Patterns of Water Resource Use

and

Continued Census of Bats in Boulder County

OVERSITE AGENCY: *City of Boulder Open Space (Clinton Miller, Wildlife Biologist)*

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STATEMENT OF OBJECTIVES AND GOALS: With the apparent loss of abundance and biodiversity of bat species in Colorado (Armstrong et al., 1994; Armstrong et al., 1995) there is a strong need for data in understanding patterns of resource use by Coloradan bats. Although some data have been gathered recently on Boulder County bats (Adams, 1995), we still have very little understanding the distribution and abundance of bat species as well as the location of summer and winter roost sites. The original goals of the study were to locate, through the use of radio telemetry, roost sites for the nine species of bats commonly present in Boulder County and to begin gathering data on patterns of water resource use. Unfortunately, funding was not available for the radio-tracking portion f the study and we still lack data on roost site locations. For 1996, I concentrated on gathering further data on species abundance and distributions by continuing to net bats at various sites throughout Boulder County and I also undertook efforts to understand water use patterns. Four hypotheses were tested: Hypothesis 1: Bat species tend to visit watering sites predominately in species groups and not as lone individuals. Hypothesis 2: Most species tend to visit watering sites multiple times per night. Hypothesis 3: Order of species visitation will be similar at all watering sites. Hypothesis 4: There is seasonal variation in species diversity at watering sites.

METHODS: The study was conducted from 30 May to 23 August 1996 with the help of Kate Thibaulk, an undergraduate field assistant from Boston College. Eleven sites (Table II) were repeatedly samples throughout the summer and all bats captured were caught in Japanese mist nets. To avoid affecting visitation patterns by bats, sites were netted at no less than 10 day intervals. If activity was low due to inclimate weather the site was sampled again, sometimes on the following night. Data were recorded on species, sex, reproductive condition, relative age, and weight. In some instances, light tags made from shrink-tubing and injected with chemoluminescent fluid were glued to the dorsal fur with superglue paste before the individual was released. Chemoluminescent colors ranging from blue, yellow, green, and white color-coded individual species. When light-tags were applied, weights of bats were not taken to lessen stress and handling time. To record the return of light-tagged individuals, we sat vigil at water holes until that night's bat activity ceased. A bat detector was used to measure activity patterns based upon the presence or absence of echolocatory calls. Activity indices were calculated per site (total activity time/total inactivity time).

***Statistics*.**--Species richness indices were calculated using both the Margalef (R1) and Menhinik (R2) equations (Ludwig and Reynolds, 1988) which adjust for differences in sample sizes. Species diversity indices were also calculated per site using the Shannon index. Species evenness was calculated per site using evenness indices E4 and E5 which are relatively unaffected by species richness.

RESULTS: A total of 2,170 net nights (70 nets x 31 nights) at 11 sites resulted in the capture of 242 individuals of nine species (Table I). Locality data for netting sites are listed in Table II. Stacked-bar graphs illustrate relative number of bats per species captured per site (Fig. 1). Stockton Cabin had the highest number of species with Bear Creek, South Shanahan pond and North Shanahan pond also ranking high in numbers. For the second year in a row, the number of males captured exceeded the number of females captured for most species (Fig. 1B). Only for *Myotis volans* were females captured numbered more than males and data for this species were strongly influenced by the 30 May Bear Creek assemblage which included a maternity colony of *M. volans*. The maternity colony was not present when the site was sampled at later dates.

<u>WITHIN SITE DATA</u>

Capture data show some species-specific temporal patterning in timing of visitation by species to watering sites.

<u>Bear Creek: General Pattern</u>.--First capture on 30 May (Fig. 2a) was *Eptesicus fuscus*. Single individuals of *E. fuscus* were captured at 2139h and 2200h. Most captures on 30 May were at 2200h and consisted of 10 female *Myotis volans*. All were obviously pregnant and represented a maternity colony. Singe individuals of *M. lucifugus* and *M. evotis* were also captured as were two individuals of *M. thysanodes*. On 2 July the assemblage of bats using the site changed (Fig. 2b). Only one *M. volans* was captured and it was a nonscrotal, adult male. Most captures were *M. lucifugus* all of which were nonscrotal, adult males representing a bachelor colony. Two individuals of *Myotis ciliolabrum* were also captured. On 11 August, *M. lucifugus* was again the first group of bats to visit the site (Fig. 2c), however number of captures was less than on 2 July (n = 1). Most captures were of *M. thysanodes* (n = 6), *M. ciliolabrum* (n = 4), and *E. fuscus* (n = 6)(Table I). ***Activity Patterns.***--Activity time lines show ebb and flow of activity at the site for 30 May and 2 July (Fig. 2a, b). No data on timing of visitation were obtained on 11 August. Highest relative activity was in July, activity index = 8.93 (Table III). The site was largely inactive on 28 June probably due to windy, rainey weather (activity index = 0.09).

<u>Stockton Cabin</u>: ***General Pattern.***--First and last capture consisted of *M. lucifugus*. Individuals of *Myotis evotis* and *M. volans* were captured intermittently and repeatedly.

Corynorhinus townsendii was captured once. *Eptesicus fuscus* was captured on three separate occasions between 2200h and 2350h (Table 1). Only at 2200 was there multiple captures consisting of both *M. volans* and *E. fuscus*. On 13 July only six bats were captured at Stockton Cabin (Fig 2b). First capture was *Myotis thysanodes* which was not captured previously on 27 June. Highest number of captures at Stockton Cabin (*n* = 26) occurred on 12 August (Fig 2c). On three occasions multiple captures of multiple species occurred. *Myotis lucifugus* (n = 5) was the earliest species captured and appeared to arrive at the site in a group of about 20 individuals. Their visitation overlap with *M. volans* (*n* = 2). *Myotis evotis* visited the site more times (six) than any other species on this date and on two of these occasions overlapped with *M. thysanodes* and on one occasion with both *M. thysanodes* and *C. townsendii*. ***Activity Patterns.***--Activity time lines for 27 June, 13 July, and 12 August shows ebb and flow of activity at the site in relation to capture times (Fig. 2a). Table III gives activity indices for capture dates. In June activity time was almost three to one, this dropped off in July (almost two to one), but skyrocketed in August (approaching 38 to one). ***North Shanahan*: *General Pattern.***--For 30 June first and most captures were of *M. lucifugus* (*n* = 11) and most of these captures occurred in the initial visitation flux of the evening and consisted of nonscrotal males representing a bachelor colony (Fig. a). *Eptesicus fuscus* was also dominant at the site (*n* = 10) and most of these, but not all, were pregnant females (Table I). This was the only site where *Lasionycteris noctivagans* was captured (*n* = 2). Also captured were *Lasiuris cinereus* and *M. thysanodes*. On 31 July, number of species captured dropped from five to two and consisted only of *M. lucifugus* which visited the site early, and *E. fuscus* which visited the site later. There was very little overlap in visitation between these species (Fig. 4b). Curiously, most *M. lucifugus* were males, but some females and young of the year also visited. For *E. fuscus* all adults were females and young of the year varied in sex (Table I). ***Activity Patterns.***--Activity data were obtained only on 31 July at North Shanahan and indicated no cessation in visitations to the site (Fig. 4b). No activity index was calculated since activity was continuous (Table III).

South Shanahan: General Patterns.--On 6 June six bats were captured. Two of these were *E. fuscus*, the others were *L. cinereus*, *M. thysanodes*, *M. volans*, and *M. lucifugus*. *Myotis lucifugus* was the first captured (Table I)(Fig. 5a). *Eptesicus fuscus* and *M. volans* overlapped in capture at 2225h (Fig. 5a). On 19 July 13 bats were captured at the site (Table I)(Fig. 5b). Of these, 11 were *M. lucifugus* which was the first to visit the site and dominated throughout the night (Fig. 5b). One individual each of *L. cinereus* and *M. ciliolabrum* was also captured (Fig. 5b). ***Activity Patterns.***--Activity was consistent during the first 50 minutes on 19 July, after which there were 3 inactive periods (Fig. 5b). Activity index for 19 July was 5.00 (Table III).

Abbey Pond*: *General Patterns.--On 1 August, most captures at the site consisted of *M. lucifugus* (n = 4) which was the first species caught and the only one observed between 2049h and 2121h (Fig. 6a). *Eptesicus fuscus* (n = 3) visited the site between 2121 and 2201 and, except for one individual of *M. thysanodes,* was the only species captured during this time. On 23 August only two individuals of one species (*M. thysanodes*) were captured. ***Activity Patterns.***--Time lines indicate overall activity at the site with two periods of inactivity on 1 August and three on 23 August (Fig. 6a, b). Activity indices varied between 2.47 on 1 August to 17.50 on 23 August (Table III).

Gregory Canyon: ***General Patterns.***--Only four individuals of three species (*M. volans, M. ciliolabrum, and Lasiurus cinereus*) were captured in four net nights (Table I). ***Activity Patterns.***--An activity index for Gregory Canyon was calculated to be 1.10 (Table III).

Red Rocks Trail: ***General Patterns.***--Five captures consisting of *E. fuscus* (n = 4) and one unidentified *Myotis* species that escaped before handling occurred on 6 July (Table I). ***Activity Patterns.***--Activity index was 4.25 on 6 July (Table III).

Buckingham Park: ***General Patterns.***--Four individuals of one species (*M. thysanodes*) were captured at this site and all were lactating females representing a maternity colony estimated to be about 20 individuals (Table I). ***Activity Patterns.***--Activity began with a strong pulse, then trailed off to low activity and eventually to zero. An activity index was not calculated.

Lindsay Pond: ***General Patterns.***--Two individuals of one species (*M. thysanodes*) were captured for one net night (Table I). Both individuals were lactating females representing a maternity colony estimated to consist of 20 individuals. ***Activity Patterns.***--Activity index at this site for 21 July was 28.00 (Table III).

Schneider Pond: ***General Patterns.***--Four individuals of one species (*M. ciliolabrum*) were captured over eight net nights (Table I). All were lactating females representing a maternity colony of not less than two individuals. ***Activity Patterns.***--Activity index for this site calculated for 27 July is 8.75 (Table III).

ACROSS SITE RICHNESS, DIVERSITY, AND EVENNESS

Table IV shows species richness, diversity, and evenness indices for the four sites with highest capture rates. Highest richness was for Stockton Cabin (R1 = 1.88, R2 = 1.25. Stockton Cabin also ranked highest in diversity (Shannon Index = 1.79). South Shanahan site was second in species richness and third in diversity, but last in evenness. Bear Creek ranked second highest in diversity and highest in species evenness. North Shanahan ranked third in richness, last in diversity, and third in evenness. Ranking last in evenness of species composition was South Shanahan.

WITHIN SITE RICHNESS, DIVERSITY, EVENNESS

Indices for species richness, diversity, and evenness were calculated for three sites where sample sizes per trapping session were high enough .

Bear Creek.--Species richness, diversity, and evenness varied throughout the summer (Table V). Highest richness was in July, whereas highest diversity occurred in August. Highest evenness among species occurred in May.

Stockton Cabin.--Species richness was highest in July as was evenness. Diversity, however, was greatest in August (Table VI).

North Shanahan.--Two nights of data separated by almost a month showed a drop in number of species from five to two consisting of a bachelor colony of *Myotis lucifugus* and a maternity colony (females and juveniles) of *Eptesicus fuscus* (Table VII). Therefore, as expected, richness and diversity drop off precipitately from June to July, however, there is an increase in the evenness due to an almost equal number of captures of both species (Table I).

EFFECTIVENESS OF LIGHT TAGGING

In an effort to understand patterns of water resource visitation by bat species in a way independent of capture data, light tags were applied to the dorsal fur of 64 bats. Because the chemoluminescent light-tags lasted approximately 12 hours, the success of observation as reliant upon return of those individuals to the site within that time. On most occasions this was not the case, but some data were gathered by this method. On 27 June two *Myotis evotis* which carried green light tags, returned to the site approximately 90 minutes after being tagged. They made several passes and were not observed again. On 1 July at Gregory Canyon, a *Myotis ciliolabrum* was tagged with a yellow light. Although it never returned to the water hole, we observed it for about 15 minutes foraging in a nearby clearing. This gave us some insight into the foraging patterns of this species. This individual was foraging in the open and at the forest edge making figure eight flight paths and alternating between two open patches separated by Ponderosa Pine trees. On 19 July a tagged *Myotis lucifugus* was observed flying through Poderosa Pine at South Shanahan, but it never was observed revisiting the water hole.

CONCLUSIONS: All eight sites tested for manic periods show high activity indices illustrating the importance of water resources to bat populations in the area. Water sources provide two needed ecological components for bats: 1) water itself and 2) attraction and concentration of insects used for food. Because water holes tend to concentrate bat activity, it is at these times that interspecific interactions (i.e. direct competition) among the assemblage may be strongest. Due to this, interactions around water holes may act to organize assemblage structure and, if so, this structure should be quantifiable.

Data collected in 1996 gave much insight into patterns of water use by the Boulder bat assemblage as well as increased understanding of species richness, diversity, and evenness at the various sites. Number of sites sampled increased by four over 1995 for a total of eleven sites. Number of bats captured was almost doubled over 1995. Generally, species diversity is highest in areas near the Flat Irons rock formations. This probably is due to the diversity of roost sites available to bats near the rocky and precipitous outcroppings. The Flat Irons may be a crucial breeding area for the Front Range bat species. This cannot be determined unless radio telemetry studies are undertaken to locate bat roosting site and an effort is made to understand roost site preferences.

In terms of species-specific patterns of water use, *Myotis lucifugus* is typically the first species to arrive at watering sites and typically does not make multiple or repeated visitations. In addition, *M. lucifugus* tends to arrive in gangs, independent of colony makeup (i.e. bachelor versus maternity). Time of visitation is usually at twilight and much of their water use and foraging at the sites occurs before dark and at a time when people still tend to be active in the Parks. Due to these two factors (i.e. single visitations and early arrivals) makes this species susceptible to disturbance at watering sites. Activity time lines indicate periods of inactivity around water holes (Fig. 1, 2 ,3 ,4, 5, 6). In some cases, inactive periods correspond with the subsequent capture of a different species and therefore, may demarcate assemblage changeover at the site. For this year, sites of high species diversity were concentrated on for gathering data to understand patterns of water resource use. Other sites, however, which are lower in diversity, should also be studied more intensely to ascertain timing patterns for species where competition for this limited resource is less, or altogether nonexistent.

Interestingly, species richness and diversity are highest at Stockton Cabin (Table IV) which is one of the smallest diameter (< 7 m) and most shallow (< 20 cm in depth) watering holes used in the study. In addition, a hiking trail passes directly through the creek at exactly where the bats are active and therefore, the potential for human disturbance at this site is high. Most of the bats using the site are males (n = 33) and not females (n = 8) and so the chance of maternity colony disturbance at Stockton Cabin is low. Diversity and Evenness are highest at Bear Creek, another relatively small water hole (diameter < 10 m and depth < 20 cm). Only more data collection will tell if smaller watering sites are truly higher in richness, diversity, and evenness or whether this pattern may perhaps be due to sampling error residing in the fact that smaller water sources are more easily netted and therefore, the statistics are biased towards netability of sites rather than actual assemblage composition. The highest number of bats captured in 1996 (Fig. 1A), however, was at North Shanahan which is the larger (diameter > 30 m. depth > 105 cm) of the watering sites sampled. This gives some evidence that capture success is not necessarily directly related to size of the water hole.

Richness, diversity, and evenness did show variability at all sites sampled (Tables V, VI and VII). More data are needed to draw strong conclusion since activity among bat species may vary night to night dependent upon many abiotic factors. Of interest, however, are sites where females from maternity sites bring their young to forage and drink, such as North Shanahan. The drop in species number from five to two (R1 from 1.243 to 0.256) (Table VII) at this site is quite dramatic. This suggest that juveniles may be affecting the structure of species assemblages at water sites in some way, something that I am particularly interested in (Adams 1996, In Press). More data need to be collected in order to understand shifting assemblage patterns through time in this area.

For the Future: Of paramount importance in managing Boulder County bats, is the location of roosting sites with the use of radio telemetry. This should be a high priority in the next phase of the study. In addition, marking individuals with numbered, plastic, splitring wrist bands would allow understanding of movement patterns among the various water sources in the area if individuals can be recaptured. This year we captured the same *Eptesicus fuscus* individual, identifiable by a tick on its tail vertebrae, at both North Shanahan and Abbey pond on consecutive nights. *Eptesicus fuscus* is know to be wide-ranging when foraging, but whether *Myotis* species move as readily from pond to pond is so far undocumented. It is currently unclear if bats typically move around to use various water resources or if they are strongly loyal to one particular source. If the latter is true, human disturbance at water holes could be more impacting and consequential. Because this is the first study to attempt at documenting temporal patterns of water use in bats, this past summers priority was to determine what methods work best. The light tagging provided some data, but not on a consistent basis and is rather time consuming as preparation of tags would require about three hours prior to netting. However, combining light tagging with another technique such as radio telemetry or Anabat sonar detection would allow for tracking and visual observations of foraging bats. More capture data are necessary in supporting patterns of species richness, diversity, and evenness at the watering holes. In addition, more data need be gathered from sites of low diversity as a comparison with high diversity sites. This would help answer questions concerning how species richness, diversity, and evenness affect temporal patterns of water use. In addition, location of roost sites is paramount in understanding water resource use patterns since distance that bats must travel to water resources may influence assemblage timing.

As things stand today, we do not yet have enough data for the City of Boulder to build a meaningful management plan for bat conservation in its open spaces. Because bats are so susceptible to disturbance, sampling of sites has been done in a conservative manner which allows for sampling to be carried out at each site three to four times per summer. Radio telemetry would allows one to follow individuals for several days without trapping at the site nearly as much. I am currently writing an NSF grant to acquire one or two Anabat sonar detection systems which is capable of distinguishing bat species by echolocation call. This will allow for noninvasive data collection at the water sites. Netting at the sites, of course, will still need to occur periodically to gather sex, weight, and reproduction condition data.

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TABLE I. *Capture data for City of Boulder 1996 bat census. Ml* = Myotis lucifugus, *Mc* = Myotis ciliolabrum, *Me* = Myotis evotis, *Mt* = Myotis thysanodes, *Mv* = Myotis volans, *Lc* = Lasiurus cinereus, *Ln* = Lasionycteris noctivagans, *Ef* = Eptesicus fuscus, *Ct* = Coryorhinus townsendii. *L = lactating, NL = nonlactating, PL = postlactating, P = pregnant, NP = nonpregnant, S = scrotal, NS = nonscrotal. ABB = Abbey Pond, BC= Bear Creek Pool, BP = Buckingham Park Creek, GC = Gregory Canyon Pool, LIN = Lindsay Pond, NSH = North Shanahan Trail Pond, RR = Red Rocks Aqueduct, REY = Reynolds Ranch, SCN = Schneider Pond, SC = Stockton Cabin Pool.*

DATE	TIME	SITE	SPECIES	AGE	SEX	REPRO	WGT.
may 30	2100	BC	Ef	Adult	Male	NS	10.9 g
may 30	2115	BC	Mv	Adult	Female	NLNP	7.9 g
may 30	2139	BC	Mt	Adult	Female	NLNP	8.0 g
may 30	2139	BC	Ef	Adult	Male	Inguinal	16.0 g
may 30	2139	BC	Ef	Adult	Male	NS	11.4 g
may 30	2139	BC	Mt	Adult	Female	NLNP	7.6 g
may 30	2200	BC	Mv	Adult	Female	PNL	7.5 g
may 30	2200	BC	Ef	Adult	Male	S	14.0 g
may 30	2200	BC	Mv	Adult	Female	P	7.4 g
may 30	2200	BC	Mv	escaped			
may 30	2200	BC	Ef	Adult	Male	NS	13.9 g
may 30	2200	BC	Mt	Adult	Male	NS	7.0 g
may 30	2200	BC	Mv	Adult	Female	PNL	8.3 g
may 30	2200	BC	Mv	Adult	Female	PNL	8.6 g
may 30	2200	BC	Mv	Adult	Female	PNL	8.0 g
may 30	2200	BC	Mv	Adult	Female	PNL	10.0 g
may 30	2200	BC	Mv	Adult	Female	PNL	8.3 g
may 30	2200	BC	Mv	Adult	Female	PNL	8.5 g

DATE	TIME	SITE	SPECIES	AGE	SEX	REPRO	WGT.
may 30	2250	BC	Ml	Adult	Male	NS	8.4 g
may 30	2255	BC	Me	Adult	Female	PNL	6.4 g
may 30	2300	BC	Mv	Adult	Female	PNL	8.6 g
June 1	none	ABB	Mc	no data			
June 6	2100	SSH	Ml	Adult	Male	NS	7.2 g
June 6	2148	SSH	Lc	Adult	Male	NS	24.0 g
June 6	2152	SSH	Ef	escaped			
June 6	2204	SSH	Mt	Adult	Male	NS	6.2 g
June 6	2225	SSH	Ef	Adult	Male	NS	15.8 g
June 6	2255	SSH	Mv	Adult	Female	NLNP	8.0 g
June 20	none	NSH	Mc	Adult	Male	NS	5.6 g
June 25	2055	GC	Mv	Adult	Female	PNL	9.5 g
June 25	none	GC	Mc	Adult	Male	NS	4.7 g
June 25	none	GC	Mc	Adult	Female	PNL	6.8 g
June 27	2127	SC	Ml	Adult	Male	NS	*
June 27	2135	SC	Me	Adult	Male	NS	*
June 27	2200	SC	Ef	Adult	Male	NS	*
June 27	2210	SC	Mv	Adult	Female	PNL	*
June 27	2215	SC	Me	Adult	Male	NS	*
June 27	2225	SC	Mv	Adult	Female	PNL	*
June 27	2230	SC	Ef	Adult	Male	NS	*
June 27	2238	SC	Me	Adult	Male	NS	*
June 27	2244	SC	Me	Adult	Male	NS	*
June 27	2319	SC	Mv	Adult	Male	NS	*

DATE	TIME	SITE	SPECIES	AGE	SEX	REPRO	WGT.
June 27	2338	SC	Mv	Adult	Female	NLNP	*
June 27	2349	SC	Me	Adult	Male	NS	*
June 27	2350	SC	Ef	Adult	Male	NS	*
June 27	2354	SC	Ml	Adult	Female	PNL	*
June 28	2120	BC	Ef	Adult	Male	NS	*
June 30	2115	NSH	Ml	Adult	Male	NS	*
June 30	2115	NSH	Ml	Adult	Male	NS	*
June 30	2115	NSH	Ml	Adult	Male	NS	*
June 30	2115	NSH	Ml	Adult	Male	NS	*
June 30	2115	NSH	Ml	Adult	Male	NS	*
June 30	2115	NSH	Ml	Adult	Male	NS	*
June 30	2115	NSH	Ml	Adult	Male	NS	*
June 30	2115	NSH	Ml	Adult	Male	NS	*
June 30	2145	NSH	Me	Adult	Female	PNL	*
June 30	2150	NSH	Ef	Adult	Female	PNL	*
June 30	2210	NSH	Ef	Adult	Female	PNL	*
June 30	2220	NSH	Ln	Adult	Male	NS	10.5 g
June 30	2235	NSH	Ef	Adult	Female	LNP	*
June 30	2235	NSH	Ef	Adult	Female	LNP	*
June 30	2235	NSH	Ml	Adult	Male	NLNP	*
June 30	2300	NSH	Lc	Adult	Male	NS	29.0 g
June 30	2310	NSH	Ln	Adult	Male	NS	*
June 30	2330	NSH	Ef	Adult	Female	LNP	*
June 30	2330	NSH	Ef	Adult	Male	NS	*

DATE	TIME	SITE	SPECIES	AGE	SEX	REPRO	WGT.
June 30	2345	NSH	Ef	Adult	Male	NS	*
June 30	2350	NSH	Ef	Adult	Male	NS	*
June 30	0030	NSH	Ml	Adult	Male	NS	*
June 30	0045	NSH	Lc	Adult	Male	NS	*
June 30	0100	NSH	Me	escaped			
June 30	0115	NSH	Ml	Adult	Male	NS	*
June 30	0130	NSH	Ef	Adult	Female	LNP	*
June 30	0135	NSH	Ef	Adult	Female	LNP	*
July 1	2127	GC	Mc	Adult	Female	LNP	*
July 1	2137	GC	Lc	Adult	Male	S	*
July 2	2104	BC	Ml	Adult	Male	NS	*
July 2	2104	BC	Ml	Adult	Male	NS	*
July 2	2104	BC	Ml	Adult	Male	NS	*
July 2	2104	BC	Ml	Adult	Male	NS	*
July 2	2104	BC	Ml	Adult	Male	NS	*
July 2	2104	BC	Ml	Adult	Male	NS	*
July 2	2104	BC	Ml	Adult	Male	NS	*
July 2	2104	BC	Ml	Adult	Male	NS	*
July 2	2104	BC	Ml	Adult	Male	NS	*
July 2	2104	BC	Ml	Adult	Male	NS	*
July 2	2114	BC	Mv	Adult	Male	NS	*
July 2	2124	BC	Mc	Adult	Male	NS	*
July 2	2124	BC	Mc	Adult	Female	NPNL	*
July 2	2134	BC	Mt	Adult	Female	PNL	*

Date	Time	Site	Species	Age	Sex	Repro	Wgt.
July 2	2134	BC	Mt	Adult	Male	NS	*
July 2	2231	BC	Ef	escaped			
July 2	2300	BC	Me	Adult	Male	NS	*
July 6	2045	RR	Myotis	escaped			
July 6	2120	RR	Ef	Adult	Male	S	15.7 g
July 6	2120	RR	Ef	Adult	Male	NS	26.4 g
July 6	2130	RR	Ef	Adult	Female	LNP	16.7 g
July 6	2200	RR	Ef	Adult	Female	PNL	17.7 g
July 13	2116	SC	Mt	Adult	Male	NS	*
July 13	2133	SC	Me	Adult	Male	NS	*
July 13	2138	SC	Me	Adult	Male	NS	*
July 13	2156	SC	Ef	Adult	Male	S	*
July 13	2240	SC	Ct	Adult	Male	S	*
July 13	2244	SC	Ef	Adult	Male	S	*
July 14	2110	BP	Mt	Adult	Female	LNP	9.8 g
July 14	2110	BP	Mt	Adult	Female	LNP	8.8 g
July 14	2110	BP	Mt	Adult	Female	LNP	8.8 g
July 14	2110	BP	Mt	Adult	Female	LNP	8.3 g
July 16	2054	BC	Ml	Adult	Male	NS	
July 16	2101	BC	Mt	Adult	Female	LNP	9.8 g
July 16	2108	BC	Ml	Adult	Male	NS	7.0 g
July 19	2100	SSH	Ml	Adult	Female	LNP	*
July 19	2118	SSH	Ml	Adult	Female	LNP	*
July 19	2118	SSH	Ml	Adult	Female	LNP	*

DATE	TIME	SITE	SPECIES	AGE	SEX	REPRO	WGT.
July 19	2118	SSH	Ml	Adult	Female	LNP	*
July 19	2124	SSH	Ml	Adult	Female	LNP	*
July 19	2124	SSH	Ml	Adult	Female	LNP	*
July 19	2124	SSH	Ml	Adult	Female	LNP	*
July 19	2128	SSH	Ml	Adult	Male	S	*
July 19	2128	SSH	Ml	Adult	Male	NS	*
July 19	2128	SSH	Mc	Adult	Female	LNP	*
July 19	2152	SSH	Lc	Adult	Male	NS	*
July 19	2214	SSH	Ml	Adult	Male	S	*
July 19	2356	SSH	Ml	Adult	Male	S	*
July 19	0008	SSH	Ml	Adult	Female	LNP	*
July 21	2113	LIN	Mt	Adult	Female	LNP	8.5 g
July 21	2115	LIN	Mt	Adult	Female	LNP	7.7 g
July 22	2100	SCN	Mc	Adult	Female	LNP	4.4 g
July 22	2100	SCN	Mc	Adult	Female	LNP	4.7 g
July 22	2129	SCN	Mc	Adult	Female	LNP	5.2 g
July 22	2129	SCN	Mc	Adult	Female	LNP	5.4 g
July 31	2045	NSH	Ml	Adult	Male	NS	7.9 g
July 31	2045	NSH	Ml	Adult	Male	S	7.1 g
July 31	2045	NSH	Ml	Adult	Male	S	7.8 g
July 31	2045	NSH	Ml	Adult	Male	S	7.7 g
July 31	2050	NSH	Ml	Adult	Female	NLNP	7.9 g
July 31	2050	NSH	Ml	Subadult	Female	NLNP	7.5 g
July 31	2055	NSH	Ml	Adult	Male	S	7.1 g

DATE	TIME	SITE	SPECIES	AGE	SEX	REPRO	WGT.
July 31	2055	NSH	Ml	Subadult	Female	NLNP	7.2 g
July 31	2100	NSH	Ml	Adult	Male	S	6.3 g
July 31	2100	NSH	Ml	Adult	Male	NS	7.1 g
July 31	2110	NSH	Ml	Adult	Male	S	6.9 g
July 31	2110	NSH	Ml	Adult	Male	S	7.3 g
July 31	2110	NSH	Ml	Adult	Male	S	5.3 g
July 31	2110	NSH	Ml	Adult	Male	S	6.9 g
July 31	2125	NSH	Ml	Adult	Female	LNP	5.5 g
July 31	2128	NSH	Ml	Adult	Male	S	6.6 g
July 31	2130	NSH	Ml	Subadult	Male	NS	6.1 g
July 31	2135	NSH	Ml	Adult	Male	S	7.7 g
July 31	2140	NSH	Ef	Juvenile	Female	NLNP	15.5 g
July 31	2200	NSH	Ml	Adult	Male	NS	7.0 g
July 31	2202	NSH	Ef	Subadult	Female	NLNP	16.3 g
July 31	2215	NSH	Ef	Adult	Female	LNP	24.0 g
July 31	2215	NSH	Ef	Adult	Female	LNP	23.0 g
July 31	2226	NSH	Ef	Adult	Female	LNP	23.3 g
July 31	2226	NSH	Ef	Juvenile	Male	NS	14.3 g
July 31	2226	NSH	Ef	Adult	Female	LNP	20.0 g
July 31	2230	NSH	Ef	Adult	Female	LNP	26.0 g
July 31	2230	NSH	Ef	Adult	Female	LNP	
July 31	2230	NSH	Ef	Adult	Female	LNP	
July 31	2230	NSH	Ef	Adult	Female	LNP	21.0 g
July 31	2240	NSH	Ef	Subadult	Male	NS	24.1 g

DATE	TIME	SITE	SPECIES	AGE	SEX	REPRO	WGT.
July 31	2245	NSH	Ef	Adult	Female	LNP	21.1 g
July 31	2245	NSH	Ml	Adult	Male	S	7.6 g
July 31	2248	NSH	Ef	Adult	Male	S	20.0 g
July 31	2249	NSH	Ef	Adult	Female	LNP	19.0 g
July 31	2249	NSH	Ef	Adult	Male	S	21.0 g
July 31	2249	NSH	Ef	Juvenile	Male	NS	
July 31	2249	NSH	Ef	Juvenile	Male	NS	12.0 g
July 31	2249	NSH	Ef	Juvenile	Female	NLNP	14.0 g
July 31	2249	NSH	Ef	Adult	Male	S	14.0 g
July 31	2249	NSH	Ef	Adult	Male	S	20.0 g
July 31	2300	NSH	Ef	Juvenile	Female	NLNP	14.0 g
July 31	2300	NSH	Ef	Juvenile	Female	NLNP	
July 31	2300	NSH	Ef	Adult	Male	S	19.3 g
July 31	2310	NSH	Ef	Adult	Female	LNP	20.0 g
July 31	2330	NSH	Ef	Adult	Male	S	18.0 g
July 31	2330	NSH	Ef	Adult	Male	S	14.0 g
July 31	2340	NSH	Ef	Adult	Male	S	23.0 g
July 31	2350	NSH	Ef	Adult	Male	S	26.3 g
July 31	2352	NSH	Ef	Adult	Female	LNP	36.0 g
Aug 1	2049	ABB	Ml	Adult	Female	LNP	7.3 g
Aug 1	2050	ABB	Ml	Adult	Male	S	7.3 g
Aug 1	2106	ABB	Ml	Adult	Male	S	7.1 g
Aug 1	2121	ABB	Ef	Adult	Male	S	20.3 g
Aug 1	2128	ABB	Mt	Adult	Male	S	7.9 g

DATE	TIME	SITE	SPECIES	AGE	SEX	REPRO	WGT.
Aug 1	2143	ABB	Ef	Adult	Female	LNP	20.3 g
Aug 1	2201	ABB	Ef	Adult	Female	LNP	24.0 g
Aug 11	2035	BC	Ml	Subadult	Female	NLNP	7.3 g
Aug 11	2038	BC	Mc	Adult	Female	NLNP	4.9 g
Aug 11	2038	BC	Mv	Juvenile	Female	NLNP	
Aug 11	2045	BC	Mt	Adult	Male	S	7.5 g
Aug 11	2045	BC	Mt	Juvenile	Female	NLNP	
Aug 11	2045	BC	Mc	Juvenile	Female	NLNP	4.6 g
Aug 11	2045	BC	Mc	Juvenile	Female	NLNP	4.3 g
Aug 11	2045	BC	Mt	Adult	Female	LNP	7.7 g
Aug 11	2045	BC	Mt	Adult	Female	NLNP	7.7 g
Aug 11	2050	BC	Mt	Adult	Male	S	7.4 g
Aug 11	2130	BC	Mt	Juvenile	Male	NS	7.4 g
Aug 11	2215	BC	Ef	Adult	Male	S	19.9 g
Aug 11	2240	BC	Ef	Adult	Male	S	19.5 g
Aug 11	2240	BC	Ef	Adult	Male	S	17.1 g
Aug 11	2245	BC	Ef	Adult	Male	S	18.1 g
Aug 11	2250	BC	Ef	Adult	Male	S	19.1 g
Aug 11	2300	BC	Ml	Adult	Male	S	6.7 g
Aug 11	2310	BC	Mc	Juvenile	Male	NS	3.4 g
Aug 11	2335	BC	Ml	Adult	Male	S	8.2 g
Aug 11	2350	BC	Ef	Adult	Male	S	15.0 g
Aug 12	2024	SC	Ml	Adult	Male	S	7.0 g
Aug 12	2024	SC	Ml	Adult	Male	S	6.8 g

DATE	TIME	SITE	SPECIES	AGE	SEX	REPRO	WGT.
Aug 12	2024	SC	Ml	Adult	Male	S	6.9 g
Aug 12	2024	SC	Mv	Adult	Female	PL	6.3 g
Aug 12	2024	SC	Ml	Adult	Male	S	7.3 g
Aug 12	2024	SC	Mv	Adult	Female	PL	6.9 g
Aug 12	2024	SC	Ml	Adult	Male	S	6.8 g
Aug 12	2049	SC	Mt	Adult	Male	S	7.0 g
Aug 12	2049	SC	Me	Adult	Male	S	5.4 g
Aug 12	2049	SC	Mt	Adult	Male	S	7.0 g
Aug 12	2049	SC	Ct	escaped			
Aug 12	2100	SC	Lc	Adult	Male	S	24.1 g
Aug 12	2109	SC	Mt	Adult	Male	S	6.5 g
Aug 12	2109	SC	Me	Adult	Male	S	5.7 g
Aug 12	2109	SC	Mt	Adult	Male	S	6.9 g
Aug 12	2141	SC	Me	Adult	Male	S	6.3 g
Aug 12	2151	SC	Mv	Adult	Male	S	7.4 g
Aug 12	2158	SC	Me	Subadult	Female	NLNP	4.9 g
Aug 12	2202	SC	Me	Juvenile	Female	NLNP	6.9 g
Aug 12	2238	SC	Mt	Adult	Male	S	6.9 g
Aug 12	2249	SC	Me	Adult	Male	S	6.3 g
Aug 12	2317	SC	Mc	Adult	Male	NS	4.2 g
Aug 12	2329	SC	Me	Adult	Male	S	5.4 g
Aug 14	2029	NSH	Mt	Juvenile	Male	NS	8.5 g
Aug 18	2110	REY	Mv	Adult	Female	PL	7.2 g
Aug 23	2040	ABB	Mt	Juvenile	Male	NS	6.6 g
Aug 23	2118	ABB	Mt	Juvenile	Male	NS	6.5 g

TABLE II. *Localities of net sites for 1996 study, all in Boulder County, Colorado*

NAME OF SITE	LOCATION	TOPOGRAPHIC COORDINATES
Abbey Pond	Casual path west from Hardscrabble Drive to Shanahan Ridge, app. 1/4 mi	T1S R70W Sec. 18
Bear Creek Pool	Junction of Mesa Trail and Bear Creek, app. 1.2 miles from Wildwood Trailhead	T1S R71W Sec. 12
Buckingham Park Creek	Take creek trail north from parking lot app. 0.25 miles	T2N R71W Sec. 26
Gregory Canyon Pool	approximately 0.5 miles N from Saddle Rock Trailhead from base of Gregory Canyon	T1S R71W Sec. 1
Lindsay Pond	South end of Dowdy Draw Trail and just north of water diversion pipe	T1S R70W Sec. 31
North Shanahan Trail Pond	Intersection of the middle and north forks of Shanahan Ridge trail	T1S R70W Sec. 18
Red Rocks Aqueduct	Head northwest on Red Rocks Trail, approximately 0.1 mile from trailhead	T1N R71W Sec. 25
Reynolds Ranch	10 mi. up Magnolia Rd from Boulder Canyon	
Schneider Pond	Northwest of intersection of US 36 and Longhorn Rd., app. 1.5 mi. up ravine leading to Old Stage Rd	T1N R71W Sec. 1
South Shanahan Trail Pond (a.k.a. Pollywog Pond)	Southwest of first right angle bend in south fork of Shanahan Ridge trail from Hardscrabble Drive access, approximately 0.5 mi.	T1S R70W Sec. 18
Stockton Cabin Pool	Intersection of Mesa Trail and Shadow Canyon Trail	T1S R71W Sec. 24

Table III. *Total active times versus total nonactive times per site per date. Numbers in parentheses are activity indices (total active time/total nonactive time).*

SITE	DATE	TOTAL TIME ACTIVE (MIN)	TOTAL TIME NONACTIVE (MIN)
Stockton Cabin	27 June 1996	149	52 (2.86)
Stockton Cabin	13 July 1996	75	42 (1.78)
Stockton Cabin	12 Aug. 1996	227	6 (37.8)
Bear Creek	30 May 1996	102	23 (4.43)
Bear Creek	28 June 1996	7	77 (0.09)
Bear Creek	2 July 1996	151	18 (8.39)
Bear Creek	16 July 1996	30	46 (0.65)
North Shanahan	31 July 1996	218	0
South Shanahan	19 July 1996	170	34 (5.00)
Abbey Pond	1 Aug. 1996	99	40 (2.47)
Abbey Pond	23 Aug. 1996	105	6 (17.50)
Lindsay Pond	21 July 1996	118	4 (29.5)
Gregory Canyon	1 July 1996	45	41 (1.10)
Red Rocks Trail	6 July 1996	85	20 (4.25)

Table IV. *Statistics of species richness, diversity, and eveness for four sites. N0 = number of secies,* n *= sample size, R1 = Margalef Index, R2 = Menhinick Index, N1 = abundant species, N2 = very abundant species, E4 = Evenness Index 4 = Hill's ratio, E5 = Evenness Index 5 = modified Hill's ratio.*

RICHNESS	Bear Creek	Stockton Cabin	N. Shanahan	S. Shanahan
N0	6 (*n* = 57)	8 (*n* = 40)	7 (*n* = 79)	6 (*n* = 20)
R1	1.23669	1.884978	1.373171	1.669041
R2	0.7947195	1.24939	0.7875616	1.341641
DIVERSITY				
Shannon Index	1.634863	1.791635	1.101503	1.189886
N1	5.128753	5.999255	3.008684	3.286706
N2	5.099042	5.540541	2.46875	2.375000
EVENNESS				
E4	0.9942069	0.9235381	0.8205415	0.7226081
E5	0.9928038	0.9082434	0.7312001	0.6013018

Table V. *Statistics for species richness, diversity, and evenness for Bear Creek site across three nights in 1996.*

RICHNESS	Bear Creek-13 May	Bear Creek-2 July	Bear Creek-11 Aug.
N0	5	6	6
R1	1.358493	1.764781	1.594645
R2	1.147079	1.455214	1.251087
DIVERSITY			
Shannon Index	1.306647	1.315658	1.609691
N1	3.693768	3.727203	5.001264
N2	3.489796	2.893617	5.500000
EVENNESS			
E4	0.9447794	0.7763508	1.099722
E5	0.9242801	0.6943441	1.124645

Table VI. *Statistics for species richness, diversity, and evenness for Stockton Cabin site across three nights in 1996.*

RICHNESS	Stock. Cab.-27 June	Stock. Cab.-13 July	Stock. Cab.-12 Aug.
N0	4	4	6
R1	1.136770	1.674332	1.617577
R2	1.069045	1.632993	1.279204
DIVERSITY			
Shannon Index	1.333736	1.329661	1.590516
N1	3.795196	3.779763	4.906279
N2	4.55	7.5	5.25
EVENNESS			
E4	1.198884	1.984251	1.070054
E5	1.270036	2.338329	1.087992

Table VII. *Statistics for species richness, diversity, and evenness for North Shanahan site across two nights in 1996.*

RICHNESS	N. Shan.-30 June	N. Shan.-31 July
N0	5	2
R1	1.24267	0.2556223
R2	1.0	.02828427
DIVERSITY		
Shannon Index	1.265904	0.6730117
N1	3.546298	1.960132
N2	3.26087	1.96
EVENNESS		
E4	0.9195138	0.9999329
E5	0.8879047	0.9998629

FIGURE CAPTIONS

Figure 1.--A) Stacked bar graph of site versus diversity. Diversity axis measures relative number of individuals captured per site throughout the 1996. BC = Bear Creek, ABB = Abbey Pond, SSH = South Shanahan, NSH = North Shanahan, SC = Stockton Cabin, RR = Red Rocks Trail, SCN = Schnieder Pond, GC = Gregory Canyon, BP = Buckingham Park, LIN = Lindsay Pond. B) Numbers of females versus males for each species captured in 1996. ML = *Myotis lucifugus*, ME = *Myotis evotis*, MC = *Myotis ciliolabrum*, MV = *Myotis volans*, MT = *Myotis thysanodes*, EF = *Eptesicus fuscus*, LC = *Lasiurus cinereus*, LN = *Lasionycteris noctivagans*, CT = *Coryorhinus townsendii.*

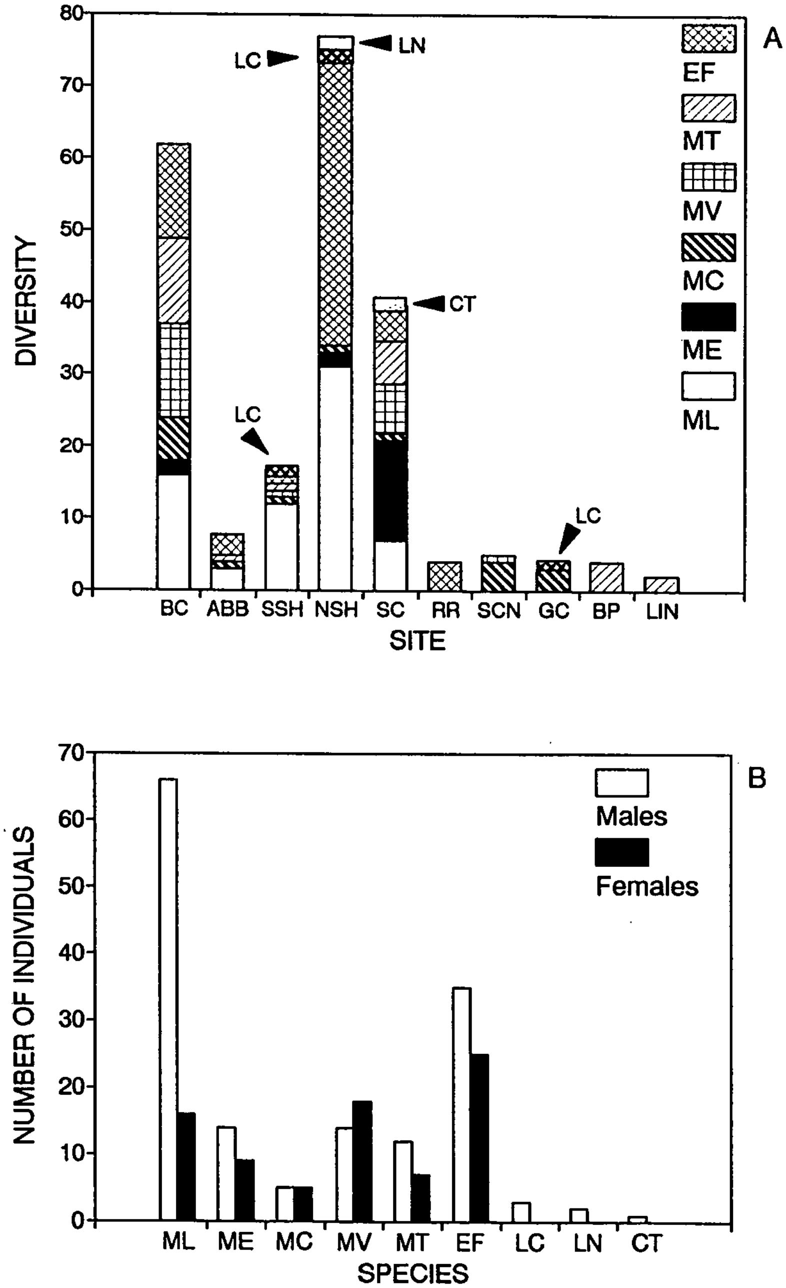
Figure 2.--Capture data for Bear Creek site in 1996 plotted in relation to time of capture for each species. Time lines indicate activity (above midline) versus inactivity (below midline) in relation to capture data at the site based upon bat detector data. Inactive periods may be longer than appear as a consequence of tick spread on the x-axis (see text for further explanation. A) 30 May, B) 2 July, C) 11 August.

Figure 3.--Capture data for Stockton Cabin in 1996 plotted in relation to time of capture for each species. Time lines are as stated in Figure 2. A) 27 June, B) 13 July, C) 12 August.

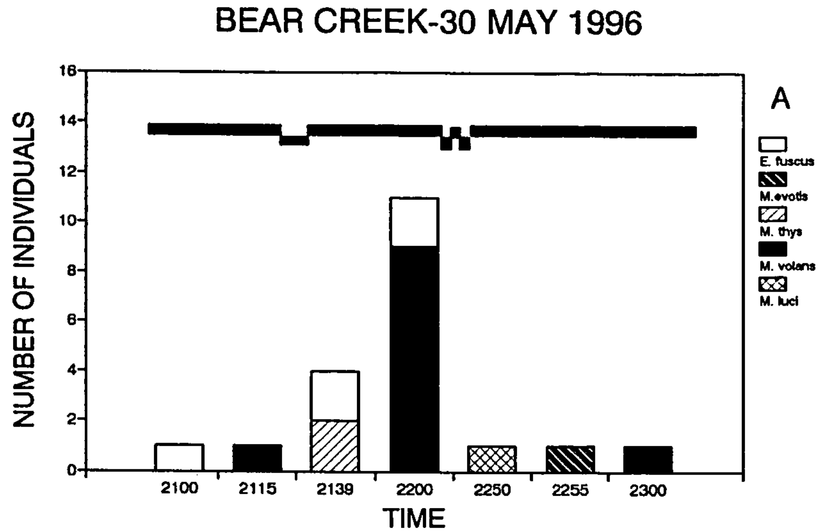
Figure 4.--Capture data for North Shanahan site in 1996 in relation to time of capture for each species. A) 30 June, B) 31 July. Time line is as stated in Figure 2.

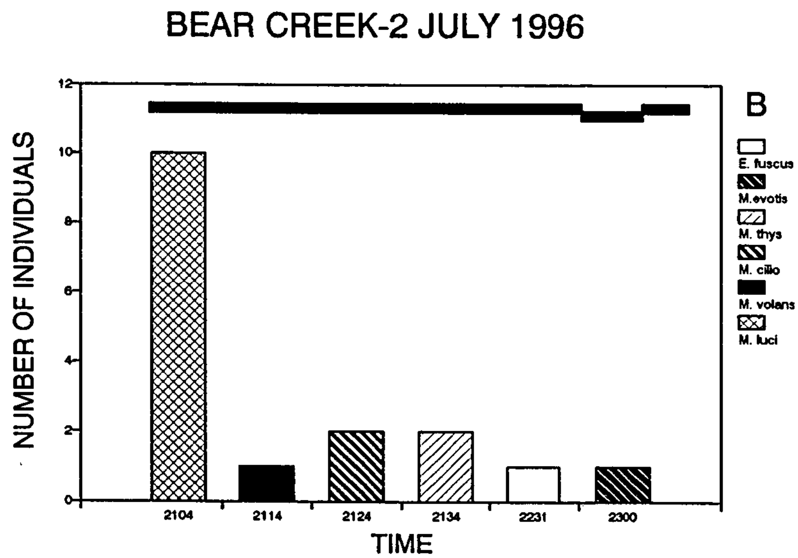
Figure 5.--Capture data for South Shanahan site in 1996 in relation to time of capture for each species. A) 6 June, B) 19 July. Time lines are as stated in Figure 2.

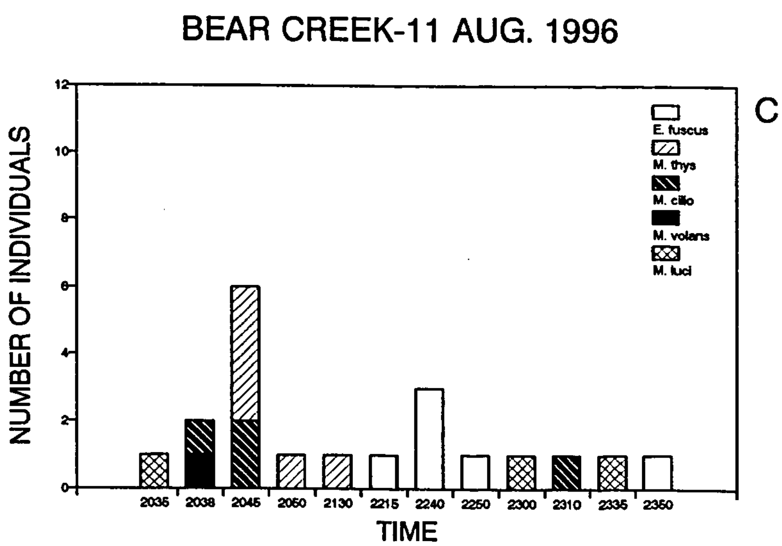
Figure 6.--Capture data for Abbey Pond site in 1996 in relation to time of capture for each species. Time lines are as stated in Figure 2. A) 1 August, B) 23 August.



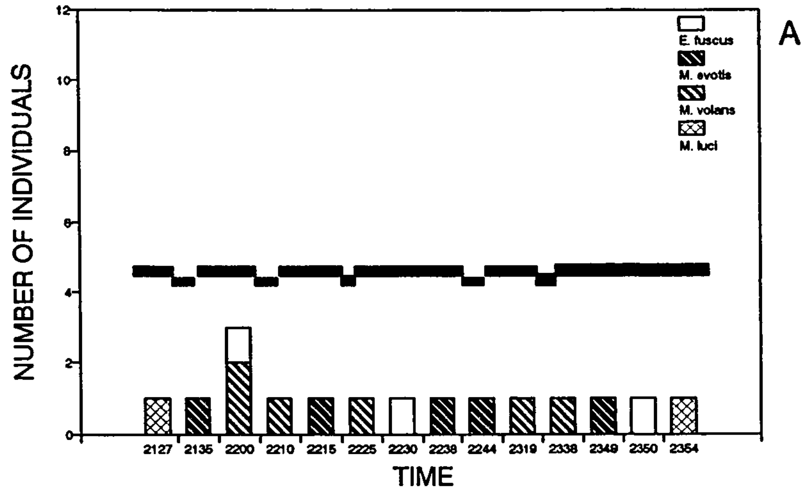
A
DIVERSITY
SITE
BC
ABB
SSH
NSH
SC
RR
SCN
GC
BP
LIN
EF
MT
MV
MC
ME
ML
LC
LN
CT
0
10
20
30
40
50
60
70
80
B
NUMBER OF INDIVIDUALS
SPECIES
Males
Females
ML
ME
MC
MV
MT
EF
LC
LN
CT
0
10
20
30
40
50
60
70


BEAR CREEK-30 MAY 1996
A
NUMBER OF INDIVIDUALS
TIME
2100
2115
2139
2200
2250
2255
2300
E. fuscus
M.evotis
M. thys
M. volans
M. luci

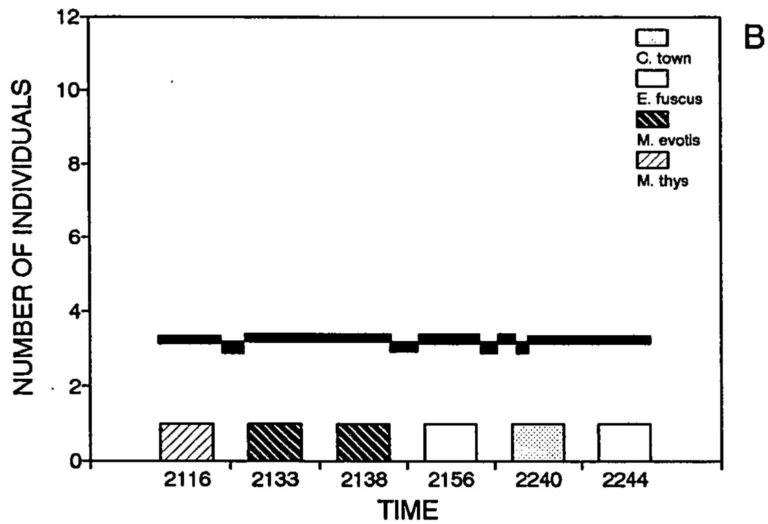

BEAR CREEK-2 JULY 1996
B
NUMBER OF INDIVIDUALS
TIME
2104
2114
2124
2134
2231
2300
E. fuscus
M.evotis
M. thys
M. cilio
M. volans
M. luci


BEAR CREEK-11 AUG. 1996
C
NUMBER OF INDIVIDUALS
TIME
2035
2038
2045
2050
2130
2215
2240
2250
2300
2310
2335
2350
E. fuscus
M. thys
M. cilio
M. volans
M. luci

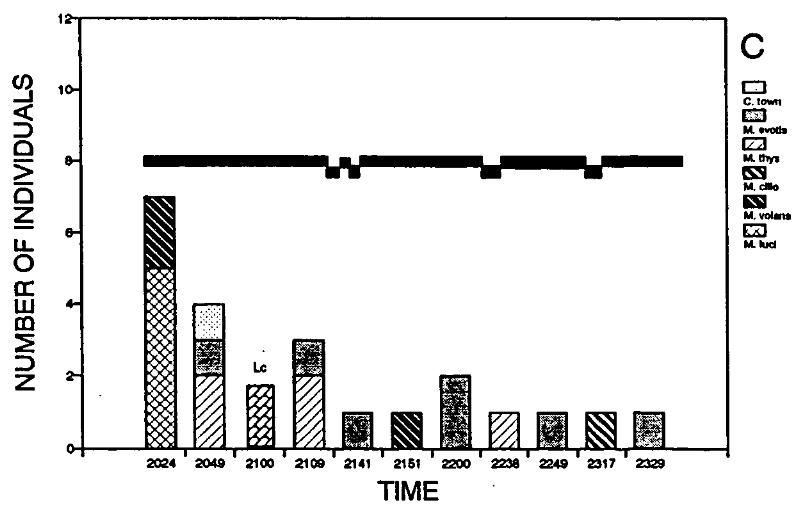
STOCKTON CABIN-27 JUNE 1996



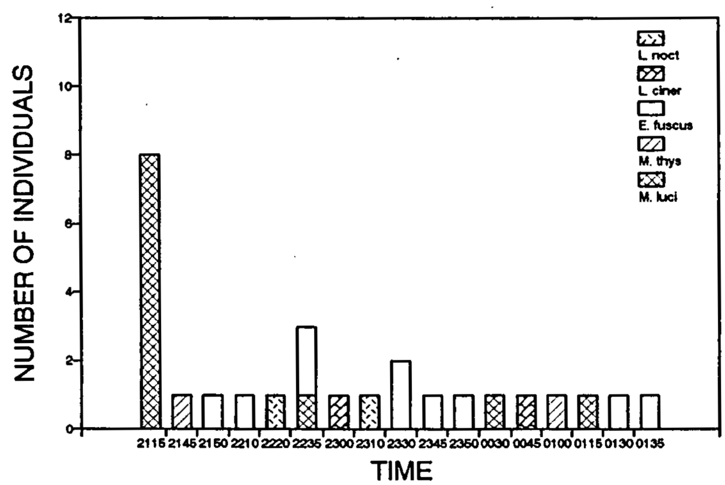
STOCKTON CABIN-13 JULY 1996



STOCKTON CABIN-12 AUG.1996

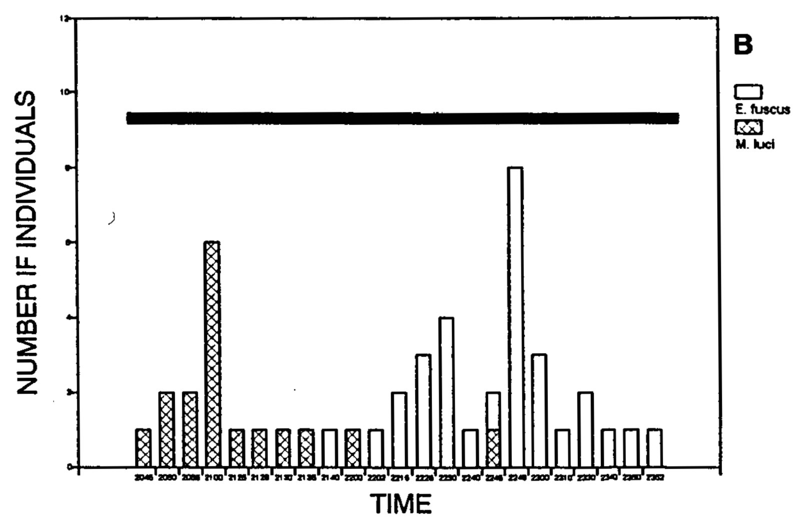


NORTH SHANAHAN-30 JUNE 1996



A

NORTH SHANAHAN-31 JULY 1996



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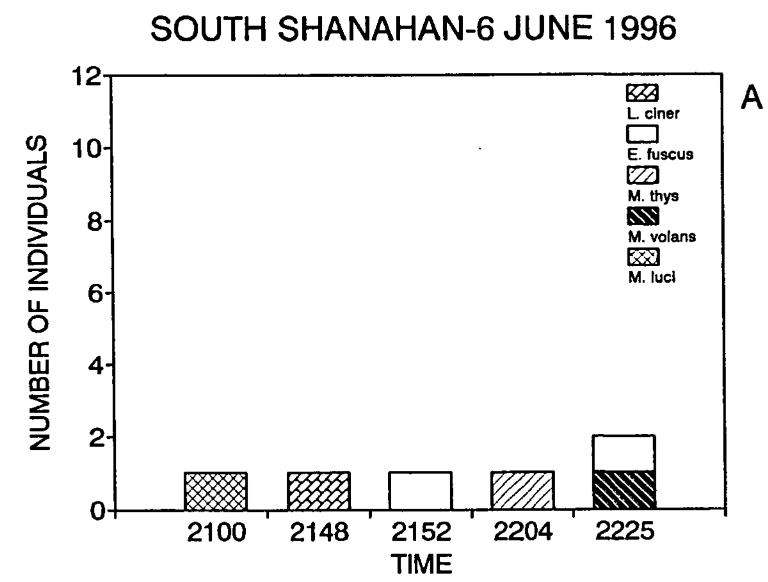
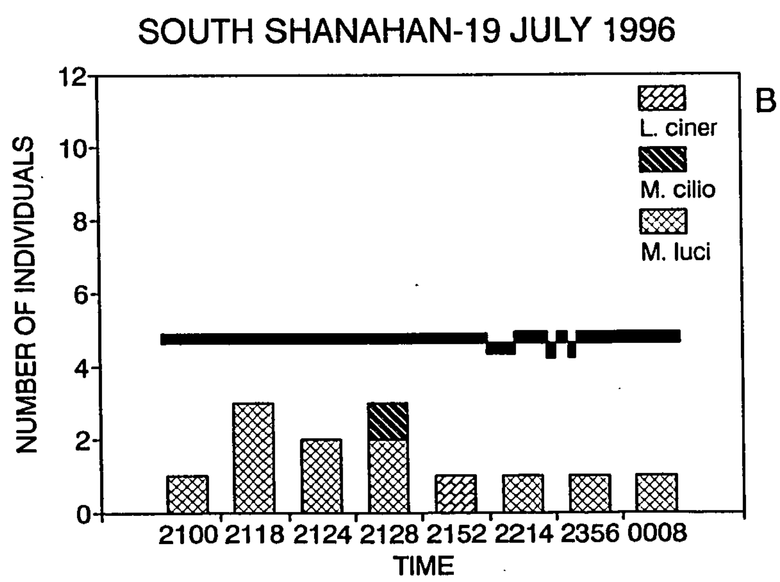
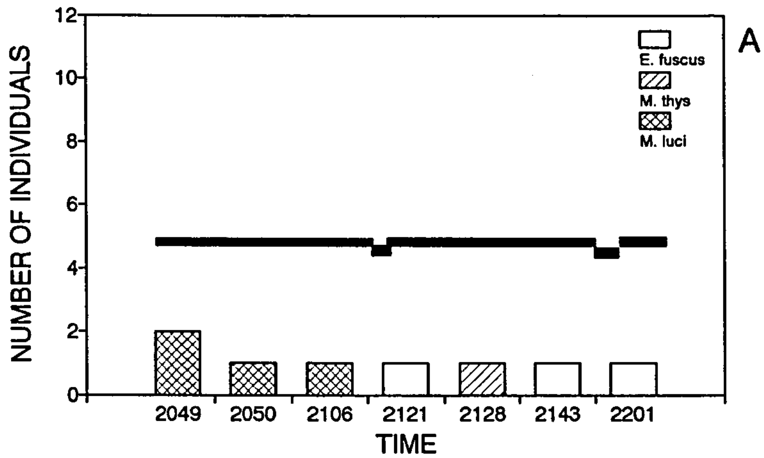

SOUTH SHANAHAN-6 JUNE 1996
A
L. ciner
E. fuscus
M. thys
M. volans
M. luci
NUMBER OF INDIVIDUALS
0
2
4
6
8
10
12
2100
2148
2152
2204
2225
TIME


SOUTH SHANAHAN-19 JULY 1996
B
L. ciner
M. cilio
M. luci
NUMBER OF INDIVIDUALS
0
2
4
6
8
10
12
2100
2118
2124
2128
2152
2214
2356
0008
TIME

ABBEY POND-1 AUG. 1996



ABBEY POND-23 AUG. 1996