Distribution, Roost Site Selection and Food Habits of Bats in Eastern South Dakota

BY

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This thesis is approved as a creditable and independent investigation by a candidate for the Master of Science degree and is acceptable for meeting the thesis requirements for this degree. Acceptance of this thesis does not imply that the conclusions reached by the candidate are necessarily the conclusions of the major department.

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Abstract

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From May 2000 to August 2002 a study was conducted to document the distribution, roost site selection, and food habits of bats in South Dakota east of the Missouri River. During the summers of 2000, 2001, and 2002, mist netting and acoustic sampling (Anabat system) censuses were conducted at 36 different sites, including state parks (S.P.), state recreation areas (R.A.), and national wildlife refuges (N.W.R.). Seven species of bat were discovered inhabiting eastern South Dakota: *Myotis septentrionalis*, *Myotis lucifugus* (subspecies *lucifugus* and *carissima*), *Myotis ciliolabrum*, *Eptesicus fuscus* (subspecies *fuscus* and *pallidus*), *Lasiurus borealis*, *Lasiurus cinereus*, and *Lasionycteris noctivagans*.

Of 52 bats captured in 2000 and 2001, the percent composition of the total population was: *Myotis lucifugus* 35%, *Eptesicus fuscus* 27%, *Lasiurus borealis* 21%, *Myotis septentrionalis* 11%, *Lasiurus cinereus* 4%, and *Lasionycteris noctivagans* 2%. Of 52 bats that were captured in 2002 along the Missouri River, the percent composition of the population was: *Myotis septentrionalis* 42%, *Eptesicus fuscus* 35%, *Myotis lucifugus* 15%, *Lasiurus borealis* 4%, and *Lasionycteris noctivagans* 4%.

Myotis lucifugus, *Eptesicus fuscus*, *Lasionycteris noctivagans*, *Lasiurus borealis*, and *Lasiurus cinereus* are found throughout South Dakota east of the Missouri River. Based on my capture data and previous voucher and literature records, the distribution of *Myotis septentrionalis* in eastern South Dakota is restricted to gallery forests along the Missouri River. Previously, *Lasionycteris noctivagans* was not considered a resident of eastern South Dakota because this bat had only been captured during the migratory season (Jones and Genoways, 1967). I captured three individuals in July (two males and one female), strongly suggesting that this species is a summer resident of eastern South Dakota.

Bat capture rates (BNN=bats/per net/per night) and species richness were greater within the Missouri River gallery forest than any other habitat in eastern South Dakota. Three of the five localities that had high capture rates (2.0 or greater BNN) were located along the Missouri River (Farm Island R.A., Karl Mundt N.W.R, and West Bend R.A.). The locality with the highest capture rate (2.6 BNN) and species richness (7 species) was Farm Island R.A.

Distribution maps and species accounts were compiled for all six bat species using mist net and acoustic data from the summers of 2000, 2001, and 2002; and from data culled from literature records and voucher records.

A radiotracking study was performed in the summer of 2002 to investigate the importance of the Missouri River gallery forest for bats in eastern South Dakota. Four species (*Myotis septentrionalis, Myotis lucifugus*, *Eptesicus fuscus* and *Lasionycteris noctivagans*) were radiotracked using small radio transmitters in order to follow the bats to their roost sites. Roost tree characteristics such as circumference, height, and stage of decay were documented for each species of roost tree. Circumference and height measurements were also taken for the available trees within 15 meters of the roost tree. Trees were considered “available” if the circumference was greater than 15 cm, because these younger trees are not decayed enough to provide roosting substrates for bats (Vonhof and Barclay, 1996).

In this study, *Myotis septentrionalis* and *Lasionycteris noctivagans* consistently used eastern cottonwoods (*Populus deltoides*) as day roosts. *Eptesicus fuscus* day roosted in eastern cottonwoods and night roosted in bur oaks (*Quercus macrocarpa)* and beneath a concrete bridge. *Myotis lucifugus* day and night roosted in eastern cottonwoods and a picnic shelter. *Myotis septentrionalis*, *Lasionycteris noctivagans,* and *Eptesicus fuscus* selected larger trees for roosts (compared to the available trees), while *Myotis lucifugus* utilized trees of the same size as those available.

Roost switching between trees and a wood picnic shelter was noted in two individual *Myotis lucifugus* of different reproductive classes. During the two weeks of radio tracking, a postlactating bat day roosted in a cottonwood tree and then night roosted in the shelter. At the beginning of the week of radiotracking, the nonreproductive bat day and night roosted in a cottonwood tree. Then a few days later, was tracked to the roost in the shelter until the battery on the tag died (a couple days). Dataloggers were placed inside the picnic shelter and a tree roost to compare temperature and humidity. Data from the dataloggers indicated that the shelter was warmer than the tree roost in the evening and early morning (1800 to 0500 hours), while the tree was warmer in the afternoon

(1200 to 1700 hours). The postlactating female may have been searching for a warmer roost to conserve energy.

Food habits of *Eptesicus fuscus* in Sioux Falls, South Dakota are described. Six hundred and twenty bats were collected from the South Dakota Department of Health in 2000 and 2001. Of these 620, only 56 bats had identifiable contents in the stomach. The stomach contents were examined with a dissecting microscope and insect parts were identified by comparing the contents to a reference collection of insects collected in South Dakota (Borror and White, 1970). Four orders of insects were identified: Coleoptera (beetles), Hemiptera (true bugs), Diptera (flies) and Lepidoptera (moths). Carabidae (ground beetles) occurred at an occurrence frequency of 29.1%, followed by unidentifiable insects (18.2%), Lepidoptera (12.2 %), unidentified Coleoptera (7.3%), Pentatomidae (stinkbugs) (7.3%), Diptera (1.8%), and hairballs (5.3%).

Table of Contents

List of Tables

List of Figures

OVERVIEW

Approximately 4,600 species of mammals currently exist on Earth and 1,200 of these are bats (Linzey, 2001). Since so many bat species exist, there should be a plethora of information about them. Yet, this is not the case due to the lack of research studies on such 'non-game' animals. Non-game animals are not considered as economically important as game animals and hence more research and funding is focused on game animals. Worldwide, studies of bats are important because these animals provide pollination for many plants, prey upon human disease vectors such as mosquitoes (Anthony and Kunz, 1977), and devour agricultural pests such as corn root worm beetles (*Diabrotica* spp.) (Whitaker, 1995). Bats are prey for higher-level carnivores thereby providing an important link in the food-web (Findley, 1993). Being the only true flying mammals, their mobility and longevity combine to make bats well suited as indicators of environmental conditions (Fenton, 1997). Their mobility gives them access to a range of habitats that may be experiencing environmental changes and their longevity increases their chances of being recaptured over many years and studied for their susceptibility to environmental changes.

Since 1861, 24 studies focused on the bats of western South Dakota (all lands in South Dakota west of the Missouri River); but only Jones and Genoways (1967) and Findley (1956) focused on the bats found in eastern South Dakota (all lands in South Dakota east of the Missouri River). These studies (Jones and Genoways, 1967; Findley, 1956) are more than 30 years old and only describe the distribution of bats within eastern South Dakota using mist net captures at foraging sites. There have been no studies in eastern South Dakota describing foraging activity, roosts, and diet of bats; and no studies in South Dakota using acoustic methods to census bats. A study was needed to begin documentation of current distributions and life history data (foraging activity, roost sites, diet) for those species of bats that occur in eastern South Dakota. My project was started in the summer of 2000, and continued through the summer of 2002. It is a first step towards filling gaps in our knowledge about the eastern South Dakota bat population. The objectives were 1) to document the current distribution of eastern South Dakota resident bats; 2) describe the types of foraging habitats that bats are utilizing in eastern South Dakota; 3) locate and describe bat roosts in eastern South Dakota; and 4) to document food habits of *Eptesicus fuscus* from Sioux Falls, South Dakota.

Chapter 1

INTRODUCTION

Twelve species of bats have been discovered in South Dakota: *Myotis evotis*, *Myotis septentrionalis*, *Myotis ciliolabrum*, *Myotis lucifugus* (subspecies: *lucifugus* and *carissima*), *Myotis thysanodes*, *Myotis volans*, *Lasionycteris noctivagans*, *Eptesicus fuscus* (subspecies: *fuscus* and *pallidus*), *Lasiurus borealis*, *Lasiurus cinereus*, *Corynorhinus townsendii*, (Choate and Jones, 1981) and *Nycticeius humeralis* (Lane et al., in press). Table 1.1 lists the current scientific name (American Society of Mammalogists), common name, and abbreviated name that is used throughout the thesis for each bat species (see Table 1.1).

Table 1.1: Scientific name, common name and abbreviated name for all bats in South Dakota

Scientific name	Common Name	Abbreviated Name
Myotis evotis evotis?	Long-eared Myotis	*M. evotis*
Myotis septentrionalis ? ?	Northern Myotis	*M. septentrionalis*
Myotis lucifugus lucifugus?	Little Brown Bat	*M. lucifugus*
Myotis lucifugus carissima?	Little Brown Bat	*M. lucifugus*
Myotis thysanodes pahasapenis?	Fringe-tailed Myotis	*M. thysanodes*
Myotis volans interior	Long-legged Myotis	*M. volans*
Lasionycteris noctivagans ? ?	Silver-haired Bat	*Lasio. noctivagans*
Eptesicus fuscus fuscus?	Big Brown Bat	*E. fuscus*
Eptesicus fuscus pallidus?	Big Brown Bat	*E. fuscus*
Lasiurus borealis borealis?	Eastern Red Bat	*Lasiu. borealis*
Lasiurus cinereus cinereus?	Hoary Bat	*Lasiu. cinereus*
Corynorhinus townsendii pallescens?	Townsend’s Big-eared Bat	*C. townsendii*
Myotis ciliolabrum ciliolabrum ?	Western Small-footed Myotis	*M. ciliolabrum*

? Indicates species found in eastern South Dakota

? Indicates species monitored by SD Natural Heritage Program

Myotis septentrionalis, M. lucifugus, E. fuscus, Lasiu. borealis, and *Lasiu. cinereus* occur state-wide (Higgins, et al. 2000). The South Dakota Natural Heritage Program monitors *C. townsendii*, *M. evotis*, *M. thysanodes, M. septentrionalis* and *Lasio. noctivagans* (Stukel and Backlund, 1997) because of their specific roost requirements or because of their rare and easily disturbed populations or roosts. Of the afore mentioned species, *C. townsendii*, *M. evotis* and *M. thysanodes* have only been captured in western South Dakota and are commonly found in the Black Hills (Jones and Genoways, 1967; Turner and Jones, 1968). *Lasionycteris noctivagans* is a summer resident of western South Dakota, but has only been documented during its migration period (August-November) in eastern South Dakota. It was not considered a state-wide resident (Jones and Genoways, 1967).

Pedersen et al. (unpublished) clearly demonstrates that conventional census method of mist netting underestimates bat populations in eastern South Dakota. Strong winds are a constant feature of the region. These winds cause the mist nets to move, making them much easier to detect by echolocating bats (Sedlock, 2001), and thereby reducing capture rates. Also, the relative abundance of tree cavity roosting species (*Lasio. noctivagans* and *M. septentrionalis*) is limited by the dearth of suitable tree roosts (Humphrey, 1975). If overall bat abundance is low, then capture rates will be low.

Alternatively, acoustic sampling has been used effectively to census bats in other regions of the United States (Everette et al., 2001; Hayes, 1997; Murray et al., 2001) by recording the echolocation sounds made by bats when they are foraging and commuting. Bats evolved the ability to produce echolocation sounds. These high frequency sounds reflect off an object and back to the ears of the bat, allowing bats to detect objects in their surroundings (Griffin, 1958). Each bat species utilizes a unique frequency range of echolocation sounds, and these sounds or "calls" can be recorded using acoustic devices. Most acoustic devices reduce the frequency of the echolocation calls making them audible to the human ear. Then these calls can then be analyzed for species identification and bat activity (bat passes per night).

For my study, both acoustic and mist netting methods were used to sample bat populations. Using both mist-nets and acoustic devices (rather than using only one method) will increase the chances that all of the species in a location will be identified (Kuenzi and Morrison, 1998). Acoustic devices detect more species than mist nets, but when bats are captured with mist nets, species identification is much more reliable (Kuenzi and Morrison, 1998; O'Farrel et al., 1999) because visual identification of captured bats is much more accurate.

The Anabat system (Titley Electronics, Australia) was chosen as the acoustic device to be used for species identification in my study. The Anabat II bat detector records the echolocation calls emitted by the bat via a broadband microphone and reduces the sounds into a frequency that is audible to the human ear. This detector is the most feasible device for this study given the need to use acoustic sampling systems in open habitats with high winds, and its relatively low cost compared to other acoustic sampling devices.

Small hand-held devices such as the D 100 (Pettersson Elektronik, Sweden) and the Bat Box III (Stag Electronics, UK) detectors were used in my study for preliminary bat censuses to determine if bats were present in a census area. Then, the Anabat was set up in areas with bats to determine which species were present. The Pettersson D 100 and Bat Box III were not used for species identification because these detectors do not preserve important call characteristics such as duration or absolute frequencies which are necessary for accurate species identification (Parsons et al., 2000). The automated Anabat detector retains the original duration of the call and monitors a wide range of frequencies produced by different species of bats. The user does not need to be present to tune or adjust anything, freeing the user to perform other methods of censusing (mist netting or roost searching).

Foraging Habitat Selection

One objective of my study was to describe the types of foraging habitats that bats use in eastern South Dakota. Several factors affect which foraging habitats bats utilize, these include: prey availability, proximity to roost, age classes of bats, bat morphological traits, and echolocation calls.

Some species of bats use certain habitats because of the relatively high abundance of insect prey. Differences in availability of prey may explain why *E. fuscus* was found to commute up to 4 km from day roosts to foraging areas where there were dense concentrations of insects (Brigham, 1989).

Additional explanations for foraging habitat selectivity are based on proximity to roost sites, and age class of bats. The closer the roost site is to the foraging site, the less energy a bat spends on commuting and can instead invest this energy on growth and reproduction. Greater distances from the roost colony to foraging habitat were correlated with decreased growth rate of *M. grisescens* (Tuttle, 1976).

The age of the bat may also influence selection of habitat. In Wyoming, juvenile and adult *M. lucifugus* foraged in different types of habitats. Once the juveniles became volant and were attempting to capture insects, they were unable to forage effectively in more cluttered environments because their flight skills were so poorly developed. To avoid the clumsy juveniles, the adults foraged in much more cluttered areas (Adams, 1997).

Morphological characteristics such as body mass, wingloading (ratio of surface area of the wing to the mass of the body), and aspect ratio (ratio of length to width of the wing) make bats adapted to certain habitats. Bats such as *M. lucifugus* with low body mass (>15 grams), low wingloadings (6 to 8 Nm^{-2}) and low aspect ratios (5.5 to 6.5) are very maneuverable (Aldridge and Rautenbach, 1987; Adams, 1997). Bats with such short, broad wings are better adapted to maneuver in cluttered habitat because their body size and wing dimensions allow the species to fly and forage efficiently in cluttered environments. Bats such as *E. fuscus* with a larger body mass (15 to 25 g), average wingloadings (8 to 12 Nm^{-2}), and average aspect ratios (6 to 8) are less maneuverable and cannot effectively forage in cluttered vegetation (Aldridge and Rautenbach, 1987). Their longer wings effectively prevent the species from flying within cluttered habitats. Therefore, bats such as *E. fuscus* fly in uncluttered habitat relying on their agility and speed to capture flying insects (Norberg and Rayner, 1987). They use their longer wings with short, pointed wingtips to twist and turn in order to capture prey.

The types of echolocation calls made by bats can also be used to predict what types of foraging habitats a bat can utilize. Echolocation call parameters such as call duration, call frequency, and slope (change in frequency over time) can be used to describe a call. When compared to low frequency calls, high frequency calls provide more structural details about a target (Griffin, 1958) enabling the bat to acquire more information about the prey in a shorter period of time, and are most effective in cluttered environments. *Myotis lucifugus* and *M. septentrionalis* have high frequency calls of short duration (38 to 78 kHz and 5 ms in *M. lucifugus*; 38 to 110 kHz and 3 ms in *M. septentrionalis*) (Fenton and Bell, 1981) and are typically encountered in cluttered habitat.

Low frequency calls are best suited for foraging in open environments because these calls travel farther and are better suited for detection of distant objects (Jones, 1999). *Eptesicus fuscus* and *Lasiu. cinereus* have low frequency, long duration calls (26 to 33 kHz and 10 ms in *E. fuscus*; 26 to 39 kHz and 15 ms in *Lasiu. cinereus*) that are well suited for open environments (Fenton and Bell, 1981).

Where possible, these characteristics (roost proximity, age class, bat morphological characteristics, and echolocation calls) were recorded during my census activities to determine the foraging habitats and distribution of *M. lucifugus*, *M. septentrionalis*, *Lasio. noctivagans*, *E. fuscus*, *Lasiu. borealis* and *Lasiu*. *cinereus* in eastern South Dakota.

MATERIALS AND METHODS

Literature Search

Bats in South Dakota belong to the Vespertilionidae (Nowak, 1994). The vespertilionid bat literature was reviewed to create a profile of life history traits and foraging habitats to determine which habitats to census in eastern South Dakota to study as many bats as possible. In comparison to urban areas, the capture rates and foraging activity of vespertilionid bats was typically much greater within forested areas, lake or river edges, prairies and marshes (Barclay, 1984; Everette et al., 2001).

Comparatively, eastern South Dakota is a mosaic landscape of cropland, wetlands and pastures. Over 31% of eastern South Dakota is composed of agricultural land (row crops, small grains, and bare ground) and only 1.5% of eastern South Dakota is woodland (deciduous or coniferous shelterbelts, woodlands, shrublands, riparian areas, and forests) (Smith et al., unpublished). Riparian areas and forests occur on state and federal land such as state parks (S.P.), state recreation areas (R.A.), and national wildlife refuges (N.W.R.) that are distributed widely across eastern South Dakota and typically include a water source. Therefore, state parks, state recreation areas, and national wildlife refuges throughout eastern South Dakota were chosen as study sites because of woodland habitat in these areas, their close proximation to a water source, and their wide distribution across eastern South Dakota.

In the summers of 2000, 2001, and 2002, 36 sites (state parks, recreation areas, and wildlife refuges) in 20 counties of eastern South Dakota were censused for bats (Appendix 1). Sites were censused for at least two nights throughout the summer field seasons to increase the possibility that bats were captured or recorded.

Distribution maps and species accounts were updated for all bat species in eastern South Dakota (Appendix 3 and Results section). A table of the distribution of South Dakota bats by county records is included in Appendix 2. The maps were created using mist net capture and acoustic data from the summers of 2000, 2001, and 2002; literature records (Findley, 1956; Jones and Genoways, 1967; Lane, *in press*; Miller, 1897; SD Natural Heritage Program Database, SD Game, Fish and Parks; and Visher, 1914); and from voucher specimens in collections. Abbreviations used for collections in which South Dakota bat specimens are deposited are: FHS (Fort Henry State Museum), KU (Kansas University Museum), SDADR (South Dakota Animal Disease Research Lab), SDSU (South Dakota State University Natural History Collection- including bats from Department of Health), UNSM (University of Nebraska State Museum) and USNM (U.S. National Museum), (Jones and Genoways, 1967).

Species accounts include mist net captures from this study as “Capture Data”, literature records as “Additional Records”, and voucher records as “Museum Records”.

Mist Netting

Bats were captured using mist nets (Avinet, New York). These nets are fine-mesh, nylon nets that span 6 to 10 meters in length and 2 meters in height. The nets were attached to 2m poles and stretched across ponds, streams, and trails. Nets were set an hour before dusk near ground level or elevated into the woodland canopy on 8m poles to catch higher flying bats. Nets were removed around 1:00 a.m. and the captured bats were identified to species, weighed, sexed, checked for reproductive condition and ectoparasites, banded, and then released after the nets were taken down.

Acoustic Methods

First, the Bat Box III or Pettersson D 100 acoustic devices were used to determine if bats were present. Then, the Anabat II bat detector (Titley Electronics, Australia) was used in addition to mist nets. The Anabat delay switch and a tape recorder were used to operate the Anabat II detector in the remote mode.

The Anabat II bat detector records the echolocation frequencies emitted by a bat using a broadband microphone. The echolocation sounds are translated into frequencies that are audible to the human ear by a frequency division system, which divides the echolocation frequencies by a predetermined ratio. The division ratio used in my study was 16 because bats in South Dakota do not echolocate greater than 100 kHz and a ratio of 16 lowers the higher frequencies into frequencies equal or less than 10 kHz, which is the upper limit for the Anabat software (Analook).

The Anabat II detectors were calibrated in the field to be sensitive only to echolocating bats and not to background noises such as insects. The sensitivity dial was set at lower settings (1-3) and slowly increased until the microphone of the Anabat detector started to detect the echolocation sounds of the bats (typically a sensitivity level of 6).

The Anabat delay switch is a timing device used to activate the Anabat II detector and a portable cassette recorder (Radio Shack 14-1128). When a bat flies over the detector, the delay switch activates the detector and recorder and places a time mark on the tape recording. The delay switch is extremely useful because sounds are recorded only when a bat flies over the detector.

The Anabat bat detector, delay switch, two 6 volt batteries, and recorder were placed inside a 42x29x15 cm (12 Quart) Tupperware? container. The equipment was placed inside the container to protect it from dew and light rain. A hole was cut in the lid of the container to allow the microphone of the Anabat detector to stick out. In order to maximize the number of bat detections, the detector was orientated vertically because at this angle there were fewer obstacles, such as trees, to block the detector's zone of reception. The Tupperware containers were taped to the shelf of a 2-meter metal ladder to elevate the Anabat above ground level to reduce the recording of non-target noises, such as insects.

Depending on the area of the site (larger sites = more detectors), up to three Anabat containers were arranged randomly throughout the study area. In most cases, the detectors remained active at the site overnight from 7:00 p.m. to 7:00 a.m. Due to the concerns that the equipment may be vandalized or stolen from some high-use public sites, censusing was discontinued when mist netting was finished (1:00 a.m.).

Activity and Species Identification

Once the acoustical output from the Anabat detector had been recorded to cassette tape, software (Anabat version 6) was used to extract call data from the tape via a ZCAIM (zero crossings analysis interface module), in order to generate computer files of the data. The ZCAIM is an electronic interface for downloading the acoustical output into the computer (Corben and O'Farrell, 1999). Files were eventually downloaded to the Analook software, which displays the data graphically in a frequency (kHz) by time (seconds) spectrogram (Fig 1.1).

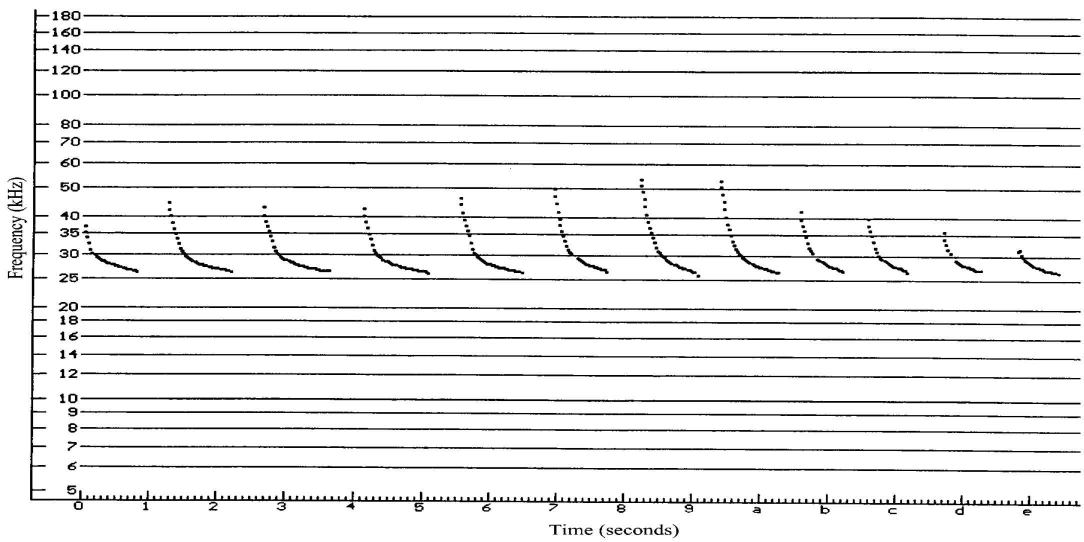

Figure 1.1: Ideal acoustical call of *Lasio. noctivagans* displayed in Analook (Corben and O'Farrell, 1999)

A bat pass is composed of several individual calls that are recorded when a bat flies near the Anabat microphone. These passes can be tallied and the bat activity level (total number of passes) of each location can be calculated. Calls are categorized into one pass if the time between each call is equal to or less than one second. The calls represented in Figure 1.1 would be considered as one "pass". To eliminate the possibility that these passes were created from just one bat flying repeatedly over the Anabat detector, visual counts and the Bat Box III or Pettersson D 100 acoustic devices were often used simultaneously during acoustic bat censuses.

The data collected by the Anabat was used to identify bat species at each location by analyzing the parameters of each call (i.e., a vocal signature). These parameters are Characteristic Slope (Sc), Maximum Frequency (Fmax), Minimum Frequency (Fmin), Mean Frequency (Fmean), Characteristic Frequency (Fc), Frequency of the Knee (Fk), Duration (Dur), Time from start of call to end of body (Tc), Time from start of call to start of body (Tk), and the time between calls (Prev and Next) (Fig 1.2). Frequencies are measured in kilohertz (kHz) and time was measured in milliseconds (ms).

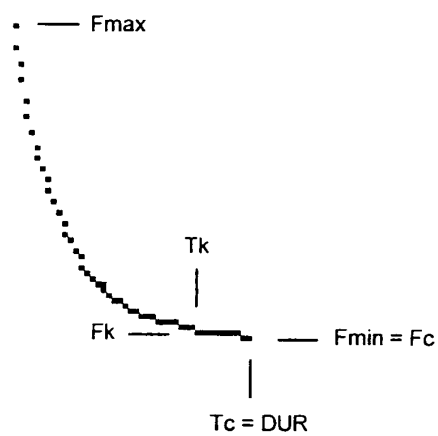

Figure 1.2: Parameters of a bat call: Fmax-Maximum Frequency, Fmin-Minimum Frequency, Fk-Frequency at the knee, Fc-Characteristic Frequency, Tk-Time at the knee, Tc-Time at the point of the Characteristic Frequency, Dur-Duration of the call (Corben and O'Farrell, 1999)

More specifically, characteristic Slope is the slope of the flattest part of the call or the part that lies between Tk (time at the knee) and Tc (time at the point of the characteristic frequency) (Fig 1.2). The flattest part of the call is also known as the 'body' of the call (Corben and O'Farrell, 1999). Maximum frequency (Fmax) is the highest frequency of the call. Minimum frequency (Fmin) is the lowest frequency of the call. Mean frequency (Fmean) is the area under the curve divided by the duration.

Characteristic frequency (Fc) is the frequency at the end of the body (flattest part of call). Frequency of the knee (Fk) is the frequency at the start of the body. Duration (Dur) is the total duration of a call in milliseconds.

South Dakota bat calls were compared to a reference call library composed of calls previously recorded from captured bats in New York, Wyoming, New Mexico, Texas, Arizona, and Utah. These prerecorded calls are available from the University of New Mexico bat call library (http://talpa.unm.edu/batcalldatabase, 2001).

Statistical Methods

Multivariate statistics (discriminant function analysis) were used instead of univariate statistics to compare calls because a call is composed of many different variables (i.e. parameters) and in order for a call to be compared to another; all the variables must be included during the statistical analysis. The South Dakota recorded bat calls were compared to the call parameters of the reference calls by using a discriminate function analysis (SAS Institute Inc, 1999). A discriminant function analysis partitions variables into subsets that tend to be highly related to each other (Johnson, 1998). An alpha level of 0.05 was chosen for the analysis over an alpha level of 0.10 because a smaller level would eliminate more type 1 errors than a higher alpha level. Type 1 errors occur when a true hypothesis (such as there are differences between the calls of bats) is rejected.

Other studies (Fenton et al., 2001; Murray et al, 2001; Obrist, 1995; Parsons and Jones, 2000; and Vaughan et al., 1997) have used discriminant function analysis to identify unknown bat calls using reference calls. Many factors such as the number of parameters, the quality of the reference calls (unculled versus culled), and the locations where the reference calls were recorded, differed among these studies. For my study, different discriminant function models were created to discover the best combination of factors to correctly identify the unknown South Dakota bat calls.

RESULTS

Statistical Results

There were four different DFA models tested. The first model involved using all 11 call parameters (Characteristic Slope-Sc, Maximum Frequency-Fmax, Minimum Frequency-Fmin, Mean Frequency-Fmean, Characteristic Frequency-Fc, Frequency of the Knee-Fk, Duration-Dur, Time from start of call to end of body-Tc, Time from start of call to start of body-Tk, and the time between calls-Prev and Next) and unculled reference calls from all localities in the call library.

The first model was rejected when a stepwise discriminate function was run because the parameters "prev" and "next" were of no significance ($p = 0.157$ and $p = 0.194$ respectively) in the discrimination of the calls (Table 1.2).

The second DFA method was with only nine parameters (Sc, Fmax, Fmin, Fmean, Fc, Fk, dur, Tc and Tk) using culled reference calls from all states. The quality of the library calls was questionable because there could be variation between calls or in the quality of the recordings. To alleviate this problem, the reference bat calls were culled by utilizing the quality (Qual) parameter (Analook software). The quality parameter indicates the smoothness of the call (lower values indicate a smoother call). This culling was necessary to eliminate the ‘outlier’ reference calls because these calls could have been affected by extraneous noise such as insects. Calls that had a ‘Qual’ over 0.25 were removed from further analysis.

Table 1.2: Statistical values from stepwise DFA Model 1

Variable	Partial R-square	F Value	P value
Dur	0.094	41.25	<0.0001
Fc	0.178	86.26	<0.0001
Fk	0.070	29.93	<0.0001
Sc	0.081	35.13	<0.0001
Fmax	0.087	37.65	<0.0001
Fmin	0.135	62.00	<0.0001
Fmean	0.085	36.85	<0.0001
Tc	0.094	41.06	<0.0001
Tk	0.121	54.75	<0.0001
Prev	0.004	1.55	0.157
Next	0.004	1.44	0.194

My concerns about the number of parameters and the quality of reference calls (second DFA Model) have been problematic for previous studies as well (Fenton et al., 2001; Murray et al, 2001; Obrist, 1995; Parsons and Jones, 2000; and Vaughan et al., 1997). Many studies have consistently used duration, frequency and slope, a much smaller subset of the data instead of all nine parameters; but there remains the possibility that different geographical dialects exist between reference calls. Murray et al. (2001) found that geography accounted for only a small percentage of the total variation in some species (including *M. lucifugus* and *M. septentrionalis*) but accounted for a high percentage of the variation in *E. fuscus* and *Lasiu. borealis*, possibly because of genetic or learned differences among populations.

To determine if there were geographical differences in the reference calls in the second DFA model, I compared parameter means for each species' reference call. The parameters of *M. lucifugus* and *Lasio. noctivagans* calls were the most similar, but the *Lasiu. cinereus* calls and *M. ciliolabrum* calls differed among localities (Table 1.3). These differences in the call parameters meant that the reference calls from different localities could not be lumped together for each bat species thus the second DFA model was rejected.

A third DFA model was run to determine if the reference calls would be categorized correctly into their species/locality sets. The correctly categorized calls would be used to identify the South Dakota bat calls. This model was run using only four parameters: a slope parameter (Sc), duration (Dur), and two frequency parameters (Fk and Fc). These frequency parameters were chosen over the others (Fmin, Fmean, and

Fmax) because most of the identifiable parts of a bat call is in the body of the call. Fk and Fc are both frequency parameters specifically dealing with the call body while Fmin, Fmax, and Fmean are very broad parameters on the entire call (Fig 1.2).

When the results of the third DFA model were obtained, the percentage of correctly classified calls was very low for some species/locality sets (Table 1.4). The New Mexico calls for *Lasio. noctivagans* (1.4%), *M. ciliolabrum* (19.2%) and *M. lucifugus* (1.2%) were all classified incorrectly as *Lasiu. cinereus* New Mexico (32.3%), *M. ciliolabrum* Arizona (41.6%), and *M. lucifugus* Arizona (32.5%) respectively. As such, these calls were eliminated from future analyses and the third model was rejected.

Instead, the *Lasio. noctivagans* calls from New York (22.6%) and *M. lucifugus* calls from Arizona (62.6%) were used. The *Lasiu. cinereus* calls from Texas (89.2%) were chosen over calls from New York (78.6%) because a higher percentage of calls were classified correctly. Better quality of the recordings or less variation between calls may be possible reasons for the higher percentages of correctly classified calls. The *M. ciliolabrum* calls from Wyoming (65.3%) were chosen over the calls from Arizona (71.4%) because Wyoming is much closer to South Dakota and the geographical difference between calls should be less.

The fourth and final DFA model was run using four parameters with a limited selection of reference calls from New Mexico (*E. fuscus*), New York (*Lasiu. borealis*, *Lasio. noctivagans*, and *M. septentrionalis*), Wyoming (*M. ciliolabrum*), Arizona (*M. lucifugus*) and Texas (*Lasiu. cinereus*). This final model was run to classify the South Dakota bat calls (Table 1.5). The fourth DFA model classified the South Dakota bat calls at each location into bat species based on the reference calls parameters.

Acoustical data added to previous mist netting records and provided a better understanding of the distribution of bats in eastern South Dakota. Acoustical data added new species records for *E. fuscus* (7 records), *Lasiu. borealis* (11 records), *Lasiu cinereus* (10 records), *Lasio. noctivagans* (6 records), and *M. lucifugus* (4 records) (Table 1.5) at some study sites.

Acoustical data identified new bat records in some locations where no capture data, literature, or voucher records existed previously: Adams Homestead (4 species), Fisher Grove R.A. (2 species), Hartford Beach R.A. (2 species), Mina R.A. (1 species), Oakwood S.P. (3 species), Platte Creek R.A. (1 species), Dell Rapids Quarry (1 species), Richmond R.A. (4 species), and Sica Hollow S.P. (3 species).

Acoustical data supported the voucher records and capture data at several locations. Of the locations with previous capture, literature, or voucher records, 63% of the time these records were matched by acoustical data.

Table 1.3: Means of reference call parameters and percent correctly identified in Model 2

Species/Locality	Parameter	Mean (C.V.)
Lasiu. cinereus/New Mexico	Duration Fc Fmax Fmin	5.3 (42.9) 26.1 (9.5) 29.3 (21.9) 25.6 (8.4)
Lasiu. cinereus/New York	Duration Fc Fmax Fmin	5.3 (39.3) 36.0 (8.6) 49.0 (20.2) 36.0 (8.8)
Lasiu. cinereus/Texas	Duration Fc Fmax Fmin	7.3 (35.9) 23.8 (12.8) 35.9 (18.5) 23.5 (8.5)
Lasio. noctivagans/New Mexico	Duration Fc Fmax Fmin	4.1 (51.0) 31.6 (21.2) 36.9 (26.0) 31.0 (20.5)
Lasio. noctivagans/New York	Duration Fc Fmax Fmin	4.0 (46.4) 31.4 (17.6) 39.6 (24.9) 31.0 (15.8)
M. ciliolabrum/Arizona	Duration Fc Fmax Fmin	2.0 (19.8) 43.0 (5.2) 52.1 (7.7) 41.8 (1.6)
M. ciliolabrum/New Mexico	Duration Fc Fmax Fmin	2.1 (52.1) 43.4 (13.4) 54.4 (18.1) 42.2 (12.3)
M. ciliolabrum/Utah	Duration Fc Fmax Fmin	2.1 (24.2) 43.3 (6.5) 54.4 (11.1) 42.3 (4.9)
M. ciliolabrum/Wyoming	Duration Fc Fmax Fmin	3.6 (43.6) 41.7 (8.0) 52.9 (10.7) 41.1 (7.0)
M. lucifugus/Arizona	Duration Fc Fmax Fmin	3.5 (41.8) 37.5 (8.7) 50.0 (14.5) 37.2 (8.0)
M. lucifugus/New Mexico	Duration Fc Fmax Fmin	3.6 (66.6) 38.1 (17.6) 47.4 (20.8) 37.1 (16.6)

Table 1.4: Group comparison matrix for Model 3

	Efus NM	*Lbor* NY	*Lcin* NM	*Lcin* NY	*Lcin* TX	*Lnoc* NM	*Lnoc* NY	*Mcil* AR	*Mcil* NM	*Mcil* UT	*Mcil* WY	*Mluc* AR	*Mluc* NM	*Msep* NY	**Percent Correctly Identified**	**TOTAL**
E. fuscus NM	**207**	2	47	9	8	8	63	1	8	0	0	6	8	10	54.9%	377
Lasiu. borealis NY	5	**73**	2	28	2	5	1	2	2	0	3	4	1	1	56.6%	129
Lasiu. cinereus NM	3	0	**52**	0	8	0	1	0	0	0	0	0	0	1	80.0%	65
Lasiu. cinereus NY	0	1	1	**11**	0	0	0	1	0	0	0	0	0	0	78.6%	14
Lasiu. cinereus TX	3	0	1	0	**91**	0	2	0	2	0	0	0	0	3	89.2%	102
Lasio. noctivagans NM	49	18	139	83	15	**6**	32	16	15	2	0	43	7	5	1.4%	430
Lasio. noctivagans NY	114	4	10	10	1	3	**52**	4	10	2	11	2	3	4	22.6%	230
M. ciliolabrum AR	0	0	0	0	0	0	0	**10**	1	3	0	0	0	0	71.4%	14
M. ciliolabrum NM	7	3	7	4	0	1	2	104	**48**	40	13	3	4	14	19.2%	250
M. ciliolabrum UT	0	0	0	0	0	0	0	66	11	**38**	22	5	0	3	26.2%	145
M. ciliolabrum WY	0	4	0	5	0	0	0	6	5	10	**62**	2	1	0	65.3%	95
M. lucifugus AR	0	1	4	33	0	1	3	11	12	18	13	**161**	0	0	62.6%	257
M. lucifugus NM	45	5	15	34	11	2	18	63	50	36	55	167	**6**	6	1.2%	513
M. septentrionalis NY	0	0	0	0	0	0	0	0	0	0	0	0	0	**6**	100%	6
TOTAL	433	111	278	217	136	26	174	284	164	149	179	393	30	53		**2627**

Table 1.5: Species-locality matrix for DFA Model 4 (bolded numbers indicate new records)

	Efus	*Lbor*	*Lcin*	*Lnoc*	*Mcil*	*Mluc*	*Msep*	**TOTAL**
Adam Home Park	**199**	**63**	**5**	**45**	0	0	0	312
American Creek R.A.	40	**14**	**2**	**2**	0	0	0	58
Cotton Park	6	5	0	0	0	0	0	11
Farm Island R.A.	229	401	**37**	**6**	2	7	0	682
Fisher Grove R.A.	0	**15**	**3**	0	0	0	0	18
Fort Sisseton Park	**45**	**17**	**5**	0	0	0	0	67
Hartford Beach R.A.	0	**27**	0	0	0	**2**	0	29
Karl Mundt NWR	2	0	0	**1**	0	0	0	3
Mina State R.A.	0	**2**	0	0	0	0	0	2
Oakwood Park	0	**31**	**5**	0	0	**1**	0	37
Platte Creek R.A.	**2**	0	0	0	0	0	0	2
Dell Rapids Quarry	**10**	0	0	0	0	0	0	10
Richmond R.A.	**1**	**105**	**9**	0	0	**1**	0	116
Sica Hollow Park	**7**	**1**	**7**	0	0	0	0	15
Sioux Falls	196	37	2	**6**	0	0	0	241
Waubay NWR	**90**	**188**	**11**	2	0	0	0	291
West Bend R.A.	95	**28**	**13**	**1**	0	**3**	0	140
West Whitlocks R.A.	0	18	2	0	0	0	0	20

Table 1.6 Voucher, literature, capture and acoustic records for bats in eastern South Dakota

Locality	*E. fuscus*	*Lasiu. borealis*	*Lasiu. cinereus*	*Lasio. noctivagans*	*M. ciliolabrum*	*M. lucifugus*	*M. septentrionalis*
Adams Home Park	A	A	A	A			
American Creek R.A.	A V	A	A	A			
Astoria	C						
Brookings	C	C V	V				
Clay Co. Park	A	A		A			
Cotton Park-Vermillion	A C V	A L	L	L			
Farm Island R.A.	A C V	A V	A	A	A V	A C	C V
Fisher Grove Park		A	A				
Fort Sisseton Park	A	A	A	C			
Hartford Beach R.A.		A				A	
Hiddenwood R.A.						C	
Karl Mundt NWR	A C	C	C	A		C	C
La Framboise R.A.	V			C		C	
Lewis Clark R.A.	C V		A				C
Mina State R.A.		A					
Mitchell	C V		V				
Myron Grove R.A.							C
Newton Hills Park	C	C					
OakLake Station		C					
Oakwood Park		A	A			A	
Platte Creek R.A.	A						
Dell Rapids Quarry	A						
Randall Creek R.A.	C						
Richmond R.A.	A	A	A			A	
Sica Hollow Park	A	A	A				
Pollock						C	
Sioux Falls	A C V	A V	A V	A		V	
Union Grove Park	C V	C				V	C V
Waubay NWR	A	A	A	A V		C	
West Bend R.A.	A C	A	A	A		A	C
West Whitlocks R.A.		A C	A C			C	

KEY: A (Acoustic records), C (Capture records 2000-2002), L (Literature records), V (Voucher records)

Capture Data

In the summer of 2000, four sites in two counties were censused and eight bats were captured: three *E. fuscus* and five *Lasiu. borealis.* Since this was the first year of my study, the census area was kept small, and efforts were focused on the training of bat sampling techniques (mist netting and acoustics).

In the summer of 2001, 34 sites in 19 counties throughout eastern South Dakota were censused and 44 bats were captured. Of these, *M. lucifugus* was captured most frequently, possibly because of the placement of mist nets near a roost. Of the 52 bats captured in 2000 and 2001, the percent composition was: *M. lucifugus* 35%, *E. fuscus* 27%, *Lasiu. borealis* 21%, *M. septentrionalis* 11%, *Lasiu. cinereus* 4% and *Lasio. noctivagans* 2% (Fig 1.3).

During the summer of 2002, nine sites in five counties along the Missouri River were censused and 52 bats were captured. Of the bats captured, the percent composition was: *M. septentrionalis* 42%, *E. fuscus* 35%, *M. lucifugus* 15%, *Lasiu. borealis* 4% and *Lasio. noctivagans* 4% (Fig 1.3). The percent composition of bat captures in the gallery forests of the Missouri River differed in comparison to sites throughout eastern South Dakota. The percentage of *M. septentrionalis, E. fuscus, and Lasio. noctivagans* captures increased along the Missouri River by 31%, 8%, and 2% respectively, while *M. lucifugus, Lasiu. borealis,* and *Lasiu. cinereus* captures decreased 20%, 17%, and 4% respectively.

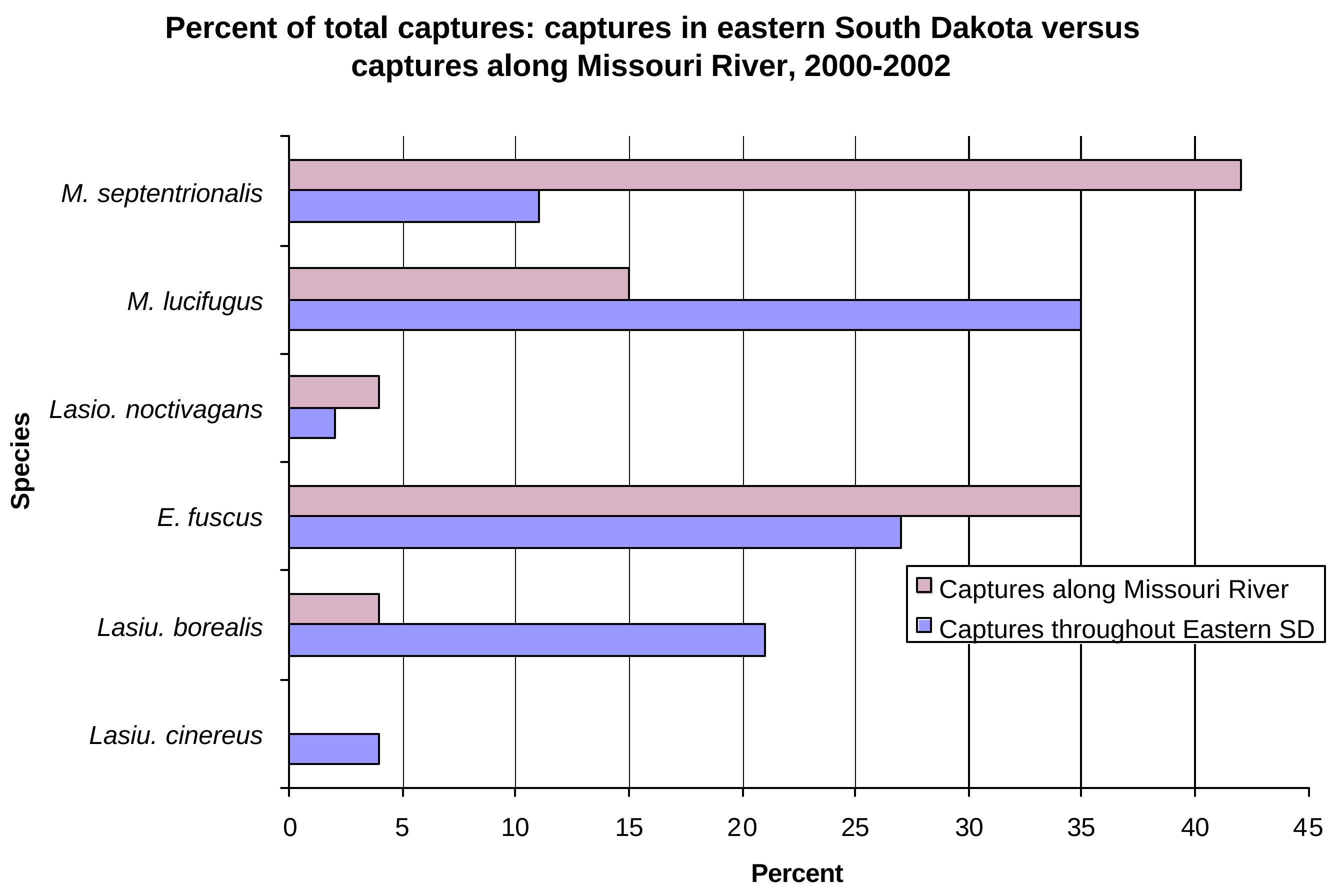

Figure 1.3: Percentage of total bat captures along the Missouri River compared to captures throughout eastern South Dakota, 2000-2002

At most sites in 2000 and 2001, capture rates (bats/per net/per night; BNN) were less than 1.0 BNN. However, two locations that were within the gallery forests of the Missouri River had greater capture rates: La Framboise R.A. with 2.3 BNN and Karl Mundt NWR with 1.43 BNN (Fig 1.4).

In 2002, when censusing efforts were concentrated along the Missouri River, capture rates at many locations were equal or greater than 1.0 BNN, which was much greater than the capture rates at the non-Missouri River locations (Fig 1.4). In all non-Missouri River locations, the BNN was less than 0.3, and in half of these, the BNN was zero. Comparatively, the lowest capture rate along the Missouri River was 0.5 BNN (Platte Creek R.A.), and the capture rates at locations within the gallery forests of the Missouri River (Farm Island R.A., Karl Mundt NWR, La Framboise R.A. and West Bend R.A.) were greater than 1.0 BNN. Evidently, bats are more abundant in gallery forest areas along the Missouri River than in open habitats of non-Missouri River locations.

There were subtle differences in the capture rates between 2001 and 2002. The capture rates at Farm Island R.A. varied from 0.4 to 2.6 BNN, Karl Mundt NWR from 1.43 to 1.0 BNN, La Framboise R.A. from 2.3 to 3.0 BNN, West Bend R.A. from 0.25 to 2.0 BNN, and West Whitlocks R.A. from 0.22 to 0.6 BNN. The capture rates may have changed between years due to better net placement or nets were set near unknown roosts, or uncontrolled factors such as weather could have contributed to the change.

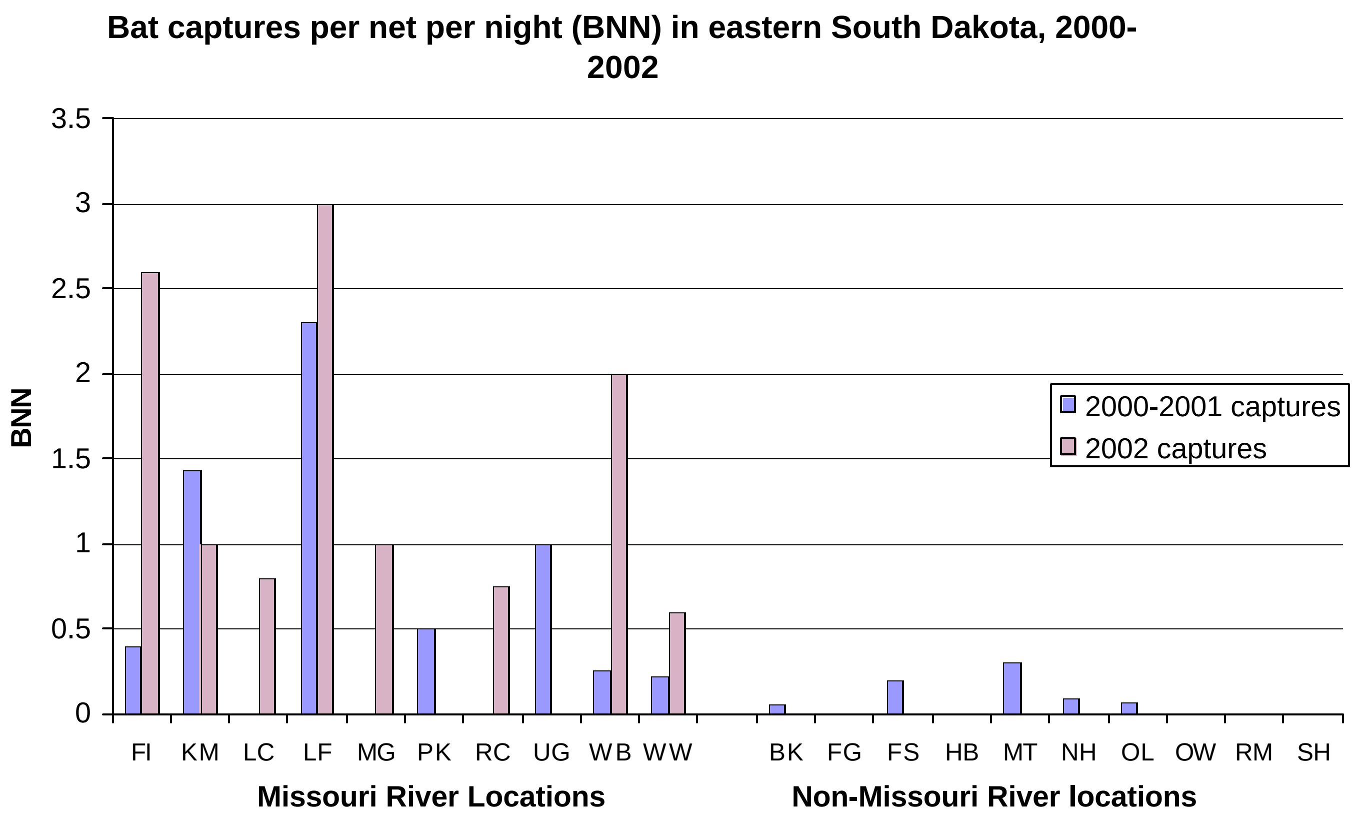

Figure 1.4: Bat captures per net per night (BNN) by Locations, eastern South Dakota 2000-2002 (based on mist net captures)

Abbreviations: FI: Farm Island R.A., KM: Karl Mundt NWR, LC: Lewis Clark R.A., LF: La Framboise R.A., MG: Myron Grove R.A., PK: Pollock, RC: Randall Creek R.A., UG: Union Grove Park, WB: West Bend R.A., WW: West Whitlocks R.A.; BK: Brookings, FG: Fisher Grove R.A., FS: Fort Sisseton Park, HB: Hartford Beach R.A., MT: Mitchell, NH: Newton Hills Park, OL: OakLake Station, OW: Oakwood Park, RM: Richmond R.A., SH: Sica Hollow Park

Species richness is an index of species diversity used to measure the total number of species in an area (Truett et al., 1994). In eastern South Dakota, seven species of bat have been previously documented (Jones and Genoways, 1967; Findley, 1956); therefore, an area with high species richness would have seven species of bat (*M. septentrionalis, M. ciliolabrum, M. lucifugus, Lasio. noctivagans, E. fuscus, Lasiu. borealis*, and *Lasiu. cinereus*).

Comparing the species richness of Missouri River locations to non-Missouri River locations, 71% of the sites had a species richness of 3.0 or more, while non-Missouri River locations only had a species richness of 3.0 or more in 50% of the sites (Figure 1.5). The locations with the highest species richness include the gallery forests of Farm Island R.A. (7 species), Karl Mundt NWR (6 species) and West Bend R.A. (6 species).

Of the seven, the only species of bat that was not found at Karl Mundt NWR or West Bend R.A. was *M. ciliolabrum*. This bat is primarily found in western South Dakota, and has only been captured in eastern South Dakota at Farm Island R.A., but based on historical distribution records, *M. ciliolabrum* may utilize habitats along the Missouri River in eastern South Dakota (Higgins et al., 2000).

Based on counts of total bat passes deciphered from Anabat sequence files, the Missouri River locations had more bat activity than non-Missouri River locations (Fig 1.6). Farm Island R.A. had the most activity with 330 passes per night and Adams Homestead S.P. was the second most active with 253 passes per night. Both of these locations consist of gallery forest habitat. Comparatively, the three locations with the least activity are Mina R.A. (6 passes), Sand Lake NWR (6 passes) and Lake Andes

NWR (8 passes) that did not have gallery forests but were wetland habitats with very few trees.

Bats were relatively more abundant in Missouri River locations than in non-Missouri River locations, as determined by the greater number of bat passes. Most of the non-Missouri River locations had fewer than 50 passes per night while only two locations along the Missouri River had fewer than 50 passes (Fig 1.6). Karl Mundt NWR, a location along the gallery forest of Missouri River, only had 57 passes but the battery power for the Anabat detector and tape recorder had died in the middle of the recording session so the portion of the tape that was not recorded was useless.

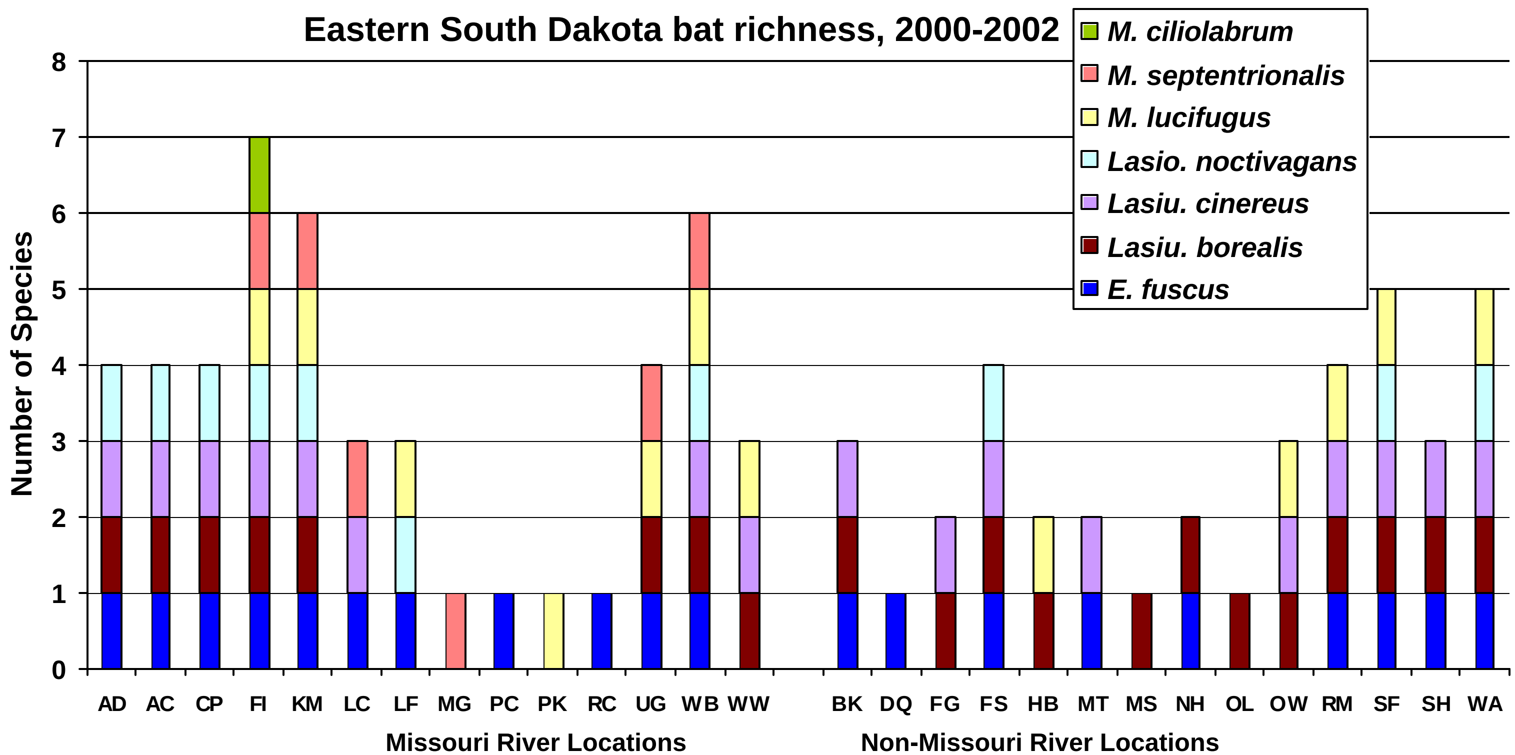

Figure 1.5: Number of bat species per location, eastern South Dakota 2000-2002 based on capture, voucher, literature, and acoustic records.

Abbreviations: AD: Adams Home Park, AC: American Creek R.A., CP: Cotton Park-Vermillion, FI: Farm Island R.A., KM: Karl Mundt NWR, LC: Lewis Clark R.A., LF: La Framboise R.A., MG: Myron Grove R.A., PC: Platte Creek R.A., PK: Pollock, RC: Randall Creek R.A., UC: Union Grove Park, WB: West Bend R.A., WW: West Whitlocks R.A.; BK: Brookings, DQ: Dell Rapids Quarry, FG: Fisher Grove R.A., FS: Fort Sisseton Park, HB: Hartford Beach R.A., MT: Mitchell, MS: Mina State R.A., NH: Newton Hills Park, OL: OakLake Station, OW: Oakwood Park, RM: Richmond R.A., SF: Sioux Falls, SH: Sica Hollow Park, WA: Waubay NWR

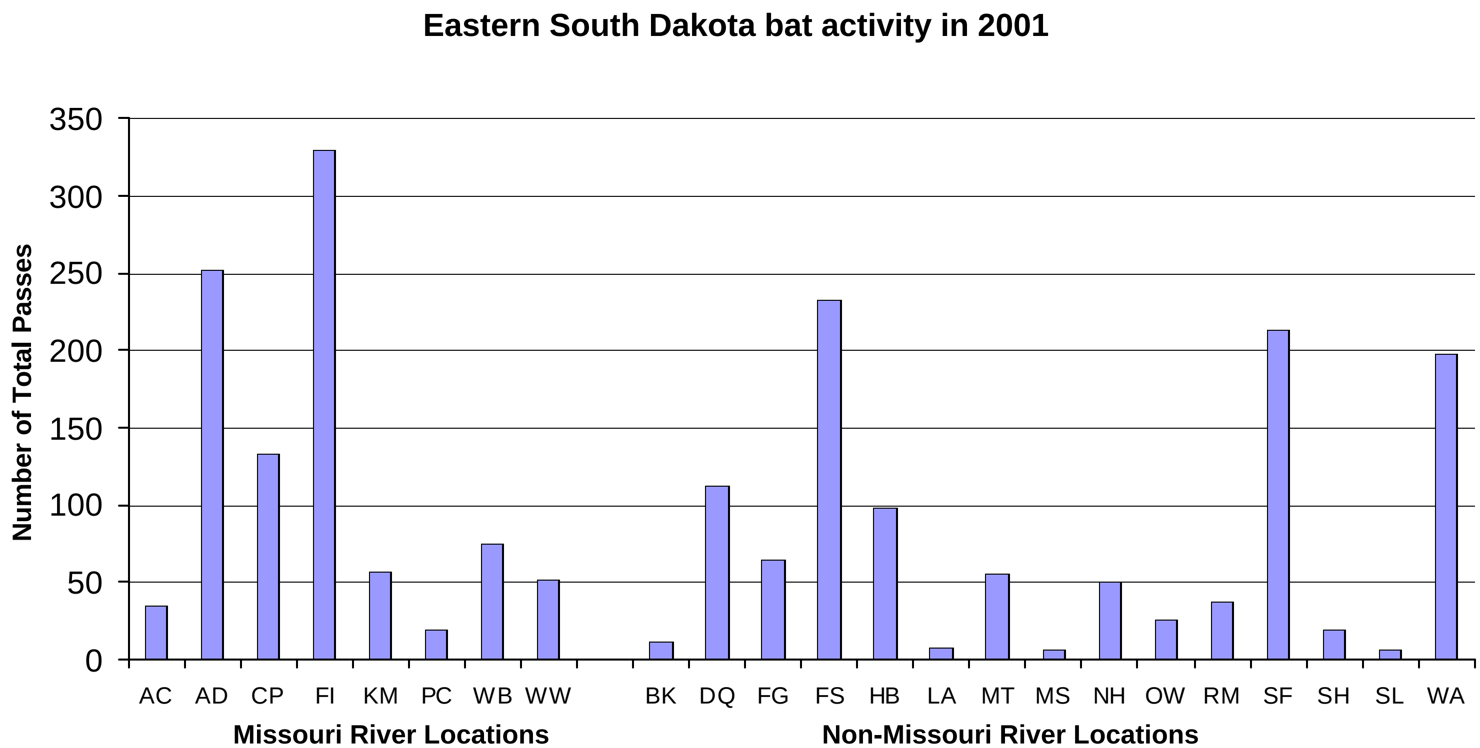

Figure 1.6: Bat activity by location, eastern South Dakota 2001

Abbreviations: AC: American Creek R.A., AD: Adams Home Park, CP: Cotton Park-Vermillion, FI: Farm Island R.A., KM: Karl Mundt NWR, PC: Platte Creek R.A., WB: West Bend R.A., WW: West Whitlocks R.A.; BK: Brookings, DQ: Dell Rapids Quarry, FG: Fisher Grove R.A., FS: Fort Sisseton Park, HB: Hartford Beach R.A., LA: Lake Andes NWR, MT: Mitchell, MS: Mina State R.A., NH: Newton Hills Park, OW: Oakwood Park, RM: Richmond R.A., SF: Sioux Falls, SH: Sica Hollow Park, SL: Sand Lake NWR, WA: Waubay NWR

SPECIES ACCOUNTS

Myotis septentrionalis (van Zyll de Jong, 1979)
Northern Long-eared Myotis

Museum records (6).—BONHOMME COUNTY: Sand Creek park, 3 (KU); Springfield, 1 (KU). HUGHES COUNTY: Farm Island R.A., 1 (TTU). STANLEY COUNTY: no specific locality, 1 (USNM).

Capture data (29).—CLAY COUNTY: Myron Grove R.A., 5. GREGORY COUNTY: Karl Mundt NWR, 11. HUGHES COUNTY: Farm Island R.A., 7, West Bend R.A., 3. UNION COUNTY: Union Grove S.P., 2. YANKTON COUNTY: Lewis and Clark R.A., 1.

Myotis septentrionalis was captured on June 16, 2001 at Union Grove S.P. (Union Co.). This bat was retained as a voucher specimen in the South Dakota State University Natural History Collection. Other captures during 2001 include: Union Grove S.P. on July 29; Karl Mundt NWR (Gregory Co.) on June 23 and August 13; and West Bend R.A. (Hughes Co.) on August 19. During the summer of 2002, *M. septentrionalis* was captured at Karl Mundt NWR on May 25, 26, 29, and July 14; Gavins Point Unit of the Lewis and Clark R.A. (Yankton Co.) on June 16; Myron Grove R.A. (Clay Co.) on June 21; West Bend R.A. on June 26; and Farm Island R.A. (Hughes Co.) on July 25.

Habitat

Myotis septentrionalis was captured in cluttered trails of cottonwood floodplain forests (Karl Mundt NWR, West Bend R.A., and Farm Island R.A.) or deciduous forested areas (Union Grove S.P.) along the Missouri River.

Reproduction

Few reproductive records exist for *M. septentrionalis* in eastern South Dakota. Gravid females were captured on June 21 and 26, 2002; lactating females were captured on July 14, 2002; postlactating females on July 14 and 25, 2002; and young of the year males were captured on July 25, 2002. The pelage of these younger males was much darker and the ears much smaller than the postlactating females. If only ear size and coloration were used to identify these younger males, they could have been easily been misidentified as another species. Previous bat identification keys have relied on pelage coloration and ear length (Higgins et al., 2000) as distinguishing characteristics. In my study, I found that these characteristics can be misleading and more specific characteristics such as tragus length and shape are more effective in the identification of bats, especially *Myotis* species (Joel Tigner, personal communication).

Myotis lucifugus carissima (Thomas, 1904)
Little Brown Myotis

Museum records (2).—WALWORTH COUNTY: Mobridge, 2 (SDSU).

Capture data (23).—CAMPBELL COUNTY: Pollock, 2. GREGORY COUNTY: Karl Mundt NWR, 2. HUGHES COUNTY: Farm Island R.A., 2, La Framboise R.A., 15. WALWORTH COUNTY: Hiddenwood R.A., 2.

Two subspecies (*M. lucifugus carissima* and *M. lucifugus luci*fugus) of *M. lucifugus* are documented in the eastern region of South Dakota. *Myotis lucifugus carissima* differs from *M. lucifugus lucifugus* in having slightly larger cranial dimensions and being paler in pelage coloration (Jones and Genoways, 1967).

In 2001, *M. lucifugus carissima* was captured at Farm Island R.A. (Hughes Co) on May 11 and July 9; Karl Mundt NWR (Gregory Co) on June 23; La Framboise R.A. (Hughes Co) on July 10; Pollock (Campbell Co.) on July 14; and Lake Hiddenwood R.A.

(Walworth Co.) on July 16. During the summer of 2002, *M. lucifugus carissima* was captured at La Framboise R.A. on July 20.

Habitat

Myotis lucifugus were captured along trails or in roosts of cottonwood floodplain forests (Farm Island R.A., Karl Mundt NWR, La Framboise R.A. and West Whitlocks R.A.); deciduous forested areas (Lake Hiddenwood R.A.); or urban areas (Pollock). These sites are located near the Missouri River, which was used as a water source and a foraging area by *M. lucifugus*. In my study, *M. lucifugus* utilized larger bodies of water, such as the Missouri River and Hiddenwood Lake, instead of smaller streams like the Vermillion or Big Sioux.

Reproduction

Few reproduction records exist for *M. lucifugus* in eastern South Dakota. A gravid female was captured on May 23, 2001; postlactating females were captured on July 10, 2001 and July 20, 2002; and a young of the year male was captured on July 28, 2002.

Myotis lucifugus lucifugus (Le Conte, 1831)
Little Brown Myotis

Museum records (4).—GREGORY COUNTY: Cedar Island, 1 (USNM). MINNEHAHA COUNTY: Sioux Falls, 1 (SDSU). STANLEY COUNTY: Ft. Pierre, 1 (USNM). UNION COUNTY: 6 mi East of Vermillion, 1 (KU).

Capture data (3).—DAY COUNTY: Waubay NWR, 1. POTTER COUNTY: West Whitlocks R.A., 2

On June 2, 2001 a *M. lucifugus lucifugus* was extracted from a building at Waubay NWR (Day Co.). This female was found crawling on the basement floor and was very dehydrated. She apparently was trapped in the basement and was weakening due to lack of food and water. The bat was given water but expired the following day and is currently a voucher specimen at South Dakota State University Natural History Collection. *Myotis lucifugus lucifugus* was also captured at West Whitlocks R.A. (Potter Co.) on May 23, 2001 and then again on July 28, 2002.

Lasionycteris noctivagans (Le Conte, 1831)
Silver-haired bat

Museum records: (2).—DAY COUNTY: Waubay NWR, 1 (USNM). KINGSBURY COUNTY: Desmet, 1 (SDSU)

Capture data: (3).—HUGHES COUNTY: La Framboise R.A., 2. MARSHALL COUNTY: Fort Sisseton S.P., 1.

Additional records: CLAY COUNTY: Vermillion (Lane et al., *in press*). STANLEY COUNTY: no specific location (SD Natural Heritage Program Database).

During the summer of 2001, a male *Lasio. noctivagans* was captured on July 18 at Fort Sisseton S.P. (Marshall Co.). This male was retained as a voucher specimen in the South Dakota State University Natural History Collection. This bat may have been a migrant, but the fall migration period starts in late August or early September (Banfield, 1974) and in July, this male should not have been migrating. In the summer of 2002, two *Lasio. noctivagans* (male and female) were captured on July 20, 2002 in La Framboise R.A. (Hughes Co.). With the addition of these records from 2002, I consider *Lasio. noctivagans* as a summer resident of eastern South Dakota.

Habitat

Lasionycteris noctivagans was captured in open areas of cottonwood floodplain forests areas (La Framboise R.A.) and other deciduous forested areas (Fort Sisseton S.P.).

Parasites

Three bat bugs (*Cimex adjunctus*) were found on a *Lasio. noctivagans* that was captured at Fort Sisseton S.P. These ectoparasites were feeding on the bat behind its ears but when disturbed, they began to move about the bat's body. This bat bug has been previously reported from *Lasio. noctivagans* by Usinger (1966).

Eptesicus fuscus fuscus (Palisot de Beauvois, 1796)
Big Brown Bat

Museum records (83*).—BEADLE COUNTY: Huron, 1 (SDSU). BON HOMME COUNTY: Sand Creek park, 13 (KU); Springfield, 17 (KU). BROOKINGS COUNTY: Brookings, 3 (SDSU), Elkton, 2 (SDSU). BRULE COUNTY: Chamberlain, 1 (SDSU). CHARLES MIX COUNTY: Dante, 1 (SDSU). CLAY COUNTY: Vermillion, 2 (SDSU); Vermillion, 2 (UNSM); Vermillion, 8 (KU). DAVISON COUNTY: Mitchell, 2 (SDSU). DUEL COUNTY: Clear Lake, 1 (SDSU). GRANT COUNTY: Milbank, 1 (SDSU). HUGHES COUNTY: Farm Island R.A., 8 (TTU); Pierre, 1 (SDSU). HUTCHINSON COUNTY: Freeman, 1 (SDSU). LAKE COUNTY: Madison, 1 (SDSU). LINCOLN COUNTY: Beresford, 4 (SDSU); Canton, 4 (SDSU); Lennox, 1 (SDSU). MINNEHAHA COUNTY: Sioux Falls, * (SDSU). MOODY COUNTY: Flandreau, 2 (SDSU); Trent, 1 (SDSU). TURNER COUNTY: Marion, 1 (SDSU); Viborg, 2 (SDSU). UNION COUNTY: Elkpoint, 1 (SDSU); Union Grove S.P., 1 (KU). YANKTON COUNTY: Yankton, 1 (SDSU).

? 600 bats were collected from Sioux Falls, there was difficulty determining fuscus from pallidus

Capture data: (24).—BROOKINGS COUNTY: Astoria, 1; Brookings-Pioneer park, 3. CLAY COUNTY: Vermillion-Cotton park, 1. DAVISON COUNTY: Mitchell-Hitchcock park, 1. GREGORY COUNTY: Karl Mundt NWR, 6; Randall Creek R.A., 3. HUGHES COUNTY: Farm Island R.A., 1; West Bend R.A., 1. LINCOLN COUNTY: Newton Hills S.P., 1. MINNEHAHA COUNTY: Old Courthouse Museum-Sioux Falls, 1. UNION COUNTY: Union Grove S.P., 2. YANKTON COUNTY: Gavins Point Unit of the Lewis and Clark R.A., 3.

Two subspecies of *E. fuscus* (*E. fuscus fuscus* and *E. fuscus pallidus*) have been documented in the eastern region of South Dakota. *Eptesicus fuscus fuscus* differs from *E. fuscus pallidus* in having a larger cranium and being darker in pelage coloration (Jones and Genoways, 1967). The zone of intergradation of the two subspecies has been described as the area between the 98th and 99th meridians and specimens from Bon Homme County were noted as being intergrades of both subspecies (Jones and Genoways, 1967). I captured both subspecies throughout the eastern region of the state with integrades of the subspecies in the Sioux Falls area.

During the summer of 2000, *E. fuscus fuscus* was captured at Pioneer park in Brookings (Brookings Co.) on August 22. During the summer of 2001, *E. fuscus fuscus* was captured at Cotton park in Vermillion (Clay Co.) on June 19; West Bend R.A. (Hughes Co.) on July 8, Union Co. S. P. (Union Co.) on July 29, Newton Hills S.P. (Lincoln, Co.) on August 9; Sioux Falls (Minnehaha Co.) on August 9, Karl Mundt NWR (Gregory Co.) on August 13, Astoria (Brookings Co.) on August 24; and Hitchcock park in Mitchell (Davison Co.) on August 28. During the summer of 2002, *E. fuscus fuscus* were captured at Randall Creek R.A. (Gregory Co.) on May 31; Gavins Point Unit of Lewis and Clark R.A. (Yankton Co.) on June 16; Karl Mundt NWR on July 10; and Farm Island Recreation Area (Hughes Co.) on July 25.

Eptesicus fuscus spends its summer reproductive seasons in eastern South Dakota and has been found in eastern South Dakota during the hibernation period (December through March). Department of Health records of *E. fuscus* captured throughout the year, indicate that this species is a year long resident of eastern South Dakota.

Habitat

Eptesicus fuscus was captured in open areas of urban areas (city parks of Brookings, Sioux Falls, Mitchell, and Vermillion); cottonwood floodplain forests (Karl Mundt NWR, Farm Island R.A., West Bend R.A., Randall Creek R.A., and Lewis and Clark R.A.); and deciduous forested areas (Union Grove S.P. and Newton Hills S.P.).

Based on acoustic data, mist net capture, and Department of Health data from 2000 and 2001, *E. fuscus* seems to be much more abundant in urban areas, or areas with nearby human structures. This is evident in light of the number of house extractions within the city of Sioux Falls each year. In 2000 alone, 251 bats were extracted from houses in Sioux Falls, of these, 243 (97%) were *E. fuscus*.

Reproduction

Excellent life history data of *E. fuscus* was derived from the Department of Health bats that were collected from Sioux Falls and tested for rabies at the South Dakota Animal Disease Research and Diagnostic Laboratory, Department of Veterinary Science at South Dakota State University. Reproductive data was recorded for each bat that tested negative for rabies in 2000. Lactating females were recorded from June 19 to July 14, juveniles from June 23 to August 18, and scrotal males from August 8 to September 18 (Fig 1.8).

Literature records note that a gravid female was captured on June 4 (Jones and Genoways, 1967) and a young of the year female was captured on July 29, 2001.

Parasites

A male *E. fuscus fuscus* was captured with six bat ticks (*Ornithodoras kelleyi*) at Hitchcock park in Mitchell. This tick has been reported on other *E. fuscus* captured at Union Grove S.P. (Jones and Genoways, 1967).

Eptesicus fuscus pallidus (Young, 1908)
Big Brown Bat

Museum records: (1).—MINNEHAHA COUNTY: Sioux Falls, * (SDSU). STANLEY COUNTY: Ft. Pierre, 1 (USNM).

? 600 bats were collected from Sioux Falls, there was difficulty determining fuscus from pallidus

Capture data: (8).—GREGORY COUNTY: Karl Mundt NWR, 2. HUGHES COUNTY: West Bend R.A., 6.

During the summer of 2002, *E. fuscus pallidus* was captured at Karl Mundt NWR (Gregory Co.) on July 10 and West Bend Recreation Area (Hughes Co.) on June 26. Four of the females captured at West Bend on June 26 were gravid while two of the females were lactating.

Lasiurus borealis borealis (Muller, 1776)
Red bat

Museum records: (6).—BONHOMME COUNTY: Springfield, 1 (KU). BROOKINGS COUNTY: Brookings, 1 (SDSU). HANSEN COUNTY: Alexandria, 1 (SDSU). HUGHES COUNTY: Farm Island R.A., 1 (TTU). MCCOOK COUNTY: Salem, 1 (SDSU). MINNEHAHA COUNTY: Sioux Falls, 1 (SDSU).

Capture data: (13).—BROOKINGS COUNTY: Brookings, 3; McCrory Gardens-Brookings, 2; Oak Lake Research Station, 1. GREGORY COUNTY: Karl Mundt NWR, 1. LINCOLN COUNTY: Newton Hills S.P., 1. POTTER COUNTY: West Whitlocks R.A., 2. UNION COUNTY: Union Grove S.P., 3.

Additional records.—CLAY COUNTY: no specific locality (Findley, 1956). HYDE COUNTY: Highmore (Jones and Genoways, 1967). JERAULD COUNTY: Lane (Jones and Genoways, 1967)

During the summer of 2000, *Lasiu. borealis* was captured in Brookings (Brookings Co.) on June 14, July 17, and August 26; and at Oak Lake Field Station (Brookings Co.) on August 23. In the summer of 2001, *Lasiu. borealis* was captured at McCrory Gardens in Brookings (Brookings Co.) on June 7; Union Grove S.P. (Union Co.) on July 29; Newton Hills S.P. (Lincoln Co.) on August 9; and Karl Mundt NWR (Gregory Co.) on August 13. In the summer of 2002, *Lasiu. borealis* was captured at West Whitlocks R.A. (Potter Co.) on July 28.

Habitat

Lasiurus borealis was captured in open areas of cottonwood floodplain forests (Karl Mundt NWR and West Whitlocks Bay R.A.); deciduous forested areas (Oak Lake Field Station, Newton Hills S.P. and Union Grove S.P.); and urban areas (city parks of Brookings). During censuses in 2000 and 2001, *Lasiu. borealis* was found to repeatedly forage in the same locality. Nets set in McCrory Gardens (Brookings) that captured *Lasiu. borealis* in 2000, also captured them in 2001.

Behavior

The flight pattern of *Lasiu. borealis* is very distinct. In open canopy sites, *Lasiu. borealis* flies in large circles along the tree line, continues to fly in the same circle for a few minutes and then repeats that same pattern at a different location. Barbour and Davis describe a similar flight pattern (1969). This behavior permits a certain degree of reliable bat identification that can discriminate *Lasiu. borealis* from other bat species usually.

Reproduction

Based on reproductive data from previous studies and capture data from 2000 to 2002, *Lasiu. borealis* is gravid in early June, parturition dates are in mid-June and juveniles are found flying around the end of August. A gravid *Lasiu. borealis* was captured on June 7, 2001; lactating *Lasiu. borealis* with young were captured on June 14, 2000 and June 29, 1953 (Jones and Genoways, 1967.). Volent juvenile *Lasiu. borealis* were captured on July 28, 2002; July 29 and August 9, 2001; and on August 23, 2000.

Migration

Lasiurus borealis migrate into eastern South Dakota in April. Findley (1956) recorded *Lasiu. borealis* active in the region as early as mid-April. On April 10 2001, observations were made by Dr. Dave Swanson and Erik Likeness (University of South Dakota) of bats foraging around the streetlights in Vermillion, S.D.

Lasiurus borealis are migrating out of South Dakota by late August or early September. In 2000 and 2001, several sites were sampled until September 7. Yet, the latest date when *Lasiu. borealis* was captured was August 26.

Lasiurus cinereus cinereus (Palisot de Beauvois, 1796)
Hoary Bat

Museum records: (14).—BONHOMME COUNTY: Sand Creek park, 3 (KU). BROOKINGS COUNTY: Brookings, 1 (SDSU). BROWN COUNTY: Houghton, 1 (KU). CLAY COUNTY: Vermillion, 1 (SDSU). DAVISON COUNTY: Mitchell, 1 (FHS). HAMLIN COUNTY: Lake Poinsett, 1 (SDSU). HYDE COUNTY: Holabird, 1 (SDSU). LAKE COUNTY: Madison, 1 (SDADR-Rabies positive). MINNEHAHA COUNTY: Sioux Falls, 4 (SDSU).

Capture data: (2).—GREGORY COUNTY: Karl Mundt NWR, 1. POTTER COUNTY: West Whitlocks R.A., 1.

Additional records.—CLAY COUNTY: Vermillion (Findley, 1956). HAND COUNTY: St. Lawrence (Jones and Genoways, 1967). STANLEY COUNTY: Ft. Pierre (Miller, 1897). WALWORTH COUNTY: near Swan Creek (Visher, 1914).

In the summer of 2001, *Lasiu. cinereus* was only captured at two locations. Individuals were captured at Karl Mundt NWR (Gregory Co.) on June 23 and on West Whitlocks R.A. (Potter Co.) on July 16. The female captured at West Whitlocks was retained as a voucher specimen in the South Dakota State University Natural History Collection.

Habitat

Lasiurus cinereus was captured in cottonwood floodplain forests along the Missouri River (Karl Mundt NWR and West Whitlocks Bay R.A.) and urban areas (Brookings, Mitchell, Sioux Falls).

Reproduction

A female *Lasiu. cinereus* was found on June 1, 1998 hanging from the steps of a wooden deck of a house in Mitchell (Mullican, 1999) with her torpid young. The best estimate for parturition date was the middle of May. This is the earliest record of reproduction of *Lasiu. cinereus* in the Northern Great Plains.

Other Species documented in eastern South Dakota

Records exist for three other species found in eastern South Dakota. These species are *Myotis ciliolabrum* (Western small-footed myotis), *Nycticeius humeralis* (Evening bat) and *Tadarida brasiliensis mexicana* (Mexican free-tailed bat). A voucher specimen from Texas Tech University is a *M. ciliolabrum* that was captured at Farm Island R.A. on July 2, 1975. In my study, acoustic records were recorded of this species at Farm Island R.A. Lane et al., (in press) reported *N. humeralis* collected from Vermillion, Clay Co. in 2000 but no animals were collected for study. One *T. brasiliensis mexicana* was captured in Menno, Hutchinson Co.; this bat was originally banded in western Oklahoma between 1952 and 1968 (Glass, 1982) and is considered to be an accidental occurrence in the state.

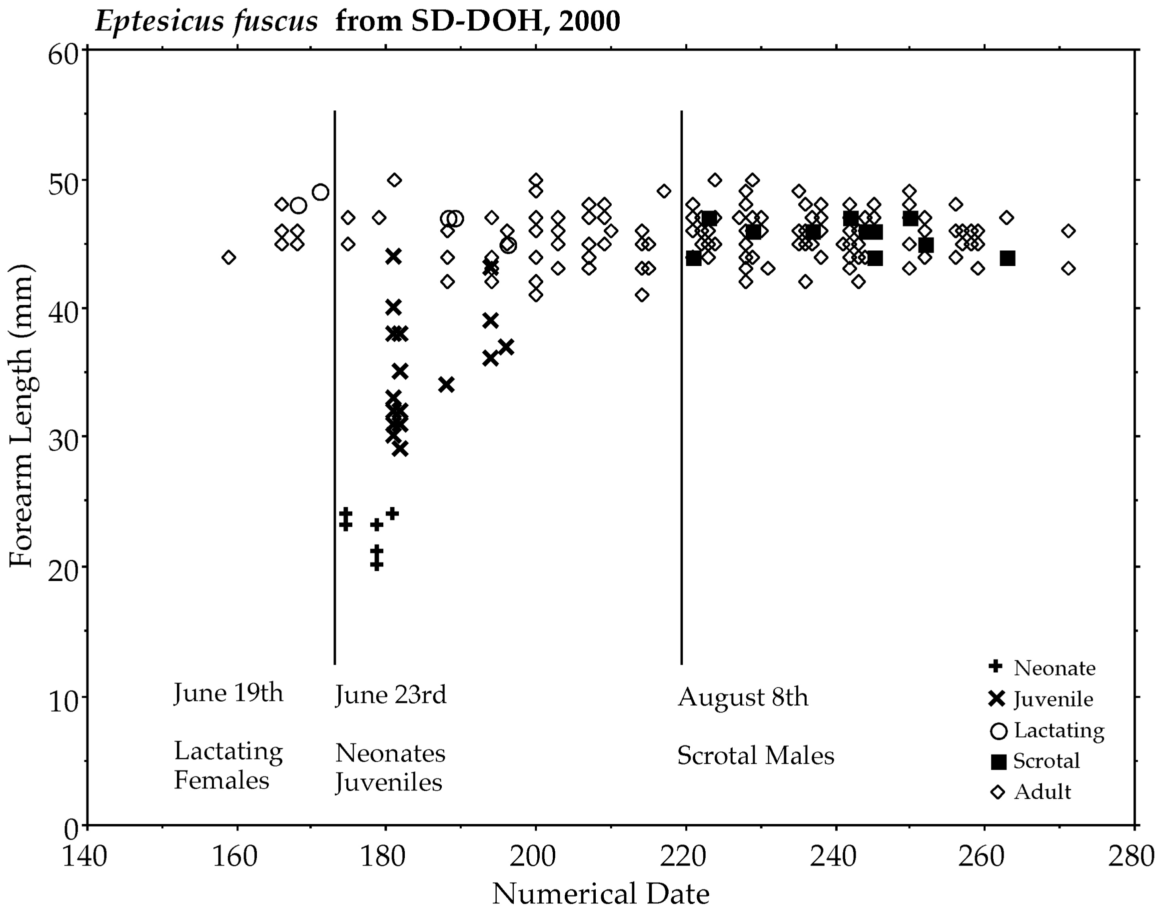

Figure 1.7: Reproductive records of *Eptesicus fuscus* from SD Department of Health, 2000

DISCUSSION

Of the twelve bat species known to inhabit South Dakota, only seven of these (*M. septentrionalis, M. lucifugus, M. ciliolabrum, Lasio. noctivagans, E. fuscus, Lasiu. borealis*, and *Lasiu. cinereus*) have been documented in eastern South Dakota (Jones and Genoways, 1967; Findley, 1956; capture and acoustic data from my study). All of the afore mentioned species except *M. septentrionalis* and *M. ciliolabrum* are currently distributed sporadically throughout eastern South Dakota (Appendix 3). *Myotis septentrionalis* was only captured along the Missouri River, and was really common (42% of all captures) along the Missouri River in 2002. Based on the capture data and previous voucher records, the current distribution of *M. septentrionalis* in eastern South Dakota is along the gallery forests of the Missouri River (Appendix 3).

The current distribution of *M. ciliolabrum* in eastern South Dakota is still unknown as this species has only been captured or acoustically documented in eastern South Dakota at Farm Island R.A.

The gallery forests in eastern South Dakota make up only a small percentage (1.5%) of the total land coverage in eastern South Dakota (Smith et al., unpublished), but woodland corridors are very important for many plant and animal species, including bats. Corridors can support a large diversity of species, sometimes the highest in the landscape (Stauffer and Best, 1980), and can enrich the ecological opportunities for mammals (Jones et al, 1985) by providing roost substrates, a diversity of prey, and protection from predators.

Trees provide roosting opportunities, an abundance of insect prey, and protection from predators along river corridors that attract bats to select these corridors as foraging and roosting habitats (Downs and Racey, 2000 and Carroll et al., 2000). The soil of each river's floodplain tends to be rich in nutrients and helps to create a greater diversity in the structure of plant communities along rivers. Hence, the insect fauna feeding on this vegetation is more diverse and dense (Stauffer and Best, 1980), creating a bonanza for bats. Repeated flooding of the river creates dead and dying trees that bats can use as roosts for resting and predator avoidance. Rivers also provides a seasonal water source, so there is an abundance of trees within the floodplain compared to the uplands and grasslands of South Dakota that cannot support many trees.

All of the these reasons may be why the capture and acoustic data from my study consistently illustrated that bats were relatively more abundant within Missouri River habitats than non-Missouri River habitats. These riparian habitats, especially the gallery forests of the Missouri River, were higher in bat activity with 253-330 passes within the gallery forests compared to less than 50 passes in half of the non-Missouri River locations; higher in species richness with 6 to 7 bat species within the gallery forests compared to only 3 bat species in 50% of the non-Missouri River locations; and higher in capture rates with 1.43-3.0 BNN in the gallery forest compared to less than 0.3 BNN in non-Missouri River locations (Table 1.7).

The lack of forests in non-Missouri River habitats may explain why these locations have such a low relative abundance and species richness. The abundance of tree cavity roosting species (*Lasio. noctivagans* and *M. septentrionalis*) is limited by the availability of suitable tree roosts (Humphrey, 1975). If such roosts do not exist, bats will not have a place to rest and protect themselves from predators. Even if a forested area does not have suitable roosts, it can still provide more protection from weather and predators than an open habitat.

Further mist netting and acoustic sampling should be continued along these riparian habitats to establish the Missouri River region as important habitat for the South Dakota bat populations, continued monitoring may also discover new species extending their ranges eastward from western South Dakota or from surrounding states.

Based on my study, I concur with previous studies (Jones and Genoways, 1967; Findley, 1956; and Higgins et al, 2000) that *M. lucifugus*, *M. septentrionalis*, *Lasiu. borealis* and *Lasiu. cinereus* are summer residents of eastern South Dakota. However, I dispute the claim that *Lasio. noctivagans* is only a migrant in eastern South Dakota. Instead, I have provided evidence that it is actually a summer resident. *Eptesicus fuscus* was also documented as a year long resident of eastern South Dakota.

Continuing the use of Department of Health bats will provide a wealth of life history information (reproductive timing, distribution, and morphological characteristics) that has not been demonstrated by capture, voucher, literature, or acoustic records. In three years, I was able to capture 104 bats, while in the same period the Department of Health acquired more than 600 specimens. Hopefully, the number of bats that are captured and killed for rabies testing will decline in subsequent years, and instead of destroying the remains, these bat specimens should be retained for further study and identification. Studying these specimens may fill in some of the gaps of knowledge on the ecology of the South Dakota bat populations.

The Anabat system and mist netting both have their limitations and their biases. The type of bat captured or recorded will depend on the habitat that the Anabat and mist nets are sampling at any point in time. Placing nets or acoustic devices in cluttered habitats will result in the capture of bats that are morphologically adaptable to forage in such habitats. In eastern South Dakota, the majority of bats were captured in woodland habitats, usually along cluttered trails. This may explain why the percentage of *M. septentrionalis* captured in 2002 along the Missouri River was so high (42%). This particular species of bat forages in cluttered habitats (Foster and Kurta, 1999).

Acoustic methods are also biased depending on what habitat type is being sampled. Yet, without acoustic devices, bats at many sampling sites in my study would not have been documented (i.e. *Lasio. noctivagans*, Adams Home Park). If the acoustic device is placed between a cluttered and an open habitat, the likelihood that the device will record bats in both habitats will be higher than if it was placed in just one habitat. Ideally, many acoustic devices should be used simultaneously in a variety of different habitats in order to record as many species as possible.

Acoustic devices are more effective than mist nets in censusing open habitats like those in eastern South Dakota. In open habitats, there is little protection from strong winds that cause mist nets to move, which makes them easier to detect by echolocating bats (Sedlock, 2001) and thereby reducing capture rates. Comparatively, acoustic devices are not influenced as greatly by weather, are relatively easier to set than mist nets, and are able to census bats that are flying nearby without actually capturing the bat.

While weather patterns can reduce the effectiveness of mist nets, species identification was much less complicated (Kuenzi and Morrison, 1998; O'Farrel et al., 1999) because visual identification of captured bats was much easier. Species identification with acoustic devices such as the Anabat is much more difficult because Analook software generates different parameter values for computer and tape recordings which are difficult to compare statistically (Barclay, 1999; White and Gehrt, 2001). Also, geographical differences (dialects) between bat calls may limit the use of reference calls from different states as an identification base for South Dakota bat calls.

In my study, Anabat calls were recorded onto tape and reference calls were obtained from online bat call libraries that had been recorded directly onto a computer system instead of remotely onto tape. The online calls were the only reference calls that I was able to use, though many attempts were made throughout the summer field season of 2002 to record reference calls of South Dakota bats. These attempts provided dismal results because of equipment failure and inclement weather. No one in South Dakota has recorded bat echolocation calls, leaving me the single option of using the reference calls from on-line reference libraries. Culling these reference calls, determining what species/locality sets to use, and determining what parameters to use by running different discriminate function models alleviated the limitations caused by comparing reference calls from different states to the tape recorded South Dakota bat calls, but this was not an ideal situation.

To effectively identify the Anabat calls, they should be compared with reference calls that are recorded on the same media (tape or computer) from captured bats in a local region, preferably the census area. As acoustic censuses continue as important means of obtaining ecological information on bat populations, biologists and managers should develop a library of bat reference calls from South Dakota bat populations. This would be an important step in future bat research, monitoring, and conservation efforts.

Table 1.7: Capture rates, activity, and species richness of bats by location, eastern South Dakota 2000-2002

Location	Capture Rate (BNN)	Activity (# of passes)	Species Richness (# of species)
Farm Island R.A.	2.6	330	7
West Bend R.A.	2.0	75	6
Karl Mundt NWR	1.43	57	6
Sioux Falls	600 house extractions	213	5
Union Grove Park	1.0	N/A	4
Adams Home Park	0.0	253	4
La Framboise R.A.	3.0	N/A	3
Fort Sisseton Park	0.2	233	4
Waubay NWR	0.0	198	5
Lewis Clark R.A.	0.8	N/A	3
West Whitlocks R.A.	0.6	52	3
Cotton Park-Vermillion	0.25	134	3
Mitchell	0.3	56	2
Richmond R.A.	0.0	38	4
American Creek R.A.	0.0	35	4
Brookings	0.06	12	3
Myron Grove R.A.	1.0	N/A	1
Newton Hills Park	0.09	51	2
Oakwood Park	0.0	26	3
Sica Hollow Park	0.0	20	3
Randall Creek R.A.	0.75	N/A	1
Pollock	0.5	N/A	1
Hartford Beach R.A.	0.0	98	2
Fisher Grove R.A.	0.0	65	2
Oak Lake Station	0.07	N/A	1
Platte Creek R.A.	0.0	20	1

Chapter 2

INTRODUCTION

Roosts are one of the essential elements for the survival of bats because they need a place to rest and seek protection from predators (Neuweiler, 2000). These roosts need to be identified for an effective bat conservation program (Fenton, 1997; Humphrey, 1975). We must determine what type of roost and the particular structural or climatic characteristics of a roost that are selected over other possible roosting substrates. If the particular characteristics of a roost are known, then we know what type of roost to protect or enhance.

Bats can be described as specialist or generalist roosters based on how many different types of roosts (caves, trees, man-made structures) that they utilize. The specialists select only one type of roost while the generalists do not seem to consistently select any particular type. Roost specialists such as *Lasiu. borealis* and *Lasiu. cinereus* select only tree foliage roosts (Constantine, 1966; Hutchinson and Lacki, 2000). Generalists such as *E. fuscus*, *M. septentrionalis*, *M. lucifugus*, *Lasio. noctivagans*, and *M. ciliolabrum* have been found roosting in buildings, tree cavities and underneath bark, caves, and rock crevices (Choate and Anderson, 1997; Martin and Hawks, 1972; Tuttle and Heaney, 1974).

Characteristics that could influence a bat's selection of a tree roost are roost tree circumference, roost height, stage of decay of the roost, and canopy cover adjacent to the roost tree. Many studies (Barclay et al., 1988; Campbell et al., 1996; Cryan et al., 2001; Foster and Kurta, 1999; Vonhof and Barclay, 1996) have compared the characteristics of bat roost trees to other trees in the immediate area to see if there was a structural difference. Roost trees were found to be larger in circumference than other trees (Barclay et al., 1988; Cryan et al., 2001) and in some cases, taller than other trees (Campbell et al., 1996; Vonhof and Barclay, 1996). Stage of decay and canopy cover adjacent to roost trees that were occupied by bats varied among species. *Myotis septentrionalis* roosted most often in living trees with greater canopy cover (Foster and Kurta, 1999) while *Lasio. noctivagans* and *E. fuscus* selected roosts in dead or dying trees with less canopy cover (Campbell et al., 1996; Cryan et al., 2001).

Availability and/or specific structural conditions of the roost tree also play an important role in roost selection. Eastern cottonwoods are the most common trees in riparian habitats of eastern South Dakota (Barkley, 1986). Because these trees may be the only type of tree at a location, bats may be limited in their roost selection. Yet, availability may not be the sole reason for roost selection. Eastern cottonwoods may be selected because this tree has certain roost characteristics that are desirable to bats, such as deeply furrowed bark on the trunk and major branches (Barkley, 1986) which may provide small crevices for roosting substrates (Vonhof and Barclay, 1996).

In the summers of 2000 and 2002, *M. septentrionalis*, *M. lucifugus*, *E. fuscus*, and *Lasio. noctivagans* were radiotracked in eastern South Dakota. Three goals were to 1) locate bat roosts; 2) describe roosts characteristics; and 3) document the movement patterns of these bats.

MATERIALS AND METHODS

During the summers of 2000 and 2002, bats were outfitted with radio transmitters (Holohil Systems, Canada). These transmitters were the smallest available, weighted 0.45 grams, and had an active life of up to two weeks. After a bat had been captured, the hair between the scapulae was clipped down as close as possible to the skin surface with small scissors. A small dab of surgical skin glue (SkinBond®) was dropped in the clipped area and a transmitter was placed upon the glue. The bat was held for a few minutes and as soon as the glue dried, the bat was released. Radiotelemetry receivers and antennae (Communication Specialists, California) were used to pick up the signals that were emitted from each transmitter and each bat was tracked from the time of its emergence from its day roost, during foraging, and then to its night roost. Bats were tracked until dawn in many instances.

Once a bat was tracked to its roost, the roost was marked using brightly colored flagging. Roost tree measurements such as height (in meters), circumference (in cm), and percent canopy cover adjacent to each roost were measured. Other characteristics such as stage (based on Thomas et al., 1979) and species of roost tree were recorded. Stage of decay was documented with a numerical value: Stage 1 trees were alive, Stage 2 trees were declining, Stage 3 trees were dead, Stage 4 trees had loose bark, Stage 5 trees were completely clean of bark, Stage 6 trees were broken, and Stage 7 trees were decomposed (Thomas et al., 1979).

Height was measured by using a 3.5 meter pole. The pole was marked in meters and placed against the tree. Then the tree height was estimated by visualizing how many poles would be needed to reach the upper canopy of the tree. To calculate the height in meters, the number of poles was multiplied by 3.5. The circumference of the tree was measured with a measuring tape. The tape was wrapped around the tree at breast height, and the free ends were pulled together snuggly against the tree and the measurement was taken. The percent canopy cover adjacent to each roost tree was measured using a densiometer (Geographic Resource Solutions, California). The percent canopy cover was estimated by determining what percent of the densiometer viewer was covered by foliage. Cover readings were taken at the roost tree in each of the four cardinal directions.

Circumference and height measurements were also taken for all species of available trees within a 15 meter radius of the roost tree. A tree was considered "available" to the bat if the circumference was greater than 15 cm because smaller trees were not mature enough to provide roosting substrates for bats (Vonhof and Barclay, 1996).

The distance in meters between roost trees, and the exact position of the roost in each tree was also determined. If more than one roost tree was found in the immediate area, the distance in meters between roost trees was measured. To determine the exact location of the roost in the tree, visual emergence counts were conducted as many times as possible throughout the field season.

Statistical Methods

Before any statistical analysis could be performed, tests were performed to see if the data fit the assumptions of parametric statistics. Tests for normal distributions of each variable were performed using the Kolmogorov-Smirnov test. The Kolmorgorov-Smirnov test is a goodness of fit test used to determine if the sample comes from a population with a specific distribution, in this case, a normal distribution (Chakravart et al., 1967). Next, the circumference of trees at each locality (Farm Island, Karl Mundt, Lewis and Clark, and La Framboise) were tested with a two-sample t-test to examine differences among sites, and to determine if roost trees differed from the available trees with respect to circumference. If all the trees in each four localities have the same means, then localities could be considered as a homogeneous habitat, making management efforts easier. The circumference and canopy cover of roost trees were tested for similarities with a bonferroni adjusted two-sample t-test to determine if roost trees differed among bat species. Bonferroni correction controls the error rate by dividing the significance level over the number of tests (Bland and Altman, 1995). The SAS system for windows (SAS Institute Inc, 1999) was used in all statistical tests with a statistical significant level of 0.05. An alpha level of 0.05 was chosen for the analysis over an alpha level of 0.10 because a smaller level would eliminate more type 1 errors (rejecting that roost selection differed among bat species) than a larger alpha level.

RESULTS

A total of 14 bats were tracked during the summers of 2000 and 2002. During the summer of 2000, *E. fuscus* (N = 2) were tracked in the town of Brookings. During the summer of 2002, *M. septentrionalis* (N = 3), *M. lucifugus* (N = 2), *Lasio. noctivagans* (N = 1), and *E. fuscus* (N = 6) were radio tracked at five different localities: Karl Mundt

NWR, Lewis and Clark R.A., West Bend R.A., La Framboise R.A., and Farm Island R.A. *Myotis septentrionalis* and *Lasio. noctivagans* roosted exclusively in eastern cottonwood trees (*Populus deltoides*). *Myotis lucifugus* and *E. fuscus* roosted in bridges, houses, a picnic shelter, eastern cottonwoods, and Bur Oaks trees (*Quercus macrocarpa*).

Myotis septentrionalis were captured and radio tracked to roosts at Karl Mundt NWR (N = 2) and at Farm Island R.A. (N = 1). One of these, a nonreproductive female (#732), was captured at Karl Mundt NWR on May 26, 2002 and radio tracked to four different eastern cottonwood roost trees over a period of six days. On the first day of radiotracking, she was tracked to the first roost, moved 6.5 m to a different roost on the second day, and stayed there for 3 days. On the 5th day, she moved 86.5 m north to roost #3 and on the 6th day moved 15 m northwest to roost #4. The circumference of the roost trees ranged from 88.3 to 141.1 cm and their height ranged from 9 to 15 m.

During visual emergence counts, the exact location of the roost was determined for bat #732 (*M. septentrionalis*). She roosted in trees that were still alive, but declining (Stage 2). One night during an emergence count, #732 was seen exiting from a cavity in a dead branch that was 6 to 9 meters from the ground.

Bat #732 was also radiotracked while foraging. She usually exited from the roost around 9:45 to 10:00 p.m. and then foraged for 30 to 40 minutes in the clearing to the south of the roost and among the surrounding trees within 100 meters of her day roost (Fig 2.1). Around 10:30 p.m., #732 left the roost area and returned around 2:00 a.m to the night roost and then went on a second bout of foraging between 3:00 and 6:00 a.m. On June 1, she was tracked back to the roost area at 2:30 a.m. and was found night roosting in the same tree she had used as a day roost. Later that afternoon she was tracked to a different day roost in the immediate area.

On July 14 2002, a post lactating female *M. septentrionalis* was captured at Karl Mundt NWR and tagged as #645. She was radiotracked to five different eastern cottonwood trees over a period of five days. On the first day of radiotracking she was tracked to roost #1, and on the 2nd day, moved 95 m northwest to roost #2. On the 3rd day, she had moved 100 m south to roost #3 and on the 4th day moved another 105 m northeast to roost #4. On the last day of radiotracking, she moved 35 m to roost #5. Roost #1, #4, and #5 were located within 20 meters of each other (Fig 2.2). The circumference of these roost trees ranged from 28 to 55 cm and height from 7 to 10m.

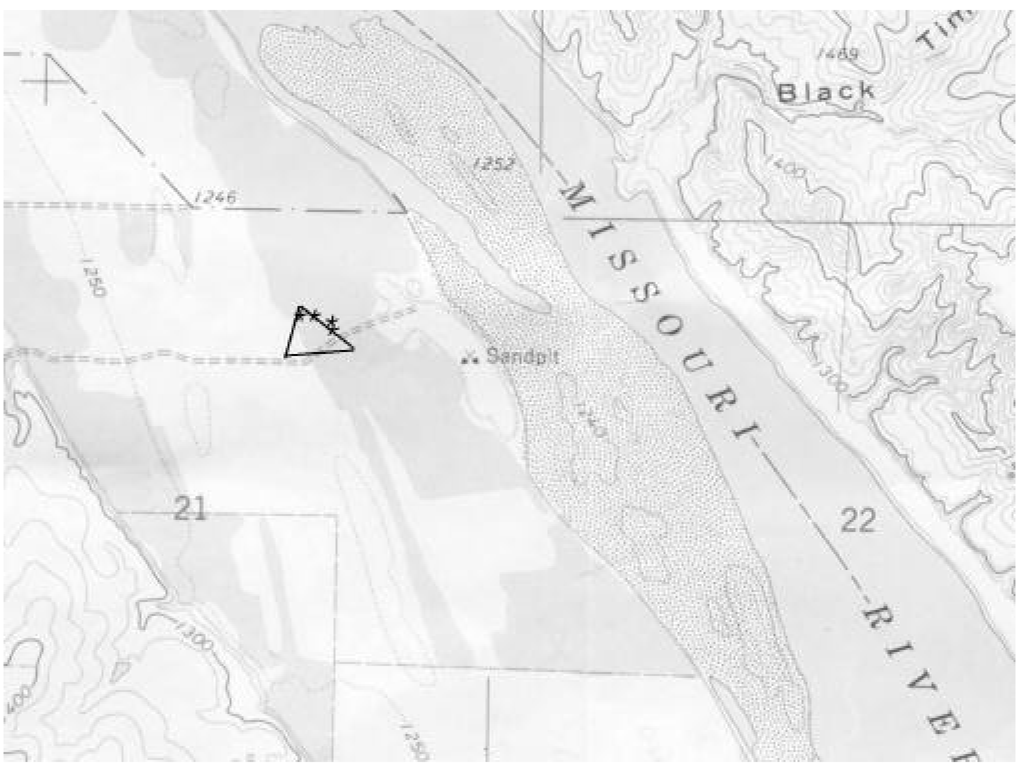

Figure 2.1: Roosts and foraging range of #732 (nonreproductive *M. septentrionalis*) in Karl Mundt NWR, 2002 (*** = Day and Night Tree roosts**)

The trees that #645 utilized as roosts differed in stage of decay and canopy cover. Two of the five roosts were still alive but declining (Stage 2) or dead with loose bark (Stage 4). The other three roosts were dead and completely clean of bark (Stage 5). Four of the five roost trees had a canopy cover of 50% or more and were surrounded by Box-elders (*Acer negundo*), Green Ash (*Fraxinus pennsylvanica*) and other eastern cottonwoods.

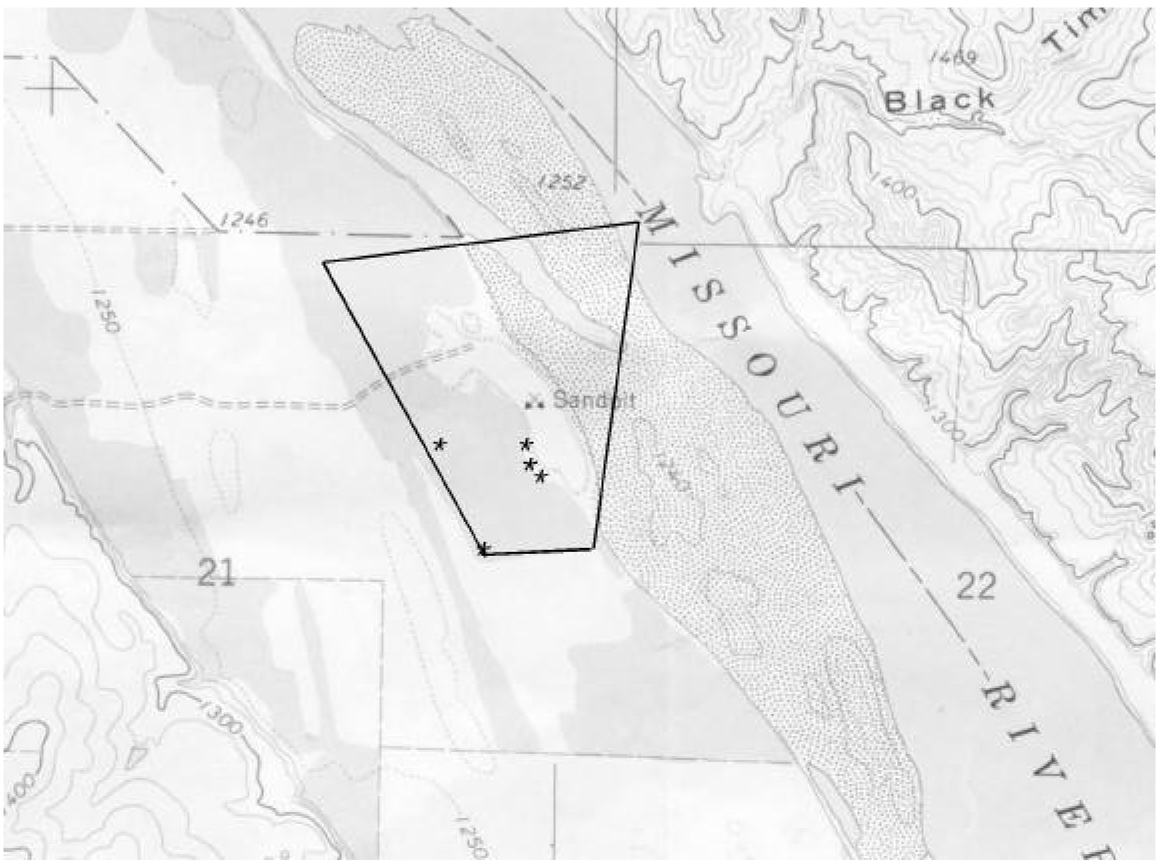

Figure 2.2: Roosts and foraging range for #645 (postlactating *M. septentrionalis*), in Karl Mundt NWR, 2002 (*** = Day Tree roosts**)

Bat #645 foraged in Karl Mundt NWR along the floodplain of the Missouri River (Fig 2.2). On July 18, she was found to forage in this area from 9:40 p.m. to 6:00 a.m.

She left the roost around 9:40 p.m. and continually foraged throughout the night with only short rests of about 10 minutes. As dawn approached (6:00 a.m.), she roosted in an eastern cottonwood tree and continued to use it as a day roost.

One *M. septentrionalis* was captured at Farm Island R.A. (about 180 km north of Karl Mundt) on July 25, 2002 and tagged as #685. She was tracked for only two days as the battery on the tag presumably died shortly after it was placed on the bat. She was roosting in a dead eastern cottonwood standing in deep water. In Michigan, *M. septentrionalis* were typically found in wetlands in which at some point during the year, roost trees had their roots submerged in water (Foster and Kurta, 1999).

In the summer of 2001, *M. lucifugus* were found roosting at La Framboise R.A. The recreation area had an abundance of available roost trees but the picnic shelter was utilized extensively. Two *M. lucifugus* were captured on July 20, 2002 and tracked to determine the extent of occupation of the picnic shelter and to identify other possible roosts. Because temperature and exposure are associated with roost selection (Humphrey, 1975), data loggers were placed in known *M. lucifugus* roosts at La Framboise R.A.

Of the two female *M. lucifugus* captured, one was postlactating (#665) and was tracked for five days; the other was nonreproductive (#553) and was tracked for seven days. The postlactating female moved frequently between roost trees. On the first day of radiotracking, she was tracked to roost #1, and on the 2nd day, moved 115 m west to roost #2. On the 3rd day, she had moved 200 m south to roost #3 and on the 4th day moved another 105 m north to roost #4, where she stayed for 2 days (Fig 2.3). Circumference of the roost trees ranged from 26.7 to 49.6 cm and height ranged from 9 to 12 m. The canopy cover of the roost trees ranged from 0 to 27% and stages of decay ranged from 2, 4, and 5.

The nonreproductive *M. lucifugus* female #553 was tracked to roost #1 on the first day of radiotracking and continued to day and night roost there for 3 days. On the 4th day of radio tracking, she moved 5 m to roost #2 and on the 5th day moved 15 m south to roost #3. The three roost trees all had a circumference of 42 cm and a height of 12 meters. The canopy cover of the roost trees ranged from 0 to 5% and stage of decay from 2 to 4.

During the entire week of radiotracking, the postlactating female #665 was night roosting in the picnic shelter and on the 6th and 7th day of radiotracking, the nonreproductive female #553 was found day and night roosting in the picnic shelter. Not only were these two bats roosting in the picnic shelter, another 20 to 30 bats could be found day and night roosting in the shelter as well. Dataloggers indicated that the shelter was warmer than the tree roost from 1800h to 0500h, while the tree roost was warmer from 1200 to 1700h (Fig 2.4). The shelter was always less humid than the tree roosts.

Both *M. lucifugus* were also tracked during foraging activity at La Framboise R.A. On July 22, they were found foraging in the clearing near the picnic shelter and along the Missouri River.

A female *Lasio. noctivagans* (#572) was also captured at La Framboise R.A. on July 20, 2002. She was radiotracked to eight different eastern cottonwood trees over a period of nine days. On the first day of radiotracking she was tracked to roost #1, and on the 2nd day, moved 30 m to roost #2. On the 3rd day, she moved 42 m northeast to roost #3 and on the 4th day moved another 80 m south to roost #4. On the 5th day of radiotracking, she was found back by roost #3, in roost #5 and stayed two days. The last three days of radiotracking, #572 moved to three new roosts that were within 10 meters of each other, all 30 m south of roost #5. The circumference of the roost trees ranged from 60.5 to 88.9 cm and height ranged from 9 to 12 meters. The canopy cover of the roost trees ranged from 7.5 to 87.5%. Only Stage 2 trees were selected. Seven of the roost trees were surrounded by Red cedars (*Juniperus virginiana*), which prevented easy access to the roost trees from ground dwelling predators.

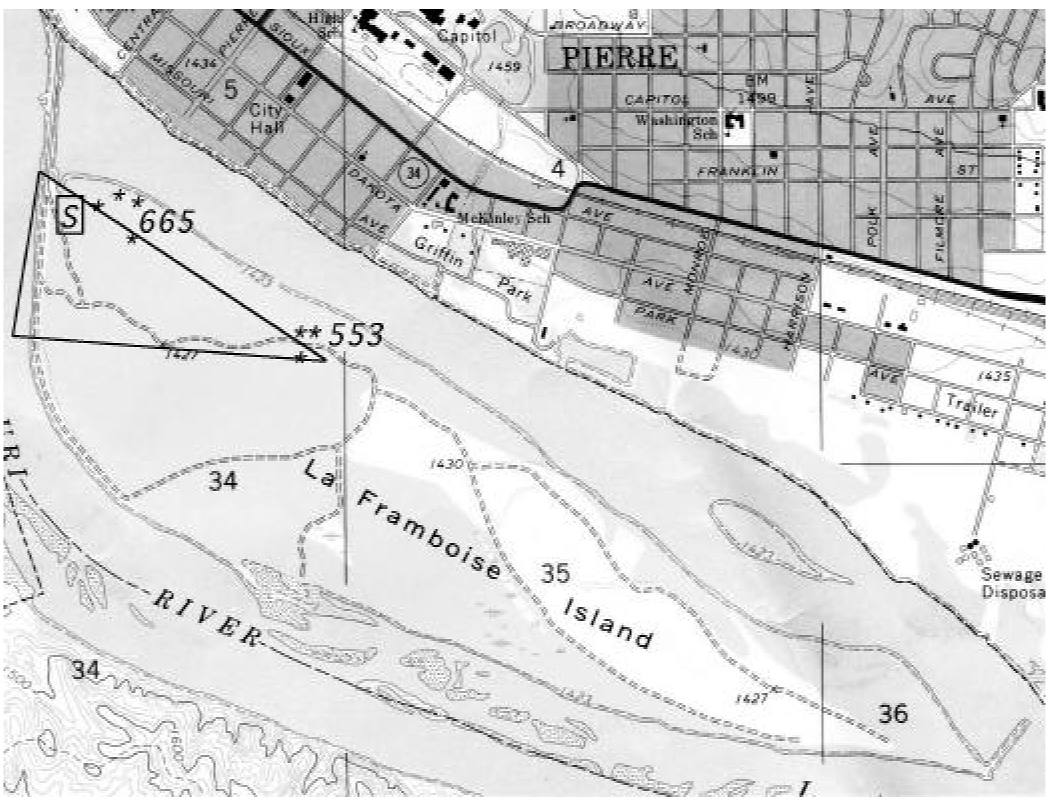

Figure 2.3: Roosts and foraging ranges for #665 (postlactating *M. lucifugus*) and #553 (nonreproductive *M. lucifugus*) in La Framboise R.A., 2002 (**S = Picnic shelter; * = Tree roost**)

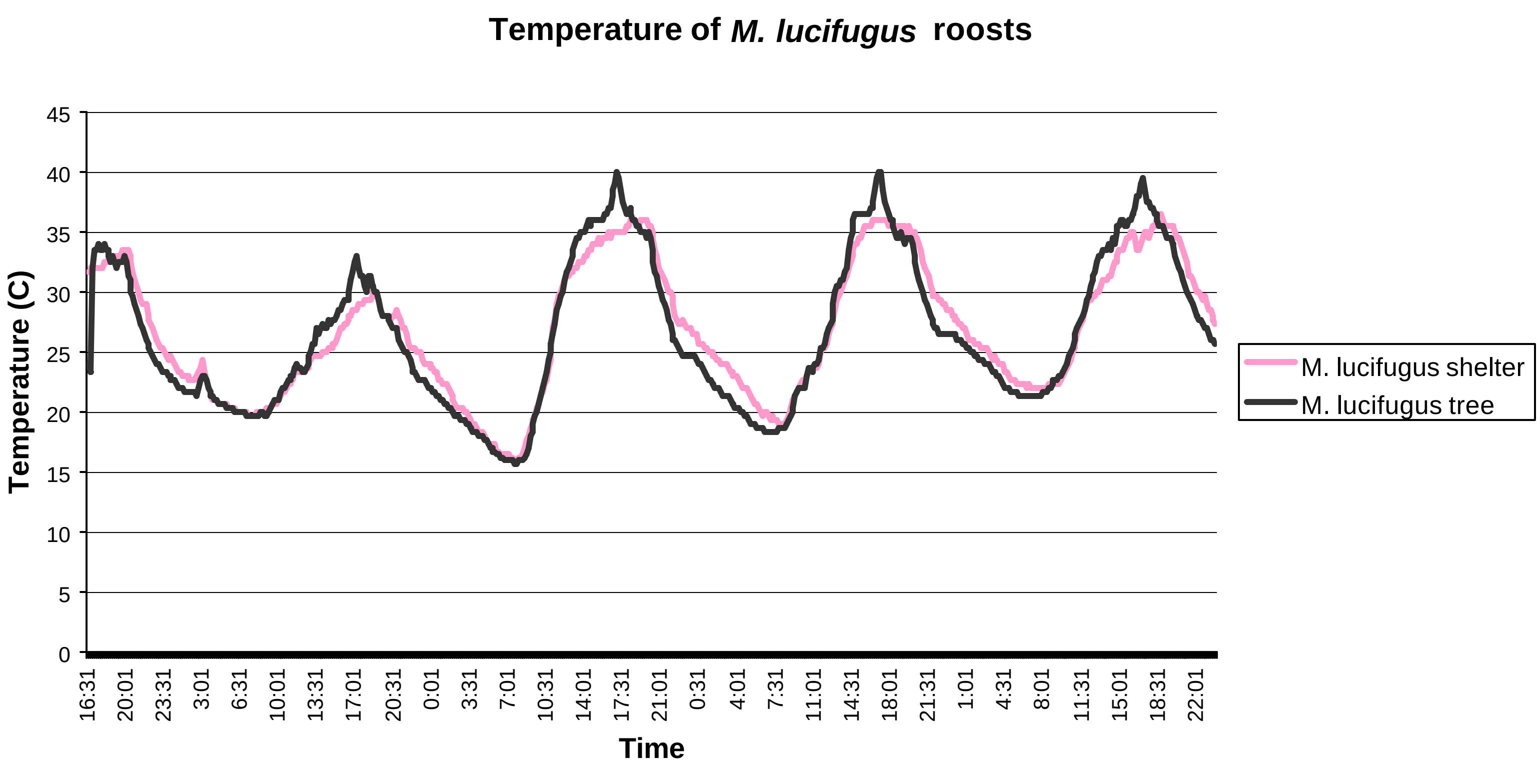

Figure 2.4: Temperature of shelter and tree of *M. lucifugus* at La Framboise R.A., South Dakota 2002

Two male *E. fuscus* (A3 and A9) were radio tracked in the city of Brookings during the summer of 2000. The bats were found roosting in private residences; A3 roosted in the eves of a garage adjacent to Pioneer Park while A9 roosted in the attic of a two-story home located between Sexauer and Pioneer Parks. Both bats foraged for a period of 60 minutes alternating between Pioneer and Sexauer Parks. The foraging range of A3 was 16 square blocks while the range of A9 was 36 square city blocks (Fig 2.5).

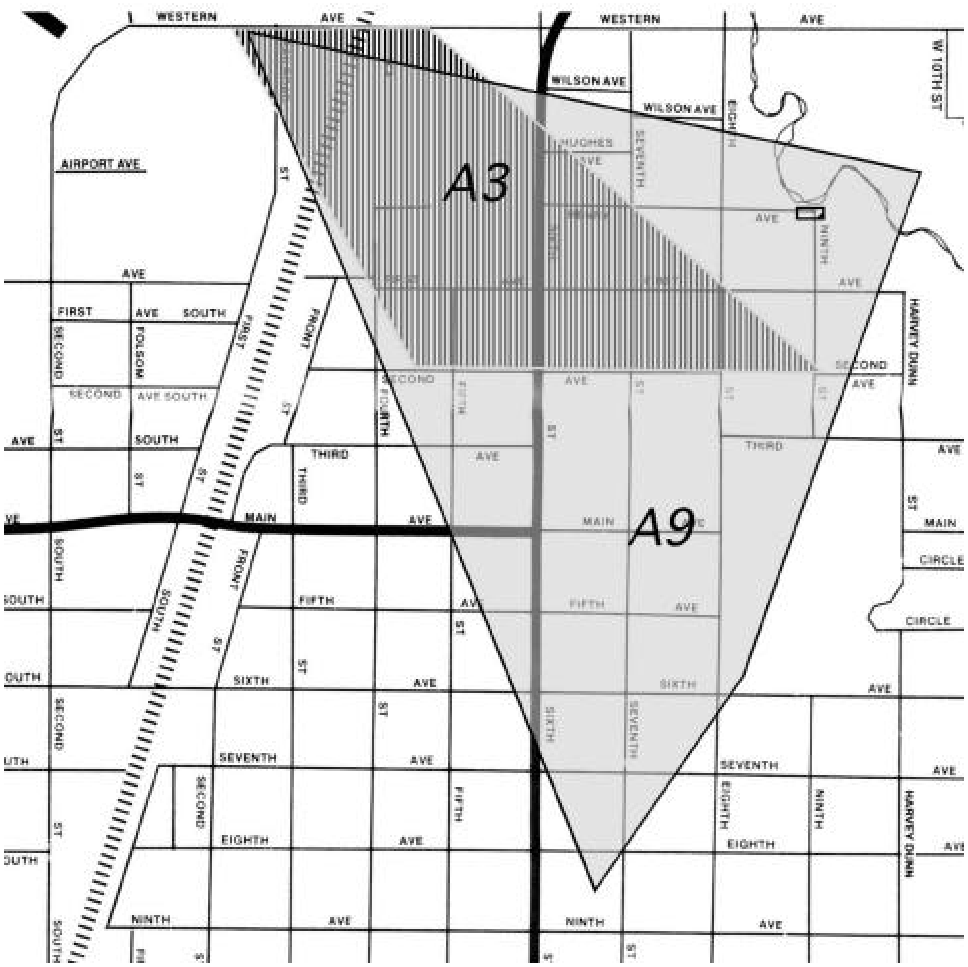

Figure 2.5: Foraging ranges of two *E. fuscus* (A3 and A9) in Brookings SD, 2000

During the summer of 2002, *E. fuscus* were tracked in Karl Mundt NWR (N = 1), Randall Creek R.A. (N = 1), Lewis and Clark R.A. (N = 2), West Bend R.A (N = 1), and Farm Island R.A. (N = 1).

On May 31 2002, a male *E. fuscus* #752, captured at Randall Creek R.A. was radio tracked foraging along Randall Creek between 10:45 and 11:30 p.m. After 11:30 p.m., #732 foraged beneath and around the stone bridge within Randall Creek R.A. The bat night roosted beneath the bridge between 11:30 and midnight and continued to roost there in a small crevice between the under side of the bridge and a support beam. No day roosts for #732 were identified.

On June 16 2002, two male *E. fuscus* were mist netted and tagged (#681 and #773) at the Gavins Point unit of Lewis and Clark R.A. The next day, #681 was found day roosting in a house on Gavins Point Drive (possibly in the garage of the house), and night roosting (11:30 p.m.) in a Bur Oak tree at the end of Gavins Point Drive (Fig 2.6). On June 18, #681 was still using the house on Gavins Point Drive as a day roost and continued to roost there for two more days. However, #681 switched to a different Bur Oak as a night roost (0.64 km from the first Bur Oak). This second night roost was along the entrance to the Chalk Bluffs Multi-Use trail in Lewis and Clark R.A. The tree roosts had circumferences of 64.4 and 55.3 cm respectively. Both trees had a height of 10 meters and were in a Stage decay of 2.

The roosts of the other *E. fuscus* (#773) were never found, but on the June 20, a faint signal was received from the Nebraska side of the river. Apparently, this bat was roosting in Nebraska and foraging in South Dakota within the loops of the Bluffs trail.

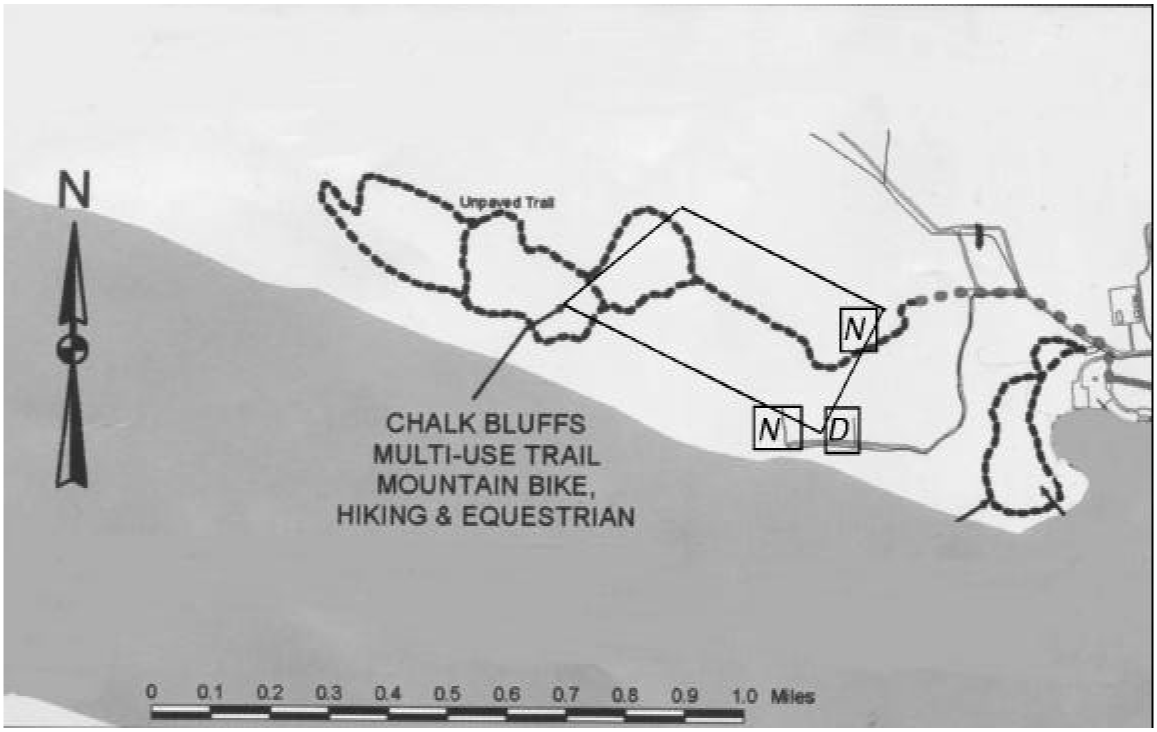

Figure 2.6: Roosts and foraging ranges of #681 (*E. fuscus*) in Lewis and Clark R.A., 2002 (**N = Night roost; D = Day roost**)

Six pregnant or lactating female *E. fuscus* were captured on June 26, 2002 at West Bend R.A. One of the lactating females was tagged as #794 and radio tracked to a house across the road from West Bend R.A. Ten bats exited, one by one, from the crevice near the apex of the roof between 10:00 to 10:15 p.m. Based on the reproductive condition of these females and the fact that they were captured together during mist netting, this roost was considered a maternity colony.

Bat #794 was also tracked to her foraging area in the older region of West Bend R.A., along the creek and trail areas. She started to forage at 10:15 p.m., continued for an hour, and then was tracked back to the house around 11:30 p.m.

On July 10 2002, a male *E. fuscus* was captured at Karl Mundt NWR and tagged as #625. He was radiotracked to three different eastern cottonwood trees over a period of six days. On the first day of radiotracking he was tracked to roost #1 and stayed for 3 days, and on the 4th day, moved 30 m west to roost #2 and stayed for 2 days. On the 6th day, he had moved 35 m southeast to roost #3. The circumference of the roost trees ranged from 64.9 to 119.8 cm and height was 11 m. Roost trees had a canopy cover from 70-100% and were in Stage decay 2.

Each night, #625 exited from the roost tree around 10:00 p.m. and then foraged within and around the edges of the refuge for an hour. Around 11:30 p.m., #625 left the refuge area and foraged around the Fort Randall Historical Site, about half a mile west of the refuge (Fig 2.7). The bat continued to forage within the clearings at the Fort Randall site for another 45 minutes and then headed back to the refuge. He foraged again in the refuge for an additional 45 minutes and returned to the day roost tree to night roost around 1:00 a.m. The time that #625 returned to night roost varied each night and could be as early as 12:15 a.m. or as late as 1:45 a.m. but the average return time was 1:00 a.m. After night roosting for a couple hours, #625 foraged again sometime between 3:00 to 6:00 a.m. Of note, the foraging range of the *E.fuscus* #625 coincided with the foraging range of *M. septentrionalis* #645 in Karl Mundt NWR.

A male *E. fuscus* was captured on July 25 2002 in Farm Island R.A., and tagged as #600. He was radiotracked to five different eastern cottonwood trees over a period of five days. On the first day of radiotracking he was tracked to roost #1, and on the 2nd day, moved 80 m north to roost #2. On the 3rd day, he returned to roost only 23 m from roost #1 and stayed in the area. Roosts #1, #3, #4, and #5 were all within 10 to 20 meters of each other.

The circumference of the roost trees ranged from 60.5 to 87.4 cm and height from 9 to 11 m. Roost trees had a canopy cover of 17.5 to 85 % and were in stage decay 2. Similar to the roost trees of *Lasio. noctivagans*, four of the *E. fuscus* roosts were surrounded by Red Cedar trees, which prevented easy access to the roost trees from ground dwelling predators.

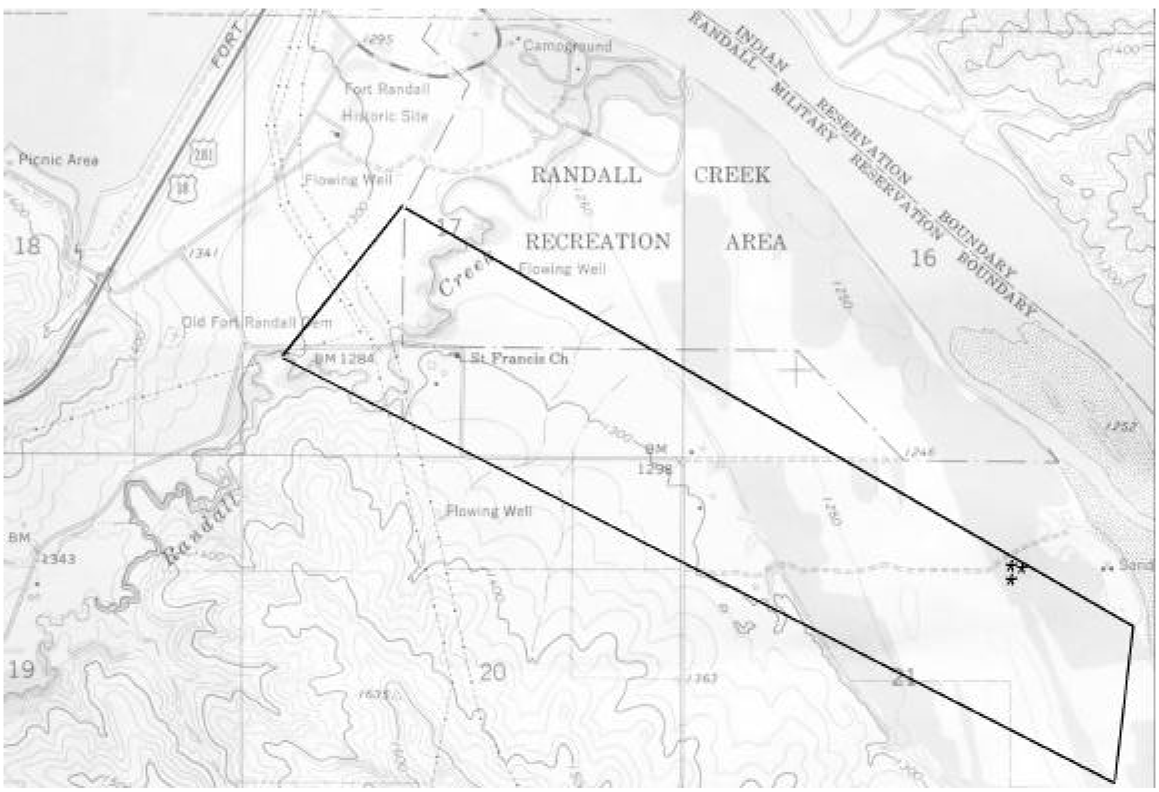

Figure 2.7: Roosts and foraging range of #625 (*E. fuscus*) in Karl Mundt NWR, 2002 **(* = Day and Night Tree roosts**)

Statistical Results

Not all the roost tree characteristics were normally distributed, so the variables were log transformed. After log transformation, height of all available trees, height of *Lasio. noctivagans* roost trees, height of *M. lucifugus* roost trees, and canopy cover of *M. septentrionalis* roost trees were still not normally distributed and were eliminated from further analysis (Table 2.1). When comparing the means of each roost tree height among bat species and to height of all available trees, there is not much difference. The height of *M. septentrionalis* (10.1 m), *Lasio. noctivagans* (10.8 m), and *E. fuscus* (10.3 m) roost trees did not differ much from the height of the available trees (10.6 m). Only *M. lucifugus* trees (12.0m) were taller than the available trees.

When the circumferences of the available trees for each location (Karl Mundt, Farm Island, La Framboise, and Lewis and Clark) were tested with a two-sample t-test, the mean circumference of Farm Island trees was statistically greater than Karl Mundt ($p = 0.002$), La Framboise ($p = 0.026$), and Lewis and Clark ($p = 0.001$) trees (Table 2.2). The circumference means of trees at Karl Mundt, La Framboise, and Lewis and Clark were not statistically different from each other and could be grouped together (Fig 2.8).

Table 2.1: Means and Kolmogorov-Smirnov value for bat roost characteristics

	Number of trees	Mean (SD)	Test for normal distribution Kolmogorov-Smirnov p value
Lasio. noctivagans roost height	8	10.8 (0.8)	0.010
E. fuscus roost height	10	10.3 (0.9)	0.150
M. lucifugus roost height	8	12.0 (1.5)	0.010
M. septentrionalis roost height	9	10.1 (2.9)	0.150
Height of available trees	104	10.6 (1.2)	0.010
Lasio. noctivagans roost circumference	8	70.5 (9.2)	0.150
E. fuscus roost circumference	10	73.7 (27.6)	0.134 (log)
M. lucifugus roost circumference	8	41.8 (7.3)	0.057
M. septentrionalis roost circumference	9	79.6 (42.0)	0.150
Circumference of available trees	138	43.6 (19.0)	0.122 (log)
Lasio. noctivagans roost canopy	8	47.5 (25.3)	0.150
E. fuscus roost canopy	10	69.2 (33.1)	0.145
M. lucifugus roost canopy	8	8.8 (10.7)	0.082
M. septentrionalis roost canopy	9	66.6 (24.2)	0.010
Circumference of available trees in Farm Island	26	55.9 (18.5)	0.150
Circumference of available trees in La Framboise	68	46.8 (19.9)	0.150 (log)
Circumference of available trees in Lewis Clark	18	36.1 (16.3)	0.098
Circumference of available trees in Karl Mundt	52	36.2 (14.5)	0.150

Table 2.2:Mean circumferences of available trees in each location and t-test values, eastern South Dakota 2002

	Mean (SD)	T-test p-values
KM circum*LC circum	KM = 36.2 (14.5)	0.415
KM circum*FI circum	LC = 36.1 (16.3)	0.002
KM circum*LF circum	LF = 46.8 (19.9)	0.136
LC circum*LF circum	FI = 55.9 (18.5)	0.050
LC circum*FI circum		0.001
LF circum*FI circum		0.026

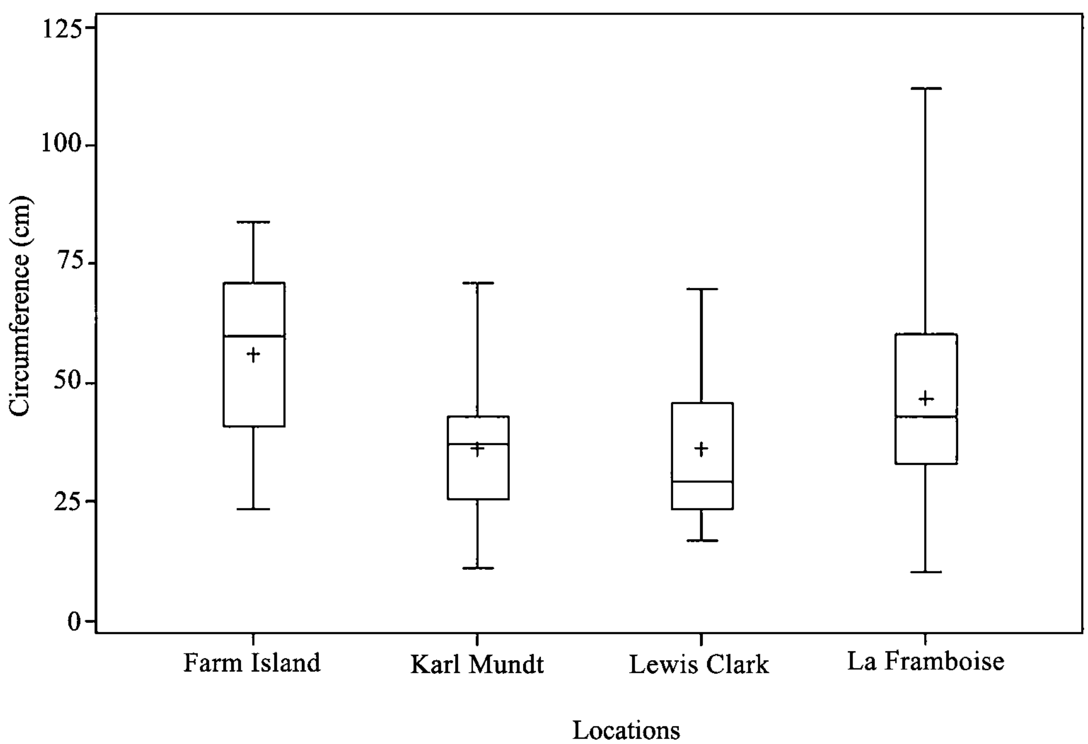

Figure 2.8: Box plot of circumferences of available trees in each location, eastern South Dakota 2002

When the circumference means of the available trees were tested against the means of each roost tree circumference with bonferroni adjusted two-sample t-tests, the mean circumferences of *E. fuscus* roost trees (p <0.0001), *Lasio. noctivagans* roost trees (p <0.001), and *M. septentrionalis* roost trees (p <0.0001) were all significantly greater than the available tree circumferences (Table 2.3). The only bat roost tree circumferences similar to that of the available trees was *M. lucifugus* (p = 0.940); (Fig 2.9). When compared to other bats, there was low variability in the circumferences of *M. lucifugus* roost trees (53.5) (Table 2.3), which suggests that *M. lucifugus* is much more selective in choosing roost trees. Conversely, *M. septentrionalis* utilized the widest range of roost trees sizes than the other bat species.

Table 2.3: Circumference means of roost trees and t-tests values, eastern South Dakota 2002

	Means (SD)	T-test p-values	Variance
Msep circum*Available	*Msep* = 79.6 (42.1)	<.0001	*Msep* = 1768.7
Mluc circum*Available	*Mluc* = 41.8 (7.3)	0.940	*Mluc* = 53.5
Lnoc circum*Available	*Lnoc* = 70.5 (9.3)	<.0001	*Lnoc* = 85.7
Efus circum*Available	*Efus* = 73.7 (27.7)	<.0001	*Efus* = 364.3
Efus circum**Lnoc* circum		0.847	
Efus circum**Msep* circum		0.638	
Efus circum**Mluc* circum		0.0006	
Msep circum**Mluc* circum		0.039	
Msep circum**Lnoc* circum		0.565	
Mluc circum**Lnoc* circum		<.0001	

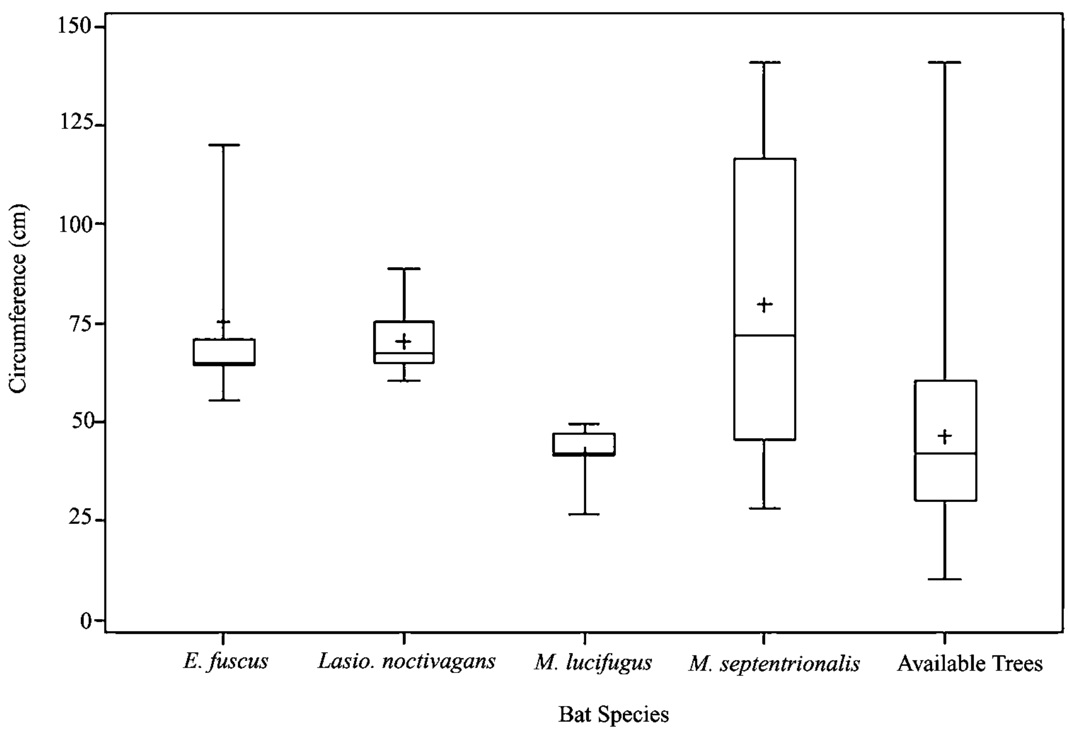

Figure 2.9: Box plot of the circumferences of roost trees by bat species, eastern South Dakota 2002

The canopy cover surrounding each roost tree was compared among bat species with bonferroni adjusted two-sample t-tests. The canopy cover surrounding the roosts of *E. fuscus* and *Lasio. noctivagans* was not significantly different (p = 0.157) (Table 2.4) suggesting that *E. fuscus* and *Lasio. noctivagans* selected roosts trees with a high percentage of canopy cover. The canopy cover surrounding the roost trees of *Lasio. noctivagans* averaged between 30 to 55% (Fig 2.10). With the largest variance in canopy cover (1066.69), *E. fuscus* selected roost trees with a wider range of canopy cover than any other bat (Fig 2.10).

Myotis lucifugus consistently selected roosts with more open canopy than *E. fuscus* (p = 0.0009) and *Lasio. noctivagans* (p = 0.005). With the smallest variance (114.38), *M. lucifugus* was more selective for roost trees with a canopy cover of less than 25% (Fig 2.10).

Table 2.4: Means of canopy cover adjacent to roosts and t-test values, eastern South Dakota 2002

	Means (SD)	T-test p-values	Variance
Efus canopy**Lnoc* canopy	*Efus* = 69.2 (33.1)	0.157	*Efus* = 1066.7
Efus canopy**Mluc* canopy	*Mluc* = 8.8 (10.7)	0.0009	*Mluc* = 114.4
Mluc canopy**Lnoc* canopy	*Lnoc* = 47.5 (25.3)	0.005	*Lnoc* = 642.8

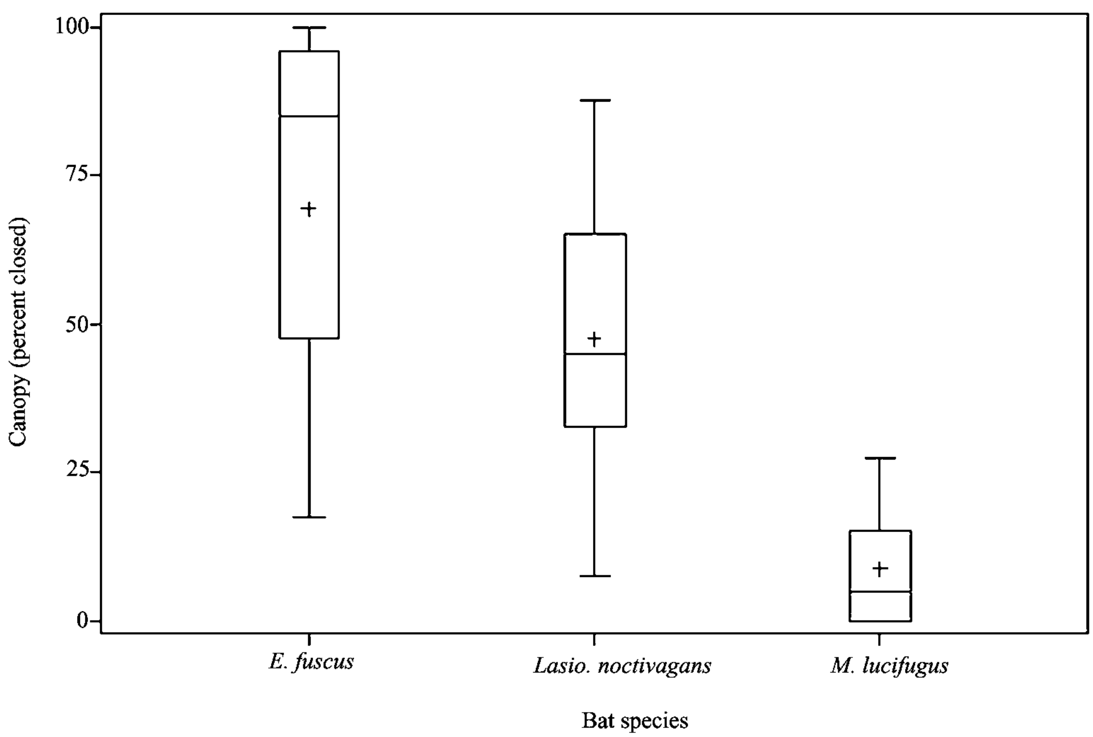

Figure 2.10: Box plot of canopy cover adjacent to each bat's roost trees, eastern South Dakota 2002

The stage of decay of roost trees was compared for each species of bat. Some species were more selective than others. In particular, *Lasio. noctivagans* and *E. fuscus* only utilized Stage 2 (declining) trees. *Eptesicus fuscus* utilized trees from 45 to 120 cm in circumference while *Lasio. noctivagans* utilized trees from 60 to 80 cm in circumference (Fig 2.11). The postlactating *M. septentrionalis* utilized Stage 2 and 5 trees while the postlactating *M. lucifugus* utilized trees in all three stages (2, 4 and 5). Larger trees were utilized by *M. septentrionalis* (20-140 cm in circumference) than *M. lucifugus* (20-50 cm).

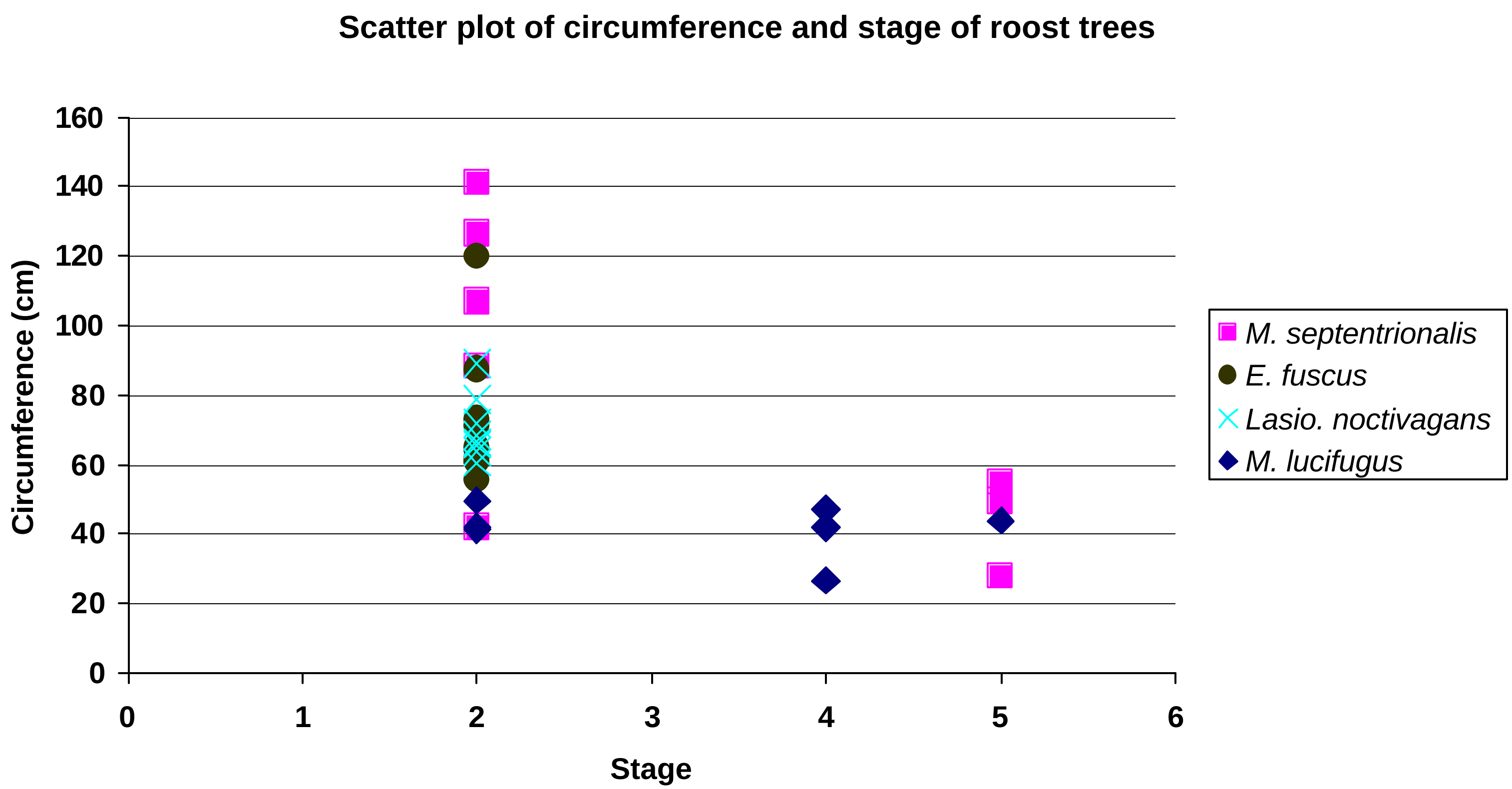

Figure 2.11: Scatter plot of circumference and stage of roost trees by bat species, South Dakota 2002

DISCUSSION

While other studies have shown that a diversity of tree species are utilized by bats for roosts (Barclay et. al, 1988; Vonhof and Barclay, 1996; Foster and Kurta, 1999), bats in South Dakota seem to be limited in their choice of roost trees. Western and eastern South Dakota may be so homogenous with respect to tree species, that the only tree to select is the one that is most available, which is also the only one in different stages of decay. The other species of trees are too small or too young to provide bat roosts. Eastern cottonwoods are considered very common along riparian zones in the Great Plains (Barkley, 1986) and ponderosa pine forests dominate in higher elevations in the Black Hills (Cryan et al., 2001). Eventhough, eastern cottonwoods were the most common species of tree that bats utilized as a roost in eastern South Dakota, the selectivity of roost characteristics (circumference, canopy, and stage) differed among bat species.

In general, *M. septentrionalis*, *E. fuscus* and *Lasio. noctivagans* did utilize trees of larger circumference than the available trees. Larger circumferences trees are important because these trees are usually older and have decayed into such a state to provide many roost substrates for bats. Bats also utilized trees of larger circumference than available trees in the Black Hills and other areas (Barclay et al., 1988; Cryan et al., 2001; Mattson et al., 1996; Vonhof and Barclay, 1996).

Lasionycteris noctivagans selected declining (Stage 2) eastern cottonwood (*Populus deltoides*) trees of circumferences between 60-80 cm. In Alberta, *Lasio. noctivagans* also roosted in *Populus* spp., especially Aspen (*Populus tremuloides*).

Aspen trees were selected over other species present in old stand forest (Crampton and Barclay, 1998) because of the furrowed bark.

In this study, *Lasio. noctivagans* switched roosts more frequently than any other species, but the roosts were always within 30 meters of each other. In the Black Hills, solitary *Lasio. noctivagans* were found to switch roosts regularly and use roosts that were very close together as well (Mattson et al, 1996). Other studies have found that even though bats switch roosts often, they stayed in familiar areas (Cryan et al., 2001).

Myotis lucifugus were more selective with regards to height, canopy cover, and circumference of roost trees. Trees selected by *M. lucifugus* were taller (12.0 m) than the available trees (10.6 m). Bats selected taller trees in southern British Columbia as well (Vonhof and Barclay, 1996) because taller trees may be more effective in preventing predation and may be easier to find than others.

Tall trees with low canopy cover (less than 25%) and small circumferences (20-50 cm) were selected more frequently by *M. lucifugus*, which may be explained because of the advanced stage of decay in some roost trees. These trees may be more suitable for roost sites because of the lack of foliage. Reproductive females may be searching for roosts with less foliage because more radiant heat from the sun would be absorbed into the roost tree, making it warmer.

Roost selection differed among reproductive classes of bats. Nonreproductive *Myotis* utilized a limited range of different stage classes of trees, while postlactating bats utilized at least three stages (2, 4, and 5). Nonreproductive *Myotis* also switched roosts less often than the postlactating females and the distance moved between trees was less.

The postlactating *M. septentrionalis* bats moved an average of 20 meters more than the nonreproductive and the postlactating *M. lucifugus* moved an average of 90 meters more than the nonreproductive females.

That is, the postlactating female *M. lucifugus* always selected the warmer roost by switching between tree roosts and man-made roosts (picnic shelter). This behavior may be attributed to the energy requirements of a postlactating female. Energy demands on females were found to be the greatest during lactation than during pregnancy (Anthony and Kunz, 1977). Females may be searching for a warmer roost to save energy. The picnic roost was probably warmer because of the clustering of many *M. lucifugus* in the roof. This clustering behavior in the evenings after feeding was noted in *Myotis* species in caves of Kansas and Oklahoma (Twente, 1955). The temperature in the clusters was always higher than the ambient temperature.

The picnic shelter was always less humid than the tree roosts but since the shelter was repeatedly selected by the postlactating bat, humidity may not be as an important factor for roost selection as temperature. In Kansas and Oklahoma, bats did not occupy the parts of caves with the highest relative humidity (Twente, 1955). For these bats, humidity seemed to be a more important factor in hibernacula selection (Barbour and Davis, 1969) than in summer roost selection.

Eptesicus fuscus will move more regularly between natural roosts than man-made structures when suitable natural sites are not available (Brigham, 1989). In areas such as Lewis and Clark R.A. that do not have mature trees, *E. fuscus* selected man-made structures and tree roosts but consistently returned to the man-made sites.

Eptesicus fuscus #600 consistently day roosted in trees at Farm Island R.A. while *E. fuscus* #681 used man-made structures as day roosts at Lewis and Clark R.A. The trees at Farm Island R.A. may be more suitable for day roosts for *E. fuscus* than the trees at other locations where the species was tracked (Lewis and Clark and Karl Mundt). The mean circumference of the trees in Farm Island R.A. were larger than the trees in Lewis and Clark, and the trees at Farm Island were also in a greater variety of decay. In the Black Hills, *E. fuscus* was found to roost only in mature forest stands with large diameter trees (Cryan et. al, 2001).

More research on what type of roosts and the particular roost characteristics utilized by each species of bat is needed in South Dakota. This information is important for effective bat management plans. Increasing the life history database on bats, reproductive and nonreproductive, in both regions of South Dakota will enhance our knowledge of bat populations and facilitate future management plans.

Chapter 3

INTRODUCTION

All bats that reside in eastern South Dakota are insectivorous (Nowak, 1994). Knowing what insects these bats prey upon is an important step towards bat conservation. Dietary studies of bats are important because these animals devour agricultural pests such as corn root worm beetles (*Diabrotica* spp.) (Whitaker, 1995), which are one of the most serious crop pests in the United States (Krysan and Miller, 1986). If studies can show that bats consume enough of these agricultural pests to make a significant impact, then bats can possibly be considered as a biological control agent, deserving further conservation efforts.

In 2000 and 2001, over 600 bats were collected throughout the state for rabies testing (South Dakota Animal Disease Research and Diagnostic Laboratory Report, 2000). A majority (98%) of the submitted bats were *E. fuscus* collected from Sioux Falls, Minnehaha County. After testing, the carcasses are usually destroyed. However, during 2000 and 2001, all bats that tested negative for rabies were saved and stomach contents of these *E. fuscus* were documented to formulate a baseline for the diet of *E. fuscus* in South Dakota.

In other states, hard bodied insects, particularly beetles, have been found in diets of *E. fuscus* (Phillips, 1966; Whitaker, 1972). Ground beetles (Carabidae) parts were found in greater frequency than other families of insects. *Eptesicus fuscus* have large powerful jaws that allow them to feed more effectively on the hard bodies of beetles (Freeman, 1981). In northeastern Kansas, Scarabaeidae (scarab beetles), Carabidae (ground beetles), and Pentatomidae (stink bugs) were found in the stomachs of *E. fuscus* (Phillips, 1966). In Indiana, Scarabaeidae, Carabidae, and Pentatomidae were found in the stomachs of *E. fuscus*, along with Formicidae (ants), Ichneumonidae (ichneumon wasps) and Lepidoptera (moths) (Whitaker, 1972).

MATERIALS AND METHODS

In 2000 and 2001, 620 bat carcasses were received by the Animal Disease Research and Diagnostic Laboratory at South Dakota State University for rabies testing. After testing, the rabies negative carcasses were transferred to our lab. Measurements such as forearm length, total length, ear length, tail length, total body length, mass, and sex and reproductive condition were taken on each carcass. Then, if any insect remains appeared in any of the stomachs, the stomachs were removed and the contents were identified.

Of the 620 bats, only 56 proved to have any stomach contents. These stomachs were preserved in plastic vials with 75% ethanol until analysis could be performed. Analysis consisted of identifying the stomach contents with a dissecting microscope. Each stomach was removed from its storage container and weighed on an assay scale (? 0.01 g). Then, the stomach was carefully cut open and placed inside a petri dish. The contents were bathed with 75% ethanol until all were removed from the lining of the stomach.

Once all the contents were contained with the petri dish, it was placed underneath a dissecting microscope and any identifiable insect parts were removed. Each petri dish of stomach contents was examined twice, a first sweep to remove any identifiable parts and a second sweep to verify that all applicable parts were removed. These sweeps were performed at different times so as to decrease the amount of human error from eyestrain. All insect parts were compared to a reference collection I made of insects collected in South Dakota. Individual insects from the collection were dissected into smaller parts in order to identify the stomach contents to order, and if possible to family.

RESULTS

Of the 56 stomachs, the contents of 20 stomachs were so mechanically broken down that nothing could be identified. Ten of these were taken from bats in April-September (Table 3.1) and were completely empty. These bats may have been captured after they had already completed the digestive processes, leading to an empty stomach or during the hibernation period when bats are not eating. Stomachs with identifiable contents were taken from bats captured in January through October (Table 3.1).

Of all the identifiable insects parts, over 90% were legs and tarsi, the remaining 10% being pieces of the body cuticle or wings. The mechanical breakdown of the contents by the stomach reduced the ability to accurately identify all the insect parts. Most of what was left either consisted of small anatomical parts such as fragments of a femur, a few segments of antennae, or something totally unidentifiable that looked like insect mush.

Table 3.1: Number of stomachs collected by month, and percentages of identifiable, empty and unidentifiable contents (Department of Health bats from 2000 and 2001)

Month	Number of Bat Stomachs	% Identifiable	% Empty	% Unidentifiable
January	1			100
April	3	33	33	33
May	1		100	
June	7	71	29	
July	7	72	14	14
August	30	74	13	13
September	3	33	33	33
October	3	67		33
November	1			100

Eptesicus fuscus is thought to stop feeding for the year around late October and doesn't feed during the hibernation period (November-March). In Indiana, Whitaker (1972) examined the stomachs of 11 bats during the third week of October and only found one with a full stomach; only one of 178 bat stomachs collected during the hibernation period held any contents. Similarly in South Dakota, only two stomachs with identifiable material were collected in October and only two stomachs collected during the hibernation period held any contents. The stomach contents from the remaining hibernating bats were unidentifiable and looked like they had been in the digestive tract for a long time based on the discoloration and digestion of the material.

Four orders of insects were identified in the stomach contents of *E. fuscus* from South Dakota: Coleoptera (beetles), Hemiptera (true bugs), Diptera (flies) and Lepidoptera (moths). Of these, the family Carabidae (ground beetles) occurred at a frequency of 29.1%, followed by unidentifiable insects at 18.2%, Lepidoptera at 12.2 %, unidentified Coleoptera at 7.3%, Pentatomidae (stinkbugs) at 7.3%, hairballs at 5.3% and Diptera at 1.8% (Table 3.2). These insects were identified by the size, shape, or design pattern of different anatomical parts. The anatomical parts used to identify the insects to family or order were: tarsi and tarsal claws for Carabidae; tibia and tarsal claws for Lepidoptera; the veins in the wings for Diptera; tarsi and the spotting design on the legs for Pentatomidae; and by elytra or the presence of a hard outer cuticle for unidentified Coleoptera (Borror and White 1970).

Table 3.2: Frequency and percents of stomach contents from all months, South Dakota Department of Health bats, 2000-2001

	Frequency	Percent
Carabidae (ground beetles)	16	29.1
Empty	10	18.2
Unidentifiable insects	10	18.2
Lepidoptera (moths)	7	12.2
Unidentifiable Coleoptera (beetles)	4	7.3
Pentatomidae (stinkbugs)	4	7.3
Hairball	3	5.5
Diptera (flies)	1	1.8

DISCUSSION

Based on the contents of the few stomachs taken from South Dakota Department of Health bats during 2000-2001, *E. fuscus* does not feed during the winter (November-March) and stops feeding sometime around late October. When feeding does resume in April, Carabidae beetles were consumed more often than other types of insects, similar to the results of a dietary analysis of *E. fuscus* from Indiana (Whitaker, 1972).

Only the percentages of coleopterans in the stomach contents of South Dakota bats were similar to other studies (Whitaker, 1972, 1995; Phillips, 1966; Hamilton, 1933). Otherwise, the frequencies of insects varied among the diets of *E. fuscus* in South Dakota to other studies. The percentages of lepidopterans were higher (12.2%) in the South Dakota bats than any other study.

Seasonal variation of insect abundance may account for some of the variability. In Indiana, coleopterans are not quite available in early spring, so bats seemed to rely on other orders. On April 2, lepidopterans made up 12.7% and dipterans 9.1% of the feces collected in the maternity colonies; while on May 3, coleopterans made up almost 100% (Whitaker, 1995). Analysis of the stomach contents of the bats from South Dakota did not reveal any preference of insects by season but most of the stomachs (80%) were collected from bats during the summer season (May-August), thereby limiting my analysis of seasonal trends in food choice.

Much more information is needed on the feeding habits of bats in South Dakota. Continued analysis of the stomach contents of bats collected from the Department of Health will add to the meager knowledge presented here. Also, collecting insects over the spring, summer, and fall seasons and correlating those collections with stomach content analysis may discover a seasonal variation to the diets of *E. fuscus* and show which insect orders are selected over others.

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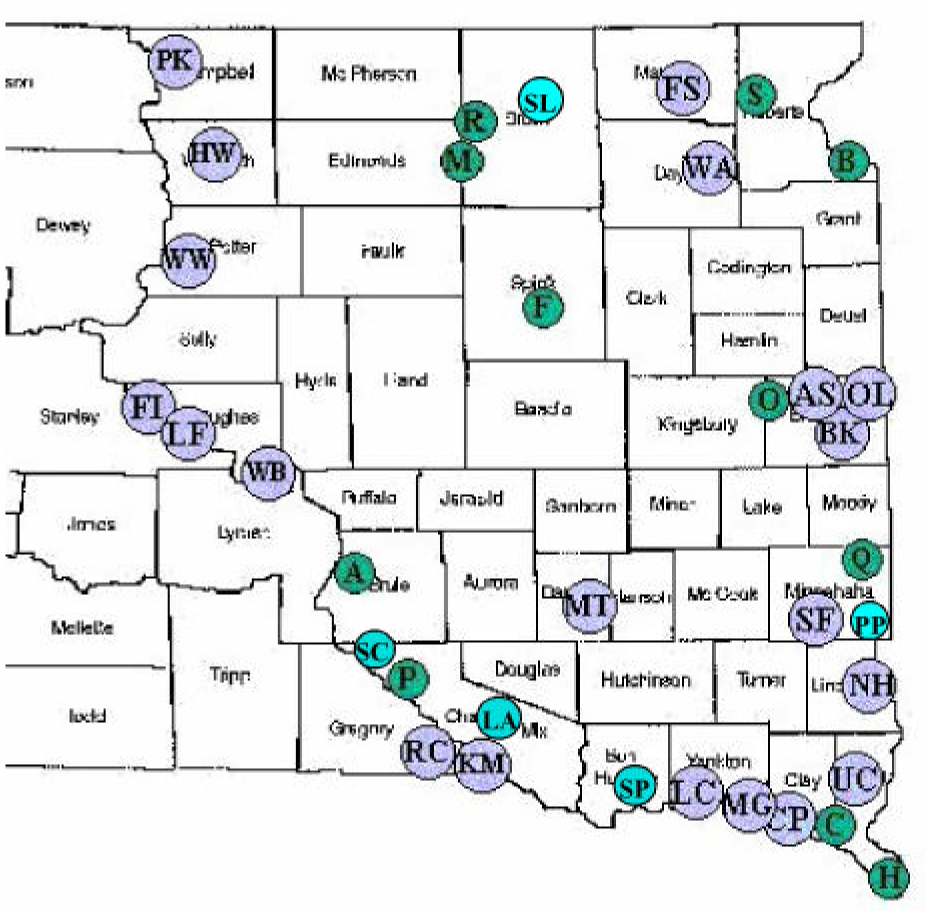
Appendix 1

SITE MAP



CAPTURE LOCATIONS: AS (Astoria), BK (Brookings), CP (Cotton Park), FI (Farm Island R.A.), FS (Fort Sisseton R.A.), HW (Lake Hiddenwood R.A.), KM (Karl Mundt NWR), LC (Lewis and Clark), LF (La Framboise R.A.), MT (Mitchell), MG (Myron Grove), NH (Newton Hills S.P.), OL (Oak Lake R.S.), PK (Pollock), SF (Sioux Falls), WA (Waubay NWR), WB (West Bend R.A.), WW (West Whitlocks Bay R.A.), UC (Union Grove S.P.)

ANABAT LOCATIONS WITHOUT CAPTURE DATA: A (American Creek R.A.), B (Hartford Beach R.A.), C (Clay Co. R.A.), F (Fisher Grove R.A.), H (Adams Homestead and Nature Preserve), LA (Lake Andes NWR), M (Mina State R.A.), O (Oakwood Lakes S.P.), P (Platte Creek R.A.), PP (Palisades S.P.), Q (Dell Rapids Quarry), R (Richmond Lake R.A.), S (Sica Hollow R.A.), SC (Sand Creek R.A.), SL (Sand Lake NWR), SP (Springfield R.A.)

Appendix 2

Distribution of eastern South Dakota bats by County (voucher, literature, and capture records)

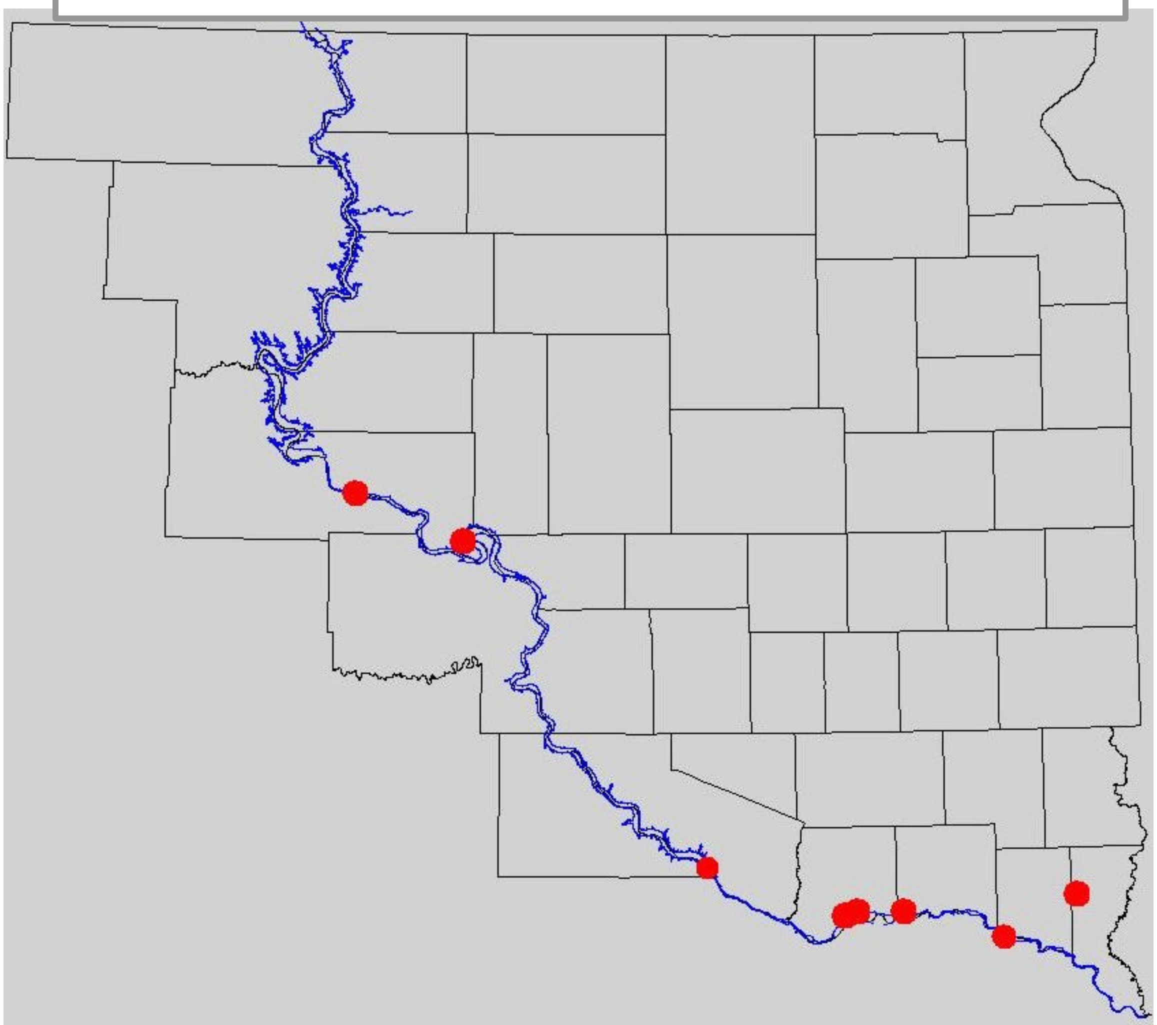
Counties	Msep	MlucC	MlucL	Lnoc	EfusF	EfusP	Lbor	Lcin
Beadle Co.					1			
BonHomme Co.	4				30		1	3
Brookings Co.					9		7	1
Brown Co.								1
Brule Co.					1			
Campbell Co.		2						
Charles Mix Co.					1			
Clay Co.	5			1	13		1	2
Davison Co.					3			1
Day Co.			1	1				
Duel Co.					1			
Grant Co.					1			
Gregory Co.	11	2	1		9	2	1	1
Hamlin Co.								1
Hand Co.								1
Hansen Co.							1	
Hughes Co.	11	17		2	11	6	1	
Hutchinson Co.					1			
Hyde Co.							1	1
Jerauld Co.							1	
Kingsbury Co.				1				
Lake Co.					1			1
Lincoln Co.					10		1	
Marshall Co.				1				
McCook Co.							1	
Minnehaha Co.			1		@	@	1	4
Moody Co.					3			
Potter Co.			2				2	1
Stanley Co.	1		1	1		1		1
Turner Co.					3			
Union Co.	2		1		4		3	
Walworth Co.		4						1
Yankton Co.	1				4			

Note: @-Over 600 records from Department of Health, there was difficulty distinguishing *fuscus* from *pallidus* because of the interbreeding of these species

Appendix 3

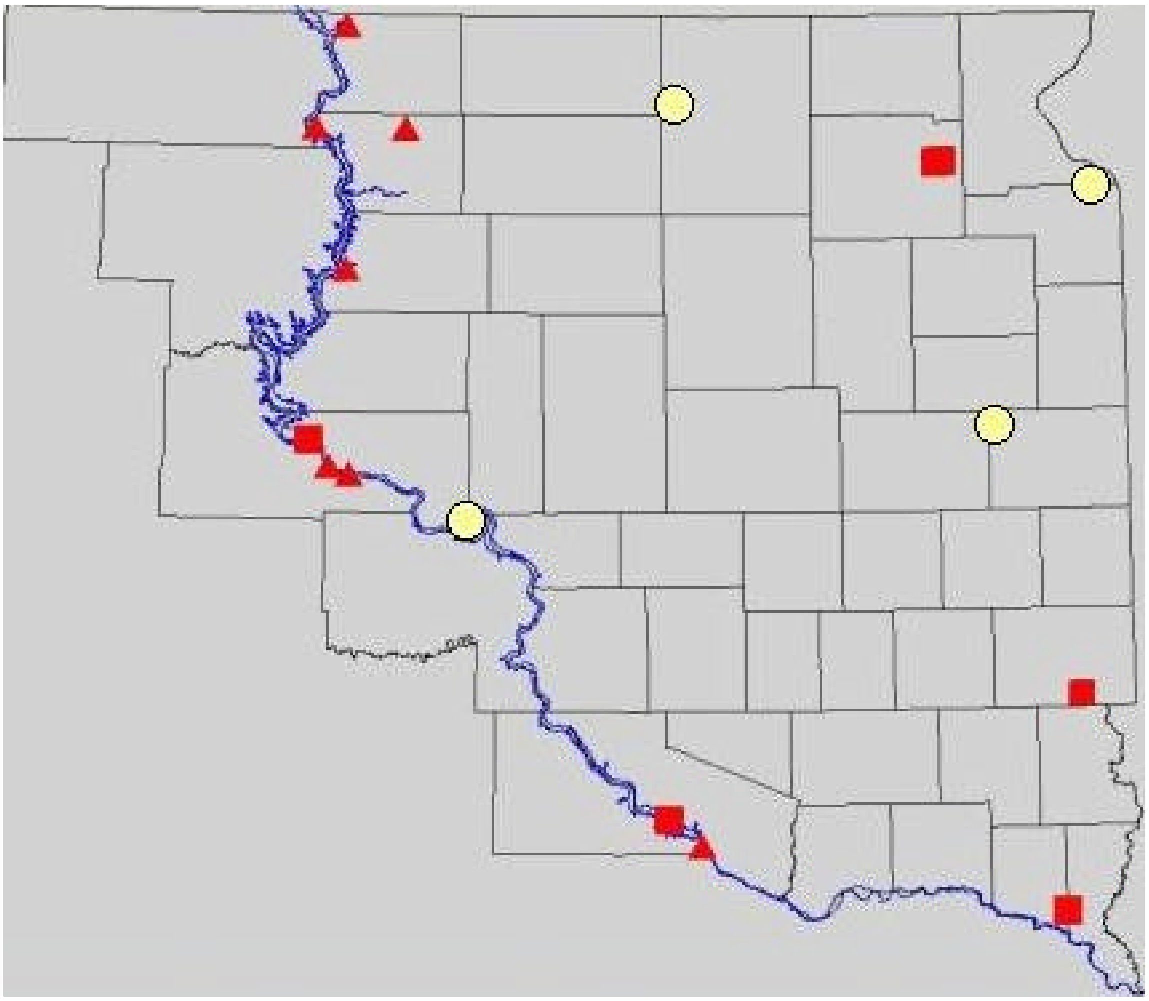
Distribution Maps

***Myotis septentrionalis*, Northern Long-eared bat**



Capture and Voucher Records

Myotis lucifugus, Little Brown bat

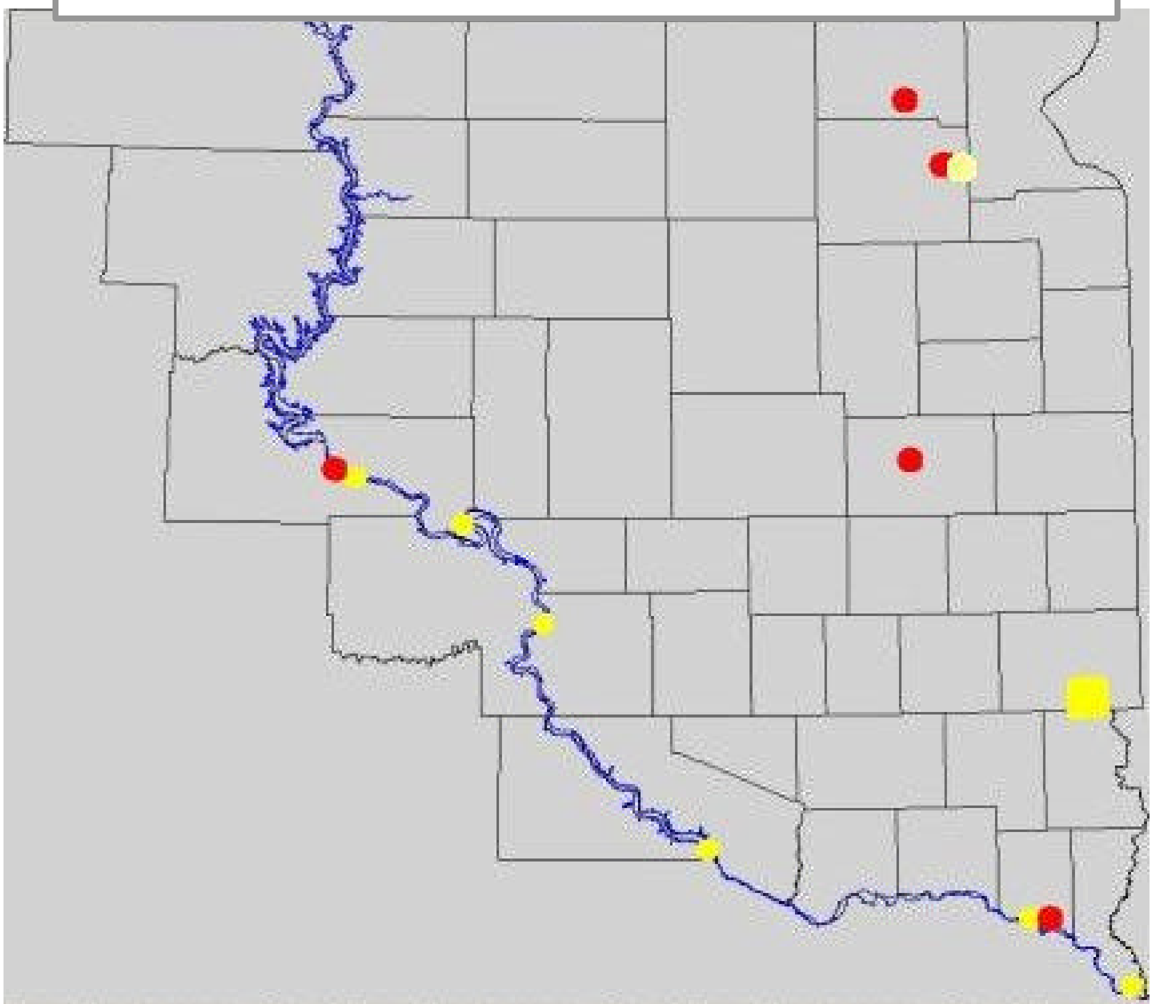


Capture and voucher Records for *Myotis lucifugus lucifugus*

Capture and voucher Records for *Myotis lucifugus carissima*

Acoustic Records

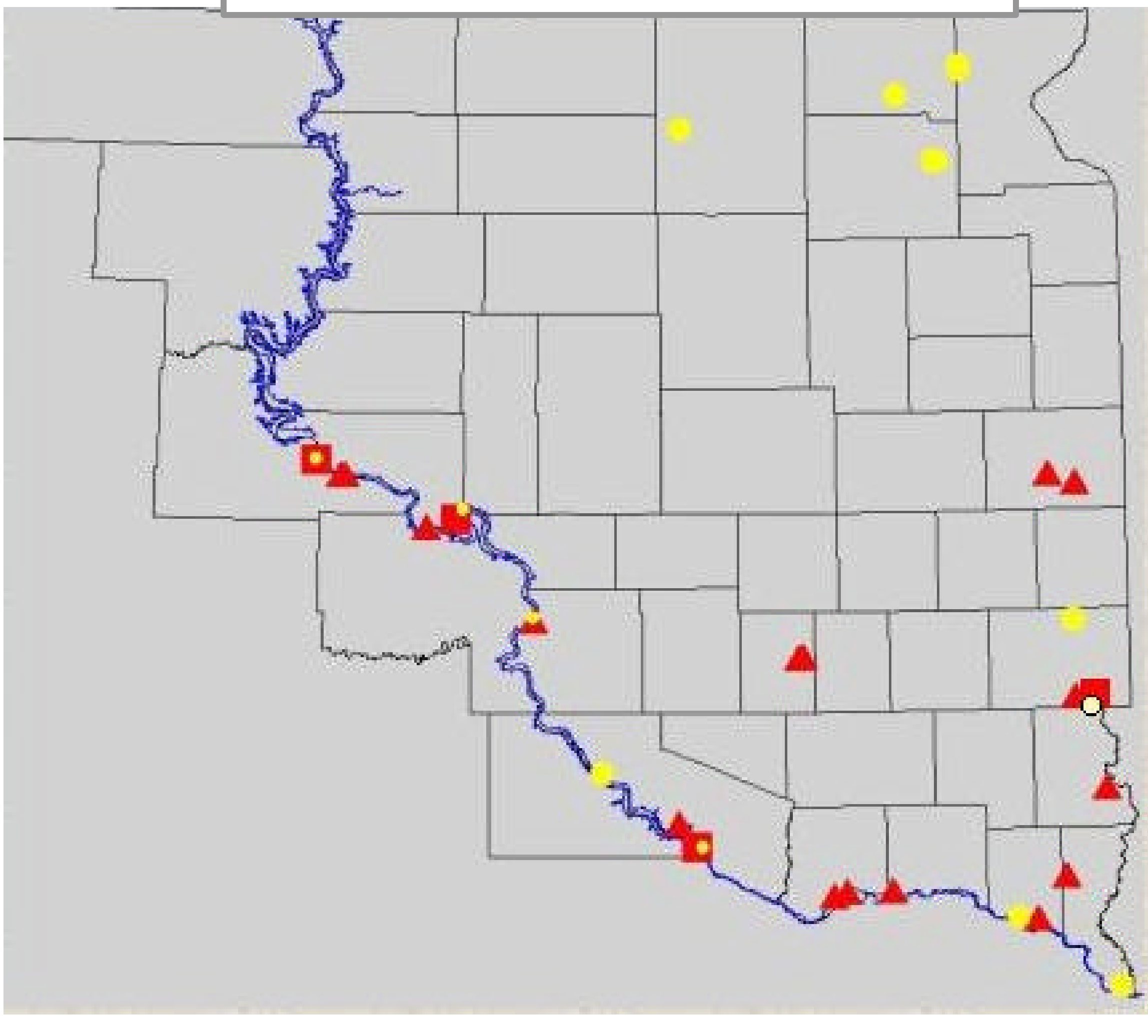
Lasionycteris noctivagans, Silver-haired bat



Capture and Voucher Records

Acoustic Records

Eptesicus fuscus, Big Brown bat

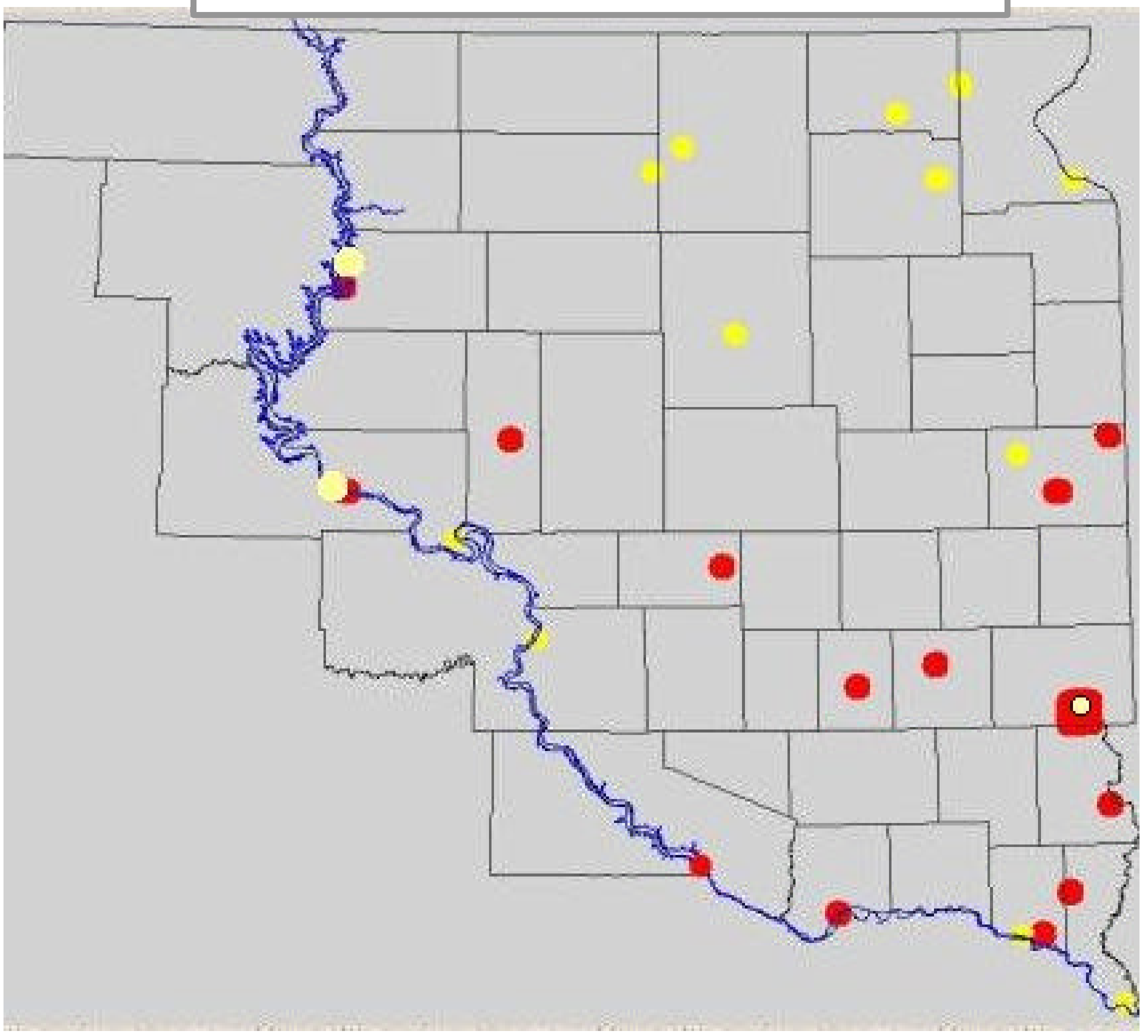


Capture and Voucher Records for *Eptesicus fuscus pallidus*

Capture and Voucher Records for *Eptesicus fuscus fuscus*

Acoustic Records

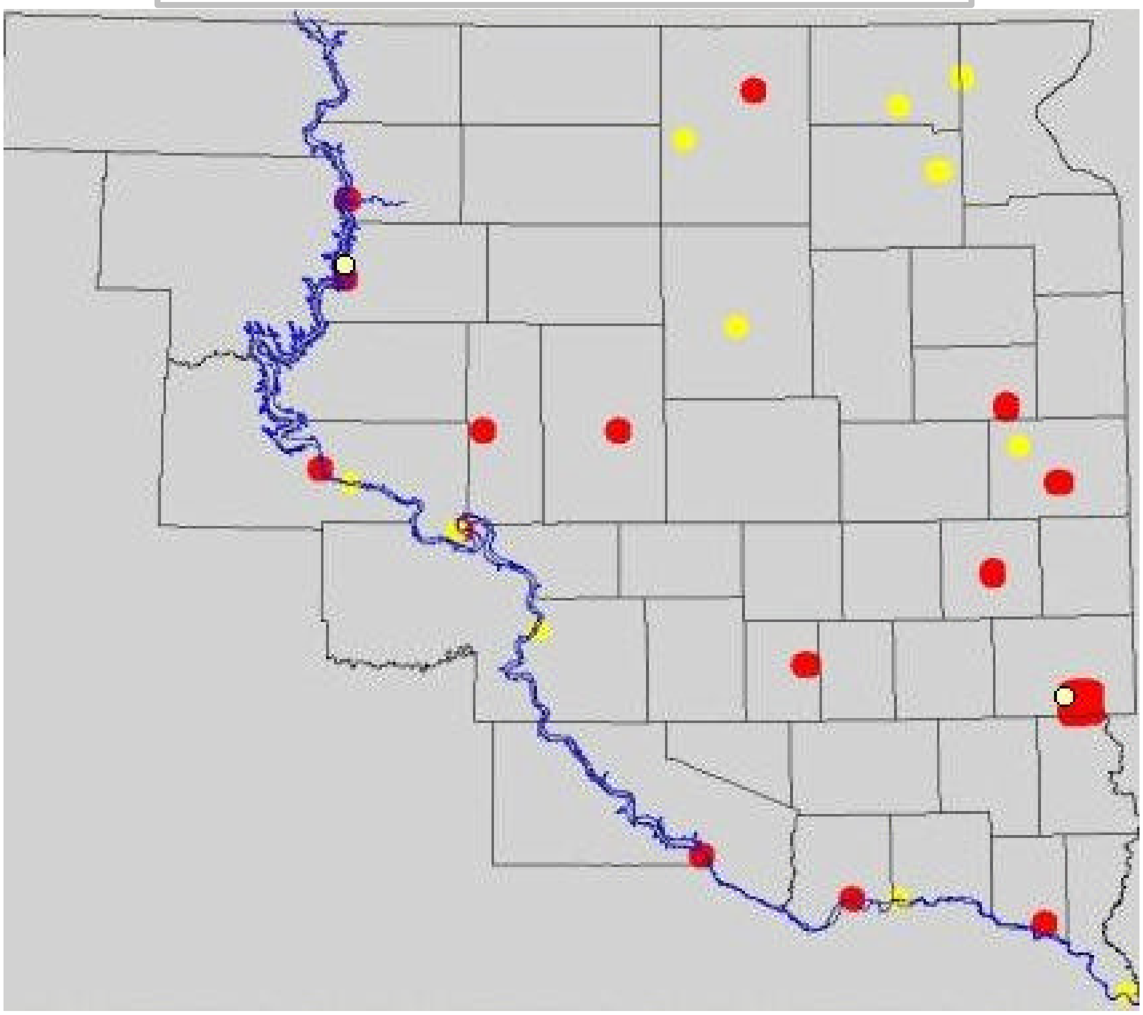
Lasiurus borealis, Red bat



Capture, Literature and Voucher Records

Acoustic Records

Lasiurus cinereus, Hoary bat



Capture, Literature and Voucher Records
Acoustic Records

Appendix 4

Capture Records from 2000-2002: Eastern South Dakota

Species	Location	County	Date	Forearm	Mass	Reproductive Condition	Sex
Lbor	1108 22^{nd} Ave-Brookings	Brookings	6/14/00	41.5 mm	12.9 g	Adult	F
Lbor	1108 22^{nd} Ave-Brookings	Brookings	6/14/00			Lactating with neonate	F
Lbor	Brookings	Brookings	7/17/00	40.0 mm	7.5 g	Adult	F
Efus	Pioneer Park-Brookings	Brookings	8/22/00	44.5 mm	17.3 g	YOY	M
Efus	Pioneer Park-Brookings	Brookings	8/22/00	45.5 mm	17.8 g	Scrotal	M
Lbor	Oak Lake Research Station	Brookings	8/23/00	38.0 mm	15.4 g	YOY	F
Lbor	McCrory Gardens-Brookings	Brookings	8/26/00	41.0 mm	10.5 g	Juvenile	F
Efus	Brookings	Brookings	8/27/00	45.0 mm	18.0 g	Adult	M
Mluc	Farm Island	Hughes	5/11/01	34 mm	5.8 g	Adult	F
Mluc	West Whitlock	Potter	5/23/01	36 mm	6.3 g	pregnant	F
Mluc	Waubay NWR	Day	6/2/01	36 mm	5.5 g	Adult	F
Lbor	McCrory Gardens	Brookings	6/7/01	42 mm	20.8 g	pregnant	F
Msep	Union Grove state park	Union	6/16/01	36 mm	6.5 g	Adult	M
Efus	Cotton Park-Vermillion	Clay	6/19/01	46 mm	14.0 g	Adult	M
Mluc	Karl Mundt NWR	Gregory	6/23/01	35 mm	7.1 g	Adult	F
Msep	Karl Mundt NWR	Gregory	6/23/01	36 mm	7.6 g	Adult	F
Mluc	Karl Mundt NWR	Gregory	6/23/01	35 mm	6.0 g	Adult	M
Lcin	Karl Mundt NWR	Gregory	6/23/01	54 mm	26.0 g	Adult	F
Efus	West Bend R.A.	Hughes	7/8/01	46 mm	23.5 g	post lactating?	F
Mluc	Farm Island	Hughes	7/9/01	35 mm	7.0 g	Adult	F
Mluc	La Framboise	Hughes	7/10/01	38 mm	9.0 g	post lactating?	F
Mluc	La Framboise	Hughes	7/10/01	38 mm	9.0 g	Adult	F
Mluc	La Framboise	Hughes	7/10/01	36 mm	8.0 g	Adult	F
Mluc	La Framboise	Hughes	7/10/01	36 mm	9.0 g	Adult	F
Mluc	La Framboise	Hughes	7/10/01	39 mm	10.0 g	post lactating?	F
Mluc	La Framboise	Hughes	7/10/01	37 mm	5.0 g	Adult	F
Mluc	La Framboise	Hughes	7/10/01	36 mm	6.0 g	Adult	M
Mluc	La Framboise	Hughes	7/10/01	36 mm	9.0 g	Adult	F
Mluc	Pollock town city	Campbell	7/14/01	37 mm	7.0 g	Adult	F
Mluc	Pollock town city	Campbell	7/14/01	35 mm	7.0 g	Adult	M
Mluc	Hiddenwood R.A.	Walworth	7/16/01	36 mm	11.0 g	Adult	F
Mluc	Hiddenwood R.A.	Walworth	7/16/01	37 mm	11.0 g	Adult	F
Lcin	West Whitlock	Potter	7/16/01	56 mm	39 g	post lactating?	F

Lnoc	Fort Sisseton Historical	Marshall	7/18/01	41 mm	11.0 g	Adult	M
Lbor	Union Grove state park	Union	7/29/01	39 mm	9.0 g	YOY	M
Lbor	Union Grove state park	Union	7/29/01	40 mm	12.0 g	Adult	F
Lbor	Union Grove state park	Union	7/29/01	42 mm	13.0 g	Adult	F
Efus	Union Grove state park	Union	7/29/01	44 mm	13.0 g	Adult	M
Efus	Union Grove state park	Union	7/29/01	48 mm	17.0 g	Adult	F
Msep	Union Grove state park	Union	7/29/01	34 mm	7.0 g	Adult	M
Efus	Old Courthouse Museum	Minnehaha	8/9/01	47 mm	17.7 g	YOY	F
Lbor	Newton Hills State Park	Lincoln	8/9/01	39 mm	12.6 g	YOY	F
Efus	Newton Hills State Park	Lincoln	8/9/01	47 mm	15.5 g	YOY	F
Lbor	Karl Mundt NWR	Gregory	8/13/01	37 mm	10.1 g	YOY	M
Msep	Karl Mundt NWR	Gregory	8/13/01	36 mm	6.3 g	Adult	F
Msep	Karl Mundt NWR	Gregory	8/13/01	34 mm	5.5 g	Adult	M
Efus	Karl Mundt NWR	Gregory	8/13/01	45 mm	15.6 g	Adult	F
Efus	Karl Mundt NWR	Gregory	8/13/01	46 mm	15.4 g	Adult	F
Efus	Karl Mundt NWR	Gregory	8/13/01	45 mm	20.4 g	Adult	F
Msep	West Bend R.A.	Hughes	8/19/01	36 mm	7.4 g	Adult	M
Efus	19797 479th Ave-Astoria	Brookings	8/24/01	45 mm	13.4 g	scrotal	M
Efus	Hitchcock Park-Mitchell	Davison	8/28/01	42 mm	16.2 g	Adult	M
Msep	Karl Mundt NWR	Gregory	5/25/02	35 mm	5.7 g	Adult	M
Msep	Karl Mundt NWR	Gregory	5/26/02	36 mm	6.6 g	Adult	F
Msep	Karl Mundt NWR	Gregory	5/26/02	36 mm	6.0 g	Adult	M
Msep	Karl Mundt NWR	Gregory	5/26/02	36 mm	6.3 g	Adult	F
Msep	Karl Mundt NWR	Gregory	5/26/02	36 mm	5.8 g	Adult	F
Msep	Karl Mundt NWR	Gregory	5/29/02	34 mm	5.2 g	Adult	M
Efus	Randall Creek RA	Gregory	5/31/02	46 mm	14.3 g	Adult	M
Efus	Randall Creek RA	Gregory	5/31/02	45 mm	15.4 g	Adult	M
Efus	Randall Creek RA	Gregory	5/31/02	46 mm	17.0 g	Adult	M
Efus	Lewis/Clark R.A.	Yankton	6/16/02	44 mm	18.2 g	Adult	M
Efus	Lewis/Clark R.A.	Yankton	6/16/02	46 mm	17.1 g	Adult	M
Efus	Lewis/Clark R.A.	Yankton	6/16/02	45 mm	15.9 g	Adult	M
Msep	Lewis/Clark R.A.	Yankton	6/16/02	35 mm	7.6 g	Adult	M
Msep	Myron Grove L.A.	Clay	6/21/02	34 mm	8.5 g	Adult	F
Msep	Myron Grove L.A.	Clay	6/21/02	34 mm	5.6 g	Adult	M
Msep	Myron Grove L.A.	Clay	6/21/02	35 mm	6.1 g	Adult	M
Msep	Myron Grove L.A.	Clay	6/21/02	33 mm	7.7 g	Adult	F
Efus	West Bend R.A.	Hughes	6/26/02	41 mm	22.3 g	Adult	F
Efus	West Bend R.A.	Hughes	6/26/02	42 mm	21.8 g	Adult	F
Efus	West Bend R.A.	Hughes	6/26/02	50 mm	26.6 g	Adult	F
Efus	West Bend R.A.	Hughes	6/26/02	45 mm	23.7 g	Adult	F
Efus	West Bend R.A.	Hughes	6/26/02	41 mm	20.9 g	Adult	F

Efus	West Bend R.A.	Hughes	6/26/02	46 mm	20.7 g	Adult	F
Msep	West Bend R.A.	Hughes	6/26/02	36 mm	8.5 g	pregnant	F
Msep	West Bend R.A.	Hughes	6/26/02	36 mm	9.2 g	pregnant	F
Efus	Karl Mundt NWR	Gregory	7/10/02	44 mm	14.4 g	Adult	M
Efus	Karl Mundt NWR	Gregory	7/10/02	47 mm	19.3 g	Adult	M
Efus	Karl Mundt NWR	Gregory	7/14/02	43 mm	15.2 g	Adult	M
Efus	Karl Mundt NWR	Gregory	7/14/02	45 mm	14.0 g	Adult	M
Efus	Karl Mundt NWR	Gregory	7/14/02	46 mm	15.6 g	Adult	M
Msep	Karl Mundt NWR	Gregory	7/14/02	35 mm	7.5 g	post lactating?	F
Msep	Karl Mundt NWR	Gregory	7/14/02	36 mm	7.3 g	lactating	F
Mluc	La Framboise R.A.	Hughes	7/20/02	39 mm	10.4 g	Adult	F
Lnoc	La Framboise R.A.	Hughes	7/20/02	41 mm	11.0 g	Adult	F
Lnoc	La Framboise R.A.	Hughes	7/20/02	41 mm	9.6 g	YOY	M
Mluc	La Framboise R.A.	Hughes	7/20/02	36 mm	7.1 g	Adult	F
Mluc	La Framboise R.A.	Hughes	7/20/02	35 mm	6.0 g	Adult	M
Mluc	La Framboise R.A.	Hughes	7/20/02	39 mm	9.0 g	Adult	F
Mluc	La Framboise R.A.	Hughes	7/20/02	38 mm	9.8 g	post lactating	F
Mluc	La Framboise R.A.	Hughes	7/20/02	38 mm	7.9 g	Adult	F
Mluc	La Framboise R.A.	Hughes	7/20/02	39 mm	8.3 g	post lactating	F
Msep	Farm Island R.A.	Hughes	7/25/02	35 mm	6.7 g	Adult	F
Msep	Farm Island R.A.	Hughes	7/25/02	37 mm	7.2 g	post lactating	F
Msep	Farm Island R.A.	Hughes	7/25/02	37 mm	7.5 g	Adult	M
Efus	Farm Island R.A.	Hughes	7/25/02	47 mm	15.8 g	Adult	M
Msep	Farm Island R.A.	Hughes	7/25/02	36 mm	6.4 g	Adult	M
Msep	Farm Island R.A.	Hughes	7/25/02	35 mm	5.7 g	YOY	M
Msep	Farm Island R.A.	Hughes	7/25/02	36 mm	7.7 g	post lactating	F
Msep	Farm Island R.A.	Hughes	7/25/02	35 mm	5.8 g	YOY	M
Mluc	West Whitlocks R.A.	Potter	7/28/02	38 mm	6.8 g	YOY	M
Lbor	West Whitlocks R.A.	Potter	7/28/02	39 mm	8.9 g	YOY	M
Lbor	West Whitlocks R.A.	Potter	7/28/02	41 mm	10.7 g	YOY	F