Final Report: Project E-3

Determination of Summer Distribution and Habitat Utilization of the Indiana Bat (*Myotis sodalis*) in Illinois

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INTRODUCTION

Myotis sodalis (Indiana bat) has been known from Illinois since it was first described as a new species (Miller and Allen 1928). Until recently, information on Illinois populations was limited to studies of one cave in the extreme southeastern region of the state (Hardin County) and one abandoned mine in north-central Illinois (LaSalle County) (Layne 1958; Hall 1962; Walley 1971; Humphrey 1978). A single *Myotis sodalis* has been reported from a cave in Madison County and winter records from a lead mine in JoDaviess County are over 30 years old (Hoffmeister 1989). In 1982, an additional hibernaculum in Monroe County was confirmed by the Indiana Bat Recovery Team [R. Clawson, pers. comm.; Illinois Department of Conservation (IDOC)/ Illinois Natural History Survey (INHS), unpubl. data].

Adult female *M. sodalis* establish maternity roosts beneath the loose bark of suitable trees (Humphrey *et al.* 1977; Cope *et al.* 1978; INHS/IDOC, unpubl. data). In Illinois juvenile and reproductively active adult female *M. sodalis* have been reported from Adams, Bond, Jackson, Johnson, Perry, Pike, Pulaski, Schuyler, Scott, Union, and Wabash/Edwards counties (Brack 1979; Sparling *et al.* 1979; Gardner and Gardner 1980; Kessler and Turner 1980; Kirkpatrick 1980; Gardner and Taft 1984; Clark and Clark 1987; Hoffmeister 1989; INHS/IDOC, unpubl. data) (Figure 1). Additional Illinois records for the Indiana bat are of migrating individuals or adult males. These records are from Adams, Christian, Cook, Hardin, McDonough, Madison, Morgan, and Sangamon counties (Thom 1981; Gardner and Taft 1983; Hoffmeister 1989; INHS/IDOC, unpubl. data).

Scant information exists on the migratory patterns of Illinois *M. sodalis*. Hall (1962) reported the recovery of a female Indiana bat (banded at Blackball Mine in LaSalle County, Illinois, on 6 December 1958) from Colossal Cave in Edmondson County, Kentucky, on 18 December 1959. Another Illinois *M. sodalis* (sex unknown, banded at Blackball Mine on 10 November 1963) was recovered at Palmyra in Marion County, Missouri, on 20 August 1966 (Walley 1971). Additional movements from an Illinois hibernaculum (Monroe County) to two separate Missouri hibernacula (Shannon and Washington counties) were discovered during the biennial winter census conducted during January and February 1989, respectively.

Human disturbance has been a detrimental factor contributing to declines in hibernating populations of Indiana bats. Flooding, ceiling collapses, and freezing, however, are all natural disasters that have been responsible for population declines in hibernacula (Hall 1962; Humphrey 1978; Brady 1982; Clawson 1987). Other factors contributing to the decline of the species through habitat alteration include stream channelization; Conlin (1976) reported that 29.7% of the interior streams in Illinois had been channelized by 1976. Deforestation for agriculture, surface strip-mining, road and utility construction, urban expansion and a host of other "progress-" related developments all adversely affect the continued existence of *M. sodalis* throughout its range.

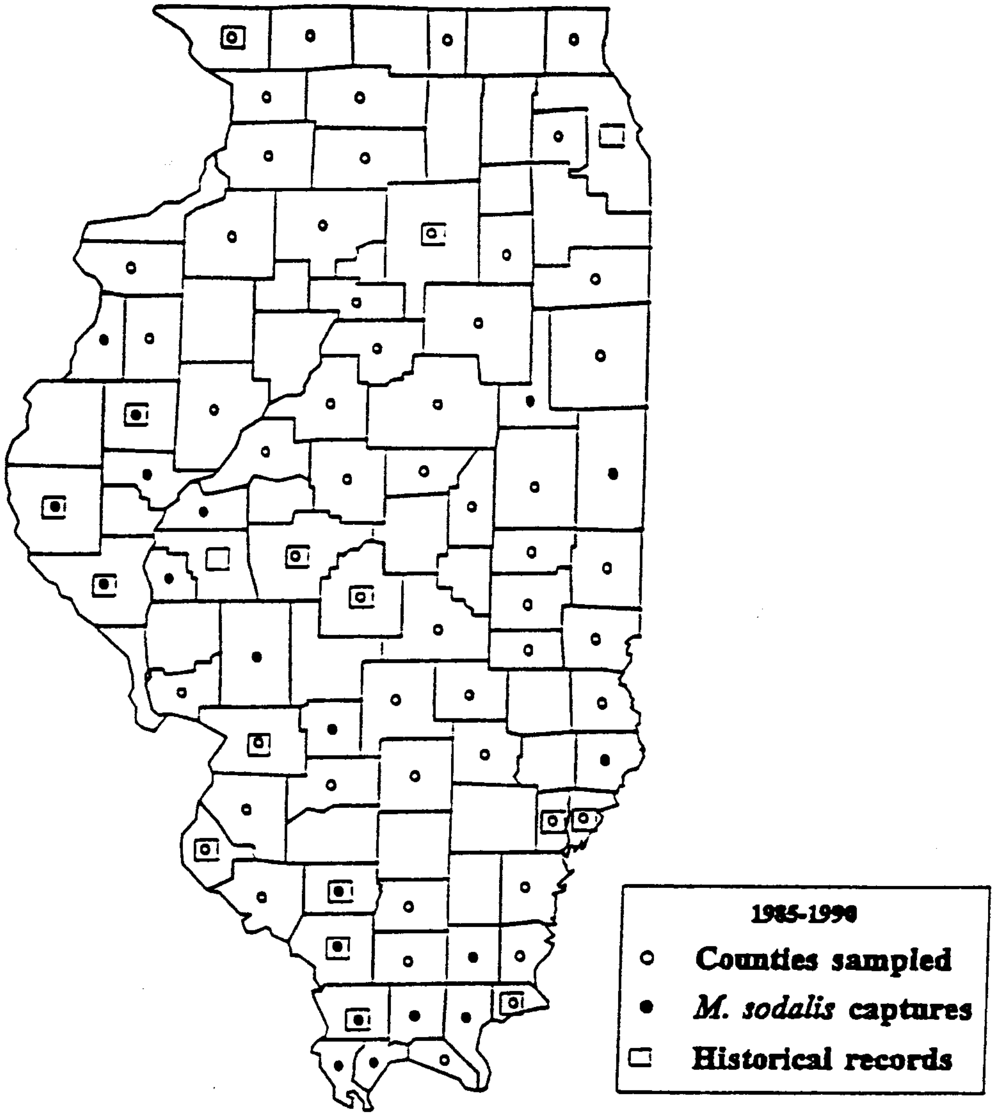


Figure 1. Distribution records of *Myotis sodalis* collected from 1985-1990 compared to statewide sampling effort and to the previously reported historical distribution of the species in Illinois.

Pesticide-induced mortality of insectivorous bats has been documented for other states and probably has contributed to the decline of Indiana bat summer populations in Illinois (Mohr 1972; Geluso *et al.* 1976; Clark *et al.* 1983). Studies in northern Missouri are being conducted to determine if *M. sodalis* are being contaminated by pesticides (R. Clawson, pers. comm.). Poor water quality and shortages in food resources may compound these adverse effects on populations.

The overall objectives of this statewide investigation were:

1. To determine the summer distribution of *M. sodalis* populations in Illinois.

2. To evaluate the status of *M. sodalis* in Illinois, based upon recognition and understanding of distribution patterns.

3. To gather data concerning all aspects of *M. sodalis* ecology, including habitat use and selection. (The following objectives pertained to radio-telemetry studies conducted on *M. sodalis*:

   A. To determine the home range size of selected sex and age classes, with emphasis on reproductively active females.
   B. To identify roosts and collect data to aid in the understanding of roost selection and preference.
   C. To determine foraging range size, describe habitat types within that range, and perform quantitative analyses of habitat types and preference.

4. To make land management recommendations that will ensure the continued existence of *M. sodalis* in Illinois.

These objectives were accomplished through cooperative efforts of the Illinois Department of Conservation and Illinois Natural History Survey personnel funded by the Region 3 Office, U.S. Fish and Wildlife Service (USDI) and the Illinois Department of Transportation, Bureau of Location and Environment, respectively. Additional cooperation was provided by the Indiana Bat/Gray Bat Recovery Team (USFWS) and the Shawnee National Forest (USDI).

MATERIALS AND METHODS

Bat Capture

Bats were captured with black, monofilament Japanese mist nets (38-mm mesh) ranging in length from 5.5 m to 18.3 m. Mist nets of equal length were stacked vertically (6.1 m to 9.1 m in height) with the end loops secured to a rope and pulley system suspended on pairs of interlocking metal masts (Gardner *et al.* 1989). Mist nets were positioned adjacent to roosts, over stream corridors and other types of flyways, and beneath forest canopies.

Data recorded for each bat captured included location, date, time of capture, height (m) in net above water (ground), sex, age (adult or juvenile), weight (g), and reproductive condition (females = nonreproductive, pregnant, lactating, post-lactating; males = scrotal or nonreproductive). Juveniles were distinguished from adults by smaller overall size and incomplete ossification of the phalangeal epiphyses. Males were considered reproductively active (scrotal = functional testes) when enlarged and fully distended epididymides were visible in pigmented sheaths in the uropatagium. Females were determined to be either lactating or post-lactating by teat examination. Pregnancy was diagnosed by abdominal palpation with care taken not to mistake a food-distended stomach for a fetus. All *M. sodalis* were banded (males on right wing, females on left wing) with sequentially numbered, size XCL plastic bands (A. C. Hughes, London, England) of various colors and immediately released at the state of capture.

Radiotelemetry Equipment and Tracking.

Efforts to capture and band *M. sodalis*, and subsequent searches for their roosts were conducted statewide; however, radio-tracking was employed at a limited number of sites. When *M. sodalis* were radio-tagged, serious BD2A radio transmitters with frequencies ranging from 172.0 to 173.0 MHz were used (Holohil Systems Ltd., Ontario, Canada). These rectangular-shaped transmitters measured 12 mm x 8 mm x 4 mm with an 11-cm whip antenna. Pre-attachment transmitter weights ranged from 0.72 to 0.82 g. Transmitters were attached with non-toxic skin-bond cement (Pfizer Hospital Products Group Inc., Largo, Florida) to the mid-sagittal dorsal surface midway between the scapulae and the external origin of the tail. At this position, hair was clipped from an area of skin large enough to accommodate the transmitter.

Model TRX-1000S tracking receivers (Wildlife Materials Inc., Carbondale, Illinois) were used to locate bats in conjunction with collapsible series F172-3FB three-element Yagi antennas (AF Antronics, Inc., White Heath, Illinois). Under optimal conditions (clear nights with dry vegetation), line-of-sight signals were received from distances up to 3 km over rolling, partially forested terrain, however, a diurnal receiving range of ≤1 km was more common. After a signal had been tracked to its source and the roost tree identified, the exact site (≤ 1-m segment) of the radio-tagged bat beneath the bark or in a cavity was determined. Distorted signals could be heard when the receiving antenna passed within 3-4 cm of the transmitter's antenna. In addition, a directional loop (null-peak) antenna Model L216-SM (AF Antronics, Inc., White Heath, Illinois) was used for pinpointing radio-tagged bats beneath bark and for recovering transmitters that had become detached from the bat.

Fixed-station tracking was conducted on selected bats to determine their foraging range. Signals were monitored with a null/peak antenna configuration from each of three stations positioned in triangular fashion surrounding the foraging area of the bat. Bearings were taken simultaneously every five minutes, synchronized, and verified via radio communication between stations.

The micro-computer software package TELEMPC (University of Missouri, Columbia, MO) was used to triangulate azimuthal data and generate point locations of bats. In addition to generating fixes, the computer program calculates: (1) home range polygons by the convex polygon, capture radius, non-circular, modified minimum, and percent home range methods; (2) the geometric center of the home range; (3) the circumference of the home range; and (4) statistics describing distances traveled between consecutive locations and daily travel. Home range polygons were overlaid on a digitized habitat cover map and analyzed in conjunction with ARC/INFO and geographic information system (GIS) software on Prime 9955-II super-minicomputer at INHS.

Roost Analysis and Habitat Evaluation

All roosts reported here were diurnal roosts of *M. sodalis*; roosts were defined as the entire tree occupied by *M. sodalis*. No artificial structures (e.g., barns, human dwellings, bridges) were used as roosts by *M. sodalis* in this study. Roost sites were defined as specific areas (≤1-m segment) of a roost tree where one or more *M. sodalis* roosted. Each roost was marked with a uniquely numbered brass tag affixed to its base and ranked according to its potential to provide roost sites beneath its bark. Ranking was based upon a visual assessment of the amount of loose and peeling bark on a tree's trunk and limbs: high = ≥25% coverage; moderate = ≥10% but <25%; low = <10%; none = devoid of loose and peeling bark. Data recorded for each roost included location in Universal Transverse Mercator (UTM) coordinates, date discovered, tree species and condition (dead or alive), relative elevation (upland or floodplain), diameter of tree at breast height (cm dbh), tree height (m), height of roost site above ground (m), type of roost site (bark or cavity), thickness of bark (cm), and total number of bats present. The sex, age, reproductive condition, and numerical identity of radio-tagged bat(s) within the roost were recorded. ARC/INFO Geographic Information System (GIS) software was used to record the nearest distance (±1 m) to paved roads, unpaved roads, perennial streams, intermittent streams, and the original point of capture of the radio-tagged bat(s) from that roost tree for which data were recorded. Where foraging range data for radio-tagged bats were collected, the relationship of their roost to the geometric center of their foraging range was measured.

Woody vegetation was measured within 0.10 ha circular plots at 32 of 39 roost tree sites in the Fishhook Creek study area. All woody stems ≥ 10 cm dbh were recorded as living or dead and by species and size (cm dbh). Understory trees, shrubs and ground cover (herbaceous and woody species) were also recorded.

Percent forest canopy closure readings were taken at each roost using a hand-held densitometer at the base of the roost and at 5-m intervals from the base in each of the four cardinal directions (eight readings total). Roosts were revisited every spring or summer after their discovery (beginning with the first roost found in 1986) through 1989 to assess their continuing suitability for roost sites and to determine their rate of attrition.

Censusing Roosts

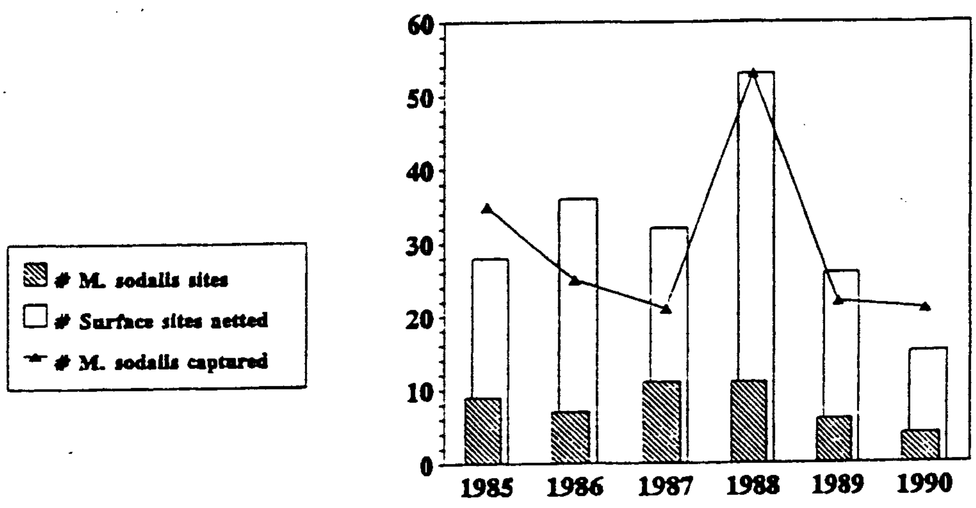
Bats emerging from roosts were counted simultaneously by two or more experienced observers. Censuses were occasionally aided by a night vision scope (15x). To keep disturbance to a minimum, no artificial lighting was used; silhouettes of bats emerging from their roosts against a sunset sky were easily recognized. Bats almost always emerged individually from the same place in the roost site. We felt that exit counts at dusk were reliable indicators of total numbers of bats in the roost since emergence times for radio-tagged *M. sodalis* and their almost immediate movement to foraging area(s) occurred before it became too dark to see. Reliability continued until mid- to late-July when juveniles were becoming volant. Bats that emerged from colonial roost sites after mid- to late-July circled the roost tree and often re-entered the roost site; this type of behavior made censuses of larger populations more difficult and less reliable.

It should be noted that 39 of the 51 roosts identified during this project were located in or near the Fishhook Creek study area in Pike/Adams Counties, Illinois. Because of the areas rural nature, varied topography availability of diverse foraging and roosting habitats, history of use by *M. sodalis*, and the cooperative attitude of landowners, this area was ideally suited for detailed studies of the Indiana bat. A detailed description of this area is presented in Gardner et al (1991).

RESULTS

Capture Data

During this study, 190 surface sites were mist netted for bats. *M. sodalis* were captured at 48 of these sites. These efforts resulted in the capture of 177 *M. sodalis* and 1432 bats of other species (Figure 2).



		1985	1986	1987	1988	1989	1990
# M. sodalis sites	▨	9	7	11	11	6	4
# Surface sites netted	□	28	36	32	53	26	15
# M. sodalis captured	▲	35	25	21	53	22	21
# Other bats captured		296	248	289	365	193	41

Figure 2. Comparison of the number of *Myotis sodalis* captures and capture sites with the total number of all sites netted and all other bats captured.

Mist netting efforts were conducted in 75 counties during this study. New records of occurrence (i.e. distribution) were recorded for 13 counties: Alexander, Bond, Ford, Henderson, Johnson, Lawrence, Macoupin, Pope, Pulaski, Saline, Schuyler, Scott, and Vermilion.

Roost Tree Selection

From May, 1986, through August, 1990 more than 340 *Myotis sodalis* were discovered roosting in 51 different trees in nine Illinois counties. Thirty-eight roosts were documented within the Fishhook Creek study area, Pike and Adams counties, Illinois (Table 1). Fourteen species were used as roosts throughout Illinois: *Ulmus rubra* (slippery elm), *Ulmus americana* (American elm), *Quercus rubra* (northern red oak), *Quercus stellata* (post oak), *Quercus alba* (white oak), *Quercus imbricaria* (shingle oak), *Carya ovata* (shagbark hickory), *Carya cordiformis* (bitternut hickory), *Carya ovalis* (sweet pignut hickory), *Acer saccharinum* (silver maple), *Acer saccharum* (sugar maple), *Populus deltoides* (cottonwood), *Fraxinus pennsylvanica* (green ash), and *Sassafras albidum* (sassafras).

Table 1. Characteristics of 48 roost trees used by *Myotis sodalis* in eight Illinois counties from 14 May 1986 - 11 July 1989.

ROOST NO.	COUNTY	DATE LOCATED	DBH (cm)	CONDITION	RELATIVE ELEVATION	HABITAT CLASS	BAT ID TRX NO.	FEMALE PG	FEMALE L	FEMALE PL	FEMALE JUV	MALE JUV	MALE ADULT	TOTAL NO. BATS
Acer saccharinum														
001	Jackson	05/20/87	31	dead	floodp	Clr	F122b	1						>1
922	Adams	05/01/87	40	alive	floodp	CC,NGz	F263a	1						1
923	Adams	05/04/87	24	dead	floodp	CC,NGz	F263a	1						1
924	Adams	05/17/88	35	dead	floodp	CC,NGz	F083		1					1
924		06/16/88					F484		1					1
926	Adams	05/18/88	50	alive	floodp	CC,NGz	F083		1					1
Acer saccharum														
002	Johnson	07/14/87	33	dead	upland	CC,Gz	M323						1	1
Carya cordiformis														
911	Pike	06/23/87	24	dead	upland	CC,NGz	F444		1					1
934	Adams	07/25/88	24	dead	upland	SwF	M182						1	1
934		07/27/88					M182						1	1
934		07/28/88					M182						1	1
Carya ovata														
009	Henderson	07/12/89	39	dead	upland	IC,NGz	F138		1					1
919	Adams	06/19/87	39	alive	upland	IC,Gz	M181						1	1
920	Adams	06/23/87	58	alive	upland	IC,Gz	M181						1	4
920		05/25/88					na	1					4	5
925	Adams	05/17/88	42	dead	upland	CC,Gz	F363	1						58
925		05/18/88					F363	1						?
925		05/19/88					F363	1						?
925		05/20/88					F363	1						?
925		06/13/88					na		1					95
925		06/14/88					F282,F163		2					?
925		06/15/88					F163		1					?
925		06/16/88					F163		1					?
925		06/20/88					F163		1					?
925		06/21/88					F163		1					?
925		06/22/88					F163		1					?
925		09/20/89					na			8		1	4	50
931	Pike	06/15/88	32	dead	upland	CC,Gz	F484		1					1
935	Adams	07/27/88	27	dead	upland	CC,Gz	M424,M721, F501			6	1	3		14

Table 1 (Continued)

ROOST NO.	COUNTY	DATE LOCATED	DBH (cm)	CONDITION	RELATIVE ELEVATION	HABITAT CLASS	BAT ID TRX NO.	FEMALE PG	FEMALE L	FEMALE PL	FEMALE JUV	MALE JUV	MALE ADULT	TOTAL # BATS
Populus deltoides														
902	Adams	09/05/86	46	dead	floodp	CC,NGz	F122a				1			10
917	Adams	07/28/87	41	dead	upland	CC,NGz	F342			1				1
917		07/29/87					F342			1				1
917		07/30/87					F342			1				1
921	Adams	05/05/87	41	dead	floodp	CC,NGz	F263a	1						3
921		05/06/87					F263a	1						1
921		05/07/87					F263a	1						1
921		05/08/87					F263a	1						1
932	Adams	06/20/88	46	dead	floodp	CC,NGz	F484		1					1
932		06/21/88					F484		1					1
Quercus alba														
939	Adams	08/04/88	18	dead	upland	CC,Gz	F501				1			1
Quercus imbricaria														
908	Pike	06/19/87	28	dead	upland	IC,Gz	M462						1	1
Quercus rubra														
901	Pike	05/14/86	41	dead	upland	IC,Gz	na	3						18
903	Pike	05/05/87	61	dead	upland	IC,Gz	M383	1					1	6
903		05/25/88					F083		1					1
913	Pike	06/25/87	22	dead	upland	CC,NGz	F444		1					1
915	Adams	07/21/87	56	dead	upland	CC,NGz	F342			1				1
915		07/22/87					F342			1				1
915		07/23/87					F342			1				1
927	Adams	05/19/88	83	dead	upland	CC,NGz	F083		1					1
928	Pike	05/20/88	64	dead	upland	IC,Gz	F083		1					1
929		05/23/88					F083		1					1
933	Adams	06/21/88	31	dead	upland	CC,Gz	F282		1					1
933		07/28/88					F501				1			1
933		08/04/88					M721			3	2	4		9
936	Adams	07/28/88	45	dead	upland	CC,Gz	M721					1		1
936		07/29/88					M721					1		1
938	Adams	07/29/88	27	dead	upland	CC,Gz	F501				1			1
938		08/02/88					F501,M721				1	1		>2
938		08/03/88					F501,M721				1	1		11
uercus stellata														
005	Macoupin	08/06/87	25	dead	upland	Pas,Gz	F541			1				>1
904	Pike	05/04/87	36	dead	upland	CC,Gz	M383						1	1
905	Pike	05/01/87	36	dead	upland	CC,Gz	M383						1	1
905		05/06/87					M383						1	1
905		05/07/87					M383						1	1
905		09/19/89					na			1				8
929	Adams	05/26/88	39	dead	upland	CC,Gz	na	?						2
ssafras albidum														
004	Johnson	07/23/87	29	dead	upland	CC,Gz	M323						1	1
918	Adams	06/18/87	8	dead	upland	CC,Gz	M181						1	4
lmus americana														
006	Saline	05/10/88	33	dead	floodp	Wetland	F263b	1						1
Ulmus rubra														
003	Johnson	07/15/87	28	dead	upland	CC,Gz	M323						1	1
007	Ford	07/15/88	78	dead	floodp	CC,NGz	F524		1					5
007		07/16/88					F524		1					> 1
008	Henderson	07/11/89	51	dead	upland	CC,NGz	F138		1					18
906	Pike	05/08/87	33	dead	upland	CC,Gz	M383						1	1
907	Pike	06/18/87	14	dead	upland	IC,Gz	M462						1	1
909	Pike	06/22/87	44	dead	upland	IC,Gz	M462						1	1
910	Pike	06/23/87	22	dead	floodp	IC,Gz	M462						1	1
910		06/25/87					M462						1	1
912	Pike	06/24/87	24	dead	upland	IC,Gz	M462						1	1
914	Pike	06/26/87	18	dead	upland	IC,Gz	M462						1	1
916	Adams	07/22/87	38	dead	upland	CC,Gz	M223					1		1
930	Adams	07/26/88	18	dead	upland	CC,NGz	M244					1		1
930		07/27/88					M244					1		1
930		07/28/88					M244					1		1
930		07/29/88					M244					1		1
930		08/02/88					M244					1		1
930		08/03/88					M244					1		1
937	Adams	07/28/88	40	dead	upland	CC,NGZ	M424					1		1

Myotis sodalis typically roosted beneath the exfoliating bark of dead trees, although other roost sites were located beneath the bark of living trees and in cavities of dead trees. Thirty-eight of the 51 roost trees in Illinois occurred in upland situations (elevations >1 m above 100-year floodplain of perennial streams) and 13 trees occurred within floodplains. Within forested habitats, 32 roost trees occurred within closed (80%-100%) canopies, and 15 were found within intermediate (30%-80%) canopies. Of the 47 roosts in forested habitats, 27 were located in areas grazed by livestock. A single roost tree was found in each of the following habitat types: (1) a palustrine wetland with emergent vegetation (contained hundreds of dead trees killed by inundation as a result of mine subsidence), (2) a heavily grazed ridgetop pasture containing a few scattered dead trees, (3) a partially wooded swine feedlot, (4) a forested island in the Mississippi River, and (5) a clearcut encircling a segment of the intermittent stream where dead trees were retained for wildlife. Roost trees were not found in forests with open canopies (10%-30%) or in habitats classified as old field (≤10% canopy closure if trees were present), residential, and agriculturally cleared lands other than pastures with scattered trees.

Mean distances (±1 m) of 56 roost sites to roads (paved or nonpaved) and streams (perennial or intermittent) were calculated (Table 1). Some roost trees were used by more than one sex, age, or reproductive group. Bats selected roosts near to intermittent streams and farthest from paved roads. Distances of roosts from paved highways were significantly ($P \leq 0.05$) greater than from nonpaved roads for all groups. Roosts of all adult female groups (pregnant, lactating, post-lactating) were farther from paved roads than roosts used by juveniles or adult males. Roosts used by reproductively active females (pregnant or lactating) were rarely <500 m from paved highways. However, a lactating adult used two roosts each during one occasion, located 145 m and 210 m from the highway in densely forested upland slopes. The remaining roost sites occupied by pregnant or lactating adults occurred more than 700 m from paved highways (Table 2).

Table 2. Mean distance (m) of 56 *M. sodalis* roost sites to be selected natural and man-made features compiled by sex, age, and reproductive groups (six of the 48 roost trees were used by more than one group).

	DISTANCE (M)			
AGE/REPRO. GROUP (x=roosts)	PAVED HWY	NONPAVED HWY	*PERENNIAL STREAM	*INTERMITTENT STREAM
Pregnant (9)	1621	774	590	116
Lactating (15)	1409	605	842	123
Postlactating (3)	1560	663	16	51
Juvenile Female (5)	827	706	1797	113
Juvenile Male (7)	965	749	2116	149
Adult Male (17)	930	564	871	193

*Determined from Fishhook Creek 7.5 minute Quadrangle, U.S. Geological Survey

ROOST SITE FIDELITY

Some roosts within the Fishhook Creek study area were used by *M. sodalis* during successive summers, documenting their significance as traditional roost sites. The recapture of a reproductively active adult female in the Fishhook Creek study area two years after she had been banded as a juvenile indicated some site fidelity. Several males were also recaptured within the Fishhook Creek study area in successive summers. Thirty-eight roost trees discovered within the Fishhook Creek study area from 1986 through 1988 were examined during 1989 and 1990 to determine their annual attrition rates. On 19 September 1989, these routine examinations accounted for the capture of one of eight *M. sodalis* that was disturbed from their roost in a tree discovered for the first time in May 1987. Additionally, thirteen of 50 *M. sodalis* were captured on 20 September 1989 in a roost tree used as a maternity site by 95 females in May 1988. No bats were discovered in the 38 roost trees during an examination in June 1990.

Foraging Data

Fixed-station tracking was conducted on summer populations of *M. sodalis* within the Fishhook Creek study area, Pike and Adams counties, in 1987 and 1988. During these two summers, 14 bats were radio-tagged and their foraging activities monitored for 43 nights (Table 3). These tracking efforts resulted in >640 locations of bats during their peak foraging times (sunset through 0100 hrs.)

Table 3. Foraging ranges of reproductively active adult female, adult male and juvenile *M. sodalis* within the Fishhook Creek study area, Pike and Adams counties, Illinois during the summers of 1987 and 1989.

Reproductive Condition Sex, and *Age	Number Bats	Number Nights	Mean Foraging Range (ha)	Mean Distance from Roost(s) to Geometric Center (km)
FEMALE				
Ad -Pregnant	2	8	51.85	1.05
Ad -Lactating	5	16	94.25	1.04
Ad -Post-lactating	1	6	212.67	2.60
Juv-Nonrep.	2	3	37.00	0.25
MALE				
Ad -Nonrep.	2	6	57.33	0.56
Juv-Nonrep.	2	4	28.25	0.54
Total	14	43		

*Ad=adult, Juv=volant juvenile

A post-lactating adult female was monitored for six nights and had the largest foraging range of any sex or age group (Table 2). Although she occupied roosts which were 2.0 km and 3.2 km from the geometric center of her foraging range, she continued to return to the same foraging area that included the floodplain forests of Fishhook Creek. Pregnant adult females had a smaller mean foraging range (51.85 ha) but they did travel distances >1 km to reach preferred foraging areas adjacent to Fishhook Creek. One lactating female traveled a mean distance of 2.4 km to reach the geometric center of her foraging area. The mean foraging range for five lactating adult females was 94.25 ha during sixteen nights of monitoring. The distances of maternity roosts from the geometric center of foraging areas used by lactating bats ranged from 0.40 to 1.49 km (mean = 1.04).

Foraging ranges for volant juveniles was expectedly small; 28.25 ha for males and 37.0 ha for males. Juveniles with small foraging ranges also remained closer to their roosts to forage. Three radio-tagged juveniles did not travel the >2.4 km- distance to Fishhook Creek to forage but remained in the vicinity of their roosts. The roost of the fourth juvenile occurred 20 m from Fishhook Creek and she, therefore, remained in the vicinity of the creek to forage. Adult males were much more nomadic in their roosting behavior but chose roosts which were not far from their preferred foraging areas. The greatest distance an adult male traveled to forage was 1.47 km during one night.

In order to assess preferences for foraging areas, the software program PREFER (Johnson 1980) was used. This program is a component ranking system; it tests the hypothesis that all components (foraging habitats) are equally preferred and compares each habitat type that was actually used by the bats for foraging to the habitat that was available to the bats. The Fishhook Creek study area was divided into eleven basis habitat cover types: agricultural, hayland/pasture, old field (<10% canopy closure in trees present), other agricultural (which included feedlots, gardens, and farmsteads), closed canopy (>80%) upland forest, intermediate canopy (>30% to <80%) upland forest, open canopy (>10% to <30%) upland forest, closed canopy floodplain forest, intermediate canopy floodplain forest, open floodplain forest, and impounded water (farm ponds) (Table 4).

Broad, easily defined habitat cover types were used to avoid the introduction of bias in the analysis of what was available to the bats for foraging.

Table 4. Habitat cover types within the 3,670 ha Fishhook Creek study area and their percent total coverage.

HABITAT COVER TYPES

Open	(ha)		Forest		(ha)	
Crop	1,589	(43.2 %)	Upland	CC	896	(24.4%)
				IC	190	(5.2 %)
Hay/ Past	669	(18.2 %)		0C	33	(<1 %)
Old Field	135	(3.7 %)	Floodplain	CC	61	(1.7 %)
				IC	15	(<1 %)
Other Ag	72	(2.0 %)		0C	5	(<1 %)
Total	2,465	(67.1 %)			1,200	(32.9 %)

CC=closed canopy (80-100%); IC=intermediate canopy (30-80%); OC=open canopy (10-30%)

Our results indicated that reproductively active adult females (pregnant, lactating, and post-lactating) preferred to forage in floodplain forests having closed canopies (canopy closure >80% dominant canopy trees). In fact, floodplain forests were ranked the first four preferred foraging habitats, sharing this important designation with only impounded water. It is important to understand that floodplain forests and impounded water (farm ponds) were the least abundant habitat types available to the bats, yet they included these types within their foraging ranges (Figure 3).

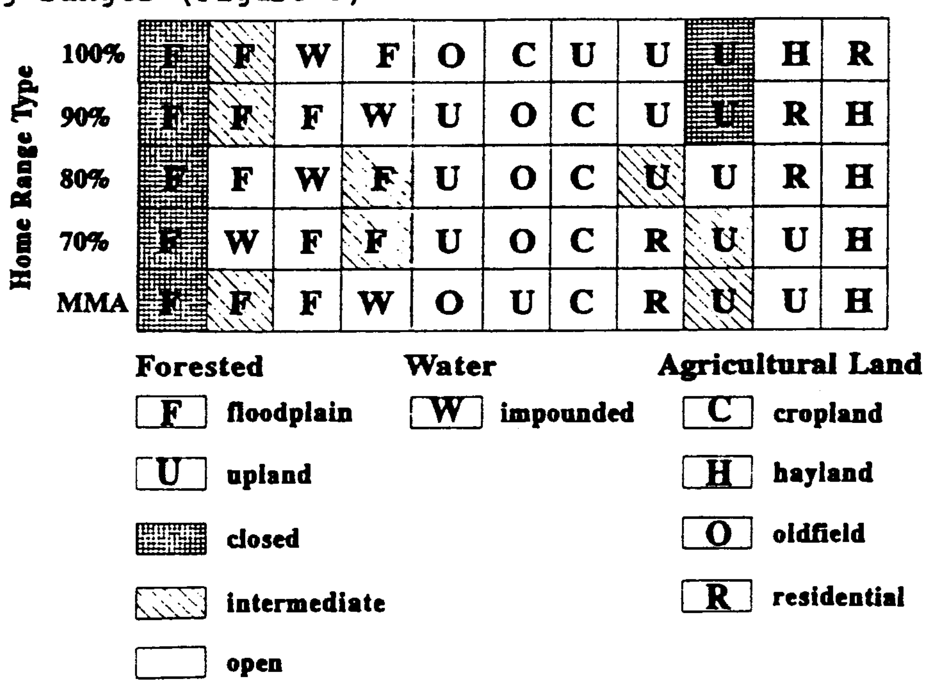


Figure 3. Foraging habitat component ranking as a result of the preference assessment program PREFER.

DISCUSSION

Although 190 sites were mist netted during this study, the locations of new county occurrence records were primarily in areas where historical records were known from adjacent counties (Figure 1). The only exceptions to this distribution were the captures of *M. sodalis* in Ford and Vermilion counties in the east central part of the state. These counties and Henderson county in western Illinois constitute the most northern summer limits for this species in Illinois. Blackball Mine in LaSalle County is approximately 50-60 miles north of a line that would connect the east-west northernmost limits and several hundred *M. sodalis* hibernate at this site. There is one summer recovery record from this site. A single *M. sodalis* was captured in northeastern Missouri approximately 150 miles southwest of the hibernaculum. Collectively, these records suggest that *M. sodalis* is absent from the northern one-third of Illinois during the summer months. Bowles and Clark (1983) speculate that long term climatic factors may operatively define the northern limit of the summer range for this species in Iowa. We believe that an examination of climatological data for Illinois and other states with summer records for *M. sodalis* would be useful. Until such an analysis is completed we feel that a firm delineation of the northern limit of *M. sodalis* summer range in Illinois is premature.

Humphrey (1978) favored research on the biology of small populations of *M. sodalis* because he felt that such populations may become increasingly important in management of the species if larger populations continue to be threatened. Despite strict conservation measures at winter caves, *M. sodalis* populations have continued to decline at an alarming rate (Clawson 1987). Studies of small summer populations in Illinois have provided much needed information concerning *M. sodalis* summer populations. As a result of the first six years of the Illinois statewide program of Indiana bat research, specific information concerning summer habitat requirements and roost tree selection have been gathered. These data will be used to update the Recovery Plan for the Indiana bat and will help to establish objectives to the protection of summer habitat.

The feasibility of using miniature radio-transmitters to study *M. sodalis* foraging and roosting ecology was proven by the results of the Illinois statewide studies. We did not ascertain how much a sudden increase in body weight affected foraging success. Male M462 was recaptured and weighed after radio-tracking his foraging activities for nine nights; his body weight had been maintained and he weighed exactly the same as he had when captured. Juvenile male M721 also maintained his weight after eight nights of radio attachment. The first *M. sodalis* to ever have had a radio attached was a juvenile; she returned to Fishhook Creek two years later as a reproductively active adult. Radio-tagging has become an accepted method for studying *M. sodalis* roosting and foraging behavior largely as a result of the precedent set by the Illinois investigations.

We assumed that roost selection by radio-tagged *M. sodalis* did not deviate substantially from nonradio-tagged bats. We observed sufficient numbers of nonradio-tagged roosting *M. sodalis* together with radio-tagged bats to support this assumption.

Previous studies have demonstrated clearly that floodplains are significant habitats to *M. sodalis* summer populations (Humphrey *et al.* 1977; Cope *et al.* 1978; USDI 1983). Our data substantiated these past findings but also illustrated that upland habitats were used by maternity populations far more extensively than previously expected. Roosts were generally close to upland, intermittent streams and farther from perennial streams than we anticipated. Two colonial maternity roosts were within 37 m of a perennial stream but the remaining six colonial roosts occurred at least 285 m away. Our data indicate that, although riparian habitats represent a biologically significant component of the domain of *M. sodalis*, this species did not limit its selection of maternity roosts to riparian habitats. Reproductively active adult females are willing to travel distances up to 2.5 km from their roosts to reach foraging areas nearer to perennial streams. The spatial relationships of roost trees to roads (paved or unpaved) may predetermine their suitability as roost sites. Colonial (>5 bats) maternity roosts occupied by pregnant or lactating adult females occurred at least 450 m from paved roads.

We feel that a variety of summer roosts in floodplains and uplands associated with perennial streams is essential to the reproductive success of *M. sodalis*. The selection of roost sites by *M. sodalis* is governed by the availability and suitability (quality) of potential roosts: (1) the quantity of loose bark (2) its ability to provide protection (microclimate) from the external environment, and (3) its relationship to roads, streams, alternate roosts, and foraging areas. If alternate roost sites are unavailable, unseasonably cool weather in spring or early autumn may affect reproductive success by delaying embryonic development or by directly increasing juvenile mortality. Competition for suitable maternity roost sites may limit the reproductive success of *M. sodalis* populations where roosts are limited.

We consider optimal roost sites to occur beneath the bark of dead trees with adequate spaces to allow for air circulation and for bats to change their position on the trunk. Although pregnant and lactating bats roosted in cavities for short periods of time, no maternity colonies were discovered in cavities during this study. *Myotis sodalis* selected a wide range of roost sites. Sex, age, and reproductive groups showed no significant differences ($P \geq 0.1$) between species of trees they selected as roost trees, but their selections were limited to certain tree species. At the Fishhook Creek study area, 19 species of dead trees were identified, however, only 10 species were used by *M. sodalis*. (Table). Species such as *Populous deltoids* (cottonwood), *Quercus rubra* (northern red oak), *Q. stellata* (post oak), *Q. imbricaria* (shingle oak), *Carya ovata* (shagbark hickory), *C. cordiformis* (bitternut hickory), and *Ulmus rubra* (slippery elm) possess morphological characteristics that make them highly suitable for *M. sodalis*. Senescent, severely injured (e.g., lightning-struck), or dead portions of these species possess bark that is tenacious (although length of persistence varies greatly according to species) and springs away from the trunk upon drying. Living C. ovata produces long strips of loosened but very persistent outer bark that allows some bats (although fewer in number) to find adequate shelter. Such species as *Acer negundo* (box elder), *Betula nigra* (river birch), *Fraxinus americana* (white ash), *Fraxinus pennsylvanica* (green ash), *Juglans nigra* (black walnut), *Prunus serotina* (wild black cherry), and *Robinia pseudoacacia* (black locust) were not used as roosts by *M. sodalis* during this study.

Humphrey *et al*. (1977) compared the thermoregulatory characteristics of an *M. sodalis* roost site beneath the bark of a dead C. cordiformis to the roosting spaces beneath the naturally exfoliating bark of a living C. ovata. We agree with Humphrey *et al*. (1977) that certain species of living trees are essential as alternate roosts during wet and/or cool weather or other unfavorable environmental conditions. Tree cavities or hollow bole portions of trunks and limbs also provide some suitable roost sites for *M. sodalis*. Although pregnant and lactating bats roosted in cavities for short periods of time, no maternity colonies were discovered in cavities during this study. Pregnant bats may use cavities as transient roosts or as gathering (staging) sites in early spring until suitable bark roosts, sheltering other *M. sodalis*, are located.

Our data indicate that *M. sodalis* have strong attachments to summer foraging and roosting habitats in Fishhook Creek and adjacent watersheds. As stated by Humphrey *et al*. (1977), traditional summer homes are essential to the reproductive success of local populations. The return of female F083 to Fishhook Creek to bear her young two years after she (known as juvenile F122 in 1986) was born there documents multiple summer fidelity in this species. Several males were also recaptured at Fishhook Creek in subsequent summers. Some roosts were used by *M. sodalis* during successive summers, further demonstrating their significance as traditional roosts. If these traditional roosts are not available, adult females are faced with finding suitable maternity sites at a time when they are already stressed from the rigors of hibernation, migration, and the increased energy costs of pregnancy.

Prior to this study, the majority of *M. sodalis* roosts were discovered only after the roost had been destroyed. Tree removal, either for harvest or land clearing (i.e., agriculture, utility and transportation rights-of-way), has been the most direct threat to *M. sodalis* summer roosts. The selective harvest of living trees, however, need not endanger summer roosts. Timber harvest activities within the Fishhook Creek study area did not directly affect known roosts or discourage bats from foraging in the harvested area. Noise and exhaust emissions from machinery could potentially disturb colonies of roosting bats, but such disturbances would probably have to be severe to cause roost abandonment. Accelerated bark sloughage or complete windfall of the roost tree may indirectly result from harvesting if the trees become more exposed to environmental rigors (e.g., rain, wind). Another indirect impact of harvesting may be increased solar heating due the to lack of shading. As a consequence, the microclimate of the roost may become unsuitable.

MANAGEMENT RECOMMENDATIONS

The use of radio transmitters during this study facilitated the location of *Myotis sodalis* roost sites and the development of spatial estimates of foraging ranges and their relationship to landscape features. The most meaningful analysis of these data logically focus on reproductively active females as their success in bearing and rearing young determines annual recruitment to the overall population. The basis for the discussion and recommendations that follow are predicated on the following assumptions:

1. The Fishhook Creek study area is representative of good to excellent summer habitat for *M. sodalis* and,

2. *M. sodalis* at Fishhook Creek are behaviorally typical of the species.

We believe that management efforts for *M. sodalis* on summer range should be focused on the prevention and elimination of activities that degrade or appreciably alter existing habitat that is currently utilized or determined to be suitable for use by the species. The merits and feasibility of habitat restoration should be evaluated but the associated costs and the length of time between the initiation of such efforts and development to suitability render this approach ineffective to address the immediate needs of the population.

In order to adequately assess the impacts of any given activity upon local populations of Indiana bats it is necessary to determine the availability of suitable roosts and to determine foraging habitat quality.

DETERMINATION OF ROOST SUITABILITY\AVAILABILITY

<u>Ranking of Potential Roost Trees</u>

Trees may be evaluated according to their potential to provide roost sites based upon a visual estimation of the amount of loose and peeling bark on the trunk(s) and main limbs:

High = ≥25% coverage
Moderate = ≥10% but >25% coverage
Low = <10% but >1% coverage
None = devoid of loose and peeling bark

Hollow bole portions (cavities) of tree trunk(s) or limbs, alive and dead, have been used as roosts by *M. sodalis*; however, these potential roosts can only be recorded as present or absent.

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Aspect and Microclimate Considerations

The maternity roosts discovered thus far (Humphrey *et al.* 1977; Gardner *et al.* 1991) were located in open or only partially closed sub-canopies which allowed bats to exit or approach their roosts unencumbered. Optimal roost microclimates are created beneath the bark of dead trees when the bats have adequate roosting spaces which allow them to move to different sides of the trunk. Roost sites exposed to intense solar radiation during mid-summer (e.g., shaded ≤25% of the daily photoperiod) may exceed potentially lethal temperatures for *M. sodalis* and are considered unsuitable for roosting.

Present Availability Assessment of Potential Roosts

It may be feasible to make complete inventories of potential roost trees (defined above) and rank their suitability within small study areas [≤32 ha (80 ac)] or such linear study areas as highway rights-of-way alignments, pipelines, and transmission lines. Limitations to conducting complete inventories include excessive lengths and widths of study corridors which intersect large areas of forest cover and the relative abundance (density) of potential roosts within the forests. In areas too large to inventory completely, such accepted minimal area sampling methods as described by Hays *et al.* (1981) must be used to determine roost tree density (e.g., point-quarter, tenth-hectare quadrate).

1. Optimal densities of potential roost trees ≥22 cm (9 in) dbh are: Upland Habitats = 64 trees/ha (27/ac)
   Floodplain Habitats = 41 trees/ha (17/ac)
2. Densities of potential roost trees less than the optimal densities stated in 1. above but ≥1 tree/ha (0.4/ac) ≥22 cm (9 in) dbh in either habitat is considered suitable roosting habitat.
3. Densities of potential roost trees of <1 tree/ha (0.4/ac) 22 cm (9 in) dbh in either habitat is considered only marginally suitable at best and would not be favorable for the establishment of maternity colonies within a given area.

DETERMINATION OF FORAGING HABITAT QUALITY

Calculated by the convex polygon method, the mean nightly foraging areas (n=16 nights) for lactating adult female *M. sodalis* (n=5) was 94.25 ha; however mean nightly foraging area calculated by the capture radius method was 344 ha. As the foraging area polygons of reproductively active adult female *M. sodalis* exhibit strong circularity we suggest that the size of the foraging area utilized is more accurately represented when calculated by the capture radius method. Cover type analyses of 344 ha circular plots at 49 *M. sodalis* capture sites throughout the state were utilized to establish standards for the classification of any given area as essential, suitable, or unsuitable summer habitat (Table 5). These standards have been provided to the Indiana bat/Graybat Recovery Team for review and consideration.

Table 5. Maximum/minimum percent cover standards for *M. sodalis* foraging habitat classification

COVER TYPE	OPTIMAL	SUITABLE	UNSUITABLE
Agricultural Cropland, Hayland Pasture, Orchards, Vineyards, Nurseries etc.	≤66%	<95%	≥95%
Urban Residential, Industrial, Utilities Commercial, Transportation, Mixed Urban	≤2%	>2% but <14%	≥14%
Forested Deciduous Mixed	≥33%	<33% but ≥5%	<5%
Water Streams, Canals, Reservoirs, Lakes, Ponds, Wetlands, Borrow Pits	≥0.1%	≤0.1% but >0	0%
Other Strip Mines, Dry Quarry Pits, Barren Land	0%	≤11%	>11%

MANAGEMENT STRATEGIES

In March of 1991 the roost tree and foraging habitat data were presented to the Indiana/Gray bat Recovery Team. Based upon the ensuing discussion the following recommendations were developed and are currently being reviewed and evaluated.

ESSENTIAL HABITAT

Essential summer habitat for the Indiana bat *(Myotis sodalis)* includes any site within the currently delineated summer range of the species that meet the following criteria:

1. Decidous forest cover ≥30% and permanent water available within a 1 km circle and,

2. Suitable roost trees located within .4 km of #1.

SUITABLE HABITAT

Suitable summer habitat for the Indiana bat *(Myotis sodalis)* includes any site within the currently delineated summer range of the species that meet the following criteria:

1. Decidous forest cover ≥5% and permanent water available within a 1 km circle and,

2. Suitable roost trees located within .4 km of #1.

IMPACT ASSESSMENT

Any activity that may result in the alteration or elimination of essential habitat as defined above shall be avoided. If avoidance is not possible, then the responsible party shall be required to mitigate for the loss of habitat at a ratio to be determined. If mitigation is not possible, the responsible party shall compensate for the loss of habitat at a ratio to be determined.

Any activity that may result in the alteration of elimination of suitable habitat as defined above shall be required to conduct a mist net survey to determine the presence or absence of *M. sodalis* at the site in question. The results of the survey shall determine whether or not the project may proceed and under what constraints.

MIST NETTING GUIDELINES FOR INDIANA BATS *(Myotis sodalis)*

The following guidelines below have been developed to:
1. Maximize the potential for capturing *M. sodalis* and,
2. Standardize mist netting procedures for this species.

SAMPLING SEASON

- May 15 - August 15
  These dates define the acceptable period for mist net efforts to document occurrence on summer range.

EQUIPMENT REQUIREMENTS

- Mist nets
  Monofilament construction of low visibility rating
  Mesh ≤ 1½"

- Hardware
  Portable, durable, and rugged - identical or similar to that described in Gardner et al (1989).

WEATHER CONDITIONS

(netting shall only be conducted under the following conditions)

- No precipitation

- Temperature ≥ 10°C

- Wind speed - still to calm

- Light conditions at net site
  - No considerations under a closed canopy
  - Cloud cover or moon < ½ full if site is in the open

SAMPLING PROCEDURES AND REGIMEN

- Net set
  - stacked nets ≥ 4m high

- Net set distances
  - 1 set/km of stream corridor

- 3 net nights per site
  (1 net night = 1 set/site)

- Netting duration
  - sunset until 0200 hrs or beyond

- Net set positioning
  - ground or water level up to canopy with enclosing foilage or banks on both sides

- Nets must be checked every 20 minutes

- No disturbance within 50 m of the nets

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