortality in a Florida maternity roost of *Myotis austroriparius* and *Tadarida brasiliensis*. Journal of Mammalogy, 67:751-754.

HERREID, C. F. II., 1967. Temperature regulation, temperature preference and tolerance, and metabolism of young and adult Free-tailed bats. Physiological Zoology, 40(1):1-23.

HILL, J.E., AND J.D. SMITH, 1984. Bats: A natural history. University of Texas Press, Austin, Texas, 243 pp.

JENNINGS, W. L. 1958. The ecological distribution of bats in Florida. Ph. D. dissert., University of Florida, Gainesville, Florida, 125pp.

KUNZ, T.H. 1974. Feeding ecology of a temperate insectivorous bat (*Myotis velifer*). Ecology, 55:693-711.

KUNZ, T.H., 1980. Daily energy budgets of free-living bats. Pp 369-392 *in* Fifth International Bat Research Conference (D.E. Wilson and A.L. Gardner, eds.). Texas Tech Press, Lubbock, Texas, 434 pp.

KUNZ, T.H., 1982. Roosting ecology. Pp 1-55 *in* Ecology of Bats (T.H. Kunz ed.). Plenum Publishing Co., New York, 425 pp.

KUNZ, T. H., 1995. Postnatal growth and development in the Mexican free-tailed bat (*Tadarida brasiliensis mexicana*). Birth size, growth rate and age estimation. Journal of Mammalogy, 76:769-783.

LICHT, P., AND P. LEITNER. 1967. Behavioral responses to high temperatures in three species of california bats. Journal of Mammalogy, 48:51-61.

MCNAB, B.K. 1982. Evolutionary alternatives in the physiological ecology of bats. Pp 151-200 *in* Ecology of Bats (T.H. Kunz ed.). Plenum Publishing Co., New York, 425 pp.

RUDOLPH, D.C., R.N. CONNER, AND J.TURNER. 1990. Competition for Red-cockaded woodpecker roost and nest cavities: Effects of resin age and entrance diameter. Wilson Bulletin, 102(1):23-36.

STUDIER, E.H. 1981. Energetic advantages of slight drops in body temperature in Little brown bats, *Myotis lucifugus*. Comparative Biochemistry and Physiology, 70A:537-540.

TUTTLE M.D., AND D.L. HENSLEY, 1993. The bat house builders handbook. University of Texas Press, Austin, Texas, 34pp.

VAUGHAN, T.A. 1986. Mammalogy. Saunders College Publishing, Philadelphia, 576 pp.

WATKINS, L.C. 1972. *Nycticeius humeralis*. Mammalian Species, 23:1-4.

WILKINS, K.T. 1989. *Tadarida brasiliensis*. Mammalian Species, 331:1-10.

TABLES

Table 1. Bat species reported to occur in Florida based on FCREPA, 1992; Brown, 1987; Jennings, 1958; Davis, 1959; and Finn, unpublished.

FAMILY	GENUS	SPECIES	SUBSPECIES	BS *	COMMON NAME	FCREPA STATUS	ABUNDANCE	DISTRIBUTION
Molossidae	*Tadarida*	*brasiliensis*	*cynocephala*	C	Brazilian free-tail	undetermined	C	state wide
	Eumops	*glaucinus*	*floridanus*	C	Wagners Mastiff bat	threatened	R	southern FL
	Molossus	*molossus*	*tropidorhynchus*	C	Pallas' bat		C	southern FL
Vespertillionidae	*Eptesicus*	*fuscus*	*fuscus*	C	Big brown bat	undetermined	R	northern 2/3
	Eptesicus	*fuscus*	*osceolus*	C	Big brown bat	undetermined	R	southern FL
	Lasionycteris	*noctivagans*	-----		Silver-haired bat		R	panhandle
	Lasiurus	*borealis*	*borealis*	C	Red bat		C	northern 2/3
	Lasiurus	*cinereus*	*cinereus*		Hoary bat		C	northern 1/3
	Lasiurus	*intermedius*	*floridanus*	C	Yellow bat	undetermined	A	statewide
	Lasiurus	*seminolis*	-----	C	Seminole bat		C	statewide
	Myotis	*austroriparius*	*austroriparius*	C	Southeastern Myotis	undetermined	A	northern 2/3
	Myotis	*grisescens*	-----	C	Grey bat	endangered	R	W. panhandle
	Myotis	*keenii*	*septentrionalis*		Keens bat	rare	R	W. panhandle
	Myotis	*lucifugus*	*lucifugus*		Little brown bat		R	northern border
	Myotis	*sodalis*	-----		Indiana bat	endangered	R	W. panhandle
	Nycticeius	*humeralis*	*humeralis*	C	Evening bat		C	northern 2/3
	Nycticeius	*humeralis*	*subtropicalis*	C	Evening bat		C	southern FL
	Pipistrellus	*subflavus*	*floridanus*	C	Eastern pipistrelle		C	peninsular FL
	Pipistrellus	*subflavus*	*subflavus*	C	Eastern pipistrelle		C	panhandle
	Corynorhinus	*rafinesquii*	*macrotis*	C	Big-eared bat	rare	U	northern 2/3
Phyllostomidae	*Artibeus*	*jamaicensis*	*parvipes*	C	Antillean Fruit bat		R	Key West

* BS = breeding status
C = confirmed breeding status
A=Abundant
C=Common
R=Rare
U=Unknown abundance

Table 2. Study sites in central Florida used to evaluate various aspects of bat house design and placement.

COUNTY	CITY	LOCATION	Date First house Placed	Date Modified	Closest Water Source	Date Occupied	Style** Occupied	Species
Orange	Winter Park	Rollins College*	8-26-93	10-13-96	15.2 m	Oct. 1996	1	*N.h*
	Winter Park	Seckbach	1-15-94	-----	0.15 km	-----	-----	-----
	Oviedo	Oviedo H.S.	9-15-94	-----	<0.3 km	-----	-----	-----
	Orlando	U.C.F.	9-21-93	7-19-95	0.15 km	-----	-----	-----
Seminole	Sanford	I.F.A.S.	2-13-94	5-4-96	0.15 km	-----	-----	-----
	Sanford	Central FL Zoo	2-11-94	5-35-96	<0.15 km	-----	-----	-----
	Sanford	Seminole C.C.*	5-13-94	4-25-95	<0.15 km	5-5-95	1&2	*N.h/T.b.c.*
	Sanford	Aikins*	6-27-94	-----	<0.15 km	late winter 1995\96	1	*N.h/T.b.c.*
Volusia	Deltona	Finn*	3-25-94	6-19-96	15.2 m	6-27-96	2	*N.h*
	Orange City	Stevens	1990	5-7-94	<0.15 km	Jan 1993	2&3	*N.h/T.b.c.*
	Lake Helen	Hill*	6-30-93	-----	<0.15 km	-----	-----	-----
Lake	Paisley	Paisley*	11-95	-----	15.2 m	May 1996	4	*N.h*
	Mt.Dora	Mt. Dora HS*	4-15-95	-----	< 0.15 km	-----	-----	-----

* also site of a Roost

** see Tuttle and Hensley, 1993 for diagram of bat house styles

1: large maternity

2: small maternity

3: old style

4: modification of 1

LOCATION	Texas Number	Treatment	Orientation	Placement	Date	Large Maternity Number	Treatment	Orientation	Placement	Date
Rollins College	1	white paint,G	SE/NW	phone poles	12-29-93	2	white paint	SE/NW	light pole	8-26-93
Seckbach	-----	-----	-----	-----	-----	2	brown paint,G	S/N	chimney	1-15-94
Oviedo H.S.	-----	-----	-----	-----	-----	2	stain,M	SE/NW	phone pole	9-15-94
U.C.F.	1	astec coating,G	SE/NW	phone pole	9-21-93	2	white paint, SF	SE/NW	phone pole	9-21-93
U.C.F. (modified)	-----	-----	SW/NE	-----	7-19-95	2	brown paint	SSE/NNW	phone pole	7-19-95
I.F.A.S.	1	stain	SE/NW	phone pole	3-8-94	2	white paint,G	SE/NW	phone pole	2-13-94
I.F.A.S.(modified)	-----	-----	-----	-----	-----	2	brown paint	SE/NW	phone pole	5-4-96
Central FL Zoo	-----	-----	-----	-----	-----	2	astec coating,G	SE/NW	palm tree	2-11-94
CFZ (modified)	-----	-----	-----	-----	-----	4	brown paint,M	N/S,E/W	4x4	5-25-96
Seminole C.C.	-----	-----	-----	-----	-----	2	white paint, R	SE/NW	phone pole	5-13-94
SCC (modified)	-----	-----	-----	-----	-----	2	brown paint	SE/NW	phone pole	4-25-95
Aikins	-----	-----	-----	-----	-----	1	stain	East	building	6-27-94
Finn	-----	-----	-----	-----	-----	2	stain, G	SE/NW	pine tree	3-25-94
Finn	-----	-----	-----	-----	-----	1	stain	East	building	6-15-96
Stevens	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
Stevens	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
Hill	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
Paisley	-----	-----	-----	-----	-----	3	brown paint	SE/NW	pole	11-95
Mt. Dora	-----	-----	-----	-----	-----	1	brown astec	East	chimney	4-15-95
Total	3					32				

Key to abbreviations on tables:

E: East
G: guano bag
M: metal roof
NW: north west
N.h.: Nycticeius humeralis
N: North

R: Reflectix insulation
SE: south east
SF: styrofaom insulation
S: south
T.b.c. Tadarida brasiliensis cynocephala
W: West

Table 3. Descriptive information on location, treatment, and placement of four bat house designs: simple, small maternity, large maternity, and Texas. All houses are >15 ft above ground, placed to receive >4 hours/day of sun. Sets of two houses on poles are placed back to back to create an additional roosting chamber between houses.

	Simple					Small Maternity				
LOCATION	Number	Treatment	Orientation	Placement	Date	Number	Treatment	Orientation	Placement	Date
Rollins College	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
Seckbach	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
Oviedo H.S.	2	stain,M,G	SE/NW	phone pole	9-15-94	2	stain,M,G	SE/NW	phone pole	9-15-94
U.C.F.	2	white paint,G	SE/NW	phone pole	9-21-93	2	white paint,SF	SE/NW	phone pole	9-21-93
U.C.F. (modified)	2	brown paint	E/W	phone pole	7-19-95	2	brown paint	SE/NW	phone pole	7-19-95
I.F.A.S.	2	astec coating,G	SE/NW	phone pole	3-1-94	2	white paint	SE/NW	phone pole	3-1-94
I.F.A.S.(modified)	2	brown astec	SE/NW	phone pole	5-4-96	2	brown paint	SE/NW	phone pole	5-4-96
C.F.Z.	2	astec coating	SE/NW	palm tree	2-11-94	2	astec coating	SE/NW	palm tree	2-11-94
CFZ (modified)	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
Seminole C.C.	2	astec coating	SE/NW	phone pole	5-13-94	2	white paint, R,G	SE/NW	phone pole	5-13-94
SCC (modified)	2	brown astec	SE/NW	phone pole	4-25-95	2	brown paint	SE/NW	phone pole	2-3-96
Aikins	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
Finn	2	stain	SE/NW	pine tree	6-4-94	2	stain	SE/NW	pine tree	6-4-94
Finn (modified)	-----	-----	-----	-----	-----	4	brown paint, M	N/S, E/W	4x4 poles	6-19-96
Stevens	-----	-----	-----	-----	-----	6	brown paint, M	N/S, E/W	4x4 poles	5-7-95
Hill	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
Paisley	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
Mt. Dora	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
Total	18					28				

Table 4 Descriptive information on location, treatment, and placement of additional bat house designs (styles). Key to abbreviations given in Table 3.

Location	Number	Treatment	Orientation	Placement	Date	Style
Rollins College	-----	-----	-----	-----	-----	-----
Seckbach	-----	-----	-----	-----	-----	-----
Oviedo H.S.	-----	-----	-----	-----	-----	-----
U.C.F.	1	none	SE	tree	5-22-92	old
I.F.A.S.	-----	-----	-----	-----	-----	-----
Central FL Zoo	3	none	N,W	tree	1991	old
Seminole C.C.	1	white paint	SE/NW	phone poles	5-13-94	Square
Seminole C.C.	1	stain,G	SE/NW	phone poles	5-13-94	Florida
SCC (modified)	-----	brown paint	SE/NW	phone poles	5-4-96	Square
Aikins	-----	-----	-----	-----	-----	-----
Finn	1	none	N/A	tree	6-15-94	old
Stevens	1	none	N/A	tree	1990	old
Stevens	2	none	S/W	building/tree	1996	PVC
Hill	3	none	W,E	building/tree	6-30-93	old
Paisley	-----	-----	-----	-----	-----	-----
Mt. Dora	-----	-----	-----	-----	-----	-----
Total	13					

Table 5. Species composition, sex, number, and source of bats used in seeding experiments. See text for details on target, source, and banding.

	Number of bats									
	Tadarida		*Nycticeius*			Banded	Source	Target	Distance	
Date	♀	♂	♀	♂	Total	(Y/N)	Colony	Location	(km)	Direction
4-3-94	3	15			18	N	SCC	Finn	16.5	NE
4-10-94		16			16	N	SCC	Finn	16.5	NE
4-15-94	1	13		1	15	Y	SCC	Finn	16.5	NE
4-16-94	9	6			15	Y	SCC	Finn	16.5	NE
4-17-94	2	4	9		15	Y	SCC	Finn	16.5	NE
4-22-94	13	2			15	Y	SCC	Finn	16.5	NE
4-28-94		16			16	Y	SCC	Finn	16.5	NE
4-30-94	1	12	2		15	Y	SCC	Finn	16.5	NE
5-4-94	7	8			15	Y	SCC	Finn	16.5	NE
5-6-94		14			14	N	SCC	Finn	16.5	NE
8-9-96	(28)*				28	N	Williamsburg	Seck	40	NE
8-25-96	5	11	4		20	N	SCC	Finn	16.5	NE
10-29-96	90	20	1	1	113	N	Wagoner**	Finn	8	E
Totals	131	137	16	2	315	106				
%	25.9	74.1	93.8	6.25						

* bats were not sexed on this date and are not included in the totals by sex.

** 1 male *Myotis austroriparius* was also included on this date

Table 6. Bat house relocation experiment Seminole Community College, Sanford, FL. Bats were evicted from an existing colony in a building and relocated to bat houses one quarter mile away

	Number of bats									
	Tadarida				*Nycticeius*					
	adult		juvenile		adult		juvenile			
Date	♀	♂	♀	♂	♀	♂	♀	♂	Total	Notes:
5-4-95					2				2	placed in Florida style house
5-5-95	14	44							58	5 bats in each house, 5 in each section of SQ
5-6-95	11	48							59	2 bats in each chamber of simple & maternity
5-7-95	11	113			3				127	20 bats in SSE, split others into all houses
5-8-95	8	60							68	simple and maternities
5-9-95	7	49			2				58	simple and maternities
5-10-95	6	18			1				25	all in W side of Florida house
5-11-95	2	9			2				13	large maternity
5-20-95	3	2			4				9	all in SSE
7-23-95	9		1	3	1				14	all in SSE
7-24-95	21	16	5	38	1		2		83	18 in SNW, 5 in each chamber of other maternitys
Totals	92	359	6	41	16	0	2	0	516	
%	20.4	79.6	14.6	87.2	100		100			

Table 7. Bat roost choice controlled tests. Results, frequencies and Chi-square p-values for pooled data (6 replications) from the first set of tests. The 95% Chi-square test statistic is 16.92 with 9 degrees of freedom. Additional Chi-square values were calculated for Tadarida only since the small numbers of Nycticeius used made statistical analysis invalid. The Chi-square value for male Tadarida was 50.64, for female Tadarida 15.33, and for all Tadarida 60.62.

	LOCATION	*Tadarida*		*Nycticeius*					Chi-Squared p value		
SUBSTRATE	IN ROOM	♀	♂	♀	♂	Total	% All	% In/On	IN only	IN/OUT	All bats
Plywood	South wall	3	18	0	0	21	23.60	27.50	0.000	0.000	0.000
Plywood	South wall	5	11	0	0	16	17.97	21.10			
1/2" Hardware cloth	North wall	2	3	0	0	5	5.60	6.60			
Fiberglass screen	North wall	1	3	0	0	4	4.50	5.30			
Guano bag	SW Corner	0	3	0	0	3	3.36	3.90			
Brick 'house'	SE Corner	0	0	0	0	0	0.00	0.00			
Nycticeius rag	NE Corner	0	0	0	0	0	0.00	0.00			
Pine bark cavity	NW Corner	1	3	7	0	11	12.40	14.50			
Behind/on		4	10	2	0	16	17.97	21.10			
None		2	10	0	1	13	14.60				
Totals		18	61	9	1	89	100	100			
			79		10						

Table 8. Bat roost choice controlled tests. Results, frequencies and Chi-square p-values for pooled data (4 replications) for second set of tests. The 95% Chi-square test statistic is 16.92 with 9 degrees of freedom. Additional Chi-square values were calculated for Tadarida only since the small numbers of Nycticeius used made statistical analysis invalid. The Chi-square value for male Tadarida was 95.69, for female Tadarida 18.67, and for all Tadarida 105.1

	LOCATION	*Tadarida*		*Nycticeius*					Chi-Squared p value		
SUBSTRATE	IN ROOM	♀	♂	♀	♂	Totals	% All	% In/On	IN only	IN/OUT	All bats
Plywood	North wall	0	2	0	0	2	3.45	6.9	0.008	0.001	0.000
Plywood	NW Corner	0	0	1	0	1	1.72	3.45			
1/2" Hardware cloth	South wall	0	2	0	0	2	3.45	6.9			
Fiberglass screen	SE Corner	0	2	0	0	2	3.45	6.9			
1/4" Hardware, pad	SW Corner	1	6	0	0	7	12.1	24.13			
Plywood, pad	South wall	0	0	0	0	0	0.00	0.00			
Fiberglass, pad	NE Corner	0	6	0	0	6	10.31	20.69			
1/2" Hardware, pad	North wall	0	0	0	0	0	0.00	0.00			
behind		2	7	0	0	9	15.52	31.03			
none		5	24	0	0	29	50				
Totals		8	49	1	0	58	100	100			
			57		0						

Table 9. Bat roost choice controlled tests. Results, frequencies, and Chi-square values for pooled data from all tests (10 replications) to determine if roost choice was influenced by orientation of roost item in the flight cage. The 95% Chi-square statistic was 16.92 with 9 degrees of freedom. The Chi-square value obtained for male Tadarida was 83.64, for female Tadarida 22.46, and 100.5 for all Tadarida. Nycticeius data were not analyzed separately due to the small number of test animals.

LOCATION	*Tadarida*		*Nycticeius*					Chi-Squared p value		
IN ROOM	♀	♂	♀	♂	Totals	% All	% In/On	IN only	IN/OUT	All bats
South wall	3	20	0	0	23	15.65	21.90	0.000	0.000	0.000
South wall	5	11	0	0	16	10.88	15.24			
North wall	2	5	0	0	7	4.76	6.67			
North wall	1	3	0	0	4	2.72	3.81			
SW Corner	1	9	0	0	10	6.80	9.52			
SE Corner	0	2	0	0	2	1.36	1.90			
NE Corner	0	6	0	0	6	4.08	5.71			
NW Corner	1	3	8	0	12	8.16	11.43			
behind	6	17	2	0	25	17.01	23.81			
none	7	34	0	1	42	28.57				
Totals	26	110	10	1	147	100	100			
		136		11						

Table 10. Data summaries for temperatures monitored at central Florida roost sites. Results of Kruskal Wallace (KW) tests performed to determine if ambient temperature and roost temperature were significantly different are presented. Percent time that roost temperature was above and below ambient and percent time that roost temperature (Tr) was above 35C and below 5C are shown. Location is given as either roost mean (Rmean) or a specific location in a roost, the first letter of each location is the orientation (south, west, north, east). The second letter is the location (wall or crevice). For Hill, R is a location beneath a metal ridge roll, and L is a location 6 inches below the ridge roll and beneath the metal roof. See Appendix A and Chapter 3 for more detail.

			Ambient				Roost				KW	% Time			
Site	Date	Location	Max	Min	Mean	Range	Max	Min	Mean	Range	Amb=Tr	Tr>amb	Tr<amb	Tr>35C	Tr<5C
Rollins	6/6/94-6/9/94	Rmean	32.78	23.41	25.94	9.37	31.07	25.2	27.37	5.87	<0.05	86.45	13.5		
Rollins	6/16/94-6/19/94	Rmean	35.16	23.65	27.04	11.51	33.24	25.42	28.36	7.82	<0.05	73.7	23		
Rollins	8/15/94-8/18/94	Rmean	31.17	23.11	26.93	8.06	51.57	19.37	28.37	32.2	<0.05	54.85	45.14	15.1	
Rollins	12/27/93-1/4/94	Rmean	25.66	13.18	19.14	12.48	22.86	14.08	17.6	8.78	>0.05	56.55	43.4		
Aikins	6/27/94-1/7/94	Rmean	36.94	23.62	28.82	13.32	43.23	23.41	30.33	19.82	<0.05	81.25	18.75	23.8	
Aikins	8/27/94-9/5/94	Rmean	37.16	23.29	27.94	13.87	38.08	22.82	27.68	15.26	>0.05	42.15	56.05	4.6	
Aikins	2/27/95-3/2/95	Rmean	28.92	14.6	20.99	14.32	30.26	14.27	21	15.99	>0.05	34.6	64.1		
Hill	3/5/94-3/7/94		33.46	15.14	27.7	18.32					<0.05				
		SC					34.19	17.07	26.06	17.12	>0.05	71.4	28.6		
		WR					45.49	16.11	28.01	29.38	<0.05	94.8	5.1	16.3	
		WL					39.99	23.04	30.83	16.95	<0.05	96.9	3.1	17.3	
		NW					38.16	15.02	26.46	23.14	<0.05	82.6	17.3	9.2	
		NC					33.48	16.56	24.47	16.92	>0.05	57.1	42.8		
Hill	9/7/94-9/14/94		34.25	23.2	26.94	11.05					<0.05				
		SC					36.02	21.46	26.75	14.56	>0.05	36.3	63.7	1.2	
		WR					47.83	21.19	27.85	26.64	<0.05	45.2	54.8	14.8	
		WL					41.92	23.11	29.19	18.81	<0.05	86.9	11.9	13.1	
		NW					37.97	21.61	26.57	16.36	>0.05	29.8	70.2	2.9	
Hill	2/24/95-2/27/95		26.1	12.76	18.89	13.34					>0.05				
		SC					24.9	11.62	18.27	13.28	>0.05	28.17	71.83		
		WR					32.76	9.15	17.78	23.61	>0.05	19.72	80.3		
		WL					27.19	12.85	19.31	14.34	>0.05	70.4	29.6		
		NC					23.28	15.47	19.39	7.81	>0.05	66.2	33.8		

			Ambient				Roost				KW	% Time			
Site	Date	Location	Max	Min	Mean	Range	Max	Min	Mean	Range	Amb=Tr	Tr>amb	Tr<amb	Tr>35C	Tr<5C
SCC	2/7/95-2/14/94		24.88	6.85	16.09	18.03									
		SC					27.65	13.1	19.87	14.55	<0.05	95.1	4.9		
		SW					26.76	11.75	19.38	15.01	<0.05	96.9	3.04		
		WC					25.11	11.61	17.72	13.5	<0.05	81.7	18.3		
SCC	2/18/94-2/21/94		18.95	7.22	11.67	11.73									
		SC					25.47	14.35	18.46	11.12	<0.05	100	0		
		SW					24.59	13.29	17.98	11.3	<0.05	100	0		
		WC					23.89	11.51	15.31	12.38	<0.05	94.4	5.6		
		WW					21.4	10.54	15.88	10.86	<0.05	100	0		
		NC					17.36	8.69	11.81	8.67	>0.05	59.2	40.8		
		NW					17.37	7.85	11.54	9.52	>0.05	52.1	47.9		
SCC	3/23/94-4/1/94		32.72	13.31	22.95	19.41									
		SC					33.46	19.2	26.42	14.26	<0.05	96.3	3.7		
		SW					33.36	17.45	25.02	15.91	<0.05	90.3	9.7		
		WC					35.23	18.2	26.12	17.03	<0.05	87.9	12	0.04	
		WW					32.28	17.03	24.36	15.25	<0.05	81	18.9		
		NC					30.45	17.16	23.59	13.29	>0.05	65.3	34.7		
		NW					31.3	15.48	23.06		>0.05	58.3	41.7		
SCC	6/3/94-6/6/94		28.16	22.5	23.8	5.66									
		SC					30.06	23.82	26.32	6.24	<0.05	94.4	5.6		
		SW					28.29	23.39	24.83	4.9	<0.05	78.8	18.3		
		WC					31.54	23.66	26.33	7.88	<0.05	78.8	18.3		
		WW					27.6	22.7	24.62	4.9	<0.05	92.9	7		
		NC					28.41	23.38	25.44	5.03	<0.05	92.9	7		
		NW					27.7	22.35	24.67	5.35	<0.05	83.1	16.9		

			Ambient				Roost				KW	% Time			
Site	Date	Location	Max	Min	Mean	Range	Max	Min	Mean	Range	Amb=Tr	Tr>amb	Tr<amb	Tr>35C	Tr<5C
SCC	7/15/94-7/18/94		29.92	23.21	25.82	6.71									
		SC					32.92	26.47	29.37	6.45	<0.05	98.5	1.5		
		SW					29.7	24.53	27.23	5.17	<0.05	88.2	11.8		
		WC					38.24	28.75	32.1	9.49	<0.05	100	0	13.25	
		WW					30.07	24.68	27.09	5.39	<0.05	91.2	8.8		
		NW					30.33	25.16	27.75	5.17	<0.05	92.6	7.3		
SCC	9/15/94-9/19/94		28.76	22.6	24.66	6.16									
		SC					32.87	24.42	28.12	8.45	<0.05	100	0		
		SW					31.61	22.89	26.65	8.72	<0.05	97.9	2.2		
		WC					34.68	25.04	20.29	9.64	<0.05	100	0		
		WW					29.05	23.14	25.99	5.91	<0.05	92.6	6.4		
SCC	9/30/94-10/4/94		29.77	20.93	24.02	8.84									
		SC					33.57	23.75	27.54	9.82	<0.05	96.8	3.2		
		SW					31.16	22.13	26.05	9.03	<0.05	91.5	7.4		
		WC					33.19	23.04	27.37	10.15	<0.05	96.8	3.2		
		WW					29.57	22.38	25.43	7.19	<0.05	86.2	13.8		
		NC					28.51	23.89	25.91	4.62	<0.05	88.3	10.6		
		NW					28.09	22.7	25.28	5.392	<0.05	86.2	13.8		
SCC	1/12/95-1/23/95		24.67	8.12	14.98	16.55									
		SC					30.35	13.54	19.39	16.81	<0.05	97.7	2.3		
		SW					27.7	12.8	18.81	14.9	<0.05	97.7	2.3		
		WC					25.66	12.78	17.09	12.88	<0.05	89.2	10.8		
		WW					23.5	12.63	17.6	10.87	<0.05	91.1	8.9		
		NC					21.73	12.26	16.43	9.47	<0.05	76.4	23.2		

			Ambient				Roost				KW	% Time			
Site	Date	Location	Max	Min	Mean	Range	Max	Min	Mean	Range	Amb=Tr	Tr>amb	Tr<amb	Tr>35C	Tr<5C
SCC	8/3/95-8/17/95		35.57	24.21	29.17	11.36									
		SC					37.73	26.94	31.32	10.79	<0.05	80.4	19.3	6.3	
		SW					37.06	24.2	30.15	12.86	<0.05	68.3	31.4	4.8	
		WC					41.74	26.39	32.51	15.35	<0.05	84.3	15.7	2.12	
		WW					36.31	24.47	30.32	11.84	<0.05	68.9	30.8	0.3	
		NC					33.48	25.26	29.63	8.22	<0.05	61	38.9		
		NW					33.84	24.51	29.54	9.33	>0.05	58.3	41.7		
SCC	11/24/95-12/3/95		26.45	8.98	17.87	17.47									
		SC					33.04	16.02	23.47	17.02	<0.05	95.7	3.8		
		SW					29.62	16.1	22.07	13.52	<0.05	95.2	4.7		
		WC					27.79	13.32	20.47	14.47	<0.05	87.1	12.9		
		WW					26.67	12.27	19.43	14.4	<0.05	78.9	21.1		
		NC					23.82	12.37	18.25	11.45	>0.05	63.2	36.4		
		NW					24.23	11.38	18.09	12.85	>0.05	63.2	36.4		
	12/3/95-12/11/95		34.42	4.057	19.14	30.36									
SCC		SC					39.41	12.3	22.49	27.11	<0.05	95.9	4.1	3.1	
		SW					45.66	7.83	23.48	37.83	<0.05	96.9	3.1	12.8	3.6
		WC					56.13	3.14	24.05	52.99	<0.05	45.6	54.4	18.5	

Table 11. R-squared values obtained from multiple regression analysis of the influence of the parameters time (T), ambient (A), and solar radiation (SR), on the variabilty of roost temperature at Rollins, Aikins, and Hill. See Table 10 for explaination of locations.

			Regression Analysis R-squared values					
Site	Date	Location	T/A/SR	Time	Amb	SR	Time/Amb	SR/Amb
Rollins	6/6/94-6/9/94	Rmean	82.12	50.08	67.22	0	73.49	76.74
Rollins	6/16/94-6/19/94	Rmean	90.51	57.99	46.76	1.3	77.1	70.05
Rollins	8/15/94-8/18/94	Rmean	----	1.6	40.4	----	40.56	----
Rollins	12/27/93-1/4/94	Rmean	72.46	0	56.99	3.48	62.3	69.85
Aikins	6/27/94-1/7/94	Rmean	95.29	12.18	95.03	6.41	94.97	95.34
Aikins	8/27/94-9/5/94	Rmean	----	0	49.56	----	57.47	----
Aikins	2/27/95-3/2/95	Rmean	98.19	19.72	97.73	33.06	97.9	97.97
Hill	3/5/94-3/7/94	Rmean	----	7.12	90.12	----	90.19	----
		SC	----	12.41	83.74	----	85.42	----
		WR	----	1.84	86.89	----	87.29	----
		WL	----	8.38	65.98	----	66.64	----
		NW	----	8.03	90.41	----	90.65	----
		NC	----	12.6	90.61	----	92.18	----
Hill	9/7/94-9/14/94	Rmean	----	6.17	94.02	----	93.38	----
		SC	----	5.04	87.51	----	87.44	----
		WR	----	3.65	93.1	----	93.25	----
		WL	----	8.66	78.82	----	79.31	----
		NW	----	6.41	93.38	----	93.36	----
Hill	2/24/95-2/27/95	Rmean	95.93	7.25	95.03	35.34	95.06	95.68
		SC	95.63	6.16	92.06	26.14	91.98	95.32
		WR	95.1	5.84	93.98	54.39	93.9	95.15
		WL	83.57	8.15	75.99	15.99	76.27	81.9
		NC	46.75	0.92	6.7	4.76	5.99	42.62

Table 12. R-squared values obtained from multiple regression analysis of the influence of the parameters time (T), ambient (A), and solar radiation (SR), on the variability of roost temperature at Seminole Community College.

			Regression Analysis R-squared values		
Site	Date	Location	Time	Amb	Time/Amb
SCC1	2/7/95-2/14/94				
		SC	0	65.88	68.8
		SW	0	73.26	73.75
		WC	0	72.56	72.5
SCC2	2/18/94-2/21/94				
		SC	14.78	42.81	60.88
		SW	5.05	61.89	68.57
		WC	27.77	41.81	73.81
		WW	1.03	63.09	64.92
		NC	10.61	55.5	69.53
		NW	1.97	78.31	81.49
SCC3	3/23/94-4/1/94				
		SC	14.54	75.43	75.35
		SW	15.89	86.12	86.27
		WC	16.43	68.68	68.44
		WW	20.78	89.06	89.09
		NC	27.86	70.94	73.14
		NW	25.81	82.77	83.67
SCC4	6/3/94-6/6/94				
		SC	0.87	27.27	25.87
		SW	1.71	36.86	37.42
		WC	0.4	24.92	28.79
		WW	0.78	50.38	52.82
		NC	0.46	34.06	33.95
		NW	1.34	43.34	44.53
SCC5	7/15/94-7/18/94				
		SC	21.3	17.19	28.09
		SW	13.05	25.24	30.61
		WC	17.5	12.84	21.55
		WW	19.9	33.02	41.98
		NW	20.5	27.01	35.46

			Regression Analysis R-squared values		
Site	Date	Location	Time	Amb	Time/Amb
SCC6	9/15/94-9/19/94				
		SC	0.03	53.68	56.39
		SW	0.04	59.97	65.78
		WC	2	37.29	35.99
		WW	0.65	61.32	63.27
SCC7	9/30/94-10/4/94				
		SC	3.16	27.32	49.4
		SW	0.06	43.44	58
		WC	0	34.37	42.57
		WW	3.75	65.66	70.23
		NC	5.94	47.04	46.71
		NW	3.43	67.54	72.82
SCC8	1/12/95-1/23/95				
		SC	21.95	71.02	70.84
		SW	18.04	76.85	77.12
		WC	29.37	69.34	70.42
		WW	30.58	88.63	88.98
		NC	47.4	69.2	77.33
SCC9	8/3/95-8/17/95				
		SC	70.64	99.1	99.24
		SW	75.48	97.63	98.74
		WC	81.18	92.79	96.32
		WW	81.15	92.97	96.44
		NC	79.14	94.02	96.52
		NW	68.26	99.35	99.33
SCC10	11/24/95-12/3/95				
		SC	19.01	56.78	63.39
		SW	22.34	66.11	72.63
		WC	11.05	41.71	43.87
		WW	20.67	55.35	61.95
		NC	19.79	35.99	43.98
		NW	16.31	48.83	53.25
SCC11	12/3/95-12/11/95				
		SC	2.51	59.68	63.64
		SW	0.43	57.74	57.79
		WC	1.98	47.3	48.08
		WW	3.71	81.02	81.18
		NC	13.16	56.18	58.88
		NW	11	78.59	79.74
SCC11a	3 Dec-11 Dec	SC	6.35	80.53	81.81
		SW	2.08	63.15	66.55
		WC	1.97	51.38	53.58

Table 13: R-squared values obtained from multiple regression analysis to determine how the variables time (T), solar radiation (SR) and ambient temperature (A) influence the variability in mean bat house temperature at Seminole Community College. The first letter in location identifies size (B=simple, S=small, L=large), the last two letters identify orientation (southeast or northwest).

				Regression Analysis R-squared values				
Date		Location	T/A/SR	Time	Amb	SR	Time/Amb	SR/Amb
May 1994		Small	96.77	18.1445	96.83	50.6	96.817	96.785
	1	SSE	96.89	17.79	96.92	53.32	96.924	96.897
		SNW	96.55	18.49	96.6	48.76	96.564	96.581
July 1994		Small	93.77	0.634	93.18	29.89	92.994	93.85
	2	SSE	97.17	2.06	95.39	27.11	95.529	96.86
		SNW	97.78	2.68	92.87	23.76	93.178	95.203
		Large	96.95	1.15	95.74	28.35	96.908	96.9
		LSE	97.19	0.644	96.4	30.01	96.345	97.22
		LNW	96.2	1.77	94.39	26.34	94.459	95.992
July 1994		Simple	-----	0	98.61	-----	98.626	-----
	3	BSE	-----	0	98.66	-----	98.658	-----
		BNW	-----	0	97.92	-----	97.959	-----
		Small	-----	0	92.53	-----	92.576	-----
		SSE	-----	0	94.37	-----	94.406	-----
		SNW	-----	0	90.28	-----	90.342	-----
		Large	-----	11.63	88.34	-----	91.117	-----
		LSE	-----	10.38	89.58	-----	91.749	-----
		LNW	-----	12.09	86.4	-----	89.938	-----
Sept 1994		Simple	-----	0	98.94	-----	99.007	-----
	4	BSE	-----	0	98.94	-----	98.95	-----
		BNW	-----	0	98.53	-----	98.672	-----
		SNW	-----	0	93.24	-----	93.309	-----
		Large	-----	0	92.5	-----	92.58	-----
		LSE	-----	0	91.86	-----	91.86	-----
		LNW	-----	0	92.8	-----	92.999	-----
March 1995		Simple	99.63	62.16	99.63	0.375	99.628	99.625
	5	BSE	99.54	61.59	99.46	1.028	99.455	99.541
		BNW	99.67	62.62	99.61	0	99.62	99.667
		LNW	99.08	64.37	99.67	0	99.774	99.04

Regression Analysis

R-squared values

Date		Location	T/A/SR	Time	Amb	SR	Time/Amb	SR/Amb
July 1995		Small	97.4	6.797	94.65	40.94	94.651	97.408
	6	SSE	97.63	7.439	95.43	42.84	95.463	97.611
		SNW	96.88	6.265	93.56	39.03	93.53	96.895
		Large	91.22	4.168	90.85	45.45	90.784	91.271
		LSE	92.76	5.999	92.67	56.07	92.766	92.623
		LNW	90.6	4.528	89.65	41.76	89.58	90.655
July 1995		Simple	98.85	0	98.6	67.34	98.861	98.608
	7	BSE	96.67	0	95.9	73.56	93.935	96.396
		BNW	96.91	0	95.5	56.69	96.063	96.754
		Small	93.34	2.161	87.6	52.33	90.475	88.567
		SSE	96.86	0	93.5	49.88	96.793	94.256
		SNW	86.1	14.41	68.75	45.73	83.543	68.486
		Large	97.31	0.256	93.77	50.47	95.233	96.864
		LSE	98.18	0	96.03	55.33	97.063	97.797
		LNW	95.36	0.709	90.21	45.24	92.118	94.861
Oct. 1995		Simple	98.01	0	91.66	50.77	99.615	97.974
	8	BSE	96.93	0	76.5	70.71	76.403	96.901
		BNW	97.46	0	96.97	20.49	97.01	97.418
		Small	50.89	8.414	39.6	15.82	50.36	40.027
		SSE	46.18	8.839	34.81	13.39	45.884	35.009
		SNW	47.85	6.667	38.42	15.99	47.183	38.992
		Large	96.33	0	96.26	23.07	96.238	96.35
		LSE	96.63	0	95.66	35.24	95.636	96.643
		LNW	95.14	0	92.34	12.43	92.301	95.163
Nov. 1995		Simple	98.6	2.667	93.97	16.72	94.044	98.441
	9	BSE	96.76	2.717	74.85	40.22	74.999	96.308
		BNW	98.83	1.878	96.5	0.013	96.492	98.831
		Small	78.5	3.679	69.9	0.731	70.417	78.133
		SSE	76.51	3.918	70.73	0	71.33	76.046
		SNW	78.25	3.39	66.44	2.194	66.873	77.962
		Large	97.92	2.725	97.83	4.391	97.919	97.833
		LSE	97.75	2.715	95.81	11.23	95.893	97.623
		LNW	97.37	2.593	95.52	0.239	95.584	97.324

Regression Analysis

R-squared values

Date		Location	T/A/SR	Time	Amb	SR	Time/Amb	SR/Amb
Jan. 1996		Simple	-----	13.54	88.67	-----	89.169	-----
	10	BSE	-----	12.19	73.52	-----	74.465	-----
		BNW	-----	13.8	99.69	-----	99.71	-----
		Small	-----	59.64	81.38	-----	85.292	-----
		SSE	-----	60.73	75.63	-----	81.334	-----
		SNW	-----	58.08	78.65	-----	82.559	-----
		Large	-----	17.5	97.23	-----	98.22	-----
		LSE	-----	15.45	96.56	-----	97.153	-----
		LNW	-----	18.66	92.33	-----	93.612	-----
Feb 1996		Simple	99.3	12.35	93.24	10.98	93.221	99.291
	11	BSE	98.61	10.74	82.53	23.14	82.489	98.587
		BNW	99.67	13.51	99.51	0.061	99.516	99.667
		Small	86.43	23.94	83.27	0	86.197	83.559
		SSE	85.13	24.77	81.44	1.722	84.769	81.713
		SNW	84.23	21.73	79.46	0.358	81.837	82.001
		Large	96.3	14.02	96.11	0.103	96.161	96.249
		LSE	98.42	12.62	97.78	2.724	97.778	98.423
		LNW	91.46	14.82	89.16	0.061	89.385	91.275
May 1996		Simple	98.4	3.374	98.27	65.27	98.333	98.379
	12	BSE	93.32	2.514	93.04	54.37	92.999	93.276
		BNW	95.6	3.904	94.03	70.49	94.152	95.639
		Small	89.51	2.812	89.13	67.47	89.063	89.536
		SSE	75.76	2.329	76.26	51.42	76.038	75.989
		SNW	91.56	3.897	90.6	71.76	90.492	91.648
		Large	96.23	2.011	93.83	64.44	93.778	94.053
		LSE	94.04	2.102	96.25	62.97	96.216	96.252
		LNW	89.67	1.847	89.01	64.26	88.913	89.655

Table 14. Comparison of temperatures in bat houses at Seminole Community College prior to bat occupation. All bat houses are painted white. Simple house are painted with insulative paint, small and large maternity houses have Reflectix insulation in two chambers. See Appendix A for more detail. Location abbreviations are explained in Table 11. t=roost temperature, r=range

						% time		
Date		Max	Mean	Min	t>35C	mean>amb	max>amb	min<amb
May	Amb	34.94	25.92	21.78				
1994	Small	40.69	26.17	20.7	15.9% (r=35.27-40.69)	59.4	79.7	81.2
	SSE	40.69	26.21	20.7	14.5% (r=35.29-40.69)	59.4	76.8	79.7
	SNW	39.86	26.24	20.8	8.7% (r=35.2-39.18)	57.9	71	76.8
July	Amb	35.28	27.47	21.51				
1994	Small	34.6	26.94	21.06		57.3	64	89.3
	SSE	34.57	26.96	21.24		54.6	58.6	85
	SNW	34.6	26.92	21.06		54.6	62.6	86.7
July	Amb	35.45	29.65	21.67				
1994	Small	33.2	26.06	21.2		61.7	69.15	100
	SSE	33.2	26.13	21.29		62.7	63.83	94.68
	SNW	32.86	25.99	21.2		59.57	69.15	100
Sept.	Amb	29.44	24.25	20.39				
1994	SNW	29.46	23.89	19.88		52.05	61.64	100
July	Amb	35.28	27.47	21.51				
1994	large	36.23	27.02	20.9	5.3% (r=35.18-36.23)	53.3	78.7	98.6
	LSE	35.9	27.05	21.09	5.3% (r=35.18-35.9)	52	74.6	94.6
	LNW	36.23	26.98	20.9	2.6% (r=35.84-36.23)	52	64	92
July	Amb	35.45	26.65	21.67				
1994	large	34.78	25.69	21.33		51.1	86.67	91.1
	LSE	34.01	25.74	21.49		53.3	86.67	80
	LNW	34.78	25.6	21.33		51.1	80	86.7
Sept.	Amb	29.44	24.25	20.39				
1994	large	33.76	24.14	19.49		45.1	78.08	95.89
	LSE	33.76	24.19	19.67		45.21	76.71	94.52
	LNW	32.42	24.08	19.49		31.51	68.49	95.89
March	Amb	28.38	17.46	7.87				
1995	LNW	27.01	17.15	7.1		39.66	65.52	99.14
July	Amb	35.45	26.65	21.67				
1994	Simple	33.94	25.75	21.01		1.06	9.57	100
	BSE	33.94	25.85	21.01		1.06	9.57	100
	BNW	33.4	25.61	21.04		0	2.13	100

Date		Max	Mean	Min	t>35C	% time mean>amb	max>amb	min<amb
Sept.	Amb	29.44	24.25	20.39				
1994	Simple	29.47	23.72	19.81		1.37	9.59	100
	BSE	29.47	23.8	19.81		5.48	9.59	98.63
	BNW	29.04	23.66	19.89		0	2.74	100
March	Amb	29.38	17.46	7.87				
1995	Simple	27.2	16.96	6.79		2.59	17.24	100
	BSE	27.2	17.02	6.79		6.9	12.93	94.83
	BNW	27.1	16.94	7.02		1.72	6.03	100

Table 15. Comparison of temperatures in Seminole Community College simple style bat houses. Bat houses were modified July 1995. Modifications included brown paint, enclosing sides and addition of metal roof. t=roost temperature, r=range

							% time			
		Max	Mean	Min	t<5C	t>35C	mean>amb	max>amb	min<amb	Comments on Bats
July 1995	Amb	34.58	25.94	18.37						
	Simple	39.07	26.62	19.19		5.3% (r=35.5-39.1)	95.79	100	51.58	No bats
	BSE	36.5	26.82	19.19		5.3% (r=35.5-36.5)	96.84	100	29.47	
	BNW	39.07	26.41	19.45		3.2% (r=35.1-39.1)	81.05	85.26	26.32	
Oct. 1995	Amb	33.35	26.17	22.96						
	Simple	42.78	26.87	22.92		7.6% (r=35.63-42.78)	96.95	98.98	39.09	No bats
	BSE	42.78	27.29	22.92		7.6% (r=35.63-42.78)	79.7	98.48	18.78	
	BNW	33.23	26.44	22.94		0%	94.92	85.28	25.89	
Nov. 1995	Amb	25.46	14.69	3.97						
	Simple	39.62	15.48	3.28	4.4% (r=3.28-4.93)	2.0% (35.13-39.62)	74.06	90.1	72.7	No bats
	BSE	39.62	16.74	3.74	3.7% (r=3.37-4.95)	2.0% (r=35.13-39.62)	85.67	90.1	23.55	
	BNW	25.75	14.21	3.28	4.4% (r=3.28-4.93)	0%	38.57	50.17	70.99	
Jan. 1996	Amb	27.04	11.39	-2.2						
	Simple	34.08	12.43	-2.83	19.7% (r=-2.83-4.98)		66.5	68.2	54.85	No bats
	BSE	34.08	12.95	-2.83	17.6% (r=-2.83-4.95)		66.75	67.15	43.96	
	BNW	26.87	11.66	-2.69	17.4% (r=-2.69-4.98)		54.61	59.42	50.24	
Feb. 1996	Amb	28.87	13.06	-3.11						
	Simple	41.06	13.92	-3.53	17.3% (r=-3.52-4.99)	1.3% (r=35.2-41.06)	68.89	86.03	80.27	No bats
	BSE	41.06	14.58	-3.53	15.1% (r=-3.53-4.99)	1.3% (r=35.2-41.06)	70.73	82.71	45.33	
	BNW	27.98	12.91	-3.43	16.6% (r=-3.43-4.95)	0%	43.9	56.32	67.18	
May 1996	Amb	34.72	26.07	19.65						
	Simple	39.67	26.75	19.56		11.9% (r=35.04-39.67)	93.97	99.15	61.54	No bats
	BSE	39.67	26.82	19.56		6.8% (r=35.04-39.67)	84.62	96.58	43.59	
	BNW	38.05	26.68	19.58		5.9%.(r=35.12-38.05)	83.76	89.74	25.64	

Table 16. Comparison of temperatures in Seminole Community College small style bat house. Dates July 1995 - January 1996, bat house is painted white. Monitoring periods February and May 1996 are after bat house was painted brown. Reflectix insulation is located in top half of front and rear chambers on all dates monitored. t=roost temperature, r=range.

							% time			
		Max	Mean	Min	t<5C	t>35C	mean>amb	max>amb	min<amb	Comments on Bats
July 1995	Amb	34.58	25.94	18.37						
	Small	39.26	27.52	19.19		42.1% (r=35.1-39.26)	87.37	100	62.11	
	SSE	37.81	26.29	19.62		3.2% (r=35.1-37.8	67.37	87.37	62.11	Most in center
	SNW	39.26	28.76	19.19		42.1% (r=35.1-39.26	93.68	100	33.68	All crevices
Oct. 1995	Amb	33.35	26.17	22.96						
	Small	42.78	31.08	24.46		42% (r=35.01-47.78)	100	100	12.18	
	SSE	38.75	31.15	24.62		21.3% (r=35.1-38.7)	100	100	11.17	All crevices
	SNW	42.78	31.02	24.46		36% (r=35.01-47.78)	99.49	100	8.63	All crevices
Nov. 1995	Amb	25.46	14.69	3.97						
	Small	31.78	16.68	3.03	5.8% (r=3.03-4.93)		70.31	97.27	62.46	
	SSE	30.9	17.18	3.37	4.1% (r=3.47-4.93)		79.18	97.27	48.81	All crevices
	SNW	31.78	16.17	3.03	5.8% (r=3.03-4.85)		65.53	74.4	62.12	All crevices
Jan. 1996	Amb	27.04	13.98	3.83						
	Small	33.17	16.33	2.41	14.3% (r=2.41-4.98)		64.84	96.7	15.38	few bats
	SSE	33.17	16.34	2.41	14.3% (r=2.41-4.98)		82.42	96.7	14.29	
	SNW	31.64	16.32	3.17	6.6% (r=3.16-4.86)		74.73	95.6	14.29	
Feb. 1996	Amb	28.87	13.06	-3.11						3 Feb most in SSE
	Small	44.08	16.29	-3.69	19.7% (r=-3.69-4.98)	6.3% (r=35.26-46.08)	92.22	100	69.1	center crevice
	SSE	44.08	17.38	-3.69	15.96% (r=-3.69-4.98)	2.88% (r=35.26-44.08)	97.56	99.78	32.69	11 Feb all
	SNW	39.38	15.19	-3.58	19.5% (r=-3.57-4.96)	3.6% (r=35.52-46.08)	64	77.86	67.88	crevices full
May 1996	Amb	34.72	26.07	19.65						
	Small	45.22	28.99	20.98		24.7% (r=35.1-45.2)	100	100	20	All crevices full
	SSE	42.75	28.94	22.29		19.1% (r=35.39-42.75)	100	100	0	
	SNW	45.22	29.09	20.98		24.7% (r=35.1-45.22)	98.88	100	12.94	

Table 17. Comparison of temperatures in Seminole Community College large style bat houses. Bat houses were modified July 1995. Modifications included brown paint, enclosing sides and addition of metal roof. t=roost temperature, r=range

							% time			
		Max	Mean	Min	t<5C	t>35C	mean>amb	max>amb	min<amb	Comments on Bats
July 1995	Amb	34.58	25.94	18.37						
	large	39.1	26.36	19.63		5.3% (r=35.34-39.1)	66.32	96.84	50.53	No bats
	LSE	39.1	26.16	19.63		5.3% (r=35.34-39.1)	61.05	95.79	49.47	
	LNW	36.93	26.62	20.09		2.1% (r=36.07-36.93)	67.37	89.47	42.11	
Oct. 1995	Amb	33.35	26.17	22.96						
	large	33.95	26.5	23.13			76.65	98.48	40.1	No bats
	LSE	33.88	26.51	23.13			77.16	94.92	36.55	
	LNW	33.95	26.49	23.29			73.6	94.92	37.56	
Nov. 1995	Amb	25.46	14.69	3.97						
	large	32.44	15.37	2.553	6.8% (r=2.53-4.77)		80.89	100	58.7	No bats
	LSE	32.44	15.76	2.53	6.8% (r=2.53-4.77)		88.4	99.32	49.83	
	LNW	26.81	15.07	2.99	4.7% (r=2.99-4.99)		64.51	91.81	49.49	
Jan. 1996	Amb	27.04	11.39	-2.2						
	large	31.05	12.49	-2.31	17.23% (r=-2.31-4.99)		81.88	96.6	50	
	LSE	29.25	12.37	-2.31	15.7% (r=-2.31-4.99)		83.33	94.17	39.32	No bats
	LNW	31.05	12.59	-1.82	15.7% (r=-1.82-4.96)		78.02	89.81	40.29	Some bats
Feb. 1996	Amb	28.87	13.06	-3.11						
	large	34.44	14.07	-3.24	18.26% (r=-3.19-4.95)		74.16	98.23	61.69	few bats 3 Feb
	LSE	32.28	13.67	-3.19	17.3% (r=-3.19-4.94)		72.06	94.28	54.99	few bats 11 Feb
	LNW	34.44	14.45	-3.24	17.4% (r=-3.24-4.95)		70.16	90.91	57.91	all crevices
May 1996	Amb	34.72	26.07	19.65						
	large	38.96	28.05	20.34		22.2% (r=35.05-38.96)	99.14	100	47.86	bats in all crevices
	LSE	38.96	27.58	20.34		18.8% (r= 35.2-38.96)	93.97	100	47.86	
	LNW	38.82	27.58	21.99		17.1% (r=35.05-38.82)	100	100	25.64	more in LNW

FIGURES

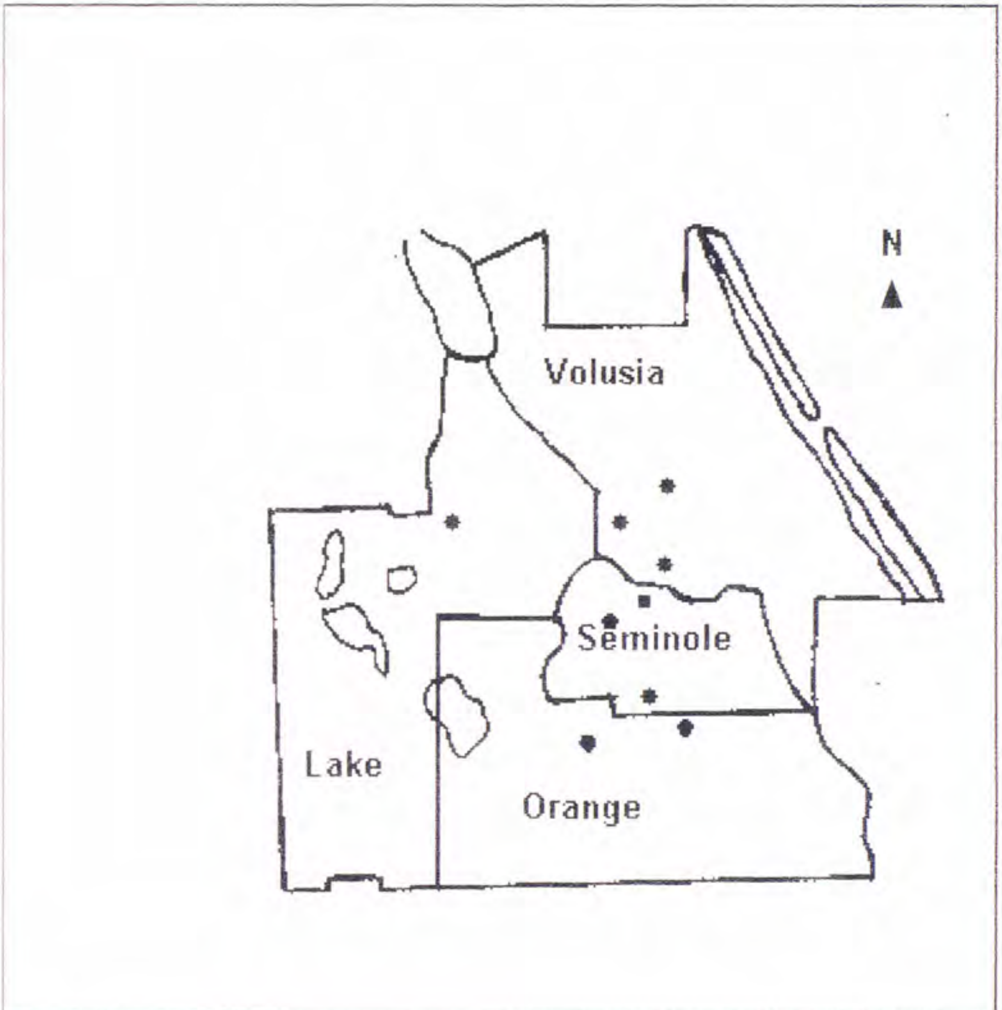


Figure 1. Approximate locations of central Florida study sites. Each dot may represent more than one site.

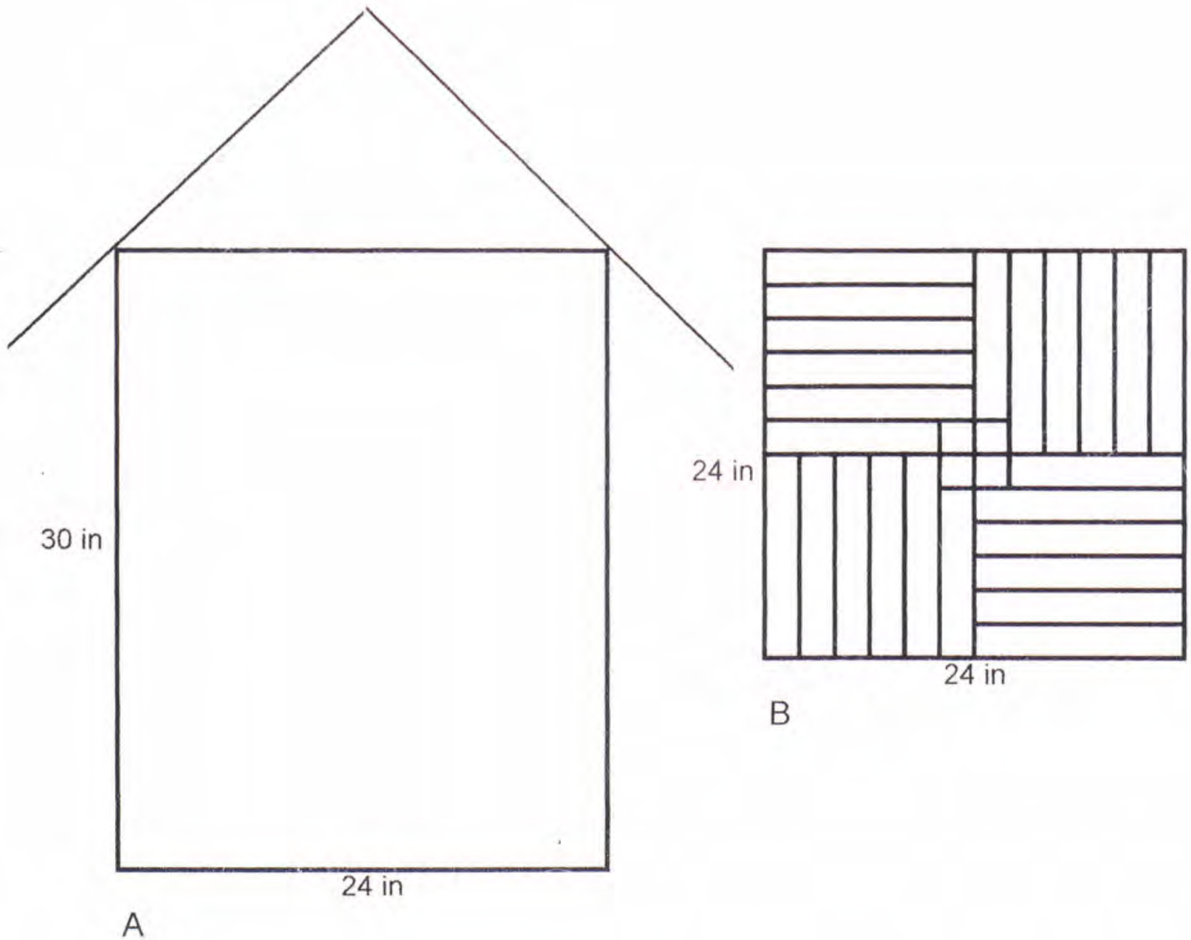


Figure 2. Square bat house design located at Seminole Community College, Sanford, FL. A is side view, B is view from the bottom. A total of eleven crevices are located in each quadrant. The broadside of house faces southeast, southwest, northeast, and northwest.

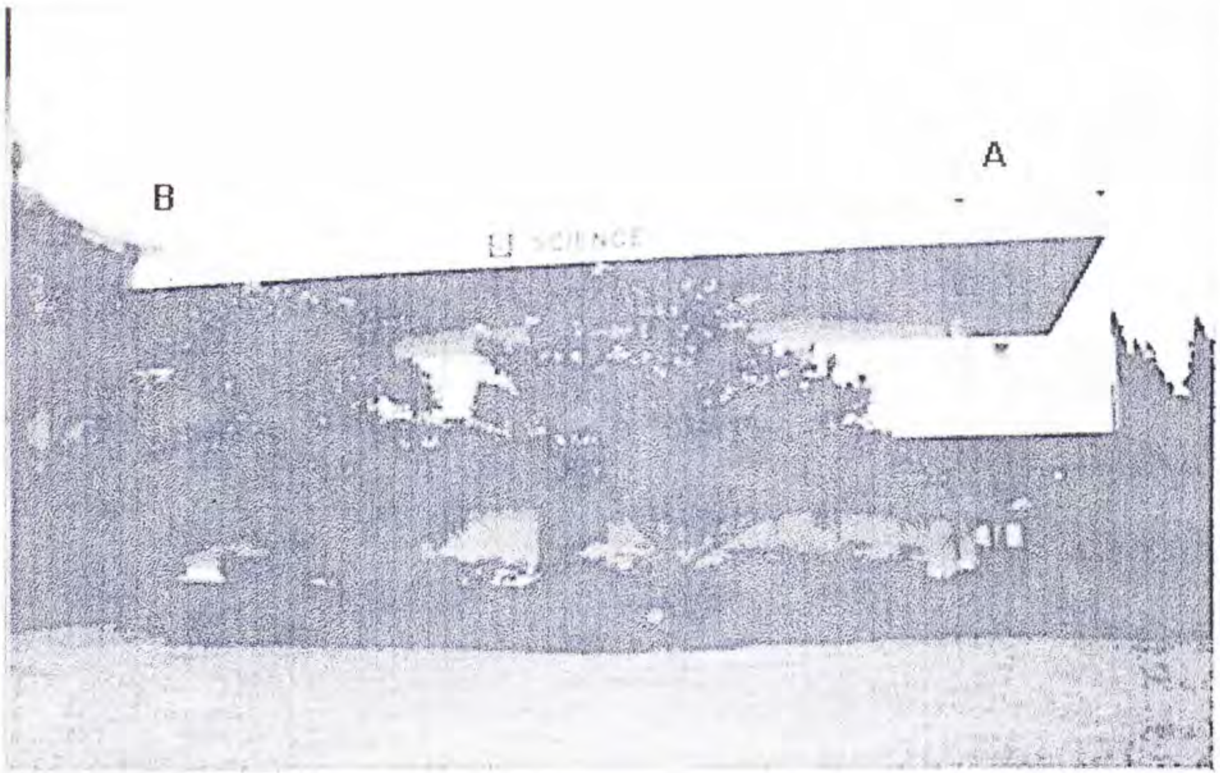


Figure 3. Building used as roost site by bats at Seminole Community College, Sanford, FL. Each dark area (A) is a space between concrete slabs that leads beneath the metal flashing. Bats enter through these spaces. The two spaces on the right have significant amounts of staining around the roost openings. An excluder (B) has been placed over the entrance on the left corner.

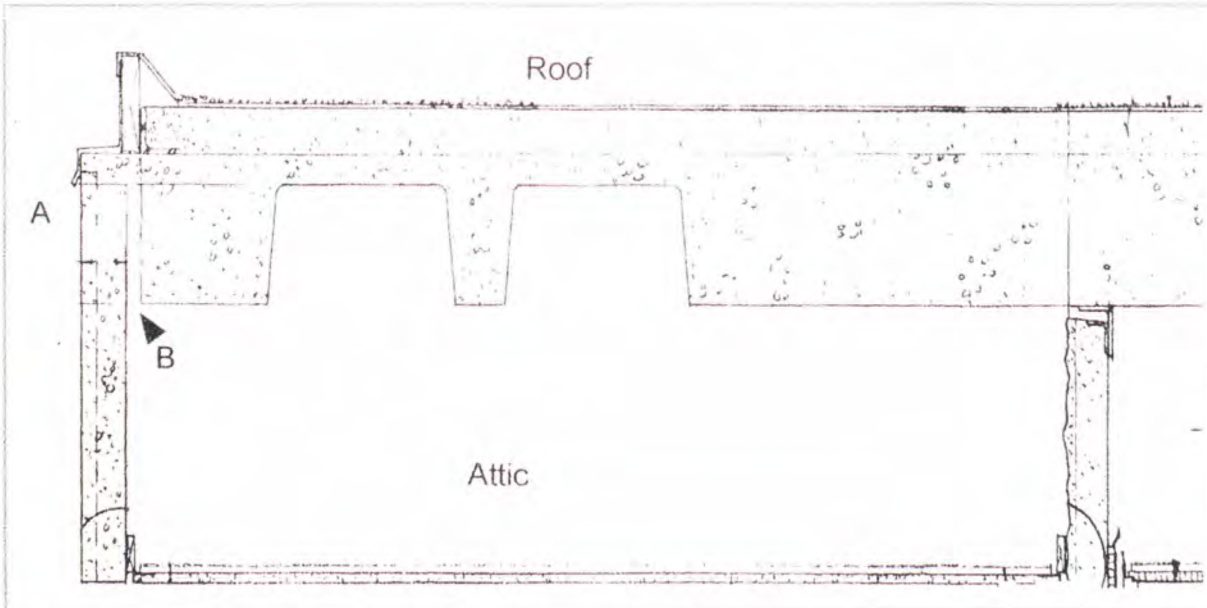


Figure 4. Schematic illustration of area used by bats in buildings at Seminole Community College. The roost entrance (A) is also shown in Figure 3(A). Bats roost in the expansion joint (B) between the outer concrete wall and the attic wall. They are also found in the space beneath the metal flashing. Bats were never seen in the open areas of the attic.

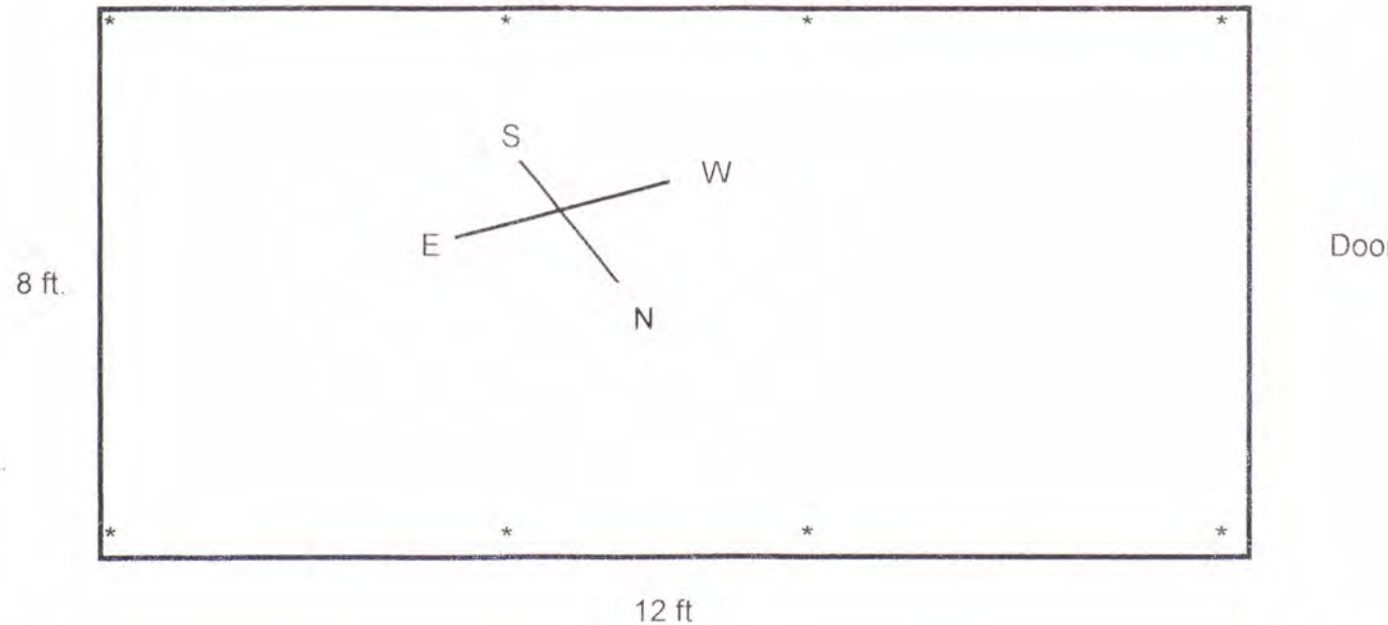


Figure 5. Diagram of flight cage used during controlled experiments. Roost choices are denoted by asteriscs (*).

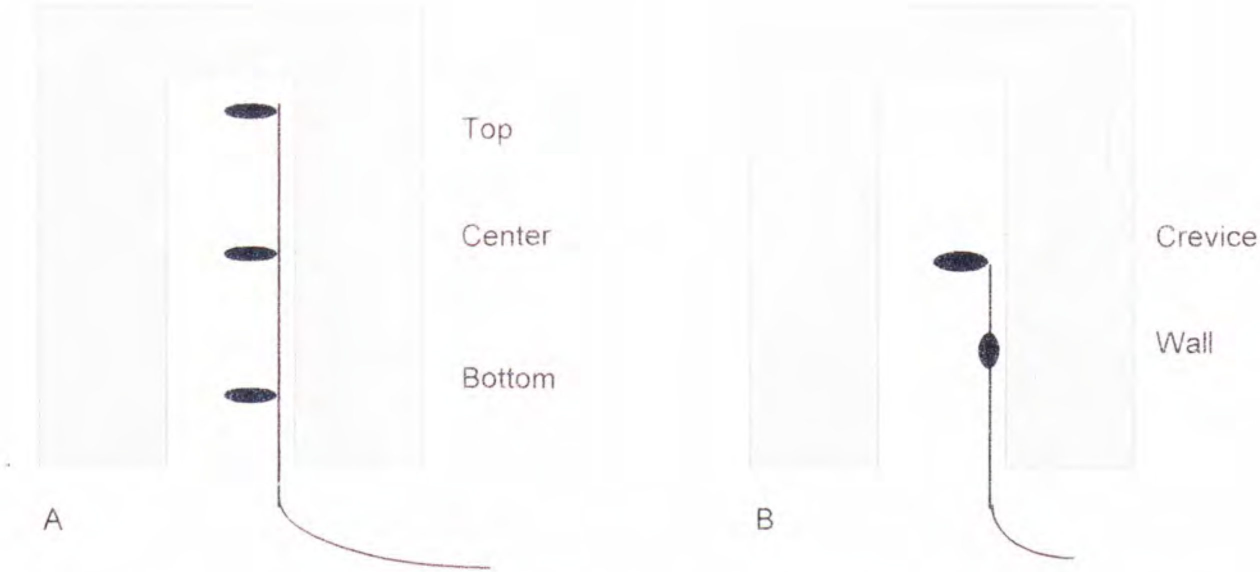


Figure 6. Schematic diagram of thermocouple placement into A. bat house crevices and B. roost crevices. Thermocouples in bat house and top thermocouple in roost diagram are positioned to monitor crevice temperature while lower thermocouple in roost diagram is positioned to monitor wall temperature. Both crevice and wall temperature were monitored only at the SCC roost.

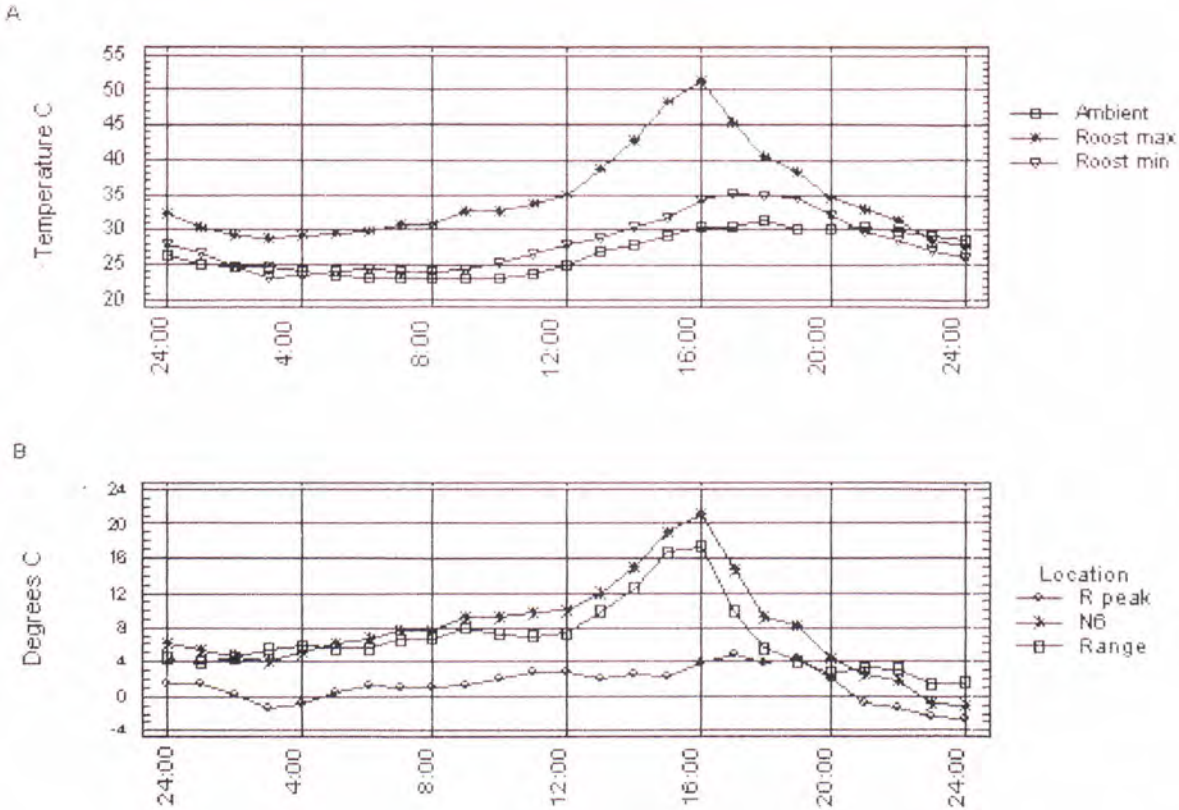


Figure 7. Time-series raw temperature profile (A) and temperature difference profile (B) for occupied roost at Rollins. 24:00 16 August - 24:00 17 August 1994. The temperature difference was obtained by subtracting ambient temperature from roost temperature. (A) illustrates maximum and minimum roost temperatures for each hour monitored, (B) shows temperature differences in two roost locations and the temperature range in the roost. See Appendix A for detail on roost structure.

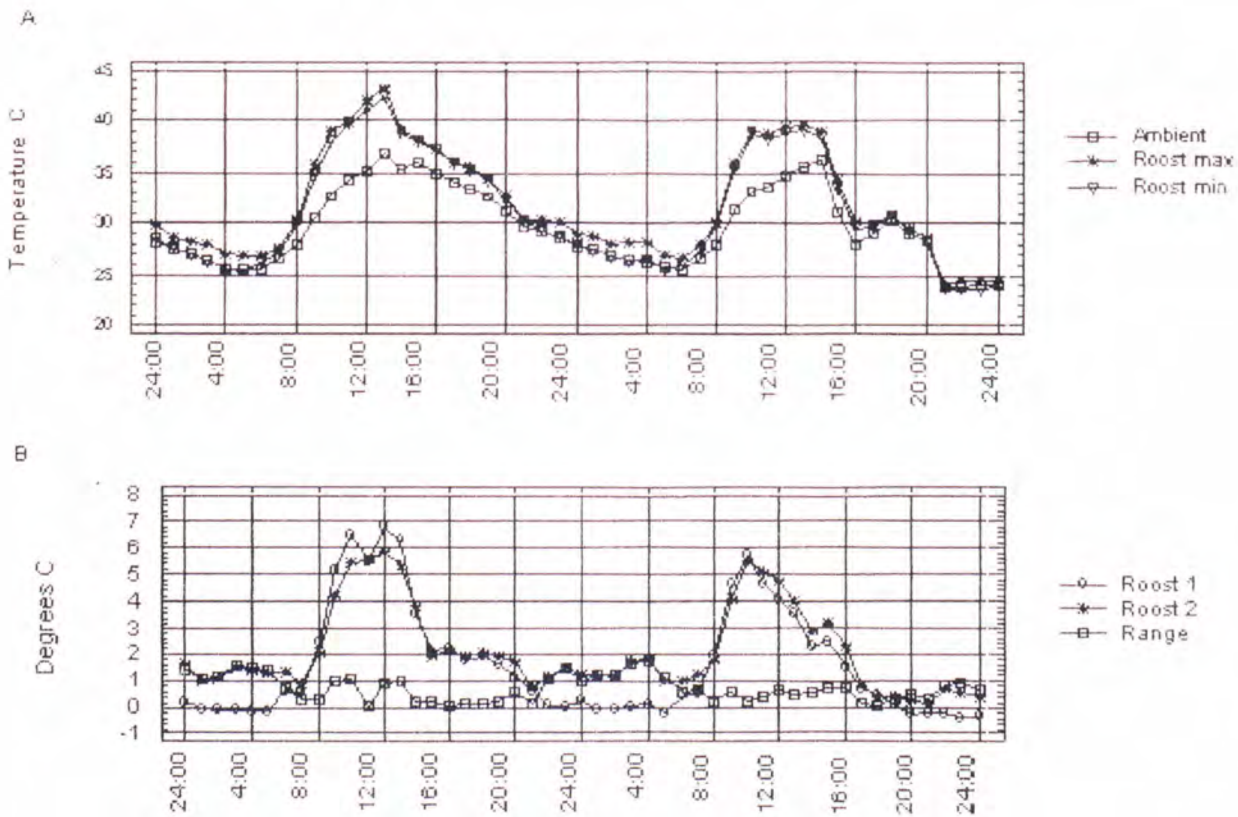


Figure 8. Time-series raw temperature profile (A) and temperature difference profile (B) for occupied roost at Aikins. 24:00 27 June - 24:00 29 June 1994. The temperature difference was obtained by subtracting ambient temperature from roost temperature. (A) illustrates maximum and minimum roost temperatures for each hour monitored, B shows temperature differences in two roost locations and the temperature range in the roost. See Appendix A for detail on roost structure.

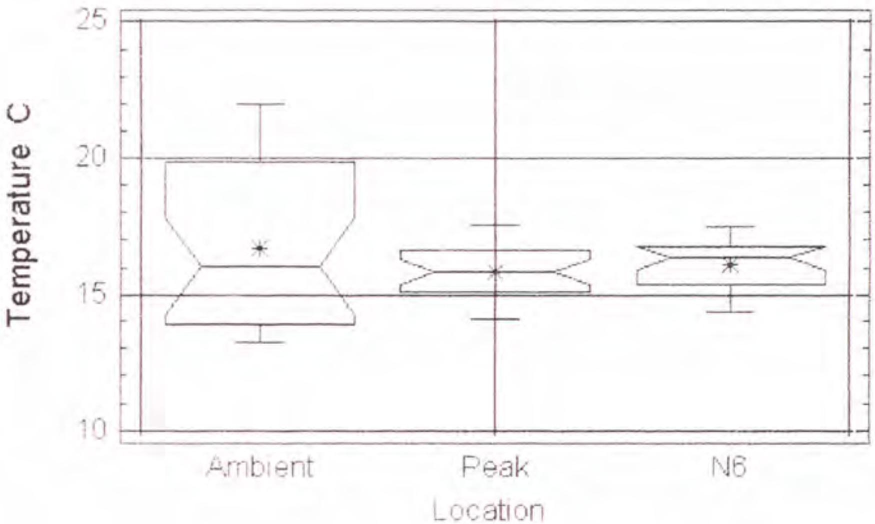


Figure 9. Box and Whisker plots for temperatures monitored in occupied roost at Rollins. 27 December 1994 - 4 January 1995. ANOVA and Kruskal-Wallis tests indicate that no significant differences exist between locations (ANOVA: F=1.51, df=2, p=0.228; Kruskal-Wallis: p=0.616). However, the range for ambient is more than twice that of either roost location. Ambient and two roost locations are shown, Peak is the crevice temperature at the peak of the roost, N6 is crevice temperature 6 feet away. Both locations are on the North side of the building. The Box-and-Whisker Plot is a graphical summary of data. The central box covers the middle 50 percent of the data, the vertical line drawn through the box is the median. The whiskers extend out to the lower and upper values of the data (the range). The mean is plotted as an asterisk (*). See Appendix A for more detail on roost structure.

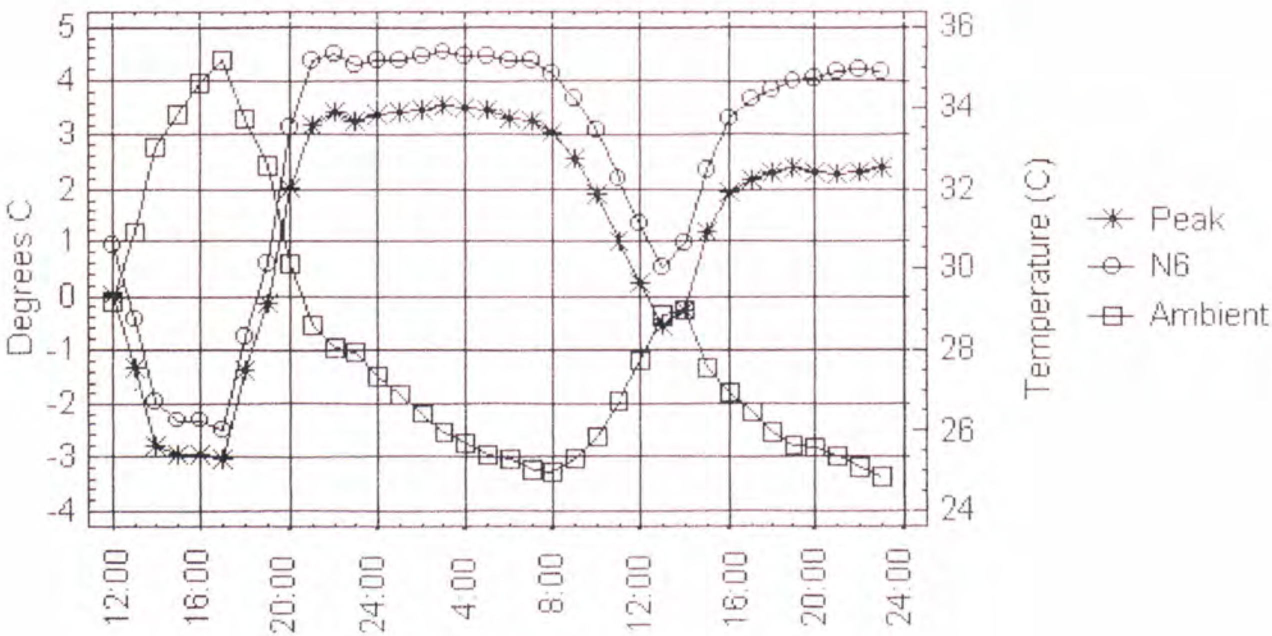


Figure 10. Time-series temperature difference profile for occupied roost at Rollins. 12:00 16 June - 24:00 17 June 1994. The scaling for Peak and N6 is on the left (temperature difference in Degrees C), while the scaling for ambient is on the right (Temperature C). Note that as ambient decreases the temperature difference increases. The difference in maximum ambient is due to a thunderstorm on 17 June. Pups are present in the roost at this time and may be a contributing factor in the stability of roost temperature. See Figure 9 and Appendix A for detail on location and roost structure.

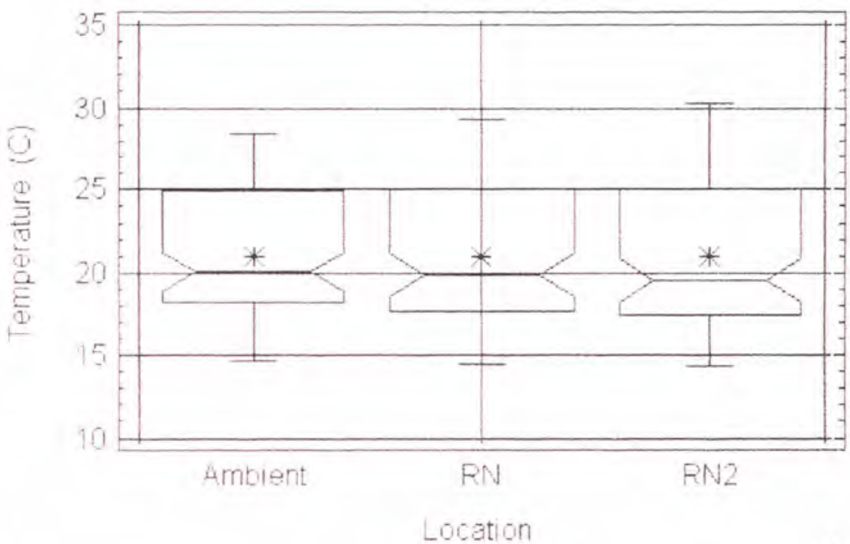


Figure 11. Box and Whisker plots for temperatures monitored in occupied roost at Aikins. 27 February - 2 March 1995. ANOVA and Kruskal-Wallis tests indicate no significant differences exist between locations (ANOVA: F=0.0, df=2, p=0.998; Kruskal-Wallis: p=0.931). Note the lack of differences in range compared to Rollins (Figure 9). Ambient and two roost locations are shown, RN is crevice temperature near the entrance of the roost and RN2 is the crevice temperature 60.9 cm inside. This roost is on the west end of an awning located on the north side of the building. See Figure 9 for explanation of Box and Whisker plots and Appendix A for more detail on roost structure.

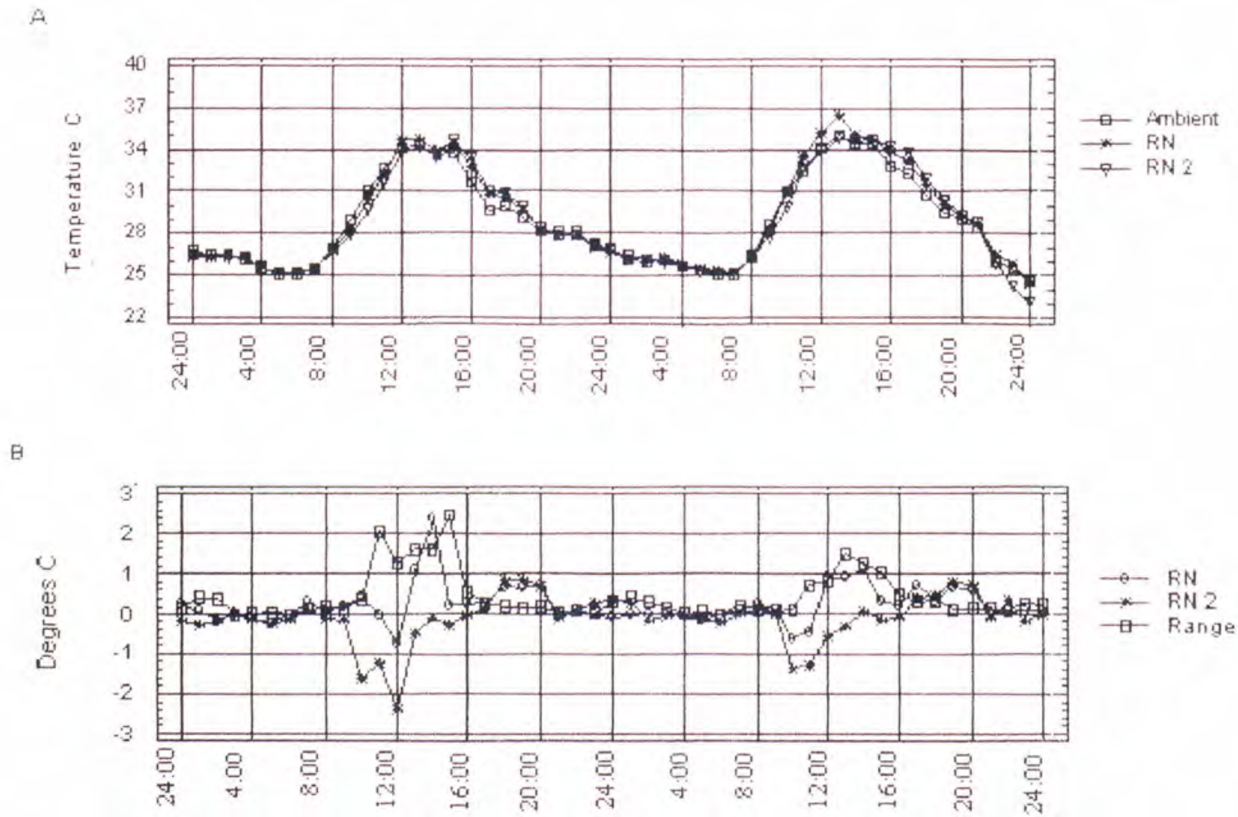


Figure 12. Time-series raw temperature profile (A) and temperature difference profile (B) for occupied roost at Aikins. 24:00 29 August - 24:00 31 August 1994. The temperature difference was obtained by subtracting ambient temperature from roost temperature. (A) illustrates roost temperatures in two roost locations for each hour monitored, (B) shows temperature differences and the temperature range in the roost. See Figure 11 and Appendix A for more detail on location and roost structure.

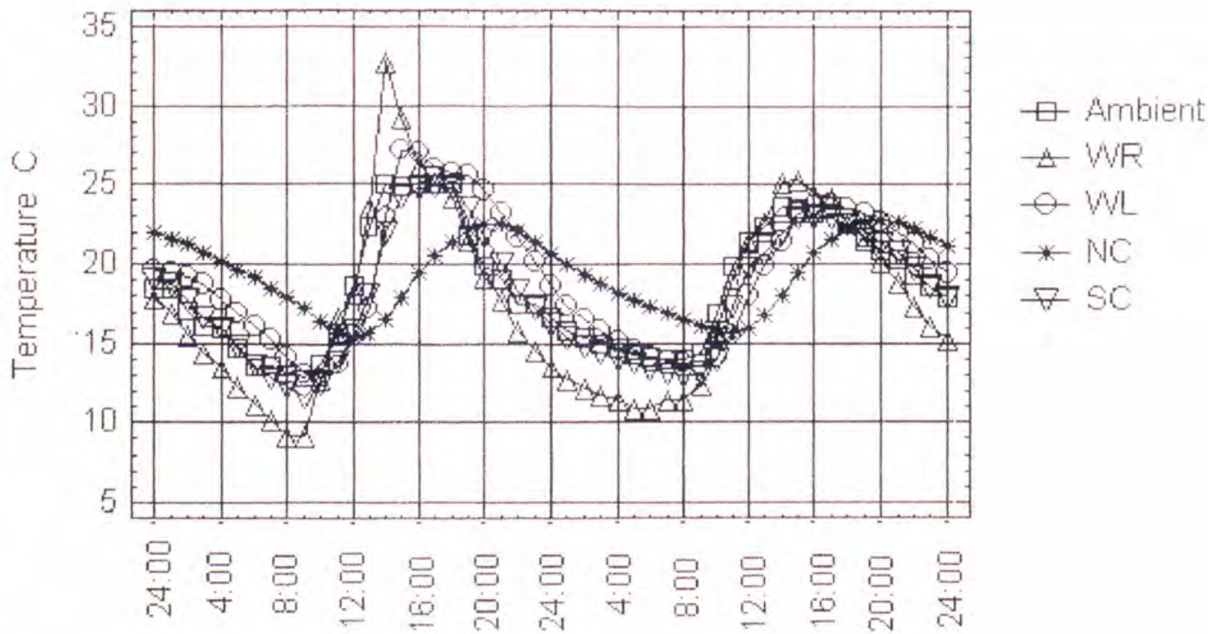


Figure 13. Time-series raw temperature profile for occupied roost at Hill. 24:00 24 February - 24:00 26 February 1995. Locations WR (beneath a metal ridge roll) and WL (beneath the metal roof) are the primary roost sites. NC and SC (crevice temperatures on North and South end of roost) are used as the primary entry and exit points. This roost was located on the west end of a one story building. See Appendix A for more detail on roost structure.

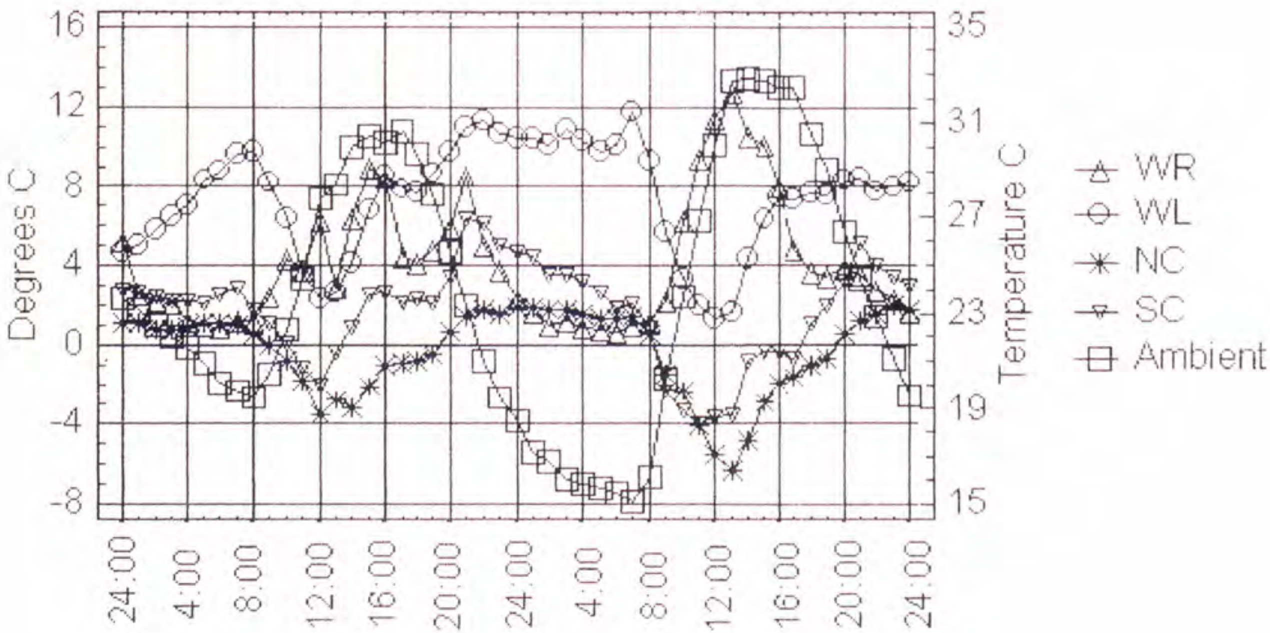


Figure 14. Time-series temperature difference profile for occupied roost at Hill. 24:00 5 May - 24:00 7 May 1994. Temperature difference was obtained by subtracting ambient from roost temperature. The scaling for location is on the left (temperature difference in Degrees C), while the scaling for ambient is on the right (Temperature C). See Figure 13 and Appendix A for more detail on location and roost structure.

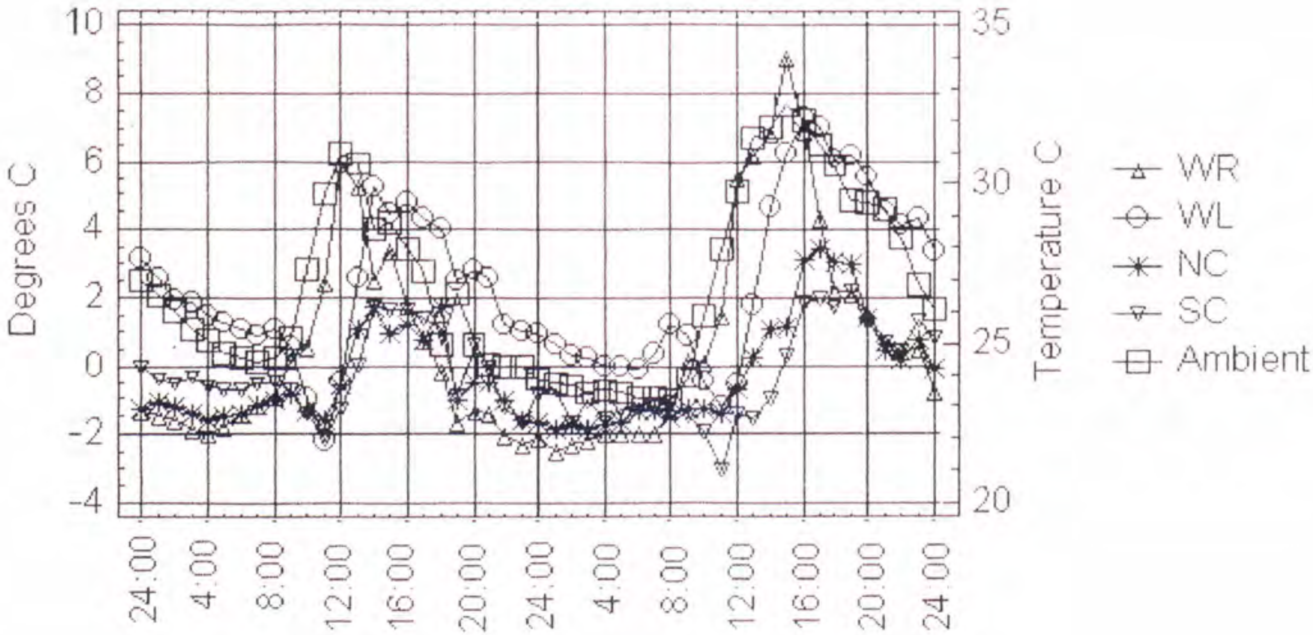


Figure 15. Time-series temperature difference profile for occupied roost at Hill. 24:00 7 September - 24:00 9 September 1994. Temperature difference was obtained by subtracting ambient from roost temperature . The scaling for temperature difference by location is on the left (temperature difference in Degrees C), while the scaling for ambient is on the right (Temperature C). See Figure 13 and Appendix A for more detail on location and roost structure.

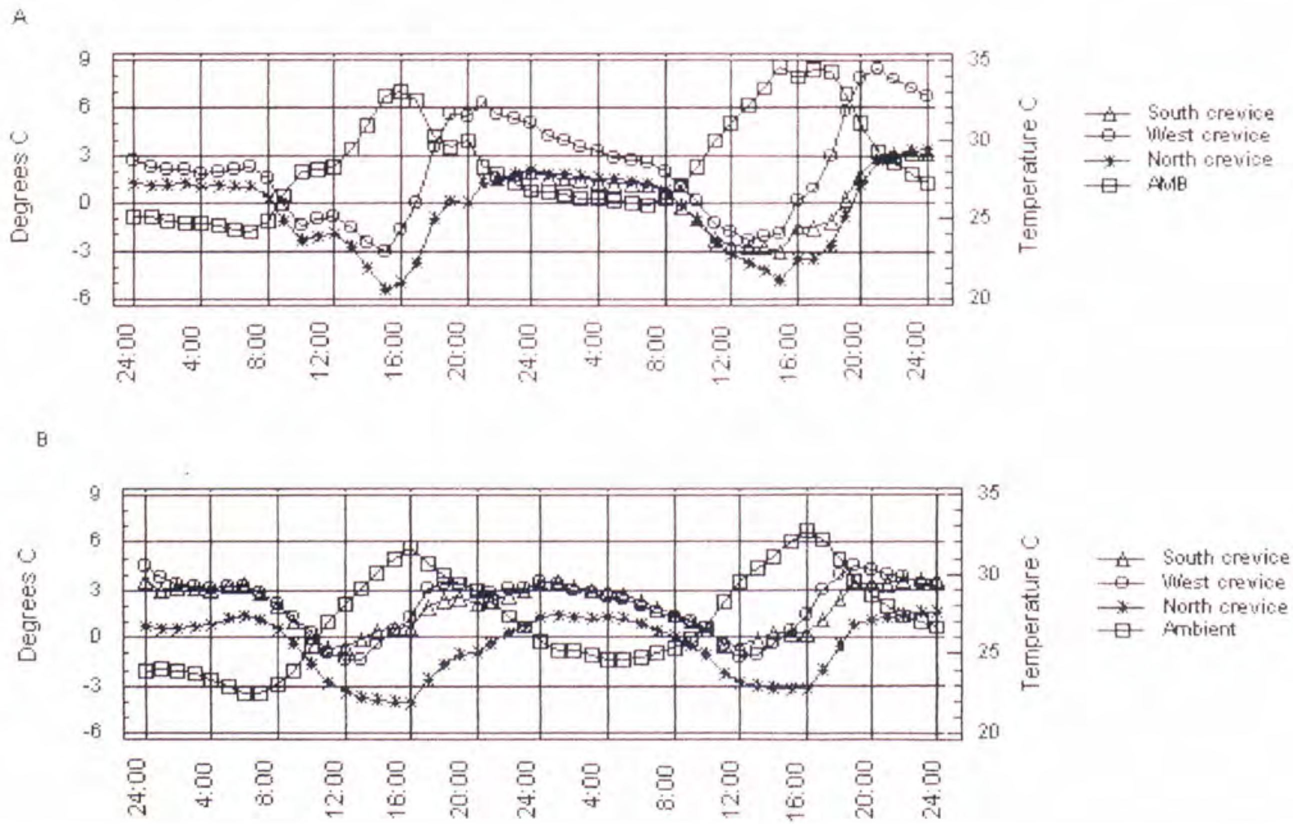


Figure 16. Time-series temperature difference profiles for Seminole Community College roost (A) with and (B) without bats. (A) was monitored 24:00 26 March - 24:00 28 March 1994, (B) was monitored 24:00 3 August - 24:00 5 August 1995. Both dates have similar ambient temperature profiles.

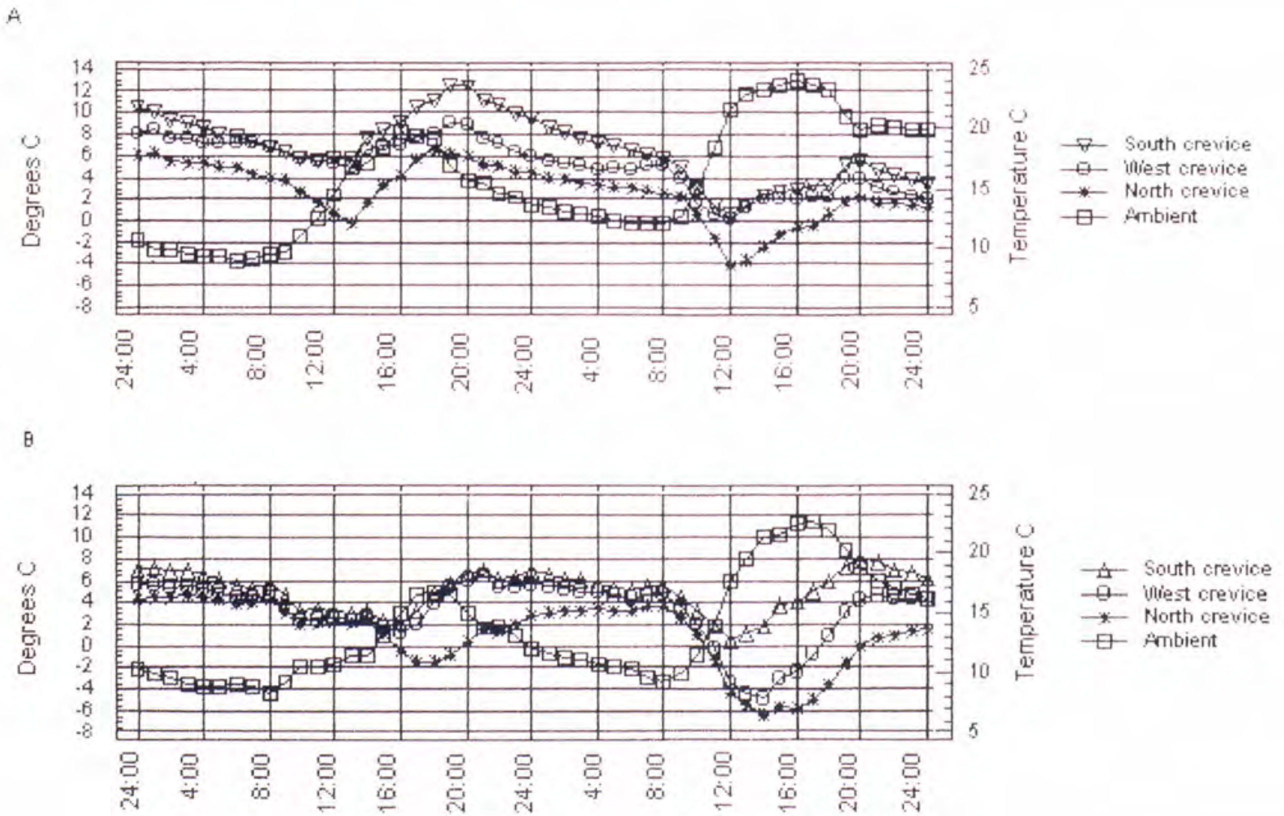


Figure 17. Time-series temperature difference profile for Seminole Community College roost (A) with and (B) without bats. (A) was monitored 24:00 16 January - 24:00 17 January 1995, (B) was monitored 24:00 25 November - 24:00 26 November 1995. Both dates have similar ambient temperature profiles.

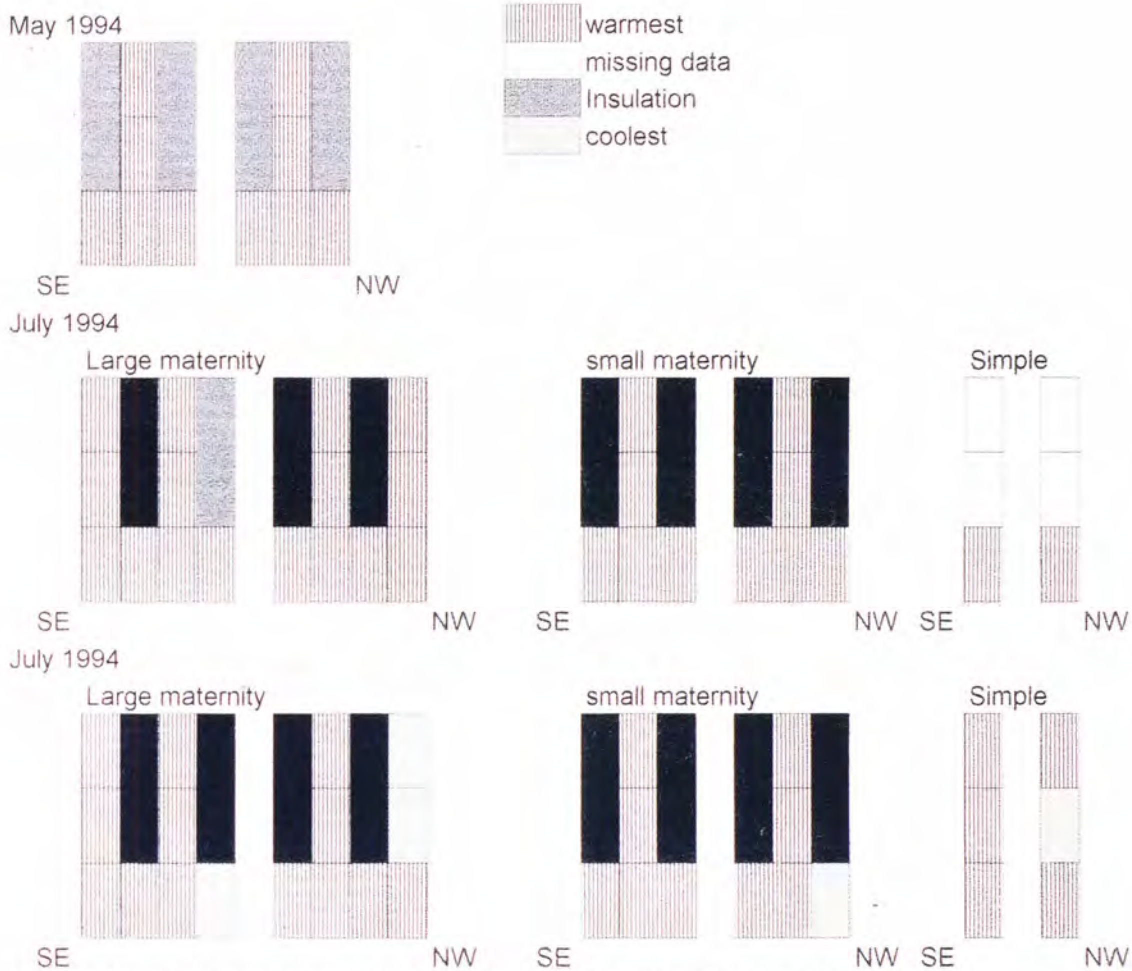
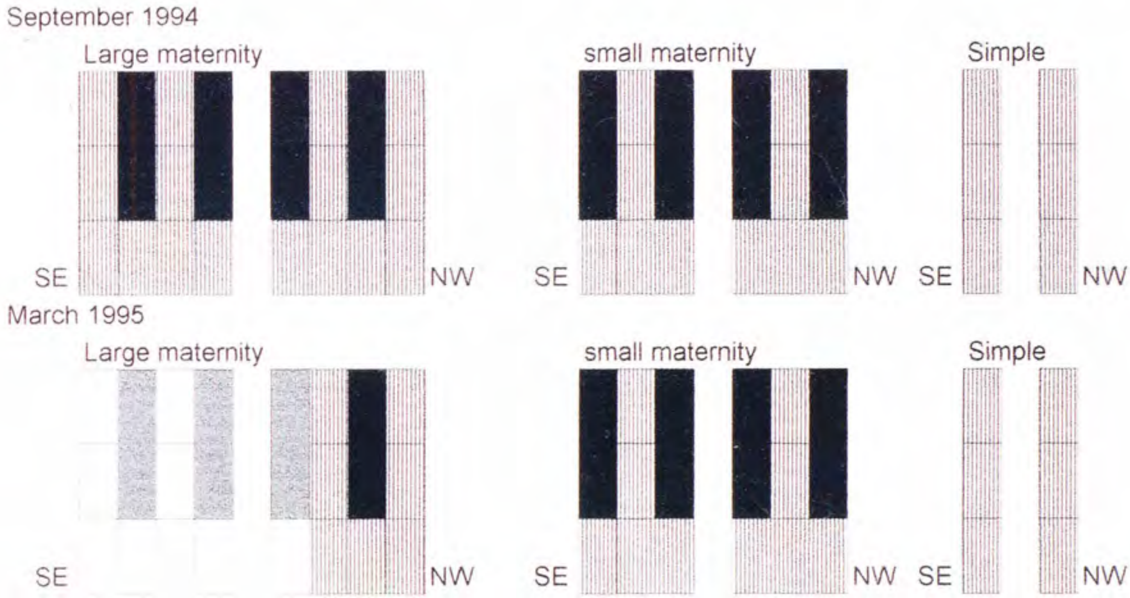


Figure 18. Schematic view of temperature differences in Seminole Community College bat houses. Differences determined by Multiple Range tests using least significant differences (95% CI). Thermocouples were placed in top, center and bottom locations of each chamber. The simple style houses consisted of one chamber, three chambers were in the small and four chambers in the large style houses. The small style houses had Reflectix insulation in the top half of the front and rear chambers. This insulation was in the top half of the second and rear chambers of the large style houses. Each square represents a thermocouple location. All houses were painted white and unoccupied.


September 1994
Large maternity
small maternity
Simple
SE
NW
SE
NW
SE
NW
March 1995
Large maternity
small maternity
Simple
SE
NW
SE
NW
SE
NW

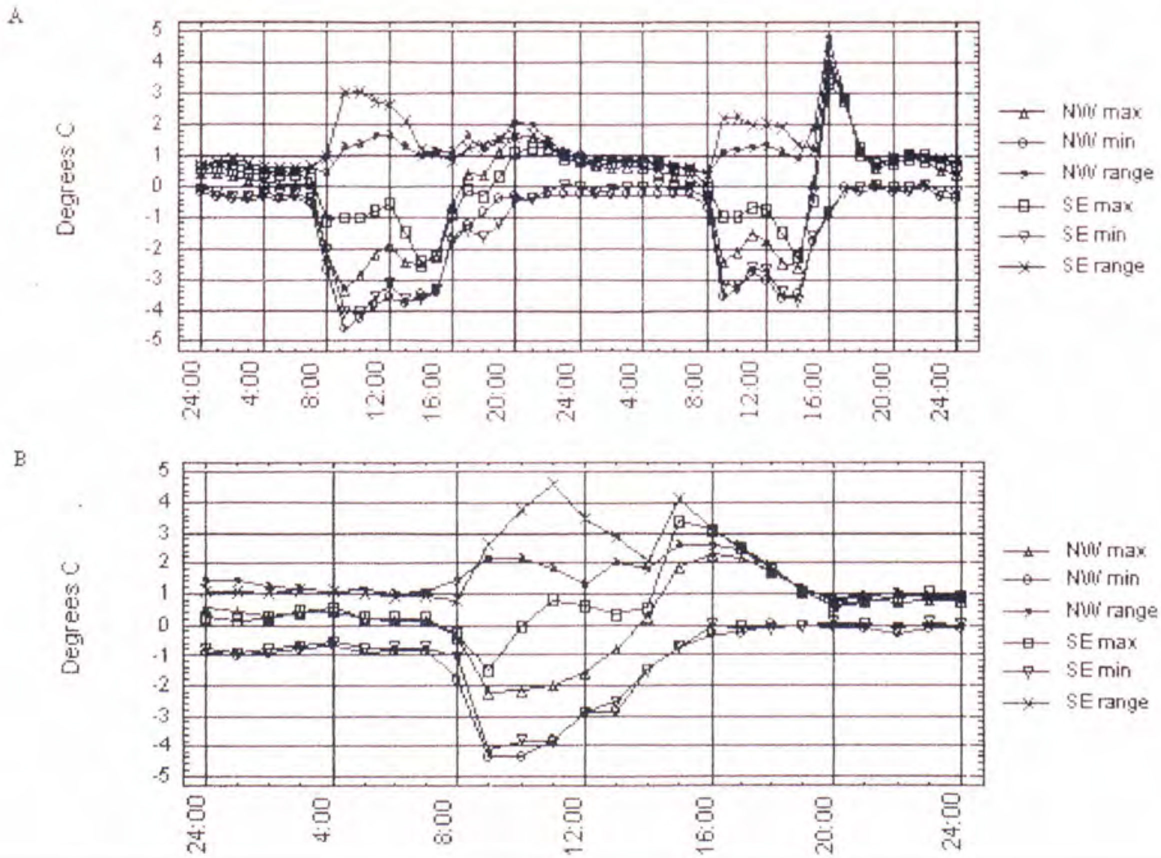


Figure 19. Time-series temperature difference profile for Seminole Community College small (A) and large (B) style bat houses. Small house (A) is for 24:00 27 July - 24:00 28 July 1994, Large house (B) is for 24:00 25 July - 24:00 26 July 1994. An equipment malfunction prevented simultaneous readings on this date. See Chapter 3 for further detail. Note that most temperature differences are negative indicating bat house temperatures are below ambient. The range in the NW houses is more narrow and NW maximum temperature is further below ambient. These houses were painted white and were unoccupied.

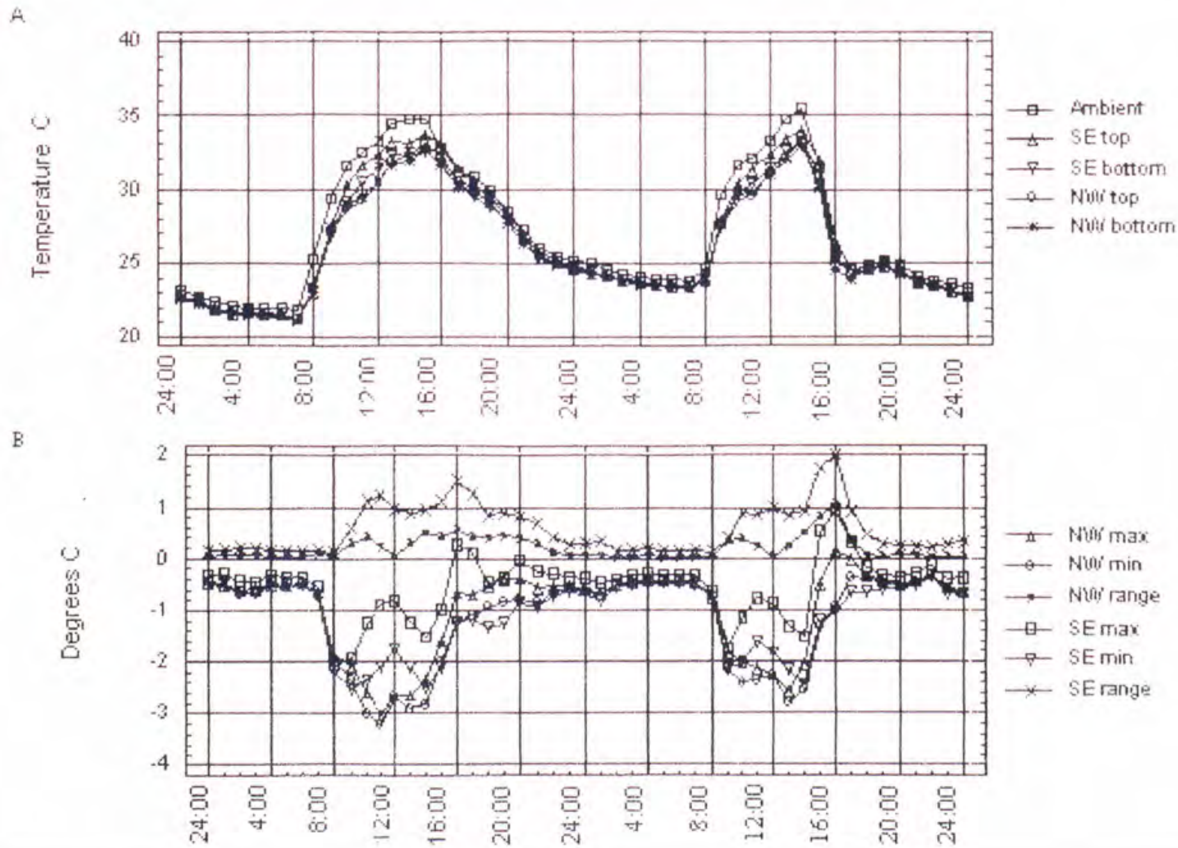


Figure 20. Time-series raw temperature profile (A) and temperature difference profile (B) for Seminole Community College simple style bat houses. 24:00 26 July - 24:00 28 July 1994. Locations in A are top and bottom of each house orientation, B is maximum, minimum and temperature range within each house orientation. Note that ambient temperature is above bat house temperature during peak day-time hours. These houses are painted white and are unoccupied.

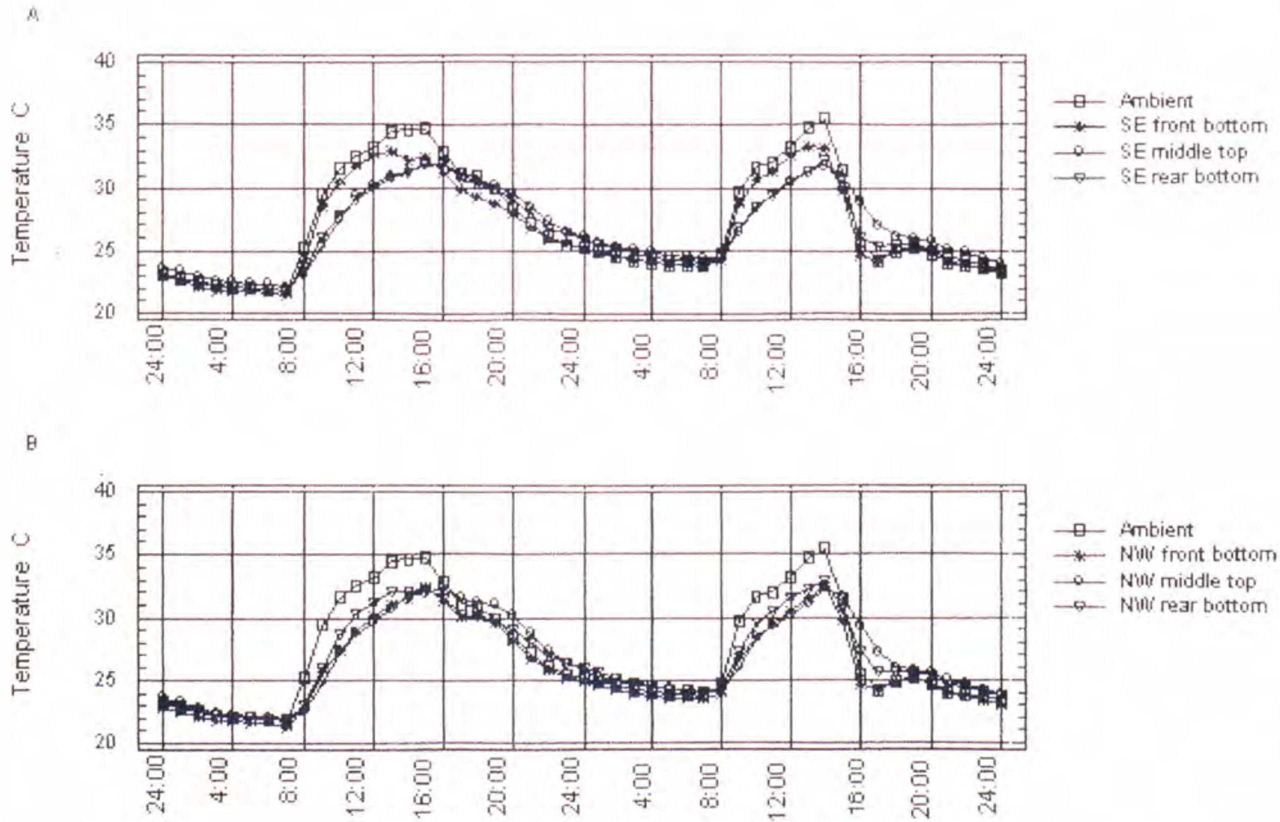


Figure 21. Time-series raw temperature profile for Seminole Community College small style bat houses. 24:00 26 July - 24:00 28 July 1994. A is southeast orientation, B is northwest orientation. Reflectix insulation is in upper 1/2 of front and rear chambers. This allows bats to roost only in bottom half of these chambers and only bottom temperature is recorded. Temperature was recorded in top, center, and bottom of the middle chamber, but only the top temperature is reported here. Note that ambient temperature is above bat house temperature during peak day-time hours. These houses were painted white and were unoccupied.

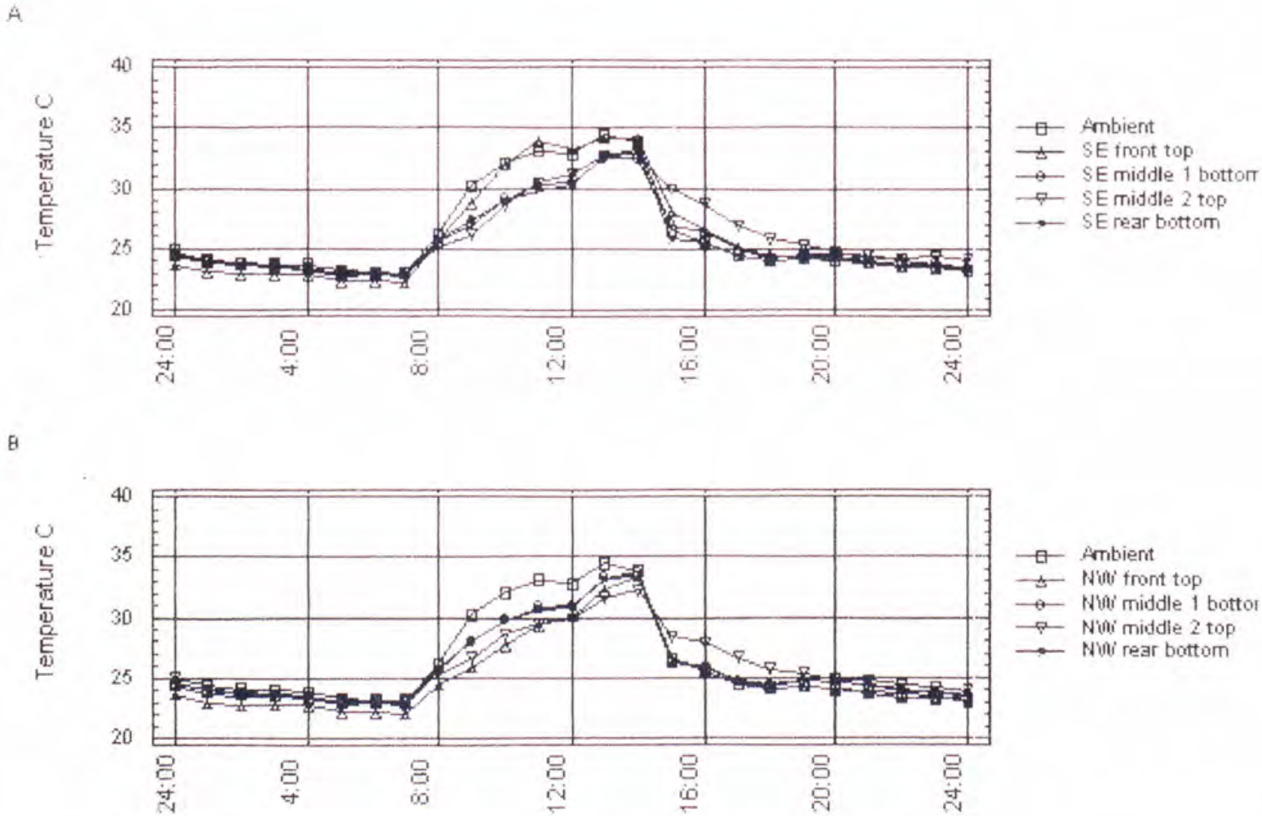


Figure 22. Time-series raw temperature profile for Seminole Community College large style bat houses. 24:00 25 July - 24:00 26 July 1994. A is southeast orientation, B is north west orientation. Reflectix insulation is in bottom 1/2 of middle 1 and rear chambers. This allows bats to roost only in bottom half of these chambers and only bottom temperature is recorded. Temperature was recorded in top, center, and bottom of the front and middle 2 chambers, but only the top temperature is reported here. Note that ambient temperature is above bat house temperature during peak day-time hours. These houses were painted white and were unoccupied.

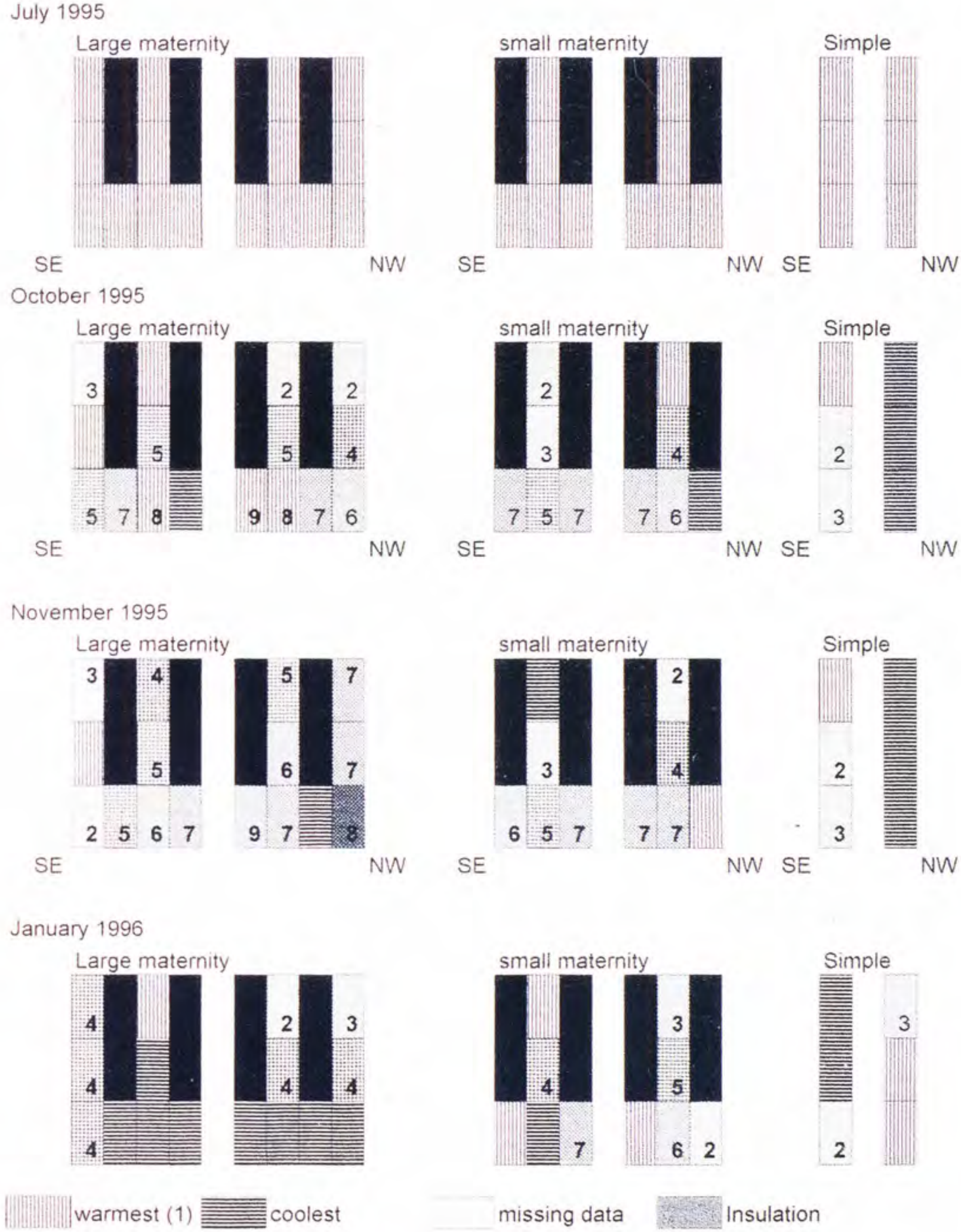


Figure 23. Schematic view of temperature differences in Seminole Community College bat houses. Differences determined by Multiple Range tests using least significant differences (95% CI). Simple and large style houses were modified in May 1995 (see text). Small houses were painted white. The simple style remained unoccupied, the large style was occupied in January 1996. Small houses were occupied on all dates, but numbers were low in July 1995. Numbers rise as mean temperature decreases.

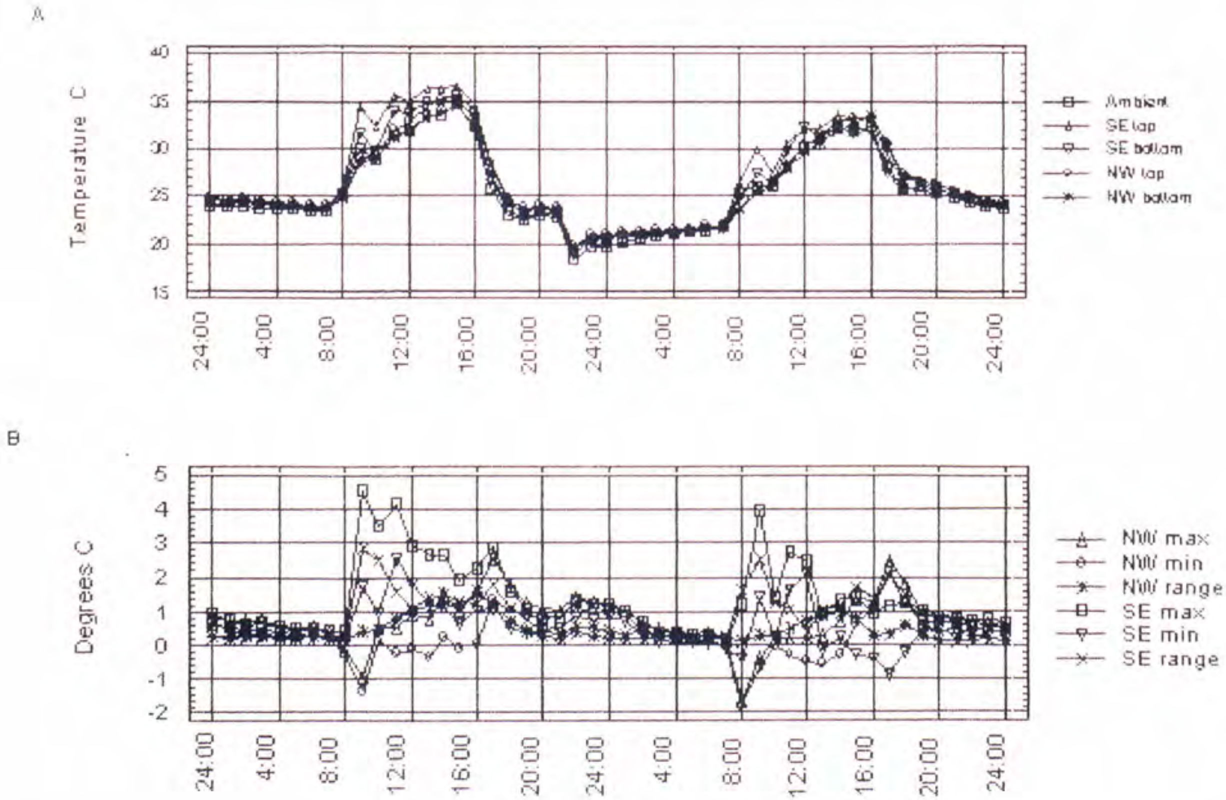


Figure 24. Time-series raw temperature profile (A) and temperature difference profile (B) for Seminole Community College simple style bat houses. 24:00 24 July - 24:00 26 July 1995. Note that bat house temperature is above ambient temperature during peak day-time hours. These houses were modified in May 1995 (see Chapter 3) and are unoccupied. See Figure 20 and Appendix A for detail on location and site.

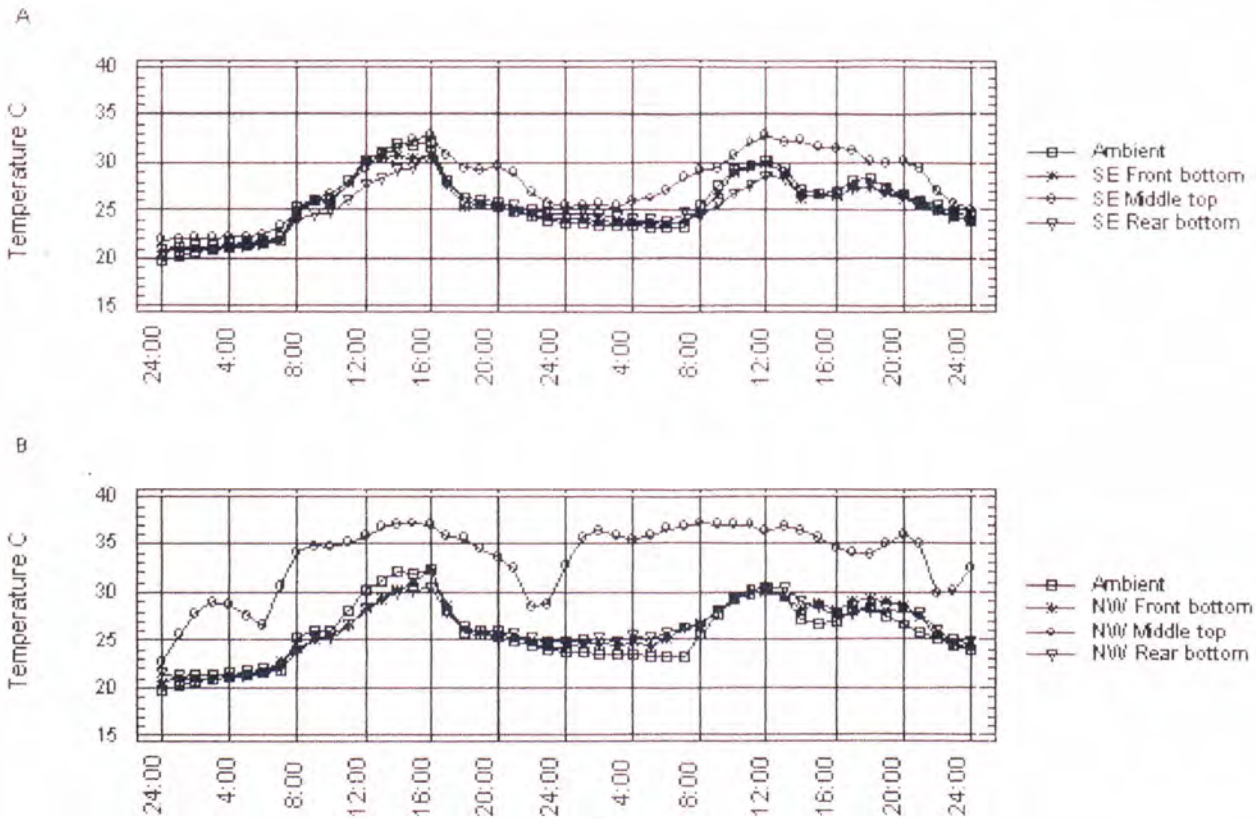


Figure 25. Time series raw temperature profile for Seminole Community College small style bat houses. 24:00 24 July - 24:00 26 July 1995. A is southeast orientation, B is northwest orientation. Note that bat house temperature is above ambient temperature during peak day-time hours. These houses were painted white. Several bats are located in the middle crevice of each house. See Figure 21 and Appendix A for more detail on location and site.

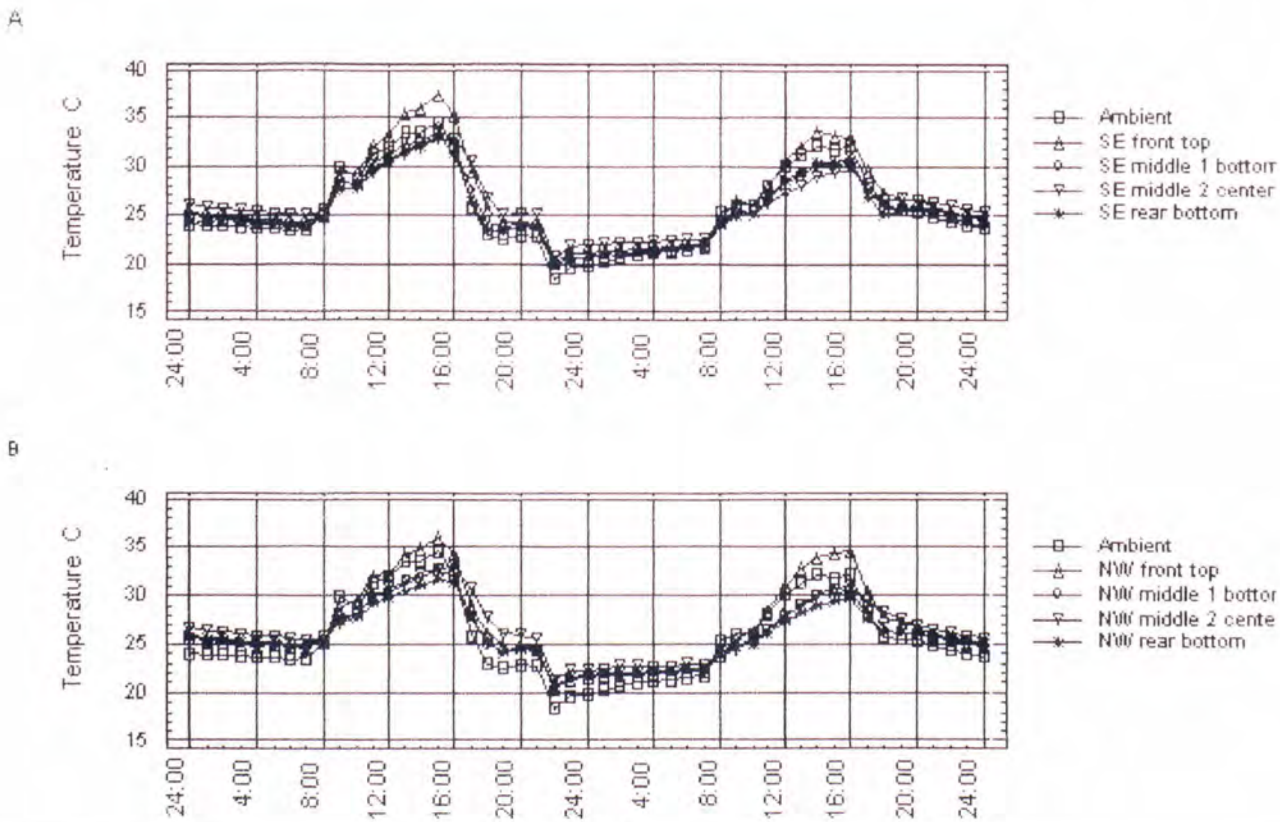


Figure 26. Time-series raw temperature profile for Seminole Community College large style bat houses. 24:00 24 July - 24:00 26 July 1995. A is southeast orientation, B is northwest orientation. Note that bat house temperature is above ambient temperature during peak day-time hours. These houses were modified in May 1995 (see Chapter 3) and remained unoccupied. See Figure 22 and Appendix A for detail on location and site.

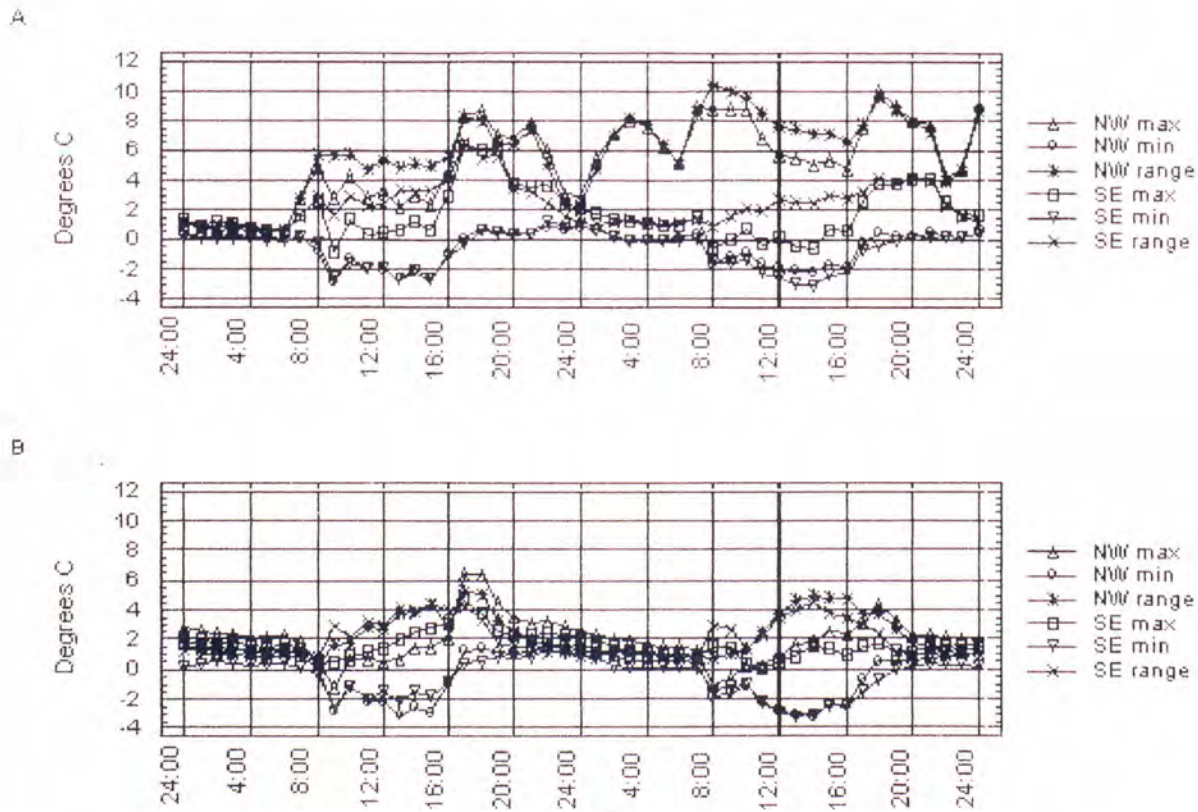


Figure 27. Time-series temperature difference profiles for Seminole Community College small (A) and large (B) style bat houses. 24:00 24 July - 24:00 26 July 1995. Bats are present in the small houses, but the large houses remain unoccupied. The small houses were painted white, the large houses were modified in May 1995. See Appendix A for more detail on site.

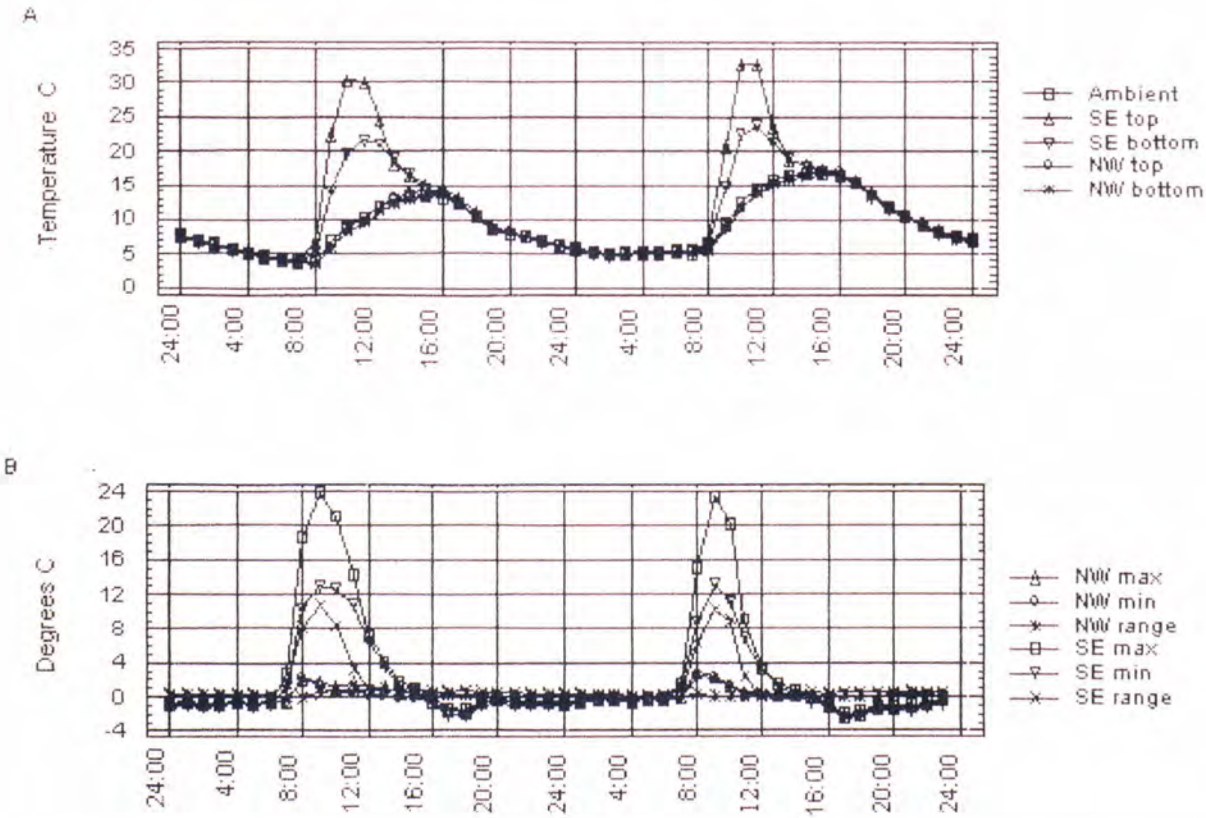


Figure 28. Time-series raw temperature profile (A) and temperature difference profile (B) for Seminole Community College simple style houses. 24:00 4 January - 24:00 6 January 1996. These houses were modified in May 1995 and remained unoccupied. See Figure 20 and Appendix A for more detail on location and site.

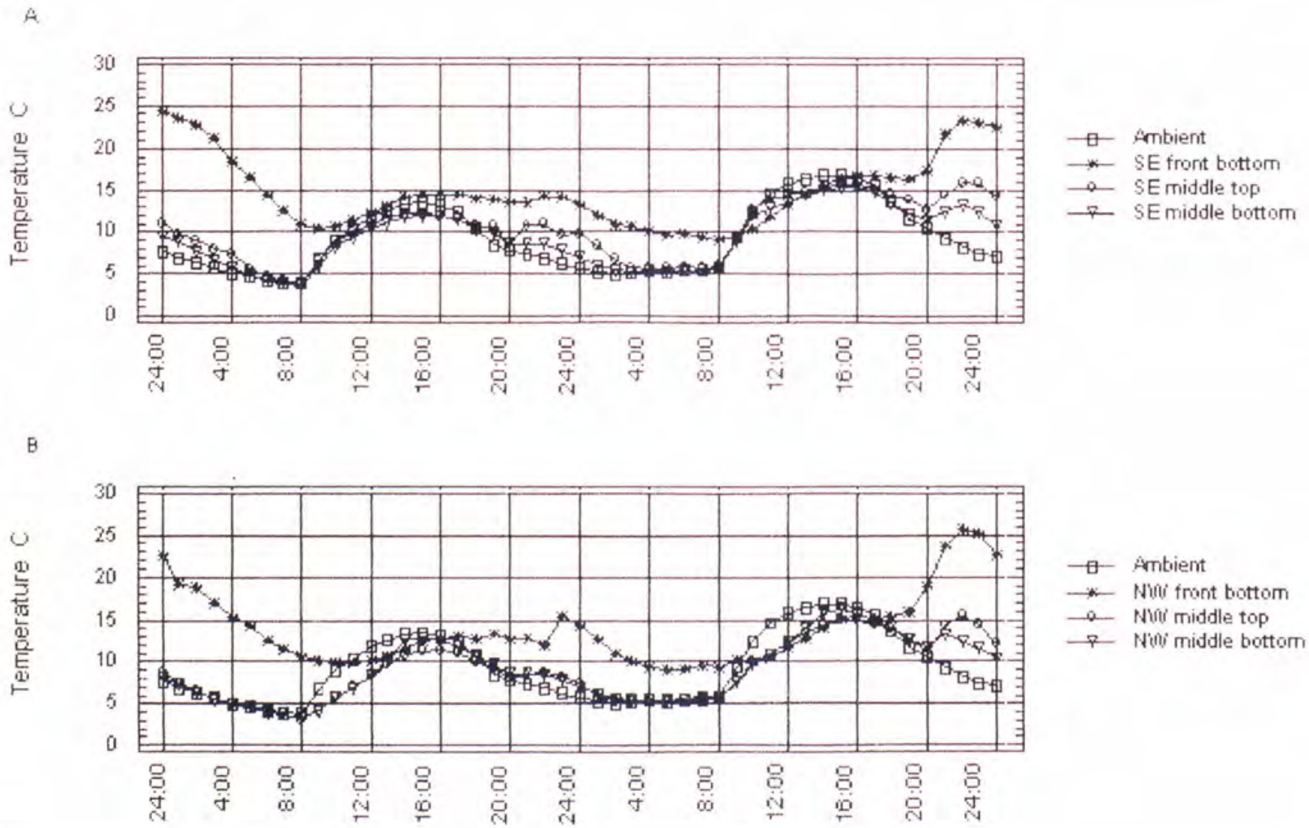


Figure 29. Time-series raw temperature profile for Seminole Community College small style houses. 24:00 4 January - 24:00 6 January 1996. A is southeast orientation, B is northwest orientation. These houses were painted white and bats were present in both orientations. See Figure 21 and Appendix A for more detail on location and site.

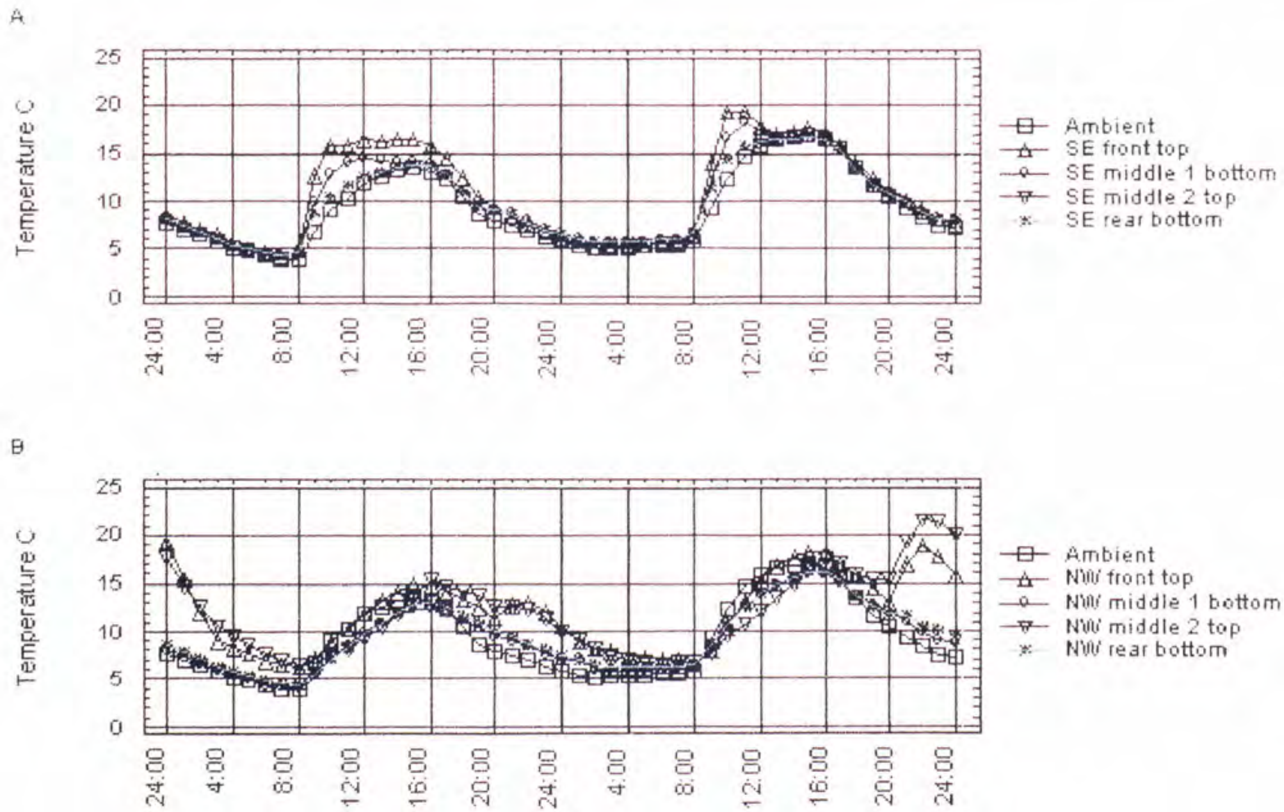
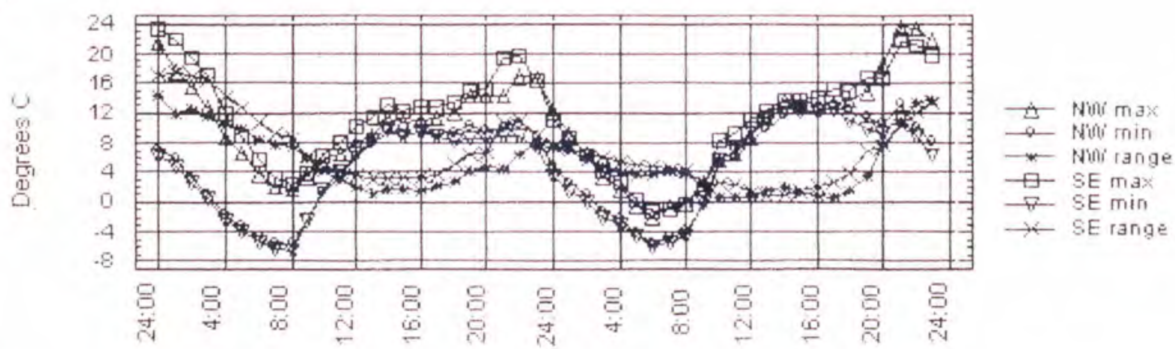


Figure 30. Time-series raw temperature profile for Seminole Community College large style bat houses. 24:00 4 January - 24:00 6 January 1996. A is southeast orientation, B is northwest orientation. These houses were modified in May 1995. Bats are present in greater numbers in the northwest house. See Figure 22 and Appendix A for detail on location and site.

A



B

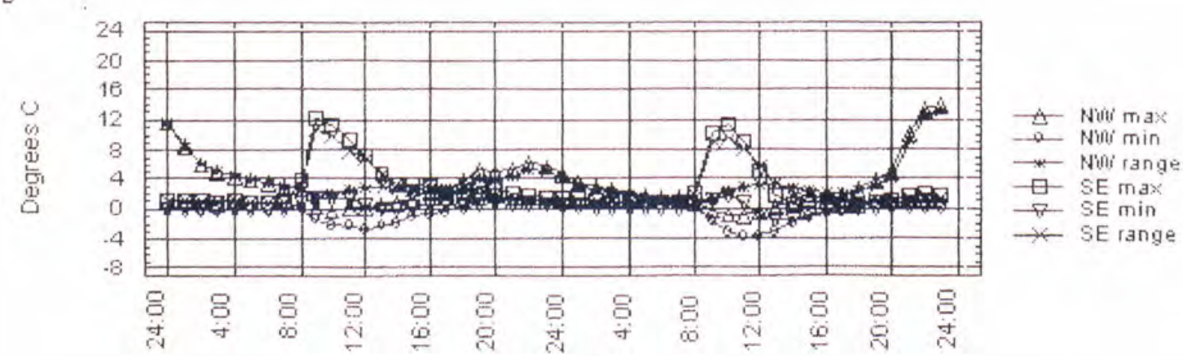


Figure 31. Time-series temperature difference profile for Seminole Community College small (A) and large (B) style bat houses. 24:00 4 January - 24:00 6 January 1996. The small houses were painted white, the large houses were modified in May 1995. Both styles are occupied, but bats are present in greater numbers in the small style houses. See Appendix A for more detail on site.

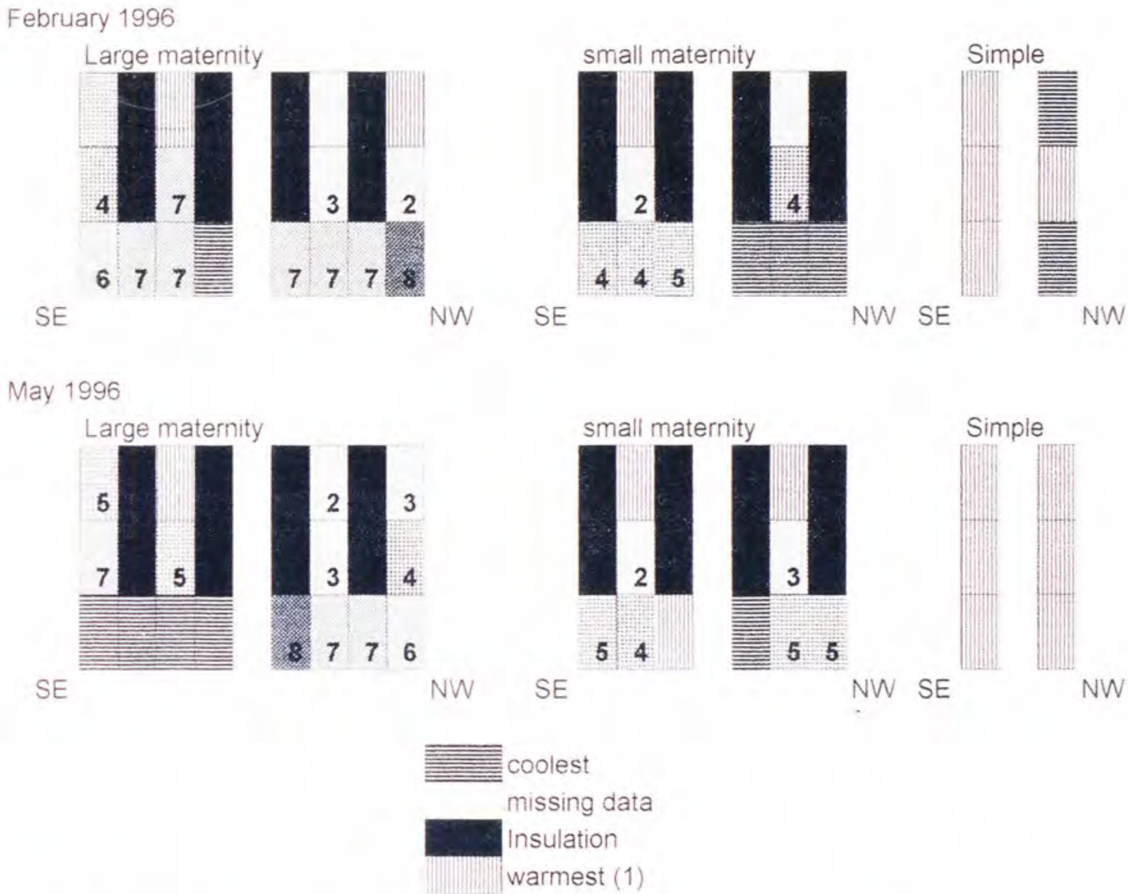
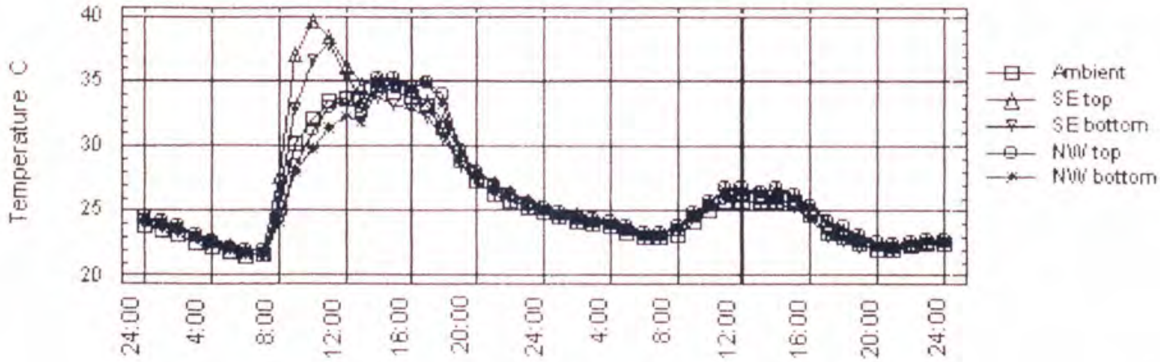


Figure 32. Schematic view of temperature differences in Seminole Community College bat houses. Differences determined by Multiple Range tests using least significant differences (95% CI). The small houses were painted dark brown, but were otherwise unmodified. The large and simple houses were modified (see text). Bats were present in the small and large style houses. The simple houses remained unoccupied. See Figure 18 and 23 for further detail.

A



B

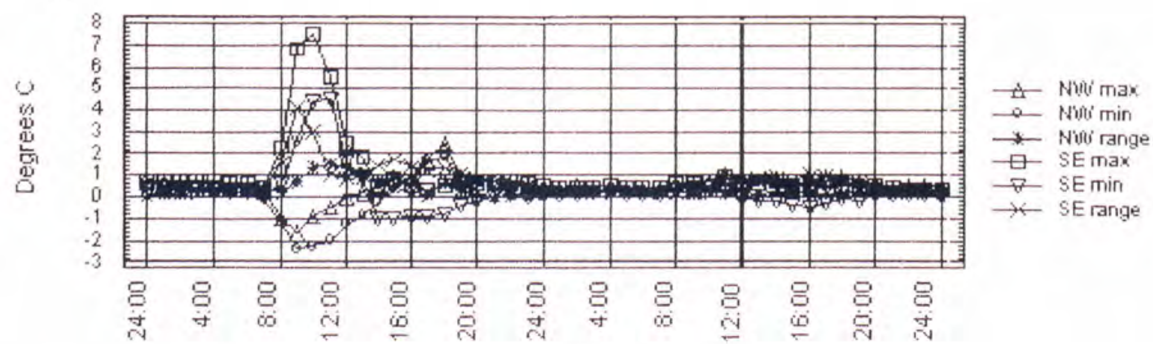


Figure 33. Time-series raw temperature profile (A) and temperature difference profile (B) for Seminole Community College simple style bat houses. 24:00 20 May - 24:00 22 May 1996. These houses were modified in May 1995 and remained unoccupied. See Figure 20 and Appendix A for more detail on location and site.

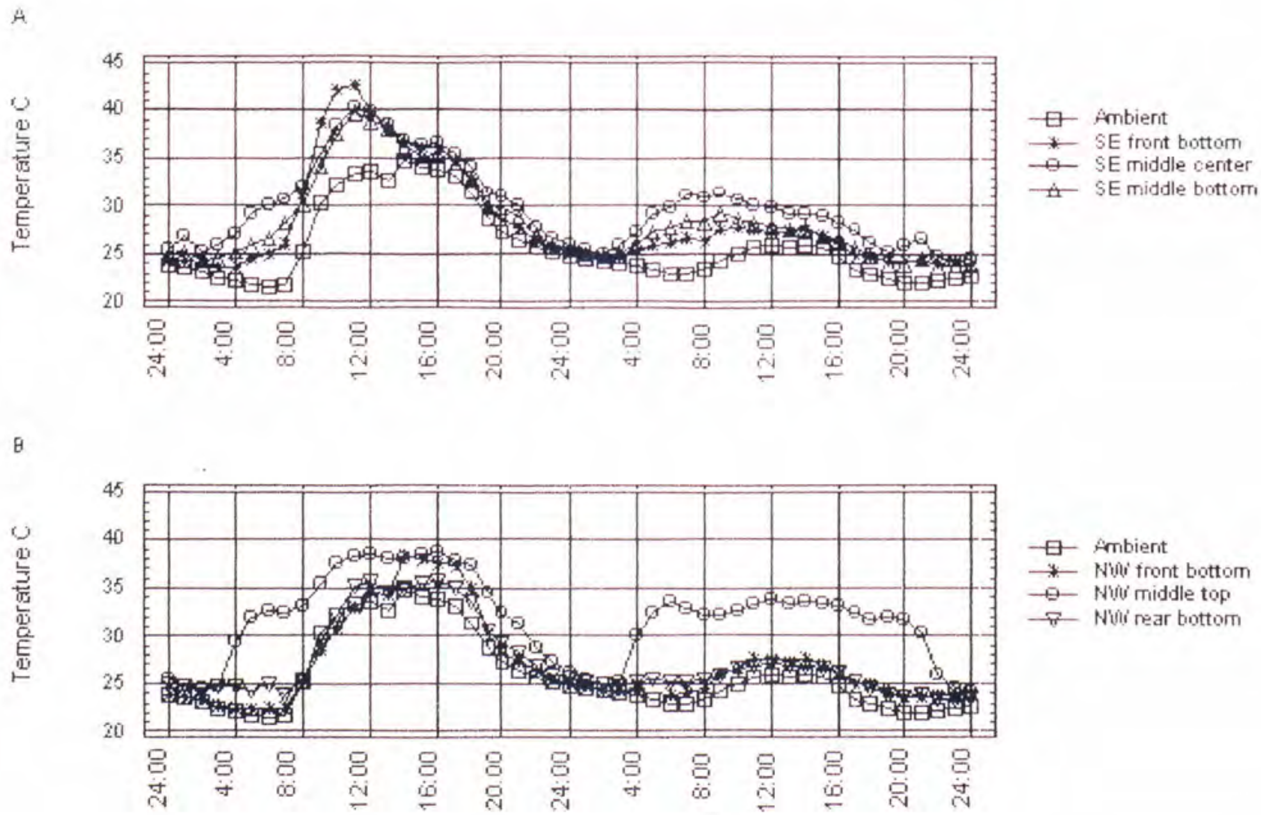


Figure 34. Time-series raw temperature profile for Seminole Community College small style bat houses. 24:00 20 May - 24:00 22 May 1996. A is southeast orientation, B is northwest orientation. This house was painted dark brown in February 1997 and was occupied. See Figure 21 and Appendix A for more detail on location and site.

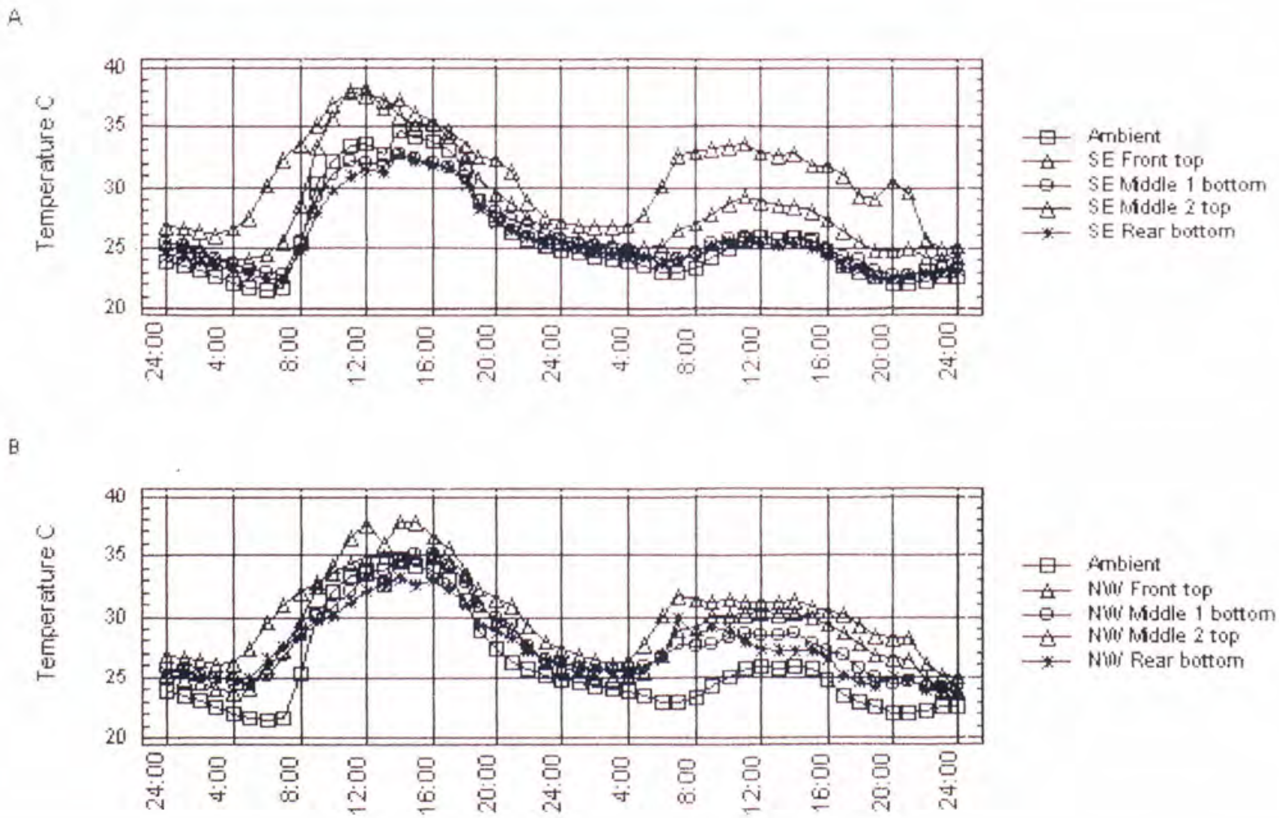


Figure 35. Time-series raw temperature profile for Seminole Community College large style bat houses. 24:00 20 May - 24:00 22 May 1996. A is southeast orientation, B is northwest orientation. These houses were modified in May 1995 and bats were present in both house orientations. See Figure 22 and Appendix A for more detail. See Figure 22 on location and site.

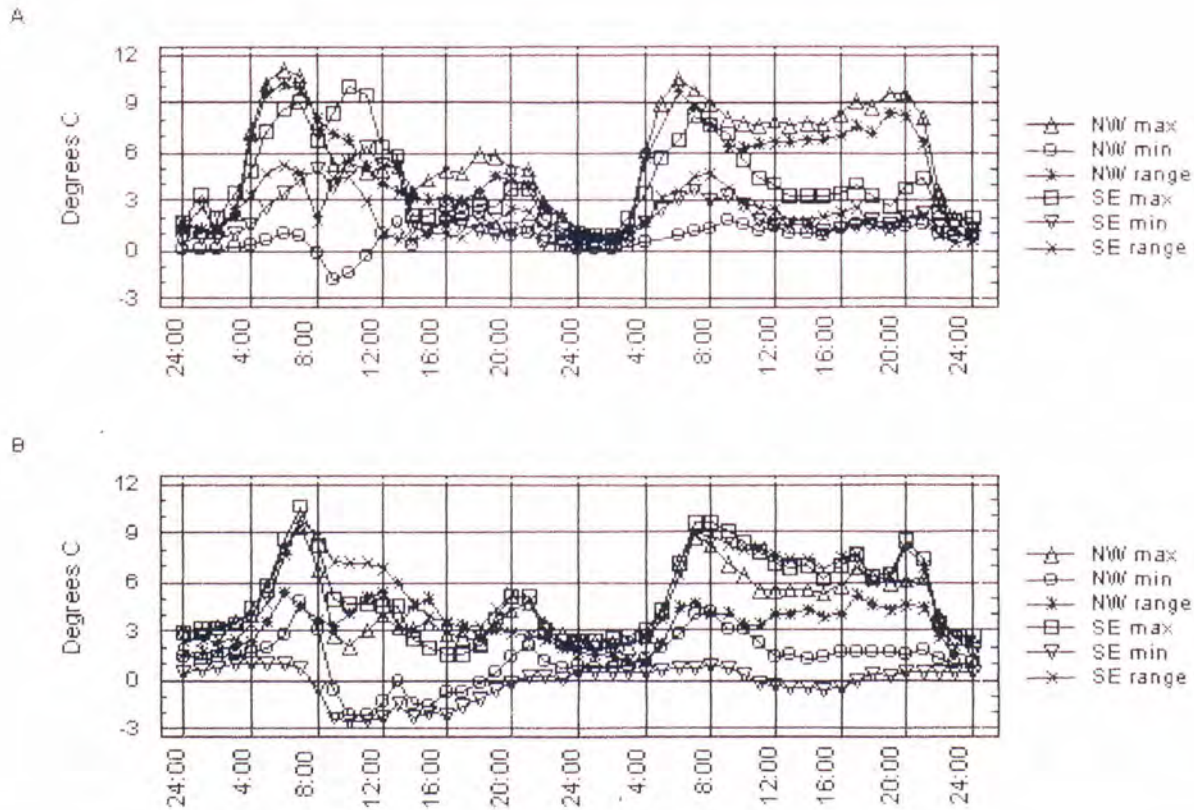


Figure 36. Time-series temperature difference profiles for Seminole Community College small (A) and large (B) style bat houses. 24:00 20 May - 24:00 22 May 1996. The small houses were painted dark brown in February 1996, the large houses were modified in May 1995. Bats were present in the small style houses in greater numbers than in the large houses. . See Appendix A for site details.

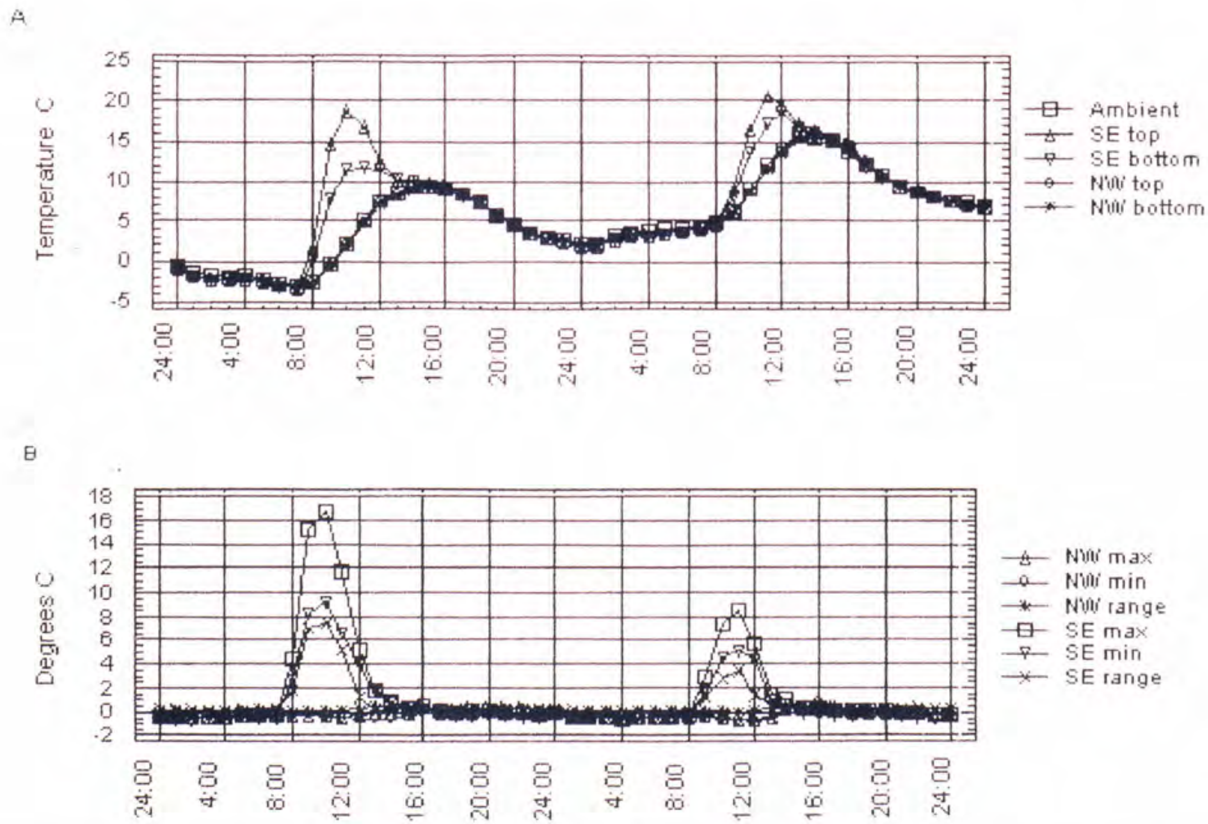


Figure 37. Time-series raw temperature profile (A) and temperature difference profile (B) for Seminole Community College simple style bat houses. 24:00 4 February - 24:00 6 February 1996. These houses were modified in May 1995 and remained unoccupied. See Figure 20 and Appendix A for more detail on location and site.

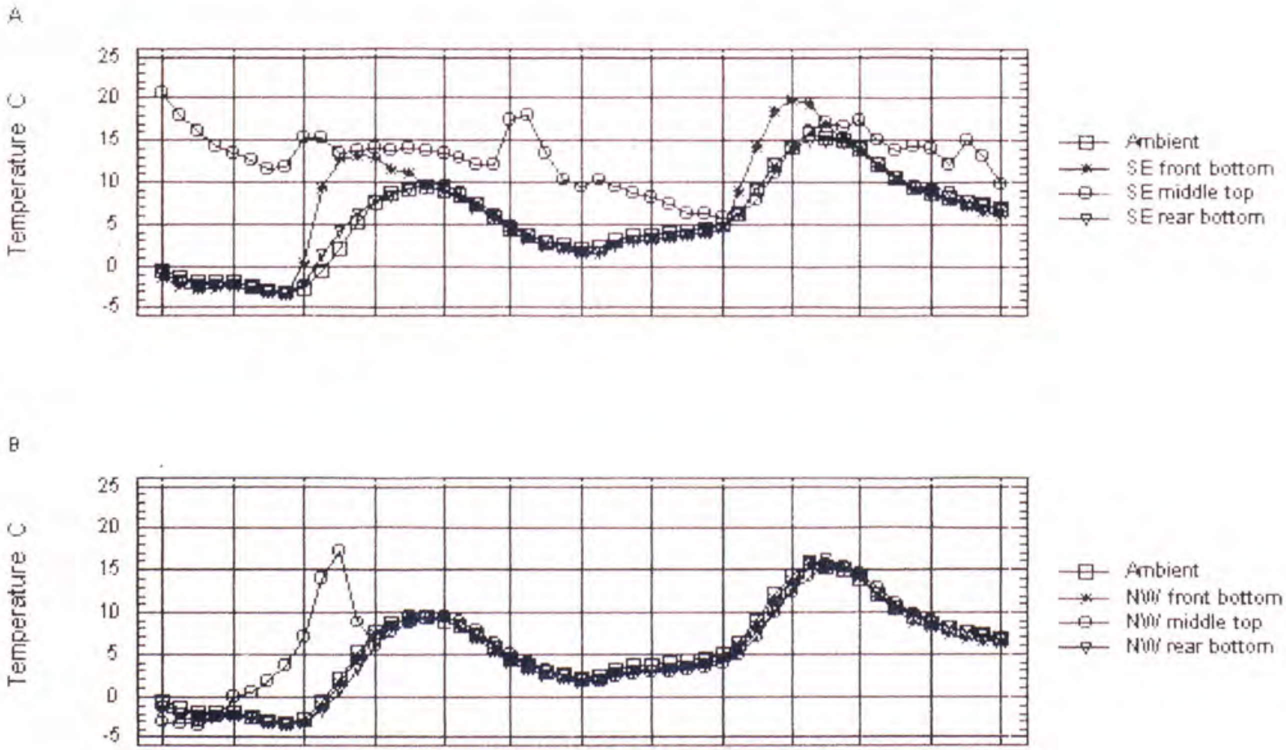


Figure 38. Time-series raw temperature profile for Seminole Community College small style bat houses. 24:00 4 February - 24:00 6 February 1996. A is southeast orientation, B is northwest orientation. These houses were painted dark brown and bats were present in both orientations. See Figure 21 and Appendix A for more detail on location and site.

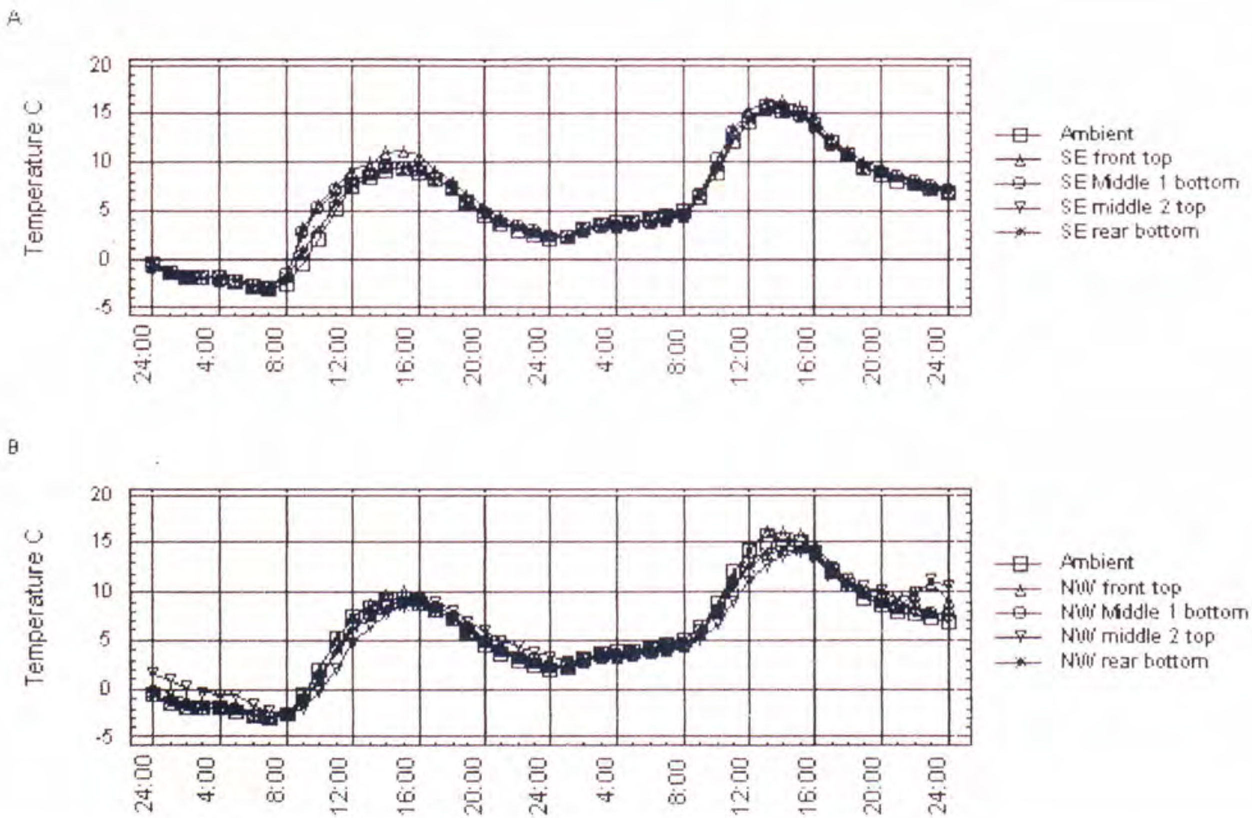


Figure 39. Time-series raw temperature profile for Seminole Community College large style bat houses. 24:00 4 February - 24:00 6 February 1996. A is southeast orientation, B is northwest orientation. These houses were modified in May 1995 and few bats were present. See Figure 22 and Appendix A for more detail on location and site.

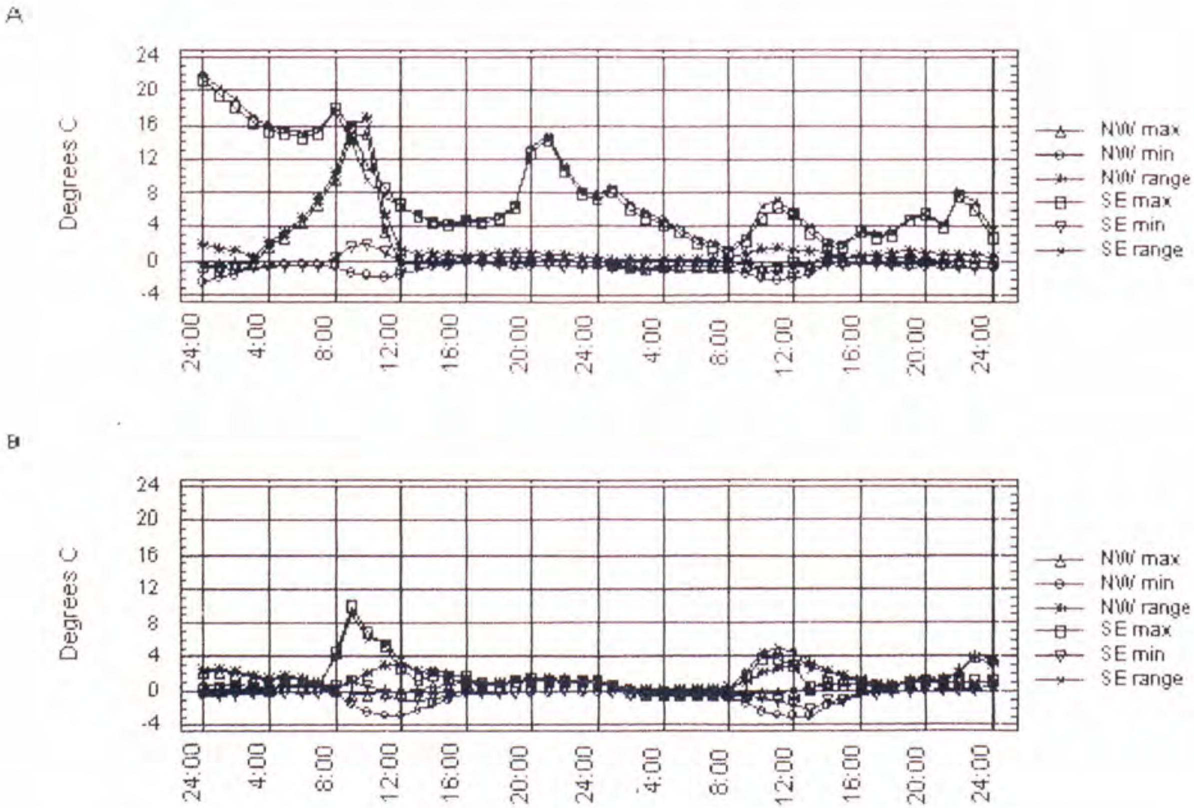


Figure 40. Time-series temperature difference profiles for Seminole Community College small (A) and large (B) style bat houses. 24:00 4 February - 24:00 6 February 1996. The small houses were painted dark brown and the large houses were modified in May 1995. Both styles were occupied, but bats were present in greater numbers in the small style houses. See Appendix A for details on site.

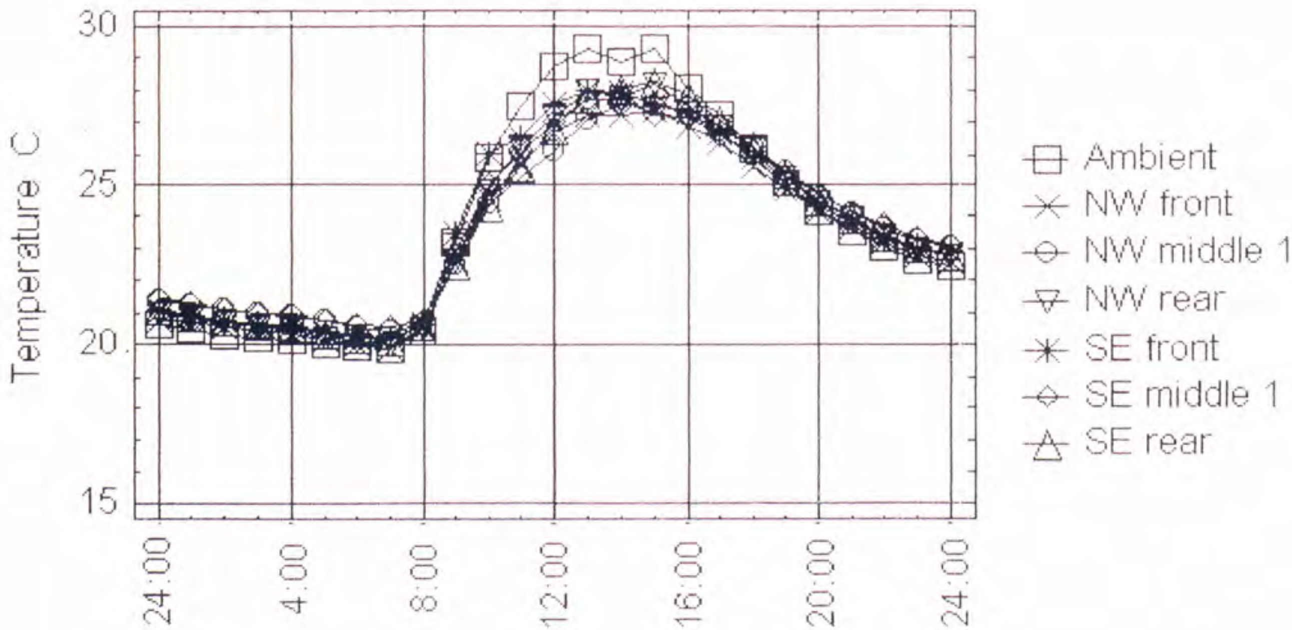


Figure 41. Time-series raw temperature profile for Rollins large style bat houses. 24:00 14 November - 24:00 15 November 1993. The NW middle chamber was occupied by 1 - 2 *Nycticeius* begining in November 1996. See Appendix A for more details on site.

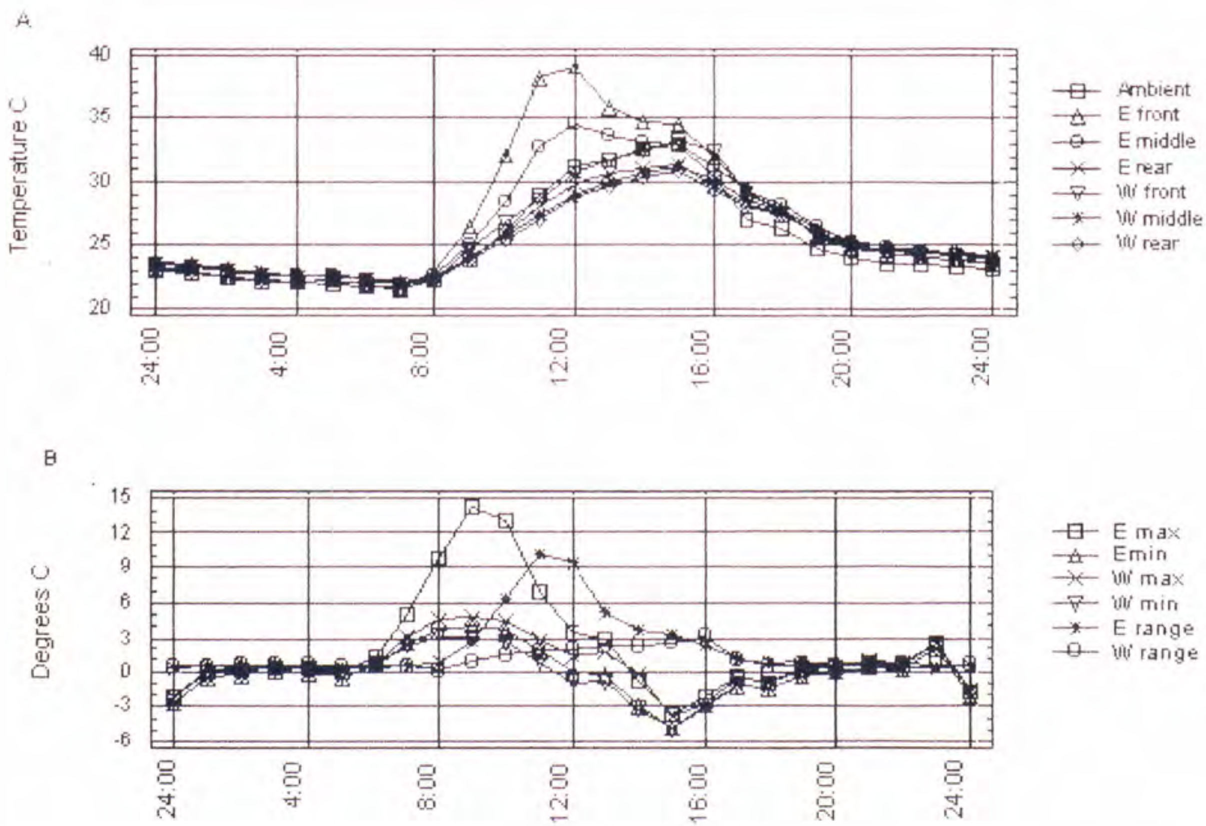


Figure 42. Time-series raw temperature profile (A) and temperature difference profile (B) for Stevens small style bat houses. 24:00 6 August - 24:00 7 August 1994. These bat houses were oriented east and west and were mounted with the modifications used at SCC. On this date both houses were unoccupied. Compare to Figure 43. See Appendix A for more detail.

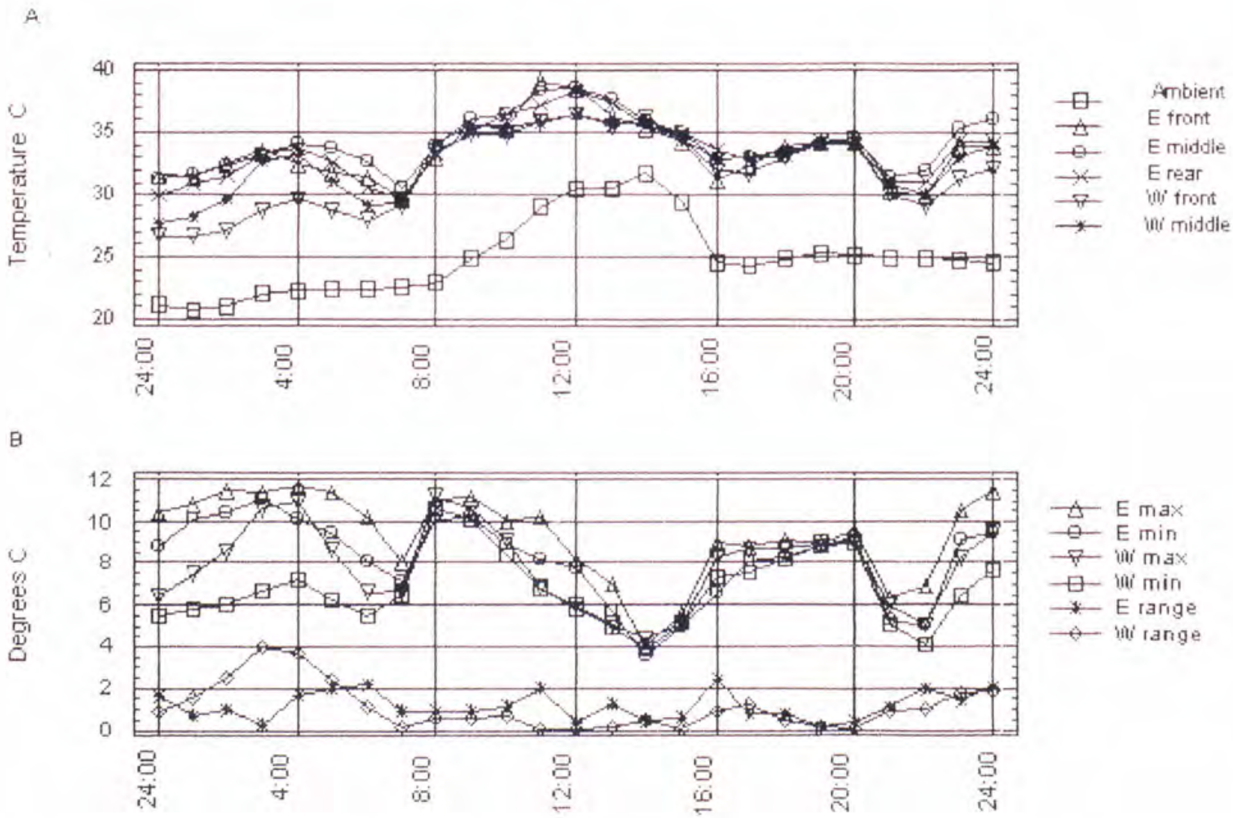


Figure 43. Time-series raw temperature profile (A) and temperature difference profile (B) for Stevens small style bat houses. 24:00 24 August - 24:00 25 August 1995. These bat houses were oriented east and west and were mounted with the modifications used at SCC. On this date both houses were occupied. Compare to Figure 42. See Appendix A for more detail.

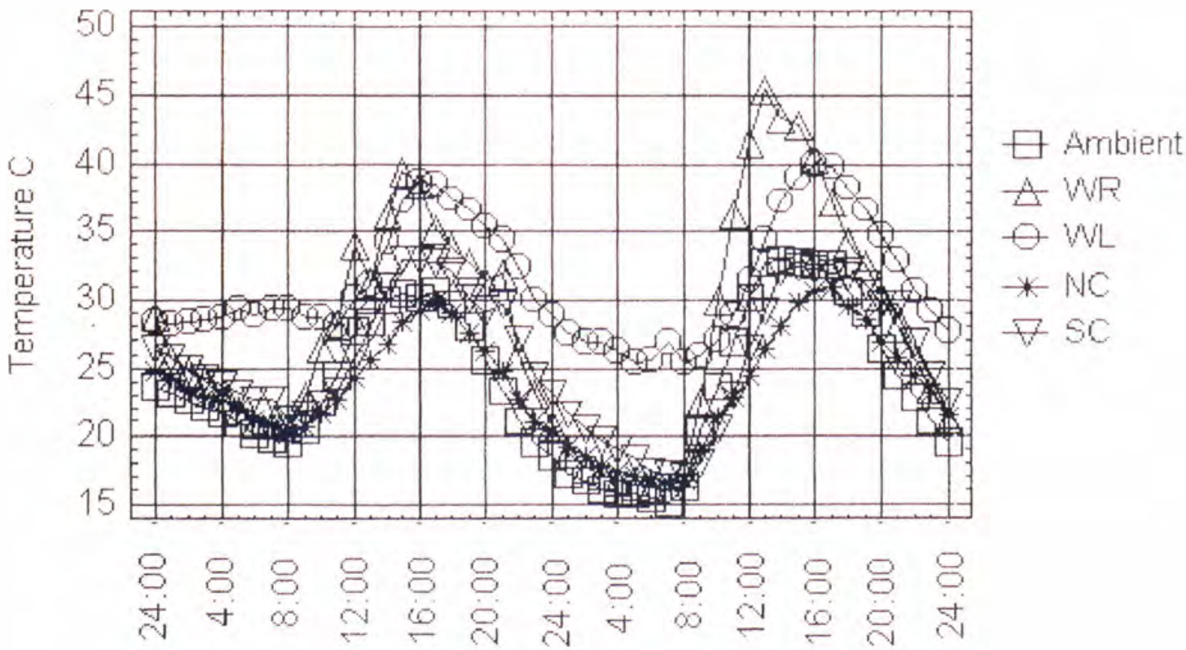


Figure 44. Time-series raw temperature profile for occupied roost at Hill. 24:00 5 May - 24:00 7 May 1994. Notice the wide range of roost temperatures available. See Figure 13 and Appendix A for more detail on location and roost structure.

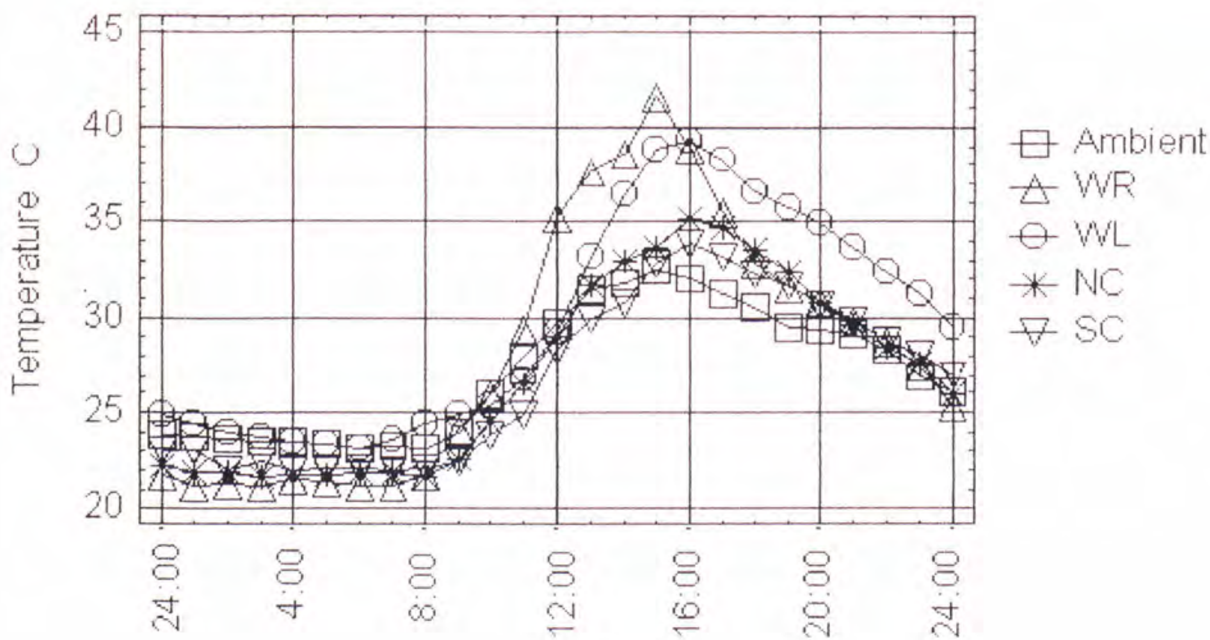


Figure 45. Time-series raw temperature profile for occupied roost at Hill. 24:00 8 September - 24:00 9 September 1994. See Figure 13 and Appendix A for more detail on location and roost structure.

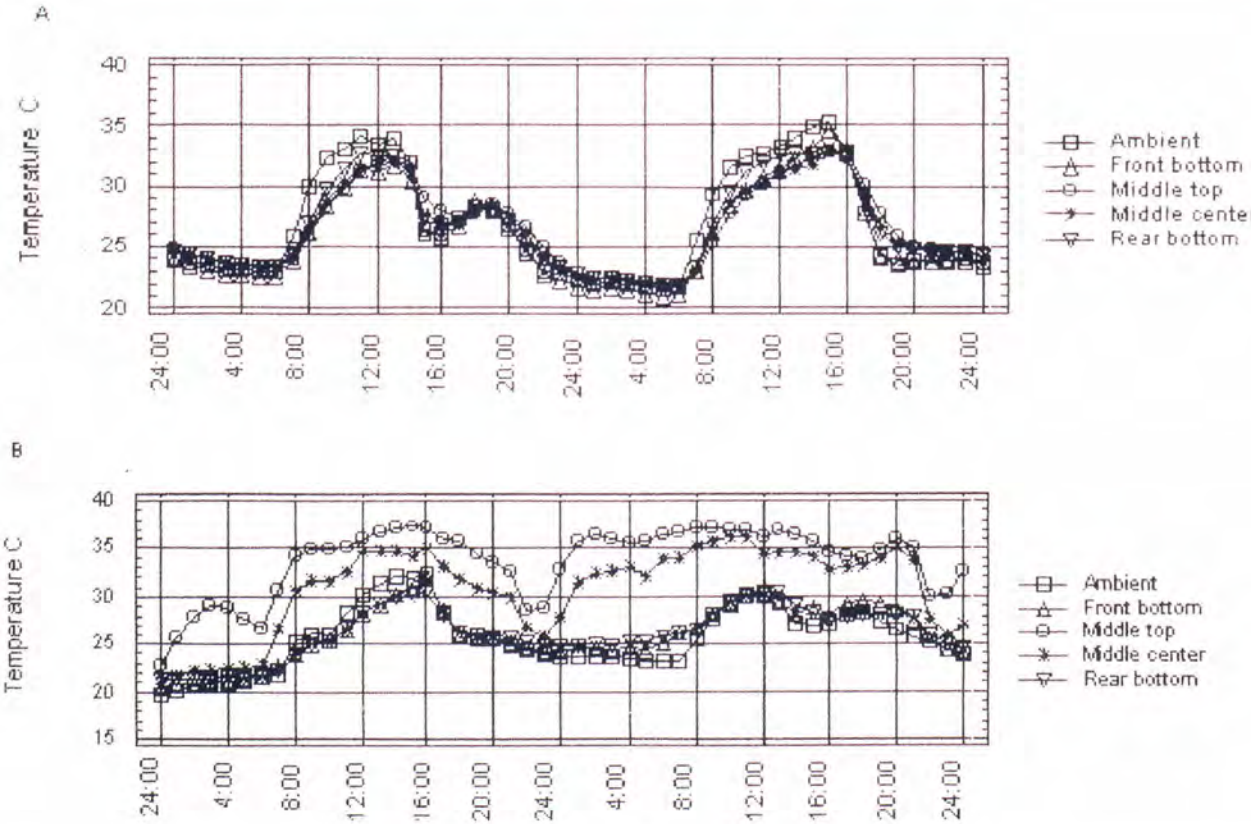


Figure 46. Time-series raw temperature profiles for Seminole Community College small maternity houses (northwest orientation), (A) without and (B) with bats. A was monitored 24:00 19 January - 24:00 20 January 1994, B was monitored 24:00 1 October - 24:00 2 October 1995. Both dates have similar ambient temperature profiles. See Figure 21 and Appendix A for more detail on location and site.

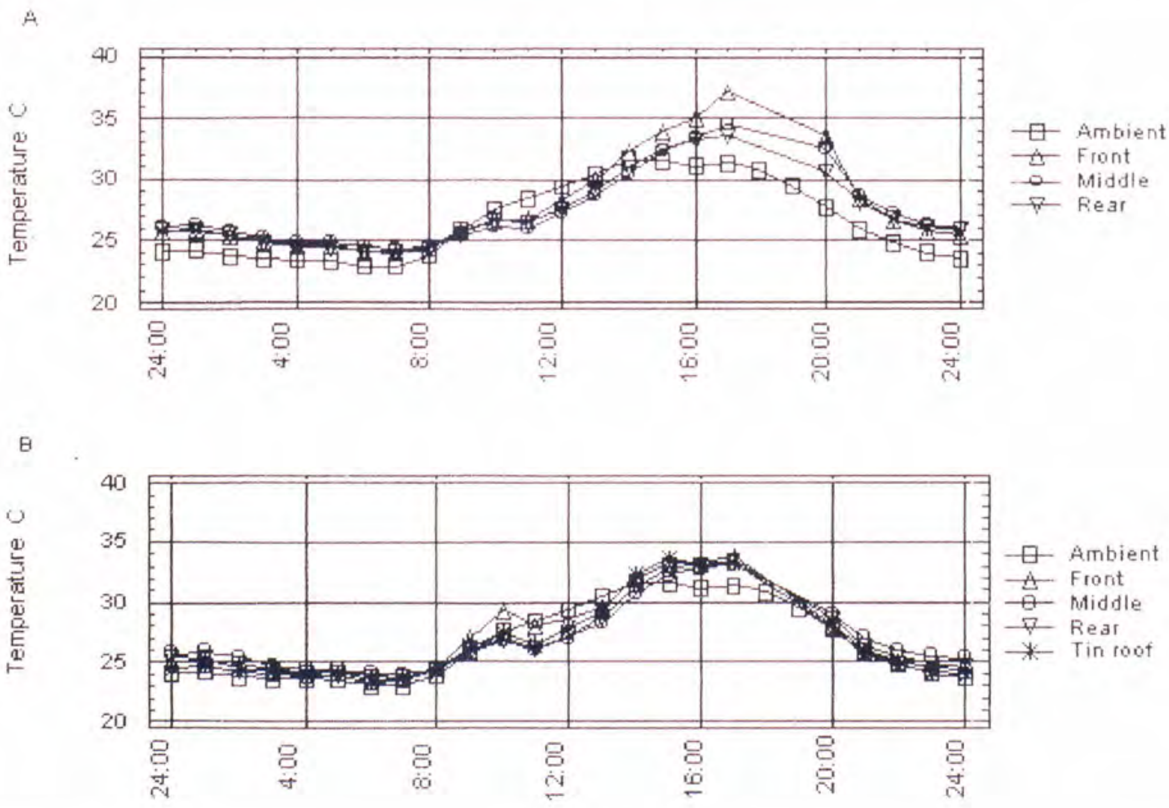


Figure 47. Time-series raw temperature profile for Finn small style houses: (A) West, (B) East. 24:00 22 August - 24:00 23 August 1996. Compare to North and South houses illustrated in Figure 48. All houses were unoccupied on this date.

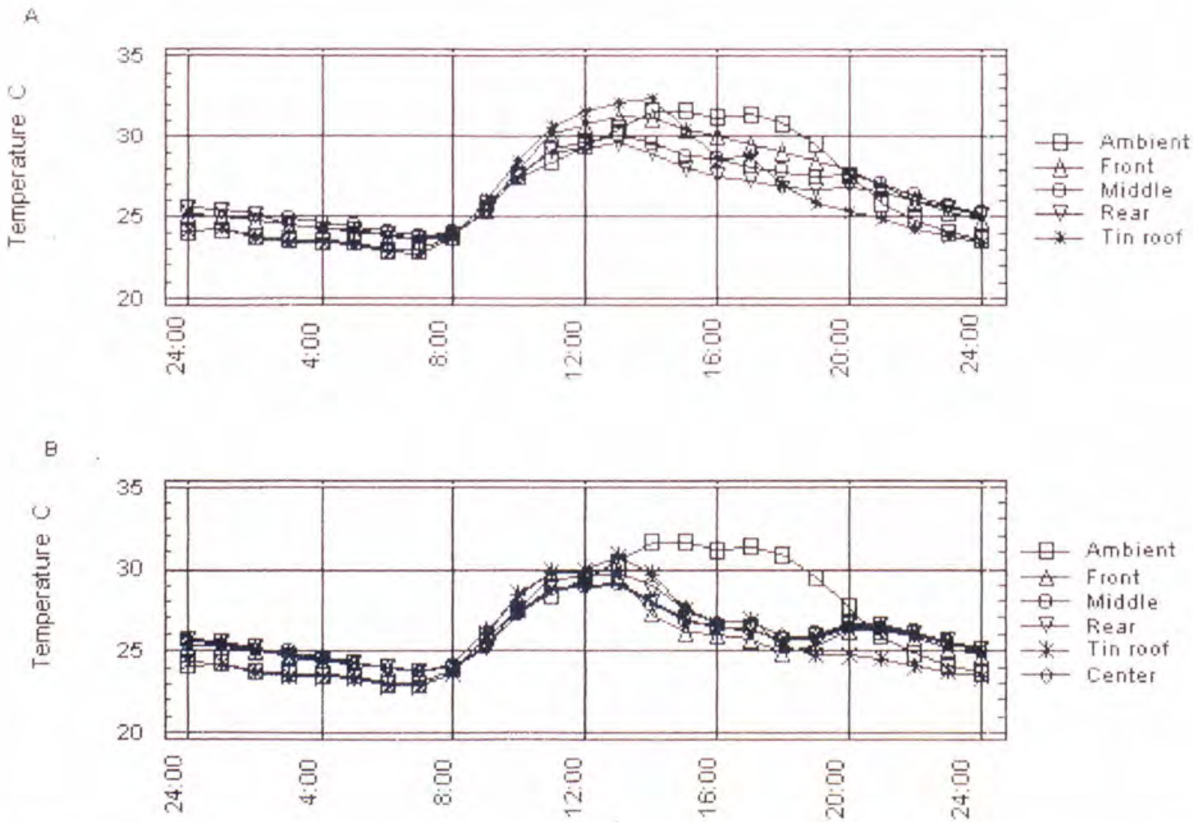


Figure 48. Time-series raw temperature profile for Finn small style houses: (A) South, (B) North. 24:00 22 August - 24:00 23 August 1996. Compare to East and West houses illustrated in Figure 47. All houses were unoccupied on this date.

APPENDICES

Appendix A

Summary and History of Central Florida Study Sites

Aikins Print Shop, Sanford, Seminole County

This site was the location of a mixed *Tadarida brasiliensis cynocephala* and *Nycticeius humeralis humeralis* colony. The estimated colony size was 200 - 500 individuals. Visual inspection revealed both species occupied the roost and segregation was not apparent. The bats were roosting in a deteriorated awning that spanned the east side of an old brick building just above the first story. The awning was only eight inches (20.32 cm) in height, and most of the bats roosted on the north end. Entry to the roosting area was made where the wood framing had deteriorated.

On 27 June 1994, I placed thermocouples in two locations to monitor roost temperature and in a third location to monitor ambient temperature. At this time a BCI large maternity house (no insulation, clear varnish) was mounted on the east side of the building, 5 feet (1.52 m) above the awning roost. Bats began to occupy the bat house in the winter of 1995/1996. On 11 June 1996, after the building was sold, the awning was torn down and on 15 June 1996 the occupied bat house was moved to the Finn site. See chapter 2 for further details on the relocation of an occupied bat house.

Central Florida Zoological Park (CFZ), Sanford, Seminole County

Several small bat houses had previously been placed on the trunks of cabbage palms (*Sabal palmetto*) on CFZ property by the zoo staff. These

houses were built by a local eagle scout and have never been occupied. On 11 February 1994, a series of six bat houses was mounted on three palm trees near the Herpetarium. The series included two each of the Bat Conservation International (BCI) simple, small maternity, and large maternity houses. Each set of two houses was placed back to back, facing southeast and northwest. All houses were painted with white insulative paint (Astec coating). On 8 May 1996, these bat houses were removed from the palms and modified in an attempt to increase the temperature profile (see Stevens below). On 25 May 1996, two sets of modified large maternity houses were placed with one set facing north and south while the other faced east and west. The closest known bat colony was the Aikins colony, 2 miles (3.92 km) to the east. To date (April 1997) these houses have not been occupied.

Finn, Deltona, Volusia County

At this site the same series of six bat houses at CFZ was mounted on the trunks of pine trees (*Pinus* sp.) near Lake Butler, March - May 1994. These houses were stained with a clear varnish and no insulation was present. In June 1994, a BCI old style house was hung from the limb of a live oak tree (*Quercus virginiana*) 150 feet (45 m) to the South of the other boxes. This bat house was placed in the same manner as the old-style house at Stevens (see below). The series of houses mounted on pines was utilized in seeding experiments (see Chapter 2). On 8 May 1996, these houses were removed from the pines and modified in the same manner as the Stevens houses. Two

sets of small maternity houses were painted dark brown and mounted with one set facing north and south (19 June 1996) while the other set faced east and west (9 August 1996). A cage was build on the east-west set to act as a half way house for the controlled release of hand-raised bat pups (Finn, 1996).

The Aikins large maternity house was moved to this site in June of 1996 (see Chapter 2 for more details). The BCI old style house and the east-west house remain unoccupied. Gray squirrels (*Sciurus carolinensis*) chewed the old style house and made it unacceptable for bats. The old Aikins house and the north-south house were occupied during the summer months (June - August 1996). See Chapter 2, Relocation of an occupied bat house, for more details.

Hill, Lake Helen, Volusia County

This site was the location of a mixed *Tadarida* and *Nycticeius* colony consisting of over 1000 individuals. The building was a small (one bedroom) 100+ year old wood house with a metal roof. The bats were roosting below the metal roof on the west end of the house. There were several entrances to roosting areas that were in the attic of the house. Although visual inspection was difficult, bats were seen roosting directly under the metal ridge-cap and in the attic against the wood portion of the roof ridge. This is the only central Florida site where I have seen bats roosting in any open areas (not in crevices). During the late summer months it was not unusual to see juvenile *Nycticeius* roosting on the outer walls of this building. Several non-BCI bat houses were placed in suboptimal locations at this site (tree trunks, shaded areas on buildings, etc.) by

the property owner. These houses remain unoccupied. She was supplied with plans to build more suitable bat houses, but never did so.

Beginning in May 1994, roost temperature was monitored on several occasions. Thermocouples were placed in five locations in the building, three of which were known to be popular roosting areas. A sixth thermocouple was placed to monitor ambient temperature. Conditions inside the living quarters of the house were made unbearable due to the presence of the bats, the smell of ammonia would make one's eyes water and breathing uncomfortable if the air conditioning unit was turned off. Eventually the tenants in the house moved out. In March 1996, the bats were evicted from the building, by wrapping the entire house in fiberglass window screen. The screen is still present. It is not known to where the bats moved.

Institute of Food and Agricultural Sciences (IFAS), Sanford, Seminole County

In March 1994, the same series of six houses was mounted on poles (donated by Florida Power, Corp.), facing southeast and northwest, at the north end of IFAS property. This location is approximately .8 km north of Lake Monroe. A Texas style house was also erected. These houses were painted white and had no insulation. On 4 May 1996, the houses were painted dark brown. The closest known colony was the Aikins colony (see above) roughly 1 mile (1.6 km) west. These bat houses remain unoccupied.

Mount Dora Head Start, Mount Dora, Lake County

This site was the location of a *Nycticeius* maternity colony. Bats were roosting under the Spanish roof tiles located on top of a chimney. In 1994, a pest control operator treated for rodents and dozens of dead bats were subsequently found in the building. Prior to this the property owner did not know bats were living here. On 15 April 1995, I evicted the bats from the roost and placed a BCI large maternity house on the east side of the chimney, 1 foot (30.5 cm) below the original roost. The bat house was painted with medium brown insulative paint (Astec coating). The bat house remains unoccupied. It is not known where the bats moved.

Oviedo High School (OHS), Oviedo, Seminole County

The series of six houses was mounted on poles at OHS, 15 September 1994. These houses were stained dark brown and had the enclosed sides, ventilation slots, and metal roof similar to the houses at Stevens. The orientation was southeast-northwest. No bat colony existed on campus and the closest bat colony was not known. These houses remain unoccupied.

Paisley, Lake County

This site was the location of a nuisance colony of *Nycticeius*. The bats were roosting on the south side of a two story log home. The roost area was a crevice along a horizontal beam that entered the upper wall of the second story. Bat houses were placed at this site on two different dates and both later became

occupied. The first was a BCI large maternity house mounted on a 4" x 4" (10.2 x 10.2 cm) pole that was extended from a porch rail located 15 feet (4.57 m) from the colony entrance. This house became occupied by a single *Nycticeius.* The second house, a large modification of the BCI large maternity house, was erected 8 November 1995, and by the first week of May 1996 it was occupied by a maternity colony (ca. 50-75 adults) of *Nycticeius*. This house was placed on a utility pole between the house and the lake (Cowpen pond). The bats seem to prefer the southeast side of the larger house, while the single *Nycticeius* found in the smaller house was always on the northwest side. Both houses face southeast and northwest. Bats were never evicted from the building, but chose to move into the bat houses, vacating the building on their own. By 27 June 1996 all bats had vacated the property. This pattern of summer occupancy also occurred with the bats that roosted in the main building.

Rollins College, Winter Park, Orange County

Several buildings on this campus have been occupied by both *Tadarida* and *Nycticeius*. When J.R. Bain did research on Florida bats (1981) this was one of his sites. The bats here have caused no significant problems with campus administrators and no plans exist to evict them from their present roosts. On 6 June 1994, two thermocouples were placed into the roosting areas used by bats in one of the buildings. A third thermocouple was mounted to collect ambient temperature. Although the bats were entering beneath the red Spanish roof tiles, the roosting area was a crevice between a 2" x 10" (5.08 x 25.4 cm) board that

runs along the upper attic wall and the outer cement block wall. This roost was on the North side of a three story dormitory building. Due to vandalism by students, all thermocouples were removed from the roost 11 February 1995.

On 26 August 1993, a set of large maternity houses was mounted on an old light pole roughly 500 feet (15.24 m) from a dormitory. Later a BCI, Texas style bat house was erected on the shore of Lake Virginia, about 1000 ft (30.5 m) South of the dormitory, on 29 December 1993. This house was originally painted white. It was repainted dark brown 13 October 1996. The large maternity houses have been steadily occupied by one - two *Nycticeius* since that date. A single bat was first noted on the date the house was painted. The last date prior to this that the houses were checked was 7 September 1996. At that time it was empty. The bat(s) consistently occupies the second crevice of the southeast house. No significant differences between temperatures in the crevices were present when this set of houses was painted white. Temperature data have not been analyzed since it was repainted in October 1996.

Sea World, Orlando, Orange County

Both *Tadarida* and *Nycticeius* have occupied buildings on park property for many years. As with other nuisance colonies, they became a problem only when the odor and guano built up to an intolerable level. I consulted with Sea World personnel about building bat houses and three sets of houses were placed on the site in the winter of 1995.

A relocation similar to that performed at SCC was attempted while one of the buildings was undergoing an exclusion. On five occasions in October, bats returning to the roost in the morning were captured and placed into bat houses roughly 1/4 mile (.4 km) away. The bats at this site were difficult to capture with hand nets due to the style of the building, and small numbers (2-4 bats) were captured and moved during the main relocation. However, once the bats were excluded, bats that were not able to re-enter the roost were captured relatively easily. The evening and morning of 17-18 October 1996, 177 bats were captured (97.7% *Tadarida*). This attempt, however, was extremely stressful to the animals and may be part of the reason for the lack of success with this relocation attempt.

Due to the large numbers of bats captured, and the amount of time they were contained, a failure occurred with the plastic bucket holding containers. The screen and cloth liner that was secured to the lower half of the bucket, pulled off under the pressure of so many bats, heat, guano, etc., and all bats ended up in the bottom of the bucket. This resulted in fatality for 9 animals (8 *Tadarida*, 1 *Nycticeius*) and was certainly highly stressful on the others. The buildup of metabolic heat in the bucket, although not measured was definitely noticeable. The animals may have suffered heat stress or suffocation due to decreased air circulation. Although I have been successful with these holding containers in the past, in the future, unless a better method is found for securing screen or cloth to the sides of the container, they will not be used for more than fifty to seventy-five animals at a time. The importance of the screen/cloth liner is to allow

the bats something to hang on to. This prevents them from all roosting on top of each other and minimizes stress. Additional buckets will be needed when the potential exists for capturing large numbers of bats.

Exclusions have continued for other buildings on park property, but the bat houses remain unoccupied. It is not known where the bats moved. A large colony exists in a highway overpass less than .8 km away. The bats may have assimilated with this colony and many bat-friendly buildings remain on park property.

Seckbach, Winter Park, Orange County

On 15 January 1994, two large maternity houses were mounted on the north and south sides of the chimney on this private residence. The houses were painted medium brown to match the chimney color. Guano bags were placed on each bat house. This site is less than 1/4 mile (.4 km) from Rollins College (see above). On 9 August 1996, 28 *Tadarida* were placed in the south facing house during a seeding experiment (see chapter 2). At this time polypropylene mesh was added to the landing pads of both houses. These houses were not occupied and were removed 2 February 1997.

Seminole Community College (SCC), Sanford, Seminole County

The majority of the research took place at the Science/Library building at SCC. I conducted a census of this colony from October 1991 through Fall 1992. This roost housed both *Tadarida* and *Nycticeius*. Bats were present and

active throughout the year and *Tadarida* made up the majority of the population. During spring parturition there was some evidence that *Nycticeius* may form smaller maternity groups separated from *Tadarida*. However, the design of this building and the area the bats were roosting in made visual inspection impossible. The population had a tendency to be greater in the summer months while the temperatures were warmer, and decreased somewhat in the winter months. This may, however, be an artifact of ambient temperature differences and the behavior of the bats in differing temperature extremes. Bats were present in the winter months and were observed flying at temperatures as low as 7.2^{0}C. For aesthetic reasons, they were evicted from the campus buildings in the spring/summer of 1995. Prior to the eviction, the colony consisted of a minimum of 1000 - 1500 bats.

On 18 November 1993, six thermocouples were placed into the roosting crevices of the Science building. Three thermocouples monitored crevice temperature of the South, West and North sides of the building. The other three thermocouples monitored the wall temperature at these locations. A seventh thermocouple was placed to monitor ambient temperature.

In May 1994, the series of six bat houses was placed near the greenhouse area of the college, near Lake Mary. (See Chapters 2 and 3 for more detail). These houses were originally painted white and Reflectix insulation was placed in the top half of the front and rear chambers of the small maternity houses, and the top half of the second and rear chambers of the large maternity houses. Guano bags were placed on the small maternity houses and on the Florida style house

(a large modification of the Texas house). Prior to the eviction in May 1995, the large and simple houses were modified to be similar to the houses at Stevens (see below). The small style houses were not modified due to the presence of a single *Tadarida*. In late May 1995, the guano bags were removed from the small maternity houses and placed on the large maternity houses. In January 1996, the small maternity houses were painted medium brown in an attempt to keep them warmer, but otherwise remained unmodified.

After the relocation, bats occupied the small maternity houses only. A single bat was seen in the Florida house on 6 June 1996. By 1 July 1996, very few bats were in the small maternity houses, with 10-15 in the southeast large style house. On 9 July, all bats had vacated all houses. The fiberglass window screen used to line the inner partitions of the bat houses had failed. It had deteriorated under the pressure of the bats and was falling out of the bat houses. After the fiberglass window screen was removed, the relocation was resumed and was successful. Again, bats were using the small maternity houses only, with a preference for the northwest house. On 24 November 1995, I added polypropylene mesh to the landing pad of the large maternity houses and removed the Reflectix insulation. On 11 December 1995, the first bats were seen in the large maternity houses and only in the northwest house. Bats did not begin using the large southeast house until 26 February 1996. In January 1996, the first bat was seen in the large square house, which was painted white. During a few weeks in March 1996, a cluster of 10-15 *Nycticeius* was using the east side, but later vacated the house. On 4 May, I painted this house medium brown. A single *Nycticeius* was seen

here 26 May - 6 June 1996. On 9 and 10 December 1996, three and 4 *Tadarida* wee seen roosting in the same location.

On 15 April 1995, I noted the Fire-Science classes burning cars near the unoccupied bat houses. Smoke from the fire was going directly into the houses. A complaint was made to the physical plant director and the burning of cars stopped here until October 1996. Sometime between 13 and 28 October, three cars were burned within 15 feet (4.57 m) of the now occupied bat houses. When I learned of this (28 October), two cars had already been removed and all bat houses were empty. Bats did return by 4 November 1996, and assurances have been made that this will not occur again (see Berry, 1996).

<u>Stevens, Orange City, Volusia County</u>

In December 1991, a colony of bats was evicted from this private residence; the bats had been roosting there since 1984. The previous year, a BCI old style house was installed to hang from the limb of a live oak. This bat house was 100% shaded. Bats were first noted in the bat house in January of 1993. On 1 July 1993, the property owner counted 112 bats leave the bat house, but by 8 July all bats were gone. I confirmed this house to be occupied by a maternity colony of *Nycticeius* in 1994. On 30 April 1994, 29 pregnant *Nycticeius* and 1 male *Tadarida* were captured as they left the bat house. By 19 June all bats were gone (see Paisley above). Several additional houses, also of BCI design, were mounted on the trunks of palm trees (*Sabal palmetto*). None of these was ever occupied.

On 7 May 1994, a set of small maternity houses that met the new BCI standards, with some small modifications, was added. These houses were mounted on 4" x 4" poles (10.2 x 10.2 cm), 4 inches (10.2 cm) apart and faced east-west. They were painted dark brown and a ventilation slot was provided on the front and back panel of each house. A single metal roof was placed over both bat houses. On 19 June, one bat was noted in the east side of this house. On 20 February 1995, this house was empty, but on 21 February 1995, nine bats were present on the east side. By 21 March, the fiberglass screen liner began to deteriorate, but the bats remained. At this time a small group of bats was in the rear chamber of the old style house. The bat population in the east-west house continued to grow and by 6 September 1995, there were over 406 bats counted exiting the houses at night. A dead *Tadarida* pup was found below the houses 7 June 1995, confirming the status of this house as a maternity site for *Tadarida*. Although the bats were not totally segregated it did appear that there were primarily *Tadarida* in the west side and primarily *Nycticeius* in the east side.

On 25 February 1996, two new sets of small maternity houses were installed. These houses were mounted back to back, only 3/4 inch (1.9 cm) apart , and were mounted facing north-south. A spacer was placed below the metal roof and polypropylene mesh was attached to the roof of the bat houses. This allowed bats to roost directly beneath the metal roof. One set of houses was painted light brown, the other dark brown. The morning of 26 February 1996, a single *Tadarida* was seen in each side of the light brown houses, and on 27 February a

Tadarida was in the south side of both dark and light brown houses. By 17 April both dark houses were packed, fewer bats were seen in the light brown houses, and bats were heard below the metal roof of both sets. All chambers appeared full in the east-west house.

University of Central Florida (UCF), Orlando, Orange County

This university also has been home to both *Tadarida* and *Nycticeius*. The university presently has a policy of excluding bat colonies as they are found. The bats have posed aesthetic problems here in the past. A large bat colony was excluded from the Education building at UCF the Winter of 1988. No accommodations were made for the bats at that time. Since the exclusion, bats have moved into other buildings on campus and have been subsequently evicted. The most recent eviction was fall of 1993.

The series of six bat houses and one Texas style house were placed here 21 September 1994, six years after the main colony was evicted. These houses were originally painted white, Styrofoam insulation (see SCC above) was in the large and small maternity houses and all houses were mounted on poles in a southeast-northwest orientation. They were placed in a clearing behind the Engineering building. Due to plans for a parking lot, the houses were moved during the summer of 1995 and at that time were modified similar to the Stevens houses (see above). However, the roof that was added was wood rather than metal and did not have the ventilation spaces I had requested. The houses are now located at the arboretum. These bat houses remain unoccupied.

Literature Cited

BAIN, J.R. 1981. Roosting ecology of three Florida bats: *Nycticeius humeralis, Myotis austroriparius* and *Tadarida brasiliensis*. M.S. thesis, University of Florida, Gainesville, 130pp.

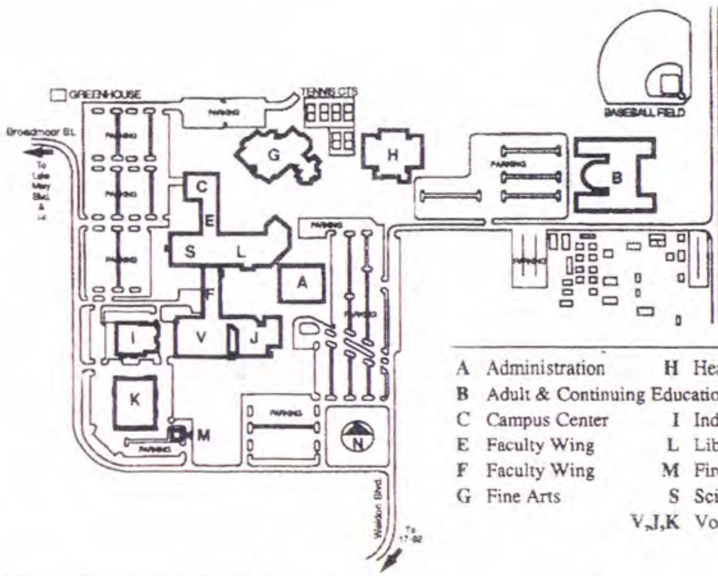
FINN, L.S. 1996. Release of handraised bat pups. Chiropteran Care, 2(3):1-2.

BERRY, M. 1996. Bats, burning cars still don't mix at SCC. The Orlando Sentinel. 17 November 1996.

Appendix B

Seminole Community College Campus Map. The bat houses are located near the green houses on Lake Mary (not shown). Buildings A, C, E, L, and S have all been occupied by bats and were excluded. Also occupied and later excluded was an elevator between L and A (not shown on map). Buildings F, V, and J were not occupied, but were excluded to prevent bats from using them in the future.

SEMINOLE COMMUNITY COLLEGE CAMPUS



- A Administration
- B Adult & Continuing Education
- C Campus Center
- E Faculty Wing
- F Faculty Wing
- G Fine Arts
- H Health
- I Industrial
- L Library
- M Fire Tower
- S Science
- V,J,K Vocational

Appendix C

Data pertaining to bat houses at Seminole Community College, Sanford, Florida. May 1994 - July 1995. SCCGp 1-5, all bat houses are painted white, small and large houses have Reflectix insulation in upper half of front and rear chambers, and second and rear chambers. SCCGp 6 - 10, large and simple bat houses have been modified (see Appendix A), SCCGp 11-12 small maternity house painted dark brown.

Appendix C.

	May '94 **SSE**	May '94 **SNW**	May '94 **Small**	July '94 **SSE**	July '94 **SNW**	July '94 **Small**	July '94 **LSE**	July '94 **LNW**
ANOVA	**>0.05**	>0.05	1.0	>0.05	>0.05	>0.05	>0.05	>0.05
Variance	>0.05	>0.05	>0.05	**<0.05**	>0.05	**<0.05**	**<0.05**	>0.05
Kruskall-Wallace	>0.05	>0.05	>0.05	>0.05	>0.05	>0.05	>0.05	>0.05
Ambient Mean	25.92	25.92	25.92	27.47	27.47	27.47	27.47	27.47
House Mean	26.21	26.24	26.17	26.96	26.92	26.94	27.05	26.98
Ambient Range	14.1	14.1	14.1	13.77	13.77	13.77	13.77	13.77
House Range	19.89	19.16	19.99	13.33	13.54	13.54	14.81	15.33
Ambient Max	35.94	35.94	35.94	35.28	35.28	35.28	35.28	35.28
House Max	40.69	39.86	40.69	34.57	34.6	34.6	35.9	36.23
Ambient Min	21.78	21.78	21.78	21.51	21.51	21.51	21.51	21.51
House Min	20.8	20.7	20.7	21.24	21.06	21.06	21.09	20.9
House Range Mean	1.16	1.13	1.44	1.42	1.25	1.65	1.94	1.77
Htemp-Ambient Mean	0.29	0.21	0.25	-0.51	-0.55	-0.254	-0.41	-0.49

	July '94 Large	July '94 SSE	July '94 SNW	July '94 Small	July '94 LSE	July '94 LNW	July '94 Large	July '94 BSE
ANOVA	>0.05	>0.05	>0.05	>0.05	>0.05	>0.05	>0.05	>0.05
Variance	**<0.05**	**<0.05**	>0.05	**<0.05**	>0.05	>0.05	**<0.05**	>0.05
Kruskall-Wallace	>0.05	>0.05	>0.05	>0.05	>0.05	>0.05	>0.05	>0.05
Ambient Mean	27.47	26.65	26.65	26.65	26.65	26.65	26.65	26.65
House Mean	27.02	26.13	25.99	26.06	25.74	25.6	25.69	25.85
Ambient Range	13.77	13.7	13.7	13.7	13.7	13.7	13.7	13.7
House Range	15.33	11.91	11.66	12	13.29	12.68	13.45	12.93
Ambient Max	35.28	35.45	35.45	35.45	35.45	35.45	35.45	35.45
House Max	36.23	33.2	32.86	33.2	34.78	34.01	34.78	33.94
Ambient Min	21.51	21.67	21.67	21.67	21.67	21.67	21.67	21.67
House Min	20.9	21.29	21.2	21.2	21.49	21.33	21.33	21.01
House Range Mean	2.35	1.36	1.14	1.59	1.64	1.42	1.88	0.57
Htemp-Ambient Mean	-0.45	-0.522	-0.652	-0.587	-0.141	-0.281	-0.206	-0.799

	July '94 BNW	July '94 Simple	Sept. '94 SNW	Sept. '94 Small	Sept. '94 LSE	Sept. '94 LNW	Sept. '94 Large	Sept. '94 BSE
ANOVA	>0.05	>0.05	>0.05	>0.05	1.0	>0.05	>0.05	>0.05
Variance	>0.05	>0.05	>0.05	>0.05	**<0.05**	>0.05	**<0.05**	>0.05
Kruskall-Wallace	>0.05	>0.05	>0.05	>0.05	>0.05	>0.05	>0.05	>0.05
Ambient Mean	26.65	26.65	24.25	24.25	24.25	24.25	24.25	24.25
House Mean	25.61	25.75	23.86	23.89	24.19	24.08	24.14	23.8
Ambient Range	13.7	13.7	9.05	9.05	9.05	9.05	9.05	9.05
House Range	12.36	12.93	9.58	9.58	14.09	12.92	14.27	9.66
Ambient Max	35.45	35.45	29.44	29.44	29.44	29.44	29.44	29.44
House Max	33.4	33.94	29.46	29.46	33.76	32.41	33.76	29.47
Ambient Min	21.67	21.67	20.39	20.39	20.39	20.39	20.39	20.39
House Min	21.04	21.01	19.88	19.88	19.67	19.49	19.49	19.81
House Range Mean	0.2	0.71	0.78	0.81	1.19	1.22	1.44	0.31
Htemp-Ambient Mean	-1.035	-0.893	-0.391	-0.349	-0.059	-0.166	-0.109	-0.444

	Sept. '94	Sept. '94	March '95	March '95	March '95	March '95	March '95	July '95
	BNW	**Simple**	LNW	Large	BSE	BNW	Simple	SSE
ANOVA	>0.05	>0.05	>0.05	>0.05	>0.05	>0.05	>0.05	>0.05
Variance	>0.05	>0.05	>0.05	>0.05	>0.05	>0.05	>0.05	**<0.05**
Kruskall-Wallace	>0.05	>0.05	>0.05	>0.05	>0.05	>0.05	>0.05	>0.05
Ambient Mean	24.25	24.25	17.46	17.46	17.46	17.46	17.46	27.41
House Mean	23.66	23.72	17.15	17.15	17.02	16.94	16.96	27.04
Ambient Range	9.05	9.05	20.51	20.51	20.51	20.51	20.51	14.46
House Range	9.15	9.66	19.91	19.91	20.41	20.08	20.41	14.26
Ambient Max	29.44	29.44	28.38	28.38	28.38	28.38	28.38	36.75
House Max	29.04	29.47	27.01	27.01	27.2	27.1	27.2	36.62
Ambient Min	20.39	20.39	7.87	7.87	7.87	7.87	7.87	22.29
House Min	19.89	19.81	7.1	7.1	6.79	7.02	6.79	22.36
House Range Mean	0.2	0.42	1.07	1.07	0.27	0.2	0.44	1.14
Htemp-Ambient Mean	-0.588	-0.516	-0.307	-0.307	-0.44	-0.53	-0.484	-0.37
	July '95	July '95	July '95	July '95	July '95	July '95	July '95	July '95
	SNW	Small	LSE	**LNW**	**Large**	**SSE**	**SNW**	**Small**
ANOVA	>0.05	>0.05	>0.05	>0.05	>0.05	**0.0**	**0.0**	**0.0**
Variance	>0.05	>0.05	**<0.05**	**<0.05**	**<0.05**	**<0.05**	**<0.05**	**<0.05**
Kruskall-Wallace	>0.05	>0.05	**<0.05**	**<0.05**	**<0.05**	**<0.05**	**0.0**	**0.0**
Ambient Mean	27.41	27.41	27.41	27.41	27.41	25.94	25.94	25.94
House Mean	27.13	27.09	27.48	27.77	27.64	26.29	28.76	27.52
Ambient Range	14.46	14.46	14.46	14.46	14.46	16.21	16.21	16.21
House Range	14.48	14.53	25.69	22.4	25.69	18.19	20.07	20 .07
Ambient Max	36.75	36.75	36.75	36.75	36.75	34.58	34.58	34.58
House Max	36.57	36.62	46.88	44.06	46.88	37.81	39.26	39.26
Ambient Min	22.29	22.29	22.29	22.29	22.29	18.37	18.37	18.37
House Min	22.09	22.09	21.66	21.66	21.19	19.62	19.19	19.19
House Range Mean	1.25	1.5	2.02	1.95	2.71	2.51	6.72	7.53
Htemp-Ambient Mean	-0.28	-0.314	0.56	0.69	0.559	0.35	2.82	1.582

	July '95	July '95	July '95	July '95	July '95	July '95	Oct. '95	Oct. '95
	LSE	**LNW**	**Large**	**BSE**	**BNW**	**Simple**	**SSE**	**SNW**
ANOVA	>0.05	>0.05	**<0.05**	>0.05	>0.05	>0.05	**0.0**	**0.0**
Variance	**<0.05**	**<0.05**	**<0.05**	>0.05	>0.05	>0.05	**<0.05**	**<0.05**
Kruskall-Wallace	>0.05	>0.05	**<0.05**	>0.05	>0.05	>0.05	**0.0**	**0.0**
Ambient Mean	25.94	25.94	25.94	25.94	25.94	25.94	26.17	26.17
House Mean	26.16	26.62	26.36	26.82	26.41	26.62	31.15	31.02
Ambient Range	16.21	16.21	16.21	16.21	16.21	16.21	10.3	10.3
House Range	19.47	16.84	19.47	17.31	19.62	19.88	14.13	18.32
Ambient Max	34.58	34.58	34.58	34.58	34.58	34.58	33.35	33.35
House Max	39.1	36.93	39.1	36.5	39.07	39.07	38.75	42.78
Ambient Min	18.37	18.37	18.37	18.37	18.37	18.37	22.96	22.96
House Min	19.63	20.09	19.63	19.19	19.45	19.19	24.62	24.46
House Range Mean	1.87	1.97	2.62	0.9	0.36	1.5	3.899	8.89
Htemp-Ambient Mean	0.21	0.6	0.42	0.88	0.47	0.671	4.97	4.83

	Oct. '95	Oct. '95	Oct. '95	Oct. '95	Oct. '95	Oct. '95	Oct. '95	Nov. 95
	Small	**LSE**	**LNW**	**Large**	**BSE**	**BNW**	**Simple**	**SSE**
ANOVA	**0.0**	**<0.05**	**<0.05**	**<0.05**	>0.05	>0.05	**<0.05**	**0.0**
Variance	**<0.05**	**<0.05**	**<0.05**	**<0.05**	**<0.05**	>0.05	**<0.05**	**<0.05**
Kruskall-Wallace	**0.0**	**<0.05**	**<0.05**	**<0.05**	>0.05	>0.05	>0.05	**0.0**
Ambient Mean	26.17	26.17	26.17	26.17	26.17	26.17	26.17	14.69
House Mean	31.08	26.51	26.49	26.5	27.29	26.44	26.87	17.18
Ambient Range	10.3	10.3	10.3	10.3	10.3	10.3	10.3	21.4
House Range	18.32	10.75	10.66	10.82	19.86	10.29	19.86	28.31
Ambient Max	33.35	33.35	33.35	33.35	33.35	33.35	33.35	25.46
House Max	42.78	33.88	33.95	33.95	42.78	33.23	42.78	31.78
Ambient Min	22.96	22.96	22.96	22.96	22.96	22.96	22.96	3.97
House Min	24.46	23.13	23.29	23.13	22.92	22.94	22.92	3.37
House Range Mean	6.4	1.46	1.48	1.98	0.95	0.26	1.65	5.58
Htemp-Ambient Mean	4.901	0.34	0.33	0.331	1.13	0.27	0.699	2.49

	Nov. 95	Nov. 95	Nov. 95	Nov. 95	Nov. 95	Nov. 95	Nov. 95	Nov. 95
	SNW	**Small**	**LSE**	**LNW**	**Large**	**BSE**	**BNW**	**Simple**
ANOVA	**0.0**	**0.0**	>0.05	>0.05	**<0.05**	>0.05	>0.05	**0.0**
Variance	**<0.05**	**<0.05**	**<0.05**	**<0.05**	**<0.05**	**<0.05**	>0.05	**<0.05**
Kruskall-Wallace	**0.0**	**0.0**	>0.05	>0.05	>0.05	>0.05	>0.05	**<0.05**
Ambient Mean	14.69	14.69	14.69	14.69	14.69	14.69	14.69	14.69
House Mean	16.17	16.68	15.76	15.07	15.37	16.74	14.21	15.48
Ambient Range	21.4	21.4	21.4	21.4	21.4	21.4	21.4	21.4
House Range	27.87	28.75	29.91	23.82	29.91	35.88	22.47	36.34
Ambient Max	25.46	25.46	25.46	25.46	25.46	25.46	25.46	25.46
House Max	30.9	31.78	32.44	26.81	32.44	39.62	25.75	39.62
Ambient Min	3.97	3.97	3.97	3.97	3.97	3.97	3.97	3.97
House Min	3.03	3.03	2.53	2.99	2.53	3.74	3.28	3.28
House Range Mean	5.21	6.97	3.27	2.02	3.88	1.38	0.35	3.38
Htemp-Ambient Mean	1.48	1.99	0.97	0.38	0.67	2.05	-0.48	0.78

	Jan. '96	Jan. '96	Jan. '96	Jan. '96	Jan. '96	Jan. '96	Jan. '96	Jan. '96
	SSE	**SNW**	**Small**	**LSE**	**LNW**	**Large**	**BSE**	**BNW**
ANOVA	**0.0**	**<0.05**	**0.0**	**<0.05**	**<0.05**	**0.0**	>0.05	>0.05
Variance	**<0.05**	>0.05	**<0.05**	**<0.05**	**<0.05**	**<0.05**	>0.05	>0.05
Kruskall-Wallace	**0.0**	**<0.05**	**0.0**	**<0.05**	**<0.05**	**<0.05**	>0.05	>0.05
Ambient Mean	13.02	13.02	13.02	13.02	13.02	13.02	13.02	13.02
House Mean	16.34	16.32	16.33	12.37	12.59	12.49	12.95	11.66
Ambient Range	23.21	23.21	23.21	23.21	23.21	23.21	23.21	23.21
House Range	30.77	28.48	30.77	31.56	32.87	33.56	36.91	29.56
Ambient Max	27.04	27.04	27.04	27.04	27.04	27.04	27.04	27.04
House Max	33.17	31.64	33.17	29.25	31.05	31.05	34.08	26.87
Ambient Min	3.83	3.83	3.83	3.83	3.83	3.83	3.83	3.83
House Min	2.41	3.17	2.41	-2.31	-1.82	-2.31	-2.83	-2.69
House Range Mean	5.79	4.22	6.19	1.99	3.78	5.32	1.11	0.23
Htemp-Ambient Mean	3.08	2.33	0.89	0.99	1.26	0.72	1.53	0.23

	Jan. '96	Feb. '96	Feb. '96	Feb. '96	Feb. '96	Feb. '96	Feb. '96	Feb. '96
	Simple	**SSE**	**SNW**	**Small**	**LSE**	**LNW**	**Large**	**BSE**
ANOVA	**<0.05**	**0.0**	**<0.05**	**0.0**	**<0.05**	**0.0**	**0.0**	>0.05
Variance	**<0.05**	**<0.05**	>0.05	**<0.05**	>0.05	**<0.05**	**<0.05**	>0.05
Kruskall-Wallace	**<0.05**	**0.0**	**<0.05**	**0.0**	**<0.05**	**0.0**	**0.0**	>0.05
Ambient Mean	13.02	13.06	13.06	13.06	13.06	13.06	13.06	13.06
House Mean	12.43	17.38	15.19	16.29	13.67	14.45	14.07	14.58
Ambient Range	23.21	31.07	31.07	31.07	31.07	31.07	31.07	31.07
House Range	36.91	47.77	42.96	47.77	35.47	35.47	37.68	44.58
Ambient Max	27.04	28.87	28.87	28.87	28.87	28.87	28.87	28.87
House Max	34.08	44.08	39.38	44.08	32.28	34.44	34.44	41.06
Ambient Min	3.83	-3.11	-3.11	-3.11	-3.11	-3.11	-3.11	-3.11
House Min	-2.83	-3.69	-3.58	-3.69	-3.19	-3.24	-3.24	-3.53
House Range Mean	2.51	8.45	5.17	10.68	2.49	5.16	6.36	1.04
Htemp-Ambient Mean	0.72	4.36	2.38	3.37	0.5	1.38	0.96	1.52

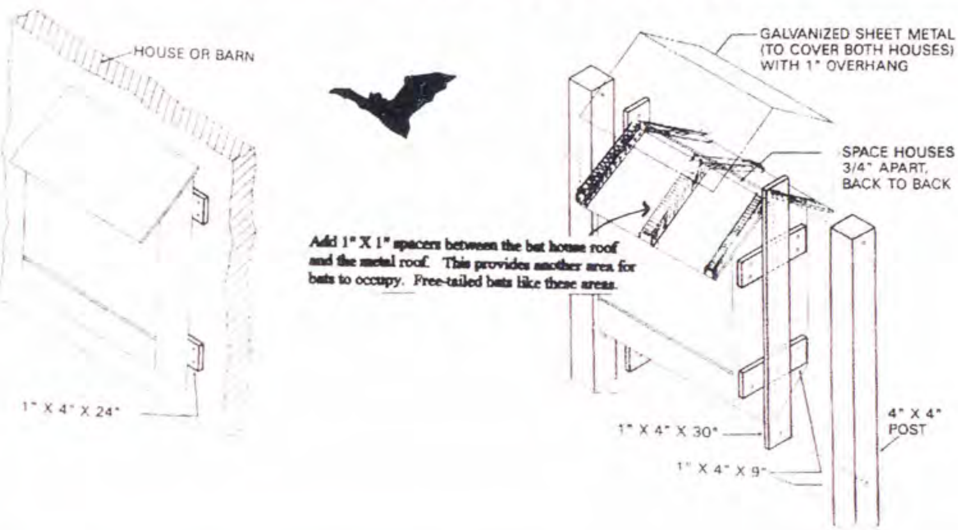
	Feb. '96	Feb. '96	May '96	May '96	May '96	May '96	May '96	May '96
	BNW	**Simple**	SSE	SNW	Small	LSE	LNW	Large
ANOVA	>0.05	**0.0**	<0.05	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**
Variance	>0.05	**<0.05**	>0.05	**<0.05**	**<0.05**	**<0.05**	**<0.05**	**<0.05**
Kruskall-Wallace	>0.05	**<0.05**	**<0.05**	**<0.05**	**0.0**	**0.0**	**<0.05**	**0.0**
Ambient Mean	13.06	13.06	26.07	26.07	26.07	26.07	26.07	26.07
House Mean	12.91	13.92	29.09	28.94	28.99	27.58	27.58	28.05
Ambient Range	31.07	31.07	15.07	15.07	15.07	15.07	15.07	15.07
House Range	31.41	44.59	20.46	24.24	24.24	18.62	18.62	24.24
Ambient Max	28.87	28.87	34.72	34.72	34.72	34.72	34.72	34.72
House Max	27.98	41.06	42.75	45.22	45.22	38.96	38.82	38.96
Ambient Min	-3.11	-3.11	19.65	19.65	19.65	19.65	19.65	19.65
House Min	-3.43	-3.53	22.29	20.98	20.98	20.34	21.99	20.34
House Range Mean	0.29	2.48	2.16	4.98	5.62	5.13	3.53	5.39
Htemp-Ambient Mean	-0.15	0.85	3.11	3.38	3.11	1.49	2.41	1.95

	May '96 BSE	May '96 BNW	May '96 Simple
ANOVA	>0.05	>0.05	>0.05
Variance	>0.05	>0.05	>0.05
Kruskall-Wallace	>0.05	>0.05	>0.05
Ambient Mean	26.07	26.07	26.07
House Mean	26.82	26.68	26.75
Ambient Range	15.07	15.07	15.07
House Range	20.11	18.47	20.11
Ambient Max	34.72	34.72	34.72
House Max	39.67	38.05	39.67
Ambient Min	19.65	19.65	19.65
House Min	19.56	19.58	19.56
House Range Mean	0.8	0.42	1.78
Htemp-Ambient Mean	0.72	0.54	0.63

Appendix D

Plans and specifications for bat house design proven to be most successful in central Florida

MOUNTING AND PLACEMENT OF YOUR BAT HOUSE



- Bat houses should be mounted 15 - 20 feet above ground.

- Mounting your house on poles or the side of a building is best. Bats which are likely to use bat houses, commonly roost in buildings. These bats are not looking at trees as potential roost sites.

- Choose a sunny area which is free from clutter.

- Be sure to caulk all seams to eliminate drafts and moisture entering the house.

- Bats like it warm, paint houses medium to dark brown.

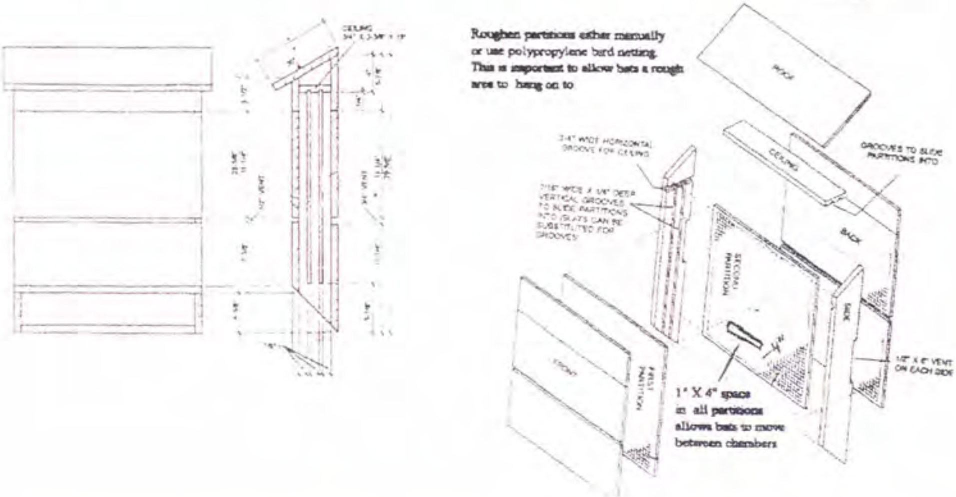
- When mounting houses in pairs be sure to roughen the backs and tops of the houses. DO NOT, use fiberglass window screen. Either roughen the wood manually or attach polypropylene bird netting.

- When houses are mounted in pairs they should face southeast and northwest. If possible mount two pairs of houses and mount one set north-south and the other east-west. This optimizes temperature profiles and choices for bats.

BUILDING A BAT HOUSE FOR FLORIDA BATS

Houses can be constructed of any type of wood. Exact measurements are not important, I know these plans can seem complicated. The important part is to have the partitions 3/4" to 1", a 7/8" space works well when using 1" X 4" boards for the sides.. If the space is any smaller the bats can't get in, larger spaces will attract wasps and mud daubers. All inner roosting surfaces should be roughened.

If constructing this house with 1"X 4" sides you will need:
1 - 8 foot board of 1" x 4" pine (or any other wood) for sides and ceiling
one half sheet of 3/8" exterior plywood for the front, back, 2 roosting partitions and the roof.



The following guidelines are suggestions to optimize the possibility of bats roosting in central Florida bat houses. There are no guarantees bats will occupy your bat house, and many bat houses take several years to become occupied.

If bats move into a bat house you've put up and you would like to be included in a research project with the University of Central Florida, Fly By Night, and Bat Conservation International, or if you have any questions, please contact Laura Seckbach Finn at 407-324-0647.

Bat house plans modified from Bat Conservation International drawings.