A STUDY OF THE CAVE BATS OF MINNESOTA WITH ESPECIAL REFERENCE TO THE LARGE BROWN BAT, EPTESICUS FUSCUS FUSCUS (BEAUVOIS)

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by

GEORGE NIELSEN RYSGAARD

A THESIS

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INTRODUCTION

Bats have figured in the legends and arts of nearly all cultures from time immemorial, and usually they have been portrayed as omens of evil. Through the ages but comparatively little has been learned of their habits and ways. Even today numerous superstitions enshroud these mystical creatures.

Because of the scantiness of knowledge concerning the bats of Minnesota, this study was seriously undertaken in the fall of 1940; although many notes had been gathered previously.

In Minnesota there are found seven species of bats which fall into two convenient arbitrary groups---those known as tree bats which roost in trees and on cliff faces and those termed cave bats which gather in caves, buildings, and hollow trees. The tree bat species are normally present during the summer months only, leaving the state each fall to migrate far southward. The cave bats, on the other hand, remain in greater or lesser numbers throughout the winter season at which time they resort to caves and buildings for shelter.

This study concerns itself solely with those species of cave bats found within the state borders of Minnesota. The presentation of this problem is not complete, many phases of life history remaining to be amended through further investigation; and in its present form is intended as but a foundation for future consideration.

The following species of cave bats are known to occur in Minnesota:

Myotis lucifugus lucifugus (LeConte) Little Brown Bat

Myotis keenii septentrionalis (Trouessart) Big-eared Little Brown Bat

Pipistrellus subflavus obscurus Miller Georgian Bat

Eptesicus fuscus fuscus (Beauvois) Large Brown Bat

RETROSPECT

Bats have received little attention from the mammalogists of this state during years past. The first published report containing notes on bats of Minnesota is that of A. E. Ames (1873). In this state list two species of bats were included, Vespertilio lucifugus LeConte (Myotis lucifugus) and Nycticejus crepuscularis Allen (Nycticeius humeralis). This latter mentioned species has never since been reported for the state and undoubtedly was a misidentification of the large brown bat, Eptesicus fuscus.

C. L. Herrick (1885) included Myotis lucifugus in his brief list of the mammals of the Big Stone Lake region. In his state publication, C. L. Herrick (1892) gave no credence to Ames' record of Nycticeius humeralis and under the heading of this species stated (p. 28), "Although not reported, this species may be found in Minnesota." He included only Myotis lucifugus and Eptesicus fuscus as found in the state.

Vernon Bailey (1887) reported Myotis lucifugus from the region of Elk River, reporting it to be found there in abundance.

The first published record of Myotis keenii septentrionalis for the state, of which I have knowledge, is that included in the annotated list

of C. E. Johnson (1916). A. R. Cahn (1921) noted Myotis keenii septentrionalis as common in Itasca County, Minnesota. Bernard Bailey (1929) and T. S. Surber (1932) both record the three species already cited.

C. A. Evans (1934) was the first to publish notes on the wintering habits of cave bats in Minnesota. Eptesicus fuscus and Myotis lucifugus were found hibernating in caves of southern Minnesota. Later with G. A. Swanson (1936) he published further notes concerning winter activities of both these species and included also Myotis keenii septentrionalis and Pipistrellus subflavus which they found in the wintering cave. This was the first report of Pipistrellus subflavus in Minnesota.

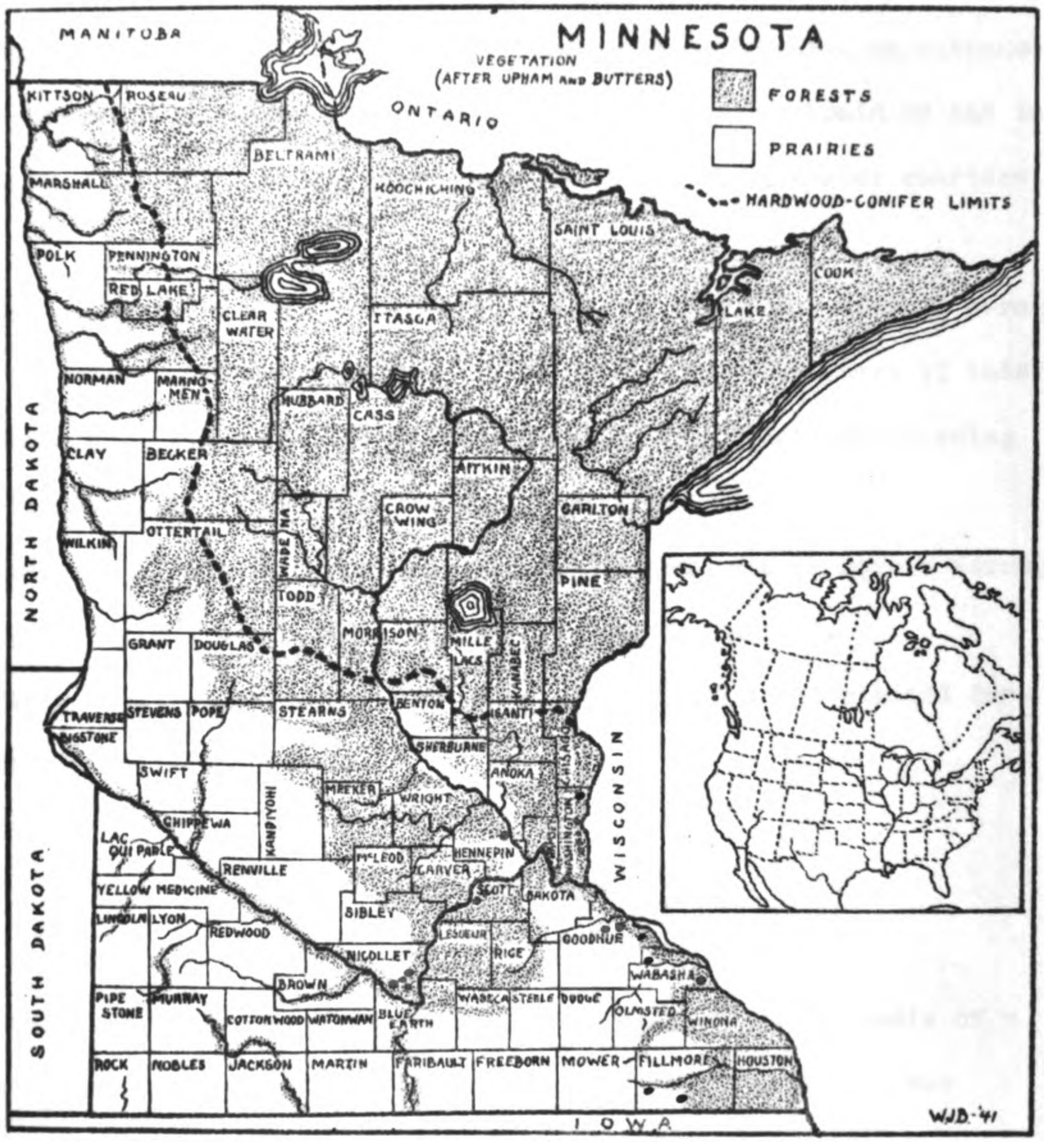
The state check-list of D. M. Hatfield (1939) included the four species of cave bats thus far known to occur in the state.

CAVES OF MINNESOTA

The caves of Minnesota are of two types, namely: the natural limestone caves of the southern portion of Minnesota and the sandstone caves which have been man made for purposes of storage, raising mushrooms, mellowing brewery products, and quarrying sandstone for abrasive material.

The natural caves of the state are primarily of the "sink hole" type. Before the glacial period immense valleys of erosion were excavated in the areas of the Galena and Trenton Limestone, producing deep, narrow, perpendicular gorges. In such narrow gorges, neither the drift nor the loess-loam was deposited in such compactness as to entirely close up the pre-existing water courses. Partially closed as they

PLATE I.



Distribution of natural and artifical caves of Minnesota

- natural caves
- artifical caves

were, the erosion action of the subterranean waters carried on a process of re-excavation, resulting in periodic collapsing of the surface soil to produce a "sink hole." The openings so produced granted an entrance to the caverns. Situated below the frost line and kept humid by the infiltration of surface water, these caves offered ideal winter quarters for bats.

The sandstone caves, being smaller in size and more exposed, were generally cooler and less humid. In the more extensive caves of this type seepage chambers existed in the innermost ramifications offering conditions similar to those found in the natural caves.

The type of cave and the conditions existing therein have a strong bearing upon the winter population as is shown in Table I.

Plate I gives the location of each cave of the state visited during the course of this study.

METHOD OF STUDY

When this study was undertaken, it was planned on the basis of a long time program to be conducted over a period of years. It was realized at the onset that if much of the desired information was to be obtained it would be necessary to mark a large number of individuals for future identification.

Many methods have been employed in the past to mark bats for study. Eisentraut (1934) placed aluminum bird bands around the bat's humerus. This method permits the recognition of banded individuals among others

TABLE I.

CAVE	TYPE	SPECIES	NO.	TEMP.	HUM.	DATE
Jordon Cave Jordon, Minn.	S.	P.s.o.	4	48.0	99%	10-24-40
Jordon Cave Jordon, Minn.	S.	P.s.o. E.f.f.	6 8	48.0 41.0	99% -	2-2-41
Nicollet Cave Minneapolis	S.	E.f.f.	7	-	-	12-1-40
Seven Caves St. Peter, Minn.	S.	P.s.o. E.f.f. M.l.l. M.k.s.	1 1 2 3	48.0 42.0 48.0 48.0	99% 86% 99% 99%	10-24-40
Seven Caves St. Peter, Minn.	S.	P.s.o. M.k.s. E.f.f.	1 1 250	48.0 48.0 40.0	99% 99% 85%	12-21-40
Sand Cave #1 Stillwater, Minn	S.	E.f.f.	40	33.5	90%	12-20-40
Sand Cave #3 Stillwater,Minn.	S.	E.f.f.	200	34.5	91%	12-22-40
Sand Cave #1 Red Wing, Minn.	S.	M.l.l. E.f.f. P.s.o. M.k.s.	3 8 1 2	- - - -	- - - -	11-11-40
Sand Cave #2 Red Wing, Minn.	S.	P.s.o. E.f.f.	2 400	45.0 35.0	99% 75%	1-3-41
Sand Cave #1 Red Wing, Minn.	S.	E.f.f. P.s.o. M.k.s.	38 1 1	- 43.0 43.0	- 95% 95%	1-3-41
Cave #1 Wabasha, Minn.	S.	E.f.f. M.k.s.	10 1	41.0 47.0	100% 100%	12-28-40
Cave #2 Wabasha, Minn.	S.	E.f.f. P.s.o.	6 2	40.5 -	92% -	12-28-40
Sand Cave #1 St. Paul, Minn.	S.	E.f.f.	31	46.5	97%	2-15-41

Minnesota caves and relative abundance of bats inhabiting each. Species: E.f.f-Eptesicus f. fuscus; P.s.o.-Pipistrellus subflavus obscurus; M.l.l.-Myotis l. lucifugus; M.k.s.-Myotis keenii septentrionalis.

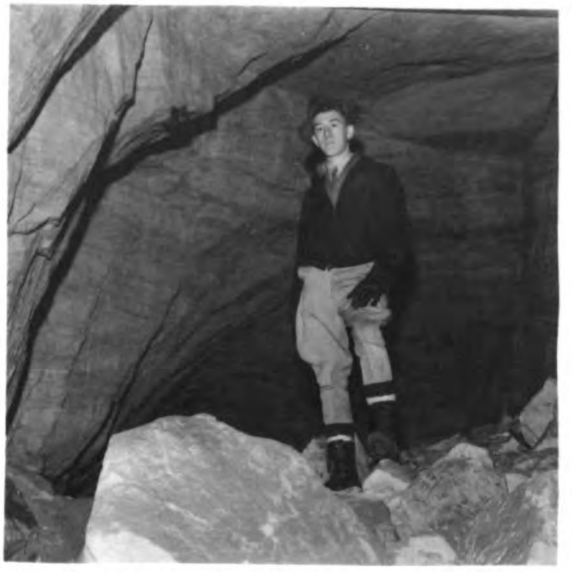
TABLE I.

CAVE	TYPE	SPECIES	NO.	TEMP.	HUM.	DATE
Cave #1 Brownsville, Minn.	S.	E.f.f.	15	37.0	-	12-28-40
Cave #2 Brownsville, Minn.	S.	E.f.f.	1	34.0	-	12-28-40
Mystery Caves Spring Valley	L.	M.k.s. M.l.l. P.s.o.	1 6 4	50.0 50.0 50.0	99% 99% 99%	10-31-40
Mazeppa Cave Mazeppa, Minn.	L.	P.s.o.	24	50.0	100%	1-4-41
Marine Cave Marine, Minn.	L.	P.s.o.	4	48.0	98%	3-1-41

Minnesota caves and relative abundance of bats inhabiting each. Species: see legend below Plate I, part 1. Caves: S-sandstone; L-limestone.

PLATE II.

1. Entrance to one of the Mystery Caves, Spring Valley, Minnesota



2. F. Poppe in interior of Sand Cave #1, Red Wing, Minnesota

3. Entrance to Cave #1, Stillwater, Minnesota

4. Natural entrance to Mazeppa Cave, Mazeppa, Minnesota

in compact clusters, but there appeared danger of wing injury in this method. Mohr (1934) employed fingerling tags which he attached to the ears. Here again banded individuals are readily discerned, however, the tags are too small to bear a return address legend of any kind and the identification numerals are difficult to decipher by torch light. Therefore it was decided to use standard No. 1 aluminum bird bands issued by the United States Bureau of Biological Survey. These bands bear a serial number on the outside and on the inside the legend "Notify Biol. Surv. Wash. D. C."

The bands are placed around the tibia, being closed tightly against the interfemoral membrane. These bands in no way inhibit the flight activity of the animals and if properly applied seldom seem to cause injury.

During the winter season of 1940-41, all known caves in Minnesota were visited and examined for bats. Capturing bats in wintering caves is comparatively simple, as most of them are found in a dormant state and may be easily plucked from the walls. Those which have secreted themselves in the crevices are quickly extracted with long forceps. More than 600 bats have been banded this past season in wintering caves of the state in this manner.

In each instance the sex has been recorded at the time of banding. Data of an ecological nature were gathered during each visit to the caves. The temperature was recorded at a distance of one foot from the resting bats. A psychrometer was employed to determine the relative humidity of the chambers of the caves.

During the summer months cave bats are found inhabiting buildings where they conceal themselves between the walls and are difficult to

capture. A butterfly net has proved efficient in capturing bats in flight. To successfully gather the entire population of a building, it is necessary to construct traps of the type described by Donald Griffin (1940). So far this method has not be attempted.

The terminology employed in analyzing banding results is the same as that now used by bird banders. A return is any recapture of a banded individual at another locality or at the same locality after the passage of a season when the bats are believed to be migrating. If the bat has moved from one locality to another, it is termed a foreign return; if it is retaken at the locality where banded but after a seasonal absence, it is known as a local return.

Genus Eptesicus Rafinesque

This genus is represented in Africa, Madagascar, Australia, Asia (except the Malay region), and America from southern Canada southward (except the Lesser Antilles). There are 45 known species. One species represented by a number of geographic races is found in America.

The ranges of the races in the United States are as follows:

E. f. bernardinus Rhoads: The Pacific coast, from western British Columbia south through western Washington, western Oregon and California to Los Angeles, west of the Cascade-Sierra Nevada Mountain chain and the Mohave and Colorado deserts.

E. f. pallidus Young: Alberta and British Columbia east of the Cascade-Sierra Nevada Mountain chain south through Rocky Mountains to New Mexico, Arizona, and northern Lower California.

E. f. peninsulae (Thomas): Southern part of Lower California, north probably to latitude 27 .

E. f. fuscus (Beauvois): Austral, Transition, and (lower edge of) Boreal zones throughout the United States and adjoining British provinces.

LARGE BROWN BAT

Eptesicus fuscus fuscus (Beauvois)

Vespertilio fuscus Beauvois, Cat. Peale's Mus., 1796,; LeConte, Proc. Acad. Nat. Sci., 1855.
Scrotophilus fuscus H. Allen, Monog. N. A. Bats., 1864.
Vespertilio (Vesperus) fuscus Coues, "Surv. 100th. Mer.," Zool.,1875.

Description

Dental formula: I-2/3; C-1/1; P-1/2; M-3/3---32.

General characters: Size large; total length, 107 to 120 mm.; tail, 39 to 52 mm.; forearm, 43 to 49 mm.; ear, 12 to 16 mm.; hind foot, 10 to 11 mm.; ears and membranes thick and leathery; color varies among specimens of the same geographic range or locality being normally dark brown or nearly black at the basal half with isabella-brown tips; below the colors are lighter, generally gray or yellowish brown.

The membranes above quite naked, having hair extensions from the proximal half of the humerus along the side of the body to the proximal half of the femur, and a small portion of the prebrachium as it joins the neck. Below a sparse growth of hair reaches from the body almost to the elbow and from the mid-point of the humerus to the mid-point of the femur. The upper fourth of the interfemoral membrane is furred.

Ears: Short and somewhat narrower than long; erect and inclined forward, broadest near middle; external basal lobe prominent, longer than high; tragus straight, blunt, relatively short, directed forward, basal lobe rounded and directed slightly forward.

Skull: Averages about 18.5 mm. in occipito-nasal length and about 12.5 mm. in zygomatic breadth; flattened above; slight angle between brain case and rostrum; conspicuous sagittal crest.

Teeth: Both upper incisors well developed, the outer being much the smaller, barely reaching to the cingulum of the inner incisor; lower incisors nearly uniform in size, crowded in convex row with crowns overlapping and trilobed; canines simple, each with distinct cingulum but no secondary cusp; height of single upper premolar greater than that of any molar.

Hibernation

Migration to the caves: It is apparent from literature that but little information is available concerning the life history of this species. Griffin (1940, p. 238) is of the opinion that the large brown bat does not migrate long distances from summer areas to wintering quarters. Although I have no banding evidence to show distances traveled by this species to reach winter caves, I am of the opinion that they traverse many miles in this state during migration. During the summer months this species is one of the less abundant forms, being found rarely in collections and seldom reported; yet in winter I have found them in large concentrations in widely scattered sandstone caves to indicate a gathering from a considerable territory. In the two caves at Red Wing, Minnesota well over a thousand individuals passed the winter season in 1940-1941.

Dates of arrival at caves: This species is particularly hardy and apparently has the ability to withstand considerable periods of inclement weather and low temperatures. During the fall season the large brown bat remains abroad long after the other cave-inhabiting species have entered the caves for the winter.

On October 24, 1940, the Seven Caves at St. Peter, Nicollet County, Minnesota were examined thoroughly; and at this date only a single Eptesicus was discovered, although representatives of the other three species were found in their normal wintering numbers. A search of the brewery caves at Jordon, Scott County, Minnesota on the same day disclosed no bats of this species.

On November 11, 1940, Frederick Poppe and the writer visited a large sandstone cave at Red Wing, Goodhue County, Minnesota. This cave had been operated commercially in former years for abrasive material but appeared to have been abandoned for some while. Eight large brown bats were discovered after a careful search of each tunnel. The walls of the cave were comparatively smooth and without fissures which might permit concealment of hibernating bats. When we emerged from the cave at 1 p.m., a severe snow storm was in progress; and we left the area immediately.

This unusually severe and unseasonal storm of November 11 terminated a mild fall season. The month of October had a mean temperature of 54° F. which was 5.1° F. warmer than normal. The mean temperature of the first ten days of November was 40.5° F. The storm commenced with a drizzling rain which changed to sleet and snow with the falling temperature which reached a minimum of 10° F. during the night. A 42 mile an hour wind accompanying the storm produced a blinding blizzard

which caused a considerable mortality among wildlife in general throughout the state.

During the course of this storm, the entrance to one of the two caves at St. Peter, Minnesota used extensively by hibernating Eptesicus was entirely closed by drifting snow. Immediately following the storm, Mr. Meyer, who operates the caves as a tourist attraction, found over a hundred dead bats at the closed entrance. The bats evidentally had been overcome by the storm while attempting to gain entrance to the snow-blocked cave. Although several other caves close at hand remained open and accessible, their habit of wintering in this particular cave caused them to continue in search of an entrance until they were exhausted and fell to the snow to die.

The Seven Caves were visited by the writer on December 21, 1940, and Mr. Meyer was questioned at this time regarding the bat mortality. He was thoroughly familiar with the bats which came there each year, and upon questioning him and checking his ability to distinguish the various species in the caves, it was decided that the dead bats found were nearly 100% Eptesicus fuscus. Cats from a nearby asylum had already carried away the carcasses, and but a single specimen, a large brown bat, was found.

The second cave used extensively as hibernating quarters by this species was examined. Approximately 100 large brown bats were found in this chamber. On March 2, 1939, this cave housed close to 200 bats of this species as recorded in my field journal report. It is entirely possible that many of the individuals customarily hibernating in this cave were too far afield at the onset of the storm to reach this cave and either died in the attempt or chose available temporary quarters

elsewhere. A visit to the brewery caves at Jordon, Minnesota was made the same day, Five large brown bats not present on October 24, 1940 were found.

On January 3, 1941, the Sandstone Cave #1 at Red Wing, Minnesota was revisited by Frederick Poppe and the writer. Ten unbanded Eptesicus were discovered. These individuals had not been encountered on November 11, 1940 when a careful survey was made of the cave. In all probability these large brown bats were driven into the cave by the storm of that date, although they may have entered at a later day after having sought temporary shelter.

Russel Berthel reported that during the night of November 11, 1940, at the height of the storm, a large brown bat flew into the window of his hotel room in St. Paul. He released the bat through the window and saw it fly to the protection afforded between two closely adjoining buildings.

An unused mushroom cave at St. Paul, Ramsey County, Minnesota, was examined by Frederick Popps and the author on November 31, 1940 at which time a total of 12 Eptesicus was found and banded. Mr. Poppe revisited this cave on January 8, 1941 and found several unbanded large brown bats in a few minutes' search. None was banded at this time. In this instance, however, the finding of bats on a subsequent visit does not necessarily indicate arrival after November 31, 1940; for it is entirely possible that some of the bats may have been overlooked on the original visit. This cave has many inaccessible concealments.

On February 15, 1941, this cave was again visited with Mr. Poppe and his brother. A number of unbanded large brown bats were found

throughout the cave and a considerable mass was uncovered when a tar paper insulation was removed from an interior door. A total of 29 unbanded individuals was found.

An abandoned cave on Nicollet Island, Minneapolis, Hennepin County, Minnesota was visited on December 1, 1940. No bats of any species were found in the cave. Five Eptesicus from the mushroom cave in St. Paul were released in the cave at the cave at this time. Another visit to the cave was made on January 23, 1941, at which time seven additional large brown bats were found and banded. On February 23, 1941, another visit to this cave revealed two unbanded individuals. Two of the formerly banded bats were nowhere to be found, and there is a possibility that the unbanded individuals found had succeeded in removing the bands, as they usually worry them with their teeth and may occasionally be successful in their efforts at removal.

These data illustrate well that the large brown bat is hardy and capable of withstanding brief periods of low temperature inasmuch as but few resorted to caves before November 11, 1940. There is definitely a certain degree of influx into the caves in mid-winter as shown in the studies of Nicollet Cave. It is probable that these unusually late arrivals were individuals which previously in the season had sought shelter in buildings, later shifting to caves.

Habits associated with hibernation: During routine banding of this species it became apparent that there existed a tendency upon the part of the males to gather in clusters during the period of hibernation, while the females seemed more given to hanging singly. Commencing on December 12, 1940, a record was kept of the distribution of the sexes in their winter quarters. The following table tabulates these data:

TABLE II.

CLUSTERS			SINGLES		
Locality	M.	F.	Locality	M.	F.
Stillwater, Minn. Cave #1 Dec. 12, 1940	19	6	Stillwater, Minn. Cave #1 Dec. 12, 1940	-	-
Red Wing, Minn. Cave #2 Dec. 28, 1940	27	2	Red Wing, Minn. Cave #2 Dec. 28, 1940	1	8
Wabasha, Minn. Cave #1 Dec. 28, 1940	2	-	Wabasha, Minn. Cave #1 Dec. 28, 1940	1	8
Wabasha, Minn. Cave #2 Dec. 28, 1940	2	-	Wabasha, Minn. Cave #2 Dec. 28, 1940	1	3
Red Wing, Minn. Cave #1 Jan. 3, 1941	-	-	Red Wing, Minn. Cave #1 Jan. 3, 1941	4	6
Red Wing, Minn. Cave #2 Jan. 4, 1941	16 22 13	2 2 -	Red Wing, Minn. Cave #2 Jan. 4, 1941	2 - -	8 3 -
Minneapolis Cave #1 Jan. 8, 1941	1	2	Minneapolis Cave #1 Jan. 8, 1941	3	1
St. Paul, Minn. Cave #1 Nov. 31, 1940	15	3	St. Paul, Minn. Cave #1 Nov. 31, 1940	6	11
Total	117	17	Total	18	48

Distribution of Eptesicus by sex in wintering caves.

These data are somewhat in contradiction with the results of Dr. Mary J. Guthrie's work with this species in Missouri. She (Guthrie, 1933, pp. 7-8) reports, "Individuals are always isolated when they hang, although when they crawl into crevices, there may be two or three together." Later she goes on to say, "Among the hibernating forms, males and females are found together."

My data show a decided preference of males to gather together in segregated groups. Usually a small number of females, averaging 10%, were found intermingled with the males in the clusters.

It is not likely that the normal sex ratio varied to any such extent. Griffin (1940, p. 186) found that, "...of 110 young Eptesicus fuscus that have been captured, 60 were males."

By many it has been assumed that bats remain in a state of deep torpor in the caves throughout the winter. Such is certainly not true of the species Eptesicus fuscus, nor any of the other cave bats, in our state. Whether the winter inactivity of bats should be termed hibernation is rather doubtful, for they are periodically active. The positions of banded individuals in various caves have been charted during this study and subsequent visits have shown clearly that these individuals aroused frequently and shifted their roosting sites. One large brown bat banded on October 24, 1940, in one of the Seven Caves at St. Peter, Minnesota, was retaken in another of the Seven Caves about 400 yards distant on December 21, 1940. Such shifting between caves is perhaps unusual in Minnesota; there is indication of more frequent shifting between caves in southern regions where temperatures are more mild (Guthrie, 1940). Throughout the winter, however, movements within the cave are common.

During these periods of activity, the bats apparently seek food and drink. Mosquitoes of several species, cave crickets, several species of spiders, Diptera, and Lepidoptera including Scoliopteryx libatrix are found inhabiting the caves during the winter. These, undoubtedly, furnish winter food. I have never witnessed a bat catch food in the

caves, but all individuals removed from the caves to the laboratory have dropped well-formed feces. None of these has been carefully examined as yet. Several times chitin particles have been removed from the mouths of bats during the winter. A banded individual handled several times during the fall of the year was retaken on February 2, 1941. In its mouth was a large piece of chitin. This large and conspicuous chiton fragment could not have been there on December 21, 1940, for on that date this individual was handled and its teeth examined to determine wear.

Whenever caves are visited, a few bats are found to be active; and on numerous occasions I have seen them lap droplets of moisture from the cave walls.

In this regard, a few observations upon three large brown bats which have been kept in captivity during the winter might not be amiss. These have been housed in an aquarium covered with screening. The soil on the bottom is frequently moistened, and a composition board cover prevents too rapid evaporation; the temperature remains close to 45° F. The bats remain in resting position and quite motionless for periods of approximately a week each, then arouse and move about actively. Meal worms and water offered at these times are greedily taken. Shortly after feeding and drinking, they resume their positions; gradually the respiratory rate slackens until but one or two barely perceptible inspirations per minute are noted. In this manner they remain for another week. Under natural conditions where temperatures are lower, periods of activity may be less frequent. It is possible that the decrease of body water during the inactive period is a factor in arousing them to activity.

Place of hibernation: Eptesicus shows no inclination to winter in

the natural caves of Minnesota. Without exception, all large brown bats have been found hibernating in artificially made caves of the sandstone type. These, generally speaking, are much less humid and cooler than natural caves and in most instances are subject to greater degrees of temperature fluctuation.

In the sandstone caves of considerable extent where various latitudes of temperature and humidity are to be found, Eptesicus appears to favor the drier and cooler sections, often near the entrance itself. There exists a definite tendency on the part of this species, however, to select sites not directly exposed to drafts.

In this regard, Dr. Guthrie (1933, p. 7) states, "Eptesicus was found..., with few exceptions, in the large, relatively dry entrance chamber." Further she (1933, p. 18) writes, "It was always very inert, and frequently hung in well illuminated and unprotected places."

It is apparent that individuals of this species pass the winter in buildings of various types, frequently in the larger cities. I have no record of concentrations of any number during the winter season in buildings, but I have notes of individuals being found during the winter months in buildings on numerous occasions. A few records are cited by Swanson and Evans (1936, p. 43), "In the winter and spring of 1932, Dr. Ralph W. Macy secured a number of bats from a large furniture store in St. Paul.... All but one...proved to be big brown bats.... An additional big brown bat was taken March 1, 1932, at a theatre in Minneapolis, and on December 7, 1934, a student brought one...of the same species taken inside the library building of the university."

Two individuals of this species were seen several times during the

winter of 1940-1941 in a warehouse building in St. Paul. It appeared at intervals of about a week to fly about in the building.

Allen (1940, p. 71) states, "In the latitude of New England this bat frequently winters in city houses or public buildings..."

I have been told that telephone linemen frequently encounter bats when the pole boxes are opened. I have seen none of these specimens, but they are likely large brown bats.

Temperament during hibernation: Eptesicus is definitely not social with other species of bats during the winter season and is never found massed with individuals of another species. In many instances the hibernating sites chosen by the large brown bats are those with environmental conditions not tolerated by the smaller species. Where Eptesicus is found in the same chamber and under similar conditions with Myotis and Pipistrellus, the large brown bat is invariably segregated from the others. One factor of importance, perhaps, in this consideration is the greater ferocity and strength of Eptesicus which may well be feared by the smaller bats.

Even among their own kind, Eptesicus sometimes display their irritability. I have seen a disturbing individual in a hibernating mass of large brown bats severely bitten by an aggressive member of the group. This species has strong jaws, and they bite viciously and cling tenaciously. In nearly all instances of my observation, they have administered their bites in the region of the neck and head.

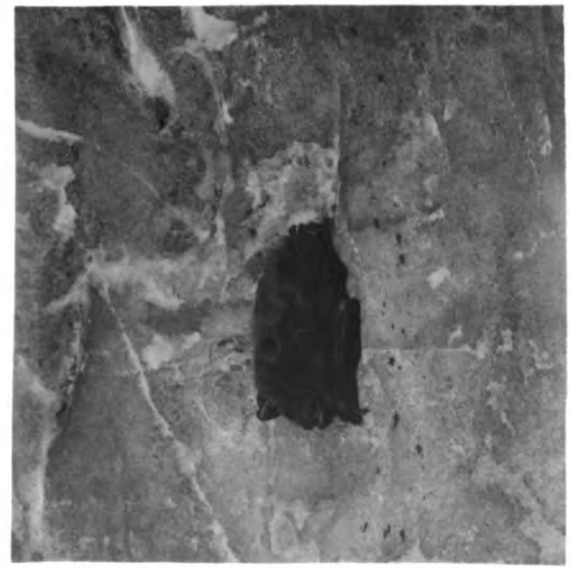
I have found a number of mutilated large brown bats, and these I attributed to such aggressive attacks by their own kind. If these wounds had been suffered from predatory animals, it would be surprising indeed that they escaped at all. In a mushroom cave at Wabasha, Minn-

PLATE III.

1. Characteristic manner of clustering on open wall of sandstone caves. Eptesicus fuscus fuscus

2. Eptesicus fuscus as sometimes found partially concealed in wall crevices and in recesses

3. Four male Eptesicus clinging to iron hook from the ceiling of an abandoned mushroom cave



4. A single Eptesicus in exposed situation near cave entrance where temperatures dropped to 20° F.

esota, I found an individual in which the left ear was represented by but a mere thread; other individuals showed bloody patches from which the hair had been torn away.

ENEMIES

Vertebrate enemies: In general, bats suffer few enemies. Perhaps their chief enemies during the period of hibernation are domestic cats, house rats, and vandal boys.

I was considerably astonished in my visits to various caves to find that a great number of them were regularly visited by cats. The tracks of cats were found leading into nearly all caves located near human habitations. Normally, bats hang well out of reach of prowling cats; but an occasional individual is to be found in a position readily accessible to enemies. Mr. Meyer, at Seven Caves, St. Peter, Minnesota, related that he had seen cats actually scale walls offering footholds and catch hibernating bats.

Following the storm of November 11, 1940, cats visited Seven Caves and carried away nearly all of the carcasses of the bats which froze to death at the snow-blocked entrance to one of the caves.

E. H. Forbush (1916, p. 68) reports, "Occasionally a low-flying bat is struck down by a cat, or one that has entered a dwelling is caught, but only two observers report to me the destruction of bats by the cat."

Rats, too, undoubtedly claim their toll of hibernating bats; for in several of the caves rat tracks were found. On March 2, 1939, I found remains of an Eptesicus fuscus in a rat tunnel in Seven Caves. The remains of another was noted at the entrance of a rat tunnel at Cave #3,

PLATE IV.

1. Myodopsylla insignis from Eptesicus fuscus fuscus

2. Spinturnix americana from Eptesicus fuscus fuscus

3. Eptesicus fuscus fuscus hanging singly in Nicollet Cave

4. Three Eptesicus fuscus in a small cluster as frequently found

Stillwater, Minnesota, on February 12, 1941.

Vandal boys are destructive when they encounter resting bats in the caves. A horrible account of boys holding burning newspapers close to hibernating masses and burning them to death was told me by Mr. Meyer. The incident took place this winter at St. Peter. Many people visiting caves gather specimens to take home as curiosities.

An account of a sparrow hawk (Falco s. sparverius) capturing and eating an Eptesicus fuscus appeared in the Auk (Stoner, 1939, p. 474). The hawk was seen to dart at an elm tree trunk and seize a bat of this species, then retire to a perch and consume its prey, dropping a portion of the skull which served to positively identify the bat. This incident was noted at 6:30 p.m. at Albany, New York.

A. K. Fisher (1893, p. 123) cites a bat in a stomach of a sparrow hawk taken in July, 1870, in Chester County, Pennsylvania; the species was not given.

A great horned owl pellet taken from the entrance of Seven Caves on December 21, 1940, contained a skull of an Eptesicus f. fuscus and a skull of a Blarina brevicauda. Errington (1940, p. 793) reports remains of a bat from the stomach of a great horned owl; the species was undetermined, but it was a Vespertilionidae.

Invertebrate enemies: Parasites also fall into the category of enemies of bats. Thus far two species of external parasites have been found upon this species. The mite, Spinturnix americana, is commonly found in considerable numbers on the upper and lower surfaces of the wing membrane. This genus has been reported from Eptesicus nilssoni (Keyserling and Blasius) and Eptesicus serotinus (Schreber) of Europe but apparently never for Eptesicus fuscus (Beauvois) (Stiles and Nolan,

1931, pp. 723-725). This mite is illustrated on Plate IV, fig. 2. A flea, Myodopsylla insignis, was taken from a specimen found in Cave #1, Red Wing, Minnesota, November 11, 1940. This genus has never been recorded for Eptesicus (Stiles and Nolan, 1931, pp. 723-725), and may be of uncommon occurrence, having been taken but once in this study. Plate IV, fig. 1 shows the microphotographic enlargement of this species of flea.

One species of internal parasite has been found in several Eptesicus examined and may be of frequent occurrence. It is Plagiorchis microcanthus Macy infesting the small intestine (Macy, 1931). A specimen of the large brown bat taken at Jordon, Minnesota on March 9, 1941 was particularly heavily infested, more than 40 individuals of this parasite having been removed.

All parasites were kindly identified by Mr. A. B. Erickson, University of Minnesota, and are now in the collection of the Department of Entomology and Economic Zoology, University of Minnesota.

Accidents: Seldom is a bat found which has not suffered some accident to the wing membranes as indicated by the scar tissue nodules. Adept as they are in maneuvering about stationary objects, it appears as though they must frequently snag the wings upon twigs and other natural obstacles. Rather severe tears seem to result in little permanent damage, healing over in due course of time and not hindering normal activity in the interim.

Spring Dispersal

Departure from the caves: Greater activity among the large brown

bats was observed in March, and many individuals which had remained in some of the deeper recesses of the caves were noted near the entrances. It may be that, incited by brief spells of warm weather, they were making ready to leave the caves.

A female large brown bat which was seen flying about the Armory of the University of Minnesota was captured on March 5, 1941. On March 18, 1941, a dead male was found on the sidewalk of the University of Minnesota campus.

In the unpublished field journals of Johan C. Hvoslef translated from Norwegian into English by Mrs. Gertrude Hanson and Mrs. Molly Endresen appears a note under the date of April 4, 1883 (for the region of Lanesboro, Minnesota) stating that on that date a large brown bat had been captured. The dental formula was given, and there exists no doubt as to the identity. With so few available spring or summer observations upon this species, this note is of additional value.

On April 11, 1941, the Jordon Cave, Jordon, Minnesota, was visited at which time no large brown bats were found. Presumably all had departed for the summer.

On the following evening at Minneapolis, Minnesota four large brown bats were seen in flight near the University of Minnesota at 7 p.m. They remained abroad in the vicinity for some little while, then disappeared one by one; and the last one observed was at 7:40 p.m. Since that day, none has been seen; although on numerous occasions the Myotis lucifugus are observed in the evening hours.

Aside from this one sight observation, this species has not been seen in evening flight. Howell (1919, p. 121) reports, "In California, Eptesicus is a very early flier, while in the East it appears at late

twilight; so the time of daily appearance varies considerably in the different parts of the range of this species."

Miscellaneous

Voice: Resting individuals, when first disturbed, utter long and drawn out raspy and gutteral notes. As they become more active, their voices become higher in pitch and clear. When fully awake and alert, squeaky staccato notes are given. I have no information as to the sounds produced while in flight.

Glandular secretions: The glandular apparatuse appears much more highly developed in this species than in other cave bats. Whenever disturbed, the large brown bat emits a pungent odor. Whether these glandular structures figure in intercommunication is not known. They may serve to mark roosting sites or as signals during the season of rut.

Terrestial locomotion: In addition to its skill in flight, the large brown bat can crawl rapidly and frequently does so. When dormant or semi-dormant individuals are knocked from the cave walls, they are too stupified to fly but are capable of comparatively rapid travel on their limbs. The body is raised on the supports of the hind feet and forearms, and the tail is arched in crawling.

In approaching a roost, the bats fly directly to it, grasping first with the clawed thums, quickly invert themselves into a suspended position, and hang head down. Frequently, upon alighting, instead of inverting themselves in this manner, they will crawl into a crecess head first. Again, they may first suspend themselves; then using their hind feet alternately, draw their bodies backwards into concealment.

On numerous occasions they have been observed to use their mouths in climbing and clinging in the same manner as parrots employ their beaks.

Weights and measurements: But very few specimens of Eptesicus have been taken for study material to date. A number of freshly killed specimens have been carefully measured and weighed. The total length averages about 113.6 mm. for the females.

For a period of time an attempt was made to measure living specimens. It soon became apparent that accurate measurements of total length and tail length could not be made from live specimens, because of their activity. Measurements of ear length, forearm, tibia, and foot could easily be made of living material; because these would have little value without the other measurements for correlation, the plan was discontinued. Some of these data have been included in Table III for whatever interest they may be. Only those specimens marked with an asterisk represent freshly killed and measured specimens. Weights, whenever available, were included.

A great many measurements might be added to this table if data were to be taken from prepared specimens in museum collections, but the author is of the opinion that the personal factor plays too important a role in such measurements to make such data of others of particular value. For that reason no measurements but his own have been included.

As future material becomes available, the series will be added to for the final compilation of this study.

Color variation: Nearly all specimens of Eptesicus examined have shown slight variation in general fur color, and all gradients from Mummy Brown to dark Van Dyke Brown are displayed. The majority of the specimens from Minnesota tend toward the darker shades.

Frequently Chestnut blotches of considerable size are found on the belly, and in many specimens slight traces of Chestnut are evident in small restricted belly areas.

Distribution

Minnesota distribution: The entire state is included in the general distribution of this species, however summer specimens are rare in collections. Undoubtedly, summer collecting will prove general distribution throughout the state. Map 1, Plate V shows the distribution of this species so far as actually known from specimens or personal observations.

All winter distribution records indicated on the map are of specimens taken from wintering caves. With the accumulation of data of bats wintering in buildings, this range will probably be much enlarged. The great need at the present time is for additional summer distribution records.

PLATE III.

Locality	Sex	T.L.	T.	Rad.	Tib.	Foot	Ear	Wt.
Minneapolis, Minn.	*F.	109.0	39.5	46.5	20.0	11.0	15.0	-
Stillwater, Minn.	*F.	126.0	52.0	49.5	20.5	10.0	15.5	23.3
Stillwater, Minn.	*F.	113.0	43.5	45.5	20.0	10.0	13.3	14.1
Stillwater, Minn.	*F.	107.5	39.0	46.0	20.2	10.5	12.9	-
St. Paul, Minn.	F.	120.2	40.5	47.8	22.0	-	15.8	21.3
St. Paul, Minn.	F.	-	-	44.7	20.9	-	15.0	21.4
St. Paul, Minn.	F.	-	-	48.0	21.5	10.0	16.7	28.4
St. Paul, Minn.	M.	119.0	39.0	44.5	21.0	10.0	15.0	-
St. Paul, Minn.	M.	120.0	39.0	45.2	20.0	-	15.0	-
Stillwater, Minn.	*M.	108.0	43.0	44.0	19.9	10.0	12.7	15.2
Minneapolis, Minn.	*F.	113.0	41.0	50.0	22.0	-	14.0	-
Jordon, Minn.	*F.	115.0	44.0	47.0	21.0	12.5	15.0	17.6

Measurements and weights of large brown bats from Minnesota.

Genus Myotis Kaup

This genus is represented in the temperate and tropical portions of both hemispheres. There are 15 species found in North America and but two of these are now known from Minnesota, Myotis keenii septentrionalis (Trouessart) and Myotis lucifugus lucifugus (Le Conte).

LONG-EARED LITTLE BROWN BAT

Myotis keenii septentrionalis (Trouessart)

Vespertilio subulatus Say, Long's Exped. Rocky Mts., II, p. 65, 1823.
Vespertilio subulatus H. Allen, Monog. N. A. Bats, 1864.
Vespertilio gryphus var. septentrionalis Trouessart, Cat. Mamm., 1897.

Description

Dental formula: I-2/3; C-1/1; P-3/3; M-3/3---38.

General characters: Size medium; total length, 80 to 90 mm.; tail, 39 to 42 mm.; forearm, 34 to 37 mm.; ear, 13.5 to 17 mm.; hind foot, 8 to 9 mm.; ears and membranes thin and nearly translucent; fur color dusky slate at the basal half with dull brown tips which have a gloss in proper light; the ventral surface paler and more yellowish.

On the uropatagium the fur occupies the basal quarter dorsally, less extensively ventrally, and a narrow line close to the body and a few scattered hairs along the membrane veins.

Ears: Long and slender, reaching 2 to 5 mm. beyond tip of nose when laid forward; broadest near middle; external basal lobe conspicuous;

tragus slender and bent slightly backward; basal lobe small.

Skull: Averages about 15 mm. in length in occipito-nasal length; posterior margin of brain case rounded; occipital ridges but faintly defined; entire skull delicate in structure.

Teeth: Upper incisors diverge at tips; first premolar longer than second and has crown a fourth again as large as first; third premolar triangular in outline; first and second molars trapeziform, the first being shorter and broader than second.

Hibernation

Migration to the caves: I have no definite information as to the distances traveled to the caves during the fall of the year. Griffin (1940a, p. 235) has shown that this species in the New England states will travel at least as much as 55 miles to winter quarters.

Although this species is rare in museum collections, it is believed to be relatively common throughout the state during the summer season. So little mammal collecting has been done in Minnesota that museum collections are sometimes not a true criterion of relative abundance. By certain observers (Cahn, 1921, p. 73) it has been reported as common in the state counties during the summer season. If this species is as common a summer resident as supposed, the majority of them must certainly migrate to caves in the states to the south of Minnesota; for it is rare in our caves in winter, only a few specimens having been found.

Hitchcock (1940, p. 56) has found this species hibernating in a cave at Wiarton, Bruce County, Ontario on October 28, 1939. In another

cave at Wilson's Corner, Quebec, 17 Myotis keenii septentrionalis on November 25, 1939. Gould (1936, pp. 103-104) found 36 individuals of this species in a cave at Cheverie, Hants County, Nova Scotia on February 11, 1935. It seems odd that wintering specimens should be found in these northern parts of the continent and yet not found in larger numbers in Minnesota caves. Much more investigation is needed to satisfy the status of this species in Minnesota during both the winter and summer season.

Oddly enough, all the specimens found wintering in Nova Scotia were males, and the two taken in Ontario by Hitchcock were males. H. B. Hitchcock does not state the sexes of the 17 long-eared little brown bats found hibernating in Ontario.

Dates of arrival at the caves: This study was commenced too late in the season to gather data on fall arrival dates. The bats of this species were found already established in the caves at St. Peter, Minnesota on October 24, 1940. Since that date no influx was noted at any of the caves.

Habits associated with hibernation: In Sand Cave #1, Red Wing, Minnesota three individuals were removed from a small drill hole in the ceiling. These three were females. All others that have been encountered in the caves have been found hanging singly.

Griffin (1940a, pp. 181-182) states, "...(this species) more often found alone in some small crevice." Gould (1936, p. 103) reports, "Most of them (long-eared little brown bats) however were found tightly packed in two drill holes in the roof, which were about five inches deep and one and a half inches in diameter."

Far too few have been encountered in the caves to determine the sex ratio. Mohr (1932, p. 2) found that of 141 specimens collected in Pennsylvania in August and September, 116 or 77% were males. He did not report any segregation of sexes during that season and was not familiar with them in hibernation quarters.

This species has been found in both the natural and the sandstone caves of the state, but always they have been found in situations of high temperature and relative humidity. They are periodically active during the winter season. On several occasions a few individuals of this species would be seen moving about the caves while others of the same species were inactive.

It has been found associated in clusters with no other species, and I can find no mention in literature that such ever occurs.

Enemies

Vertebrate enemies: This species is probably subject to the same enemies as Eptesicus. Its habit of selecting roosts in the innermost chambers of the caves may make it less vulnerable to predation.

Invertebrate enemies: No parasites have been removed from this species by myself. Stiles (1931, p. 712) reports Myodopsylla insignis as an external parasite. There is great need for parasitological work on all species of bats in the United States.

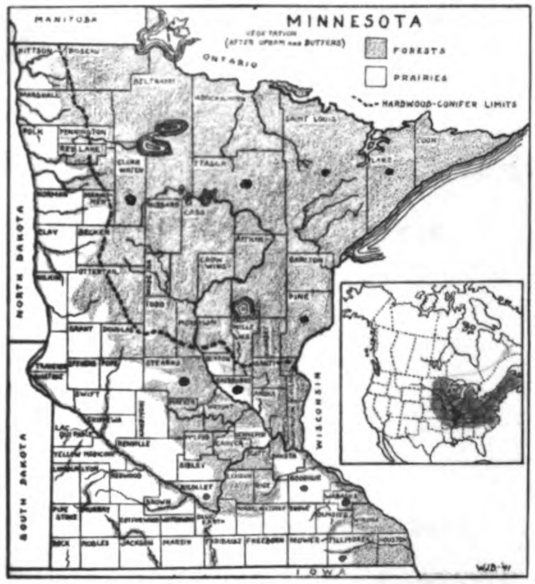
Distribution

Minnesota distribution: The entire state is probably included in

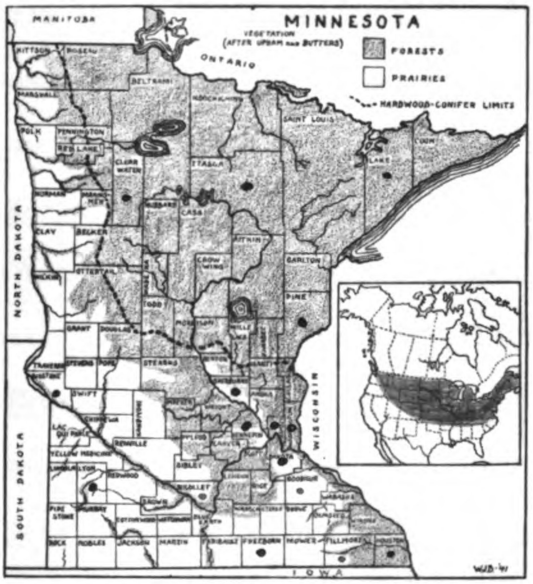
the general distribution of this species. Map 2, Plate V. shows the distribution by counties in winter and summer as now known from definite records. Undoubtedly much could be added to extend this range if intensive field work were conducted throughout the state.

PLATE V.

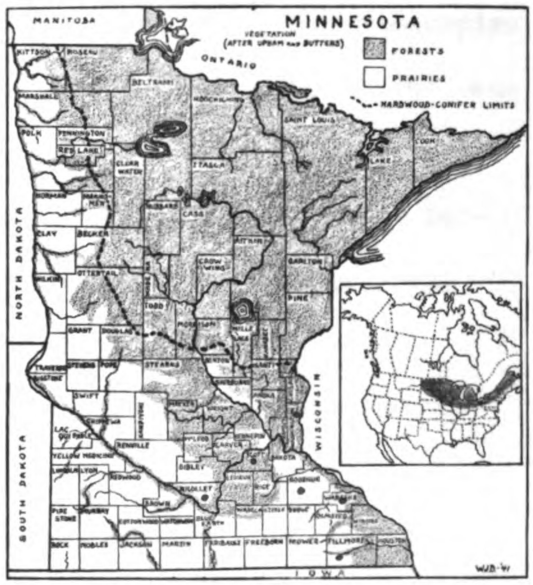
Map 1. Distribution of Eptesicus f. fuscus in Minnesota and general range in the U. S.
- winter
- summer



Map 2. Distribution of Myotis keenii septentrionalis in Minnesota and in the U. S.
- winter
- summer



Map 3. Distribution of Myotis l. lucifugus in Minnesota and general range in the U. S.
- winter
- summer



Map 4. Distribution of Pipistrellus subflavus obscurus in Minnesota and the U. S.
- winter
- summer

LITTLE BROWN BAT

Myotis lucifugus lucifugus (LeConte)

Vespertilio lucifugus LeConte, McMurtie's Cuvier, *Animal Kingdom*, I, 1831.
Vespertilio affinis H. Allen, *Monog. N. A. Bats*, 1864.
Vespertilio gryphus var. *lucifugus* H. Allen, Monog. N. A. Bats, 1893.

Description

Dental formula: I-2/3; C-1/1; P-3/3; M-3/3---38.

General characters: Size medium; total length, 80 to 90 mm.; tail, 37 to 40 mm.; forearm, 36 to 40 mm.; ear, 12 to 14 mm.; hind foot, 7 to 9 mm.; ears and membranes rather thick and leathery; fur dusky slate at base and dull brown with gloss above; below fur paler and more yellowish.

The membranes are entirely naked except where body fur extends in a narrow line at the base of wings and uropatagium where the fur occupies the basal fourth on the dorsal side and about the basal fifth on the ventral surface.

Ears: Short and pointed; reach just to tip of nose when laid forward; basal lobe broad but not conspicuous; tragus short, blunt, bent slightly forward; basal lobe prominent and large.

Skull: Gradual sloping forehead; broad muzzle and palate; brain case broad and inflated posteriorly.

Teeth: Upper incisors diverge at tips, crown of first bicuspidate while that of second unicuspidate; second incisor the smaller; first premolar always larger than second but varies in this relationship; crown of first lower premolar longer than second; third premolar subquadrate.

Hibernation

Migration to the caves: This species is the most commonly encountered bat during the summer months in Minnesota, being stated by B. Bailey (1929, p. 155) as the "...most common of our bats, outnumbering all other species by probably one hundred to one." Yet in winter it is more rare than Myotis keenii septentrionalis in the caves of the state. It has been found in four caves as indicated on the distribution map.

When the St. Peter caves were visited on October 24, 1940, a few bats of this species were found already established for the winter, and since that date no influx was evident. The exact date at which they entered the caves or usually enter the caves is not known, but notes gathered by G. Swanson (1941) give some indication of migration dates. In personal correspondence, he gave the following notes:

"During the first week of September, 1932, Martin K. Nelson, game warden at Fertile, Minnesota, took me to a farm just a few miles from that town, at which there had been reported a large colony of bats. We were prepared with nets and an apiarists' bellows which we hoped would enable us to catch some of the bats. When we arrived there was not a bat remaining but the farmer assured us that they had left not more than a few days earlier, that is, about the end of August. He reported that there had been a large group of bats, and that they had been spending the daytime hours between the walls of the house. We investigated the spots to which the farmer referred and found large piles of bat dung, so I have no doubt the story was true. The farmer reported that the bats had spent most of the summer in that area, and that their

squeaking could be heard every day from within the house. We had no opportunity of seeing even one specimen, but of course they must have been either big brown bats or Myotis."

This is an indefinite but interesting record, and in all probability the species was Myotis l. lucifugus, the most common bat of the state, and the one usually encountered in such situations.

Bernard Bailey (1929, p. 155) collected specimens of the little brown bat in Sherburne County, Minnesota on September 16 and 25, 1924. His latest fall record is for one seen October 5, 1921.

An interesting account of migrating Myotis lucifugus was reported by Zimmerman (1937, p. 363). At Black River Falls, Wisconsin on October 29, 1936, hundreds of dead and dying Myotis lucifugus were found on the streets of the town. Others were found clinging to the sides of buildings, awnings, and store fronts. He expressed the belief that they had become exhausted during a long flight the night before in their southward migration which had been prompted by a sudden cold wave through the northern portion of the state. It is likely that many had dashed themselves to death against obstacles in the town. Such lighted obstacles have resulted in the death of a considerable number of migrating tree bats as reported by Saunders (1930, p. 225) from the lighthouse at Long Point, Lake Erie.

It is evident from reports of other workers that the annual departure from summer roosts varies considerably. In Iowa, Sherman (1929, p. 321) found over a period of fourteen years that the latest date of departure was October 16 and the earliest date was September 19. The median date on which the summer roost was deserted was October 3.

In as much as this species is common in summer and rare in winter, it may be assumed, perhaps, that the majority of them migrate to caves situated to the south of Minnesota. Griffin (1940, p. 231), through his banding activities has shown that this species will travel as much as 156 miles to its home roost, and it is likely that they are capable of much greater distances of flight.

In the caves of southern Illinois and Missouri this species is found in large numbers during the winter season. Fifty bats collected for me at Grafton, Illinois and shipped to Minnesota this past winter were almost all Myotis lucifugus, five being Pipistrellus subflavus obscurus. This was a random sample of the cave in which they were found, indicating the large numbers of this species found there during the winter season.

In these more southern localities, the bats are not limited as much by climatic conditions as here in Minnesota; and they are permitted to indulge in greater activity throughout the winter season. Guthrie (1933, p. 17) writes, "Specimens were quite torpid until mid-January when some activity was observed; numbers increased on February 6 and conspicuously on February 20 after a maximum of 77° and a minimum of 63° F. had been recorded on February 10." The increase of numbers in the caves during early February was credited to northward moving bats.

In these southern areas the cave bats may and apparently do hunt out of doors periodically through the winter season when brief mild periods permit. In Minnesota there certainly would be few days before middle March that bats would venture out of doors on their own accord.

Habits associated with hibernation: On several occasions little brown bats were found in small crevices, but ordinarily they were to be found hanging singly. Too few were observed to secure data on either sex ratio or sex segregation. In New York, A. A. Allen (1920, pp. 56-57) found the sex ratio of young Myotis lucifugus to be 48 males to 53 females. Mohr (1932, pp.2-3), in studying the bats of the Pennsylvania caves, discovered a preponderance of males. Of 406 specimens, 56% were males; in another group of 113, 68% were males. Mohr (1939, p. 44) later wrote, "Myotis l. lucifugus shows a steady preponderance of males: 64.5 percent in the tunnels and 70 percent in Woodward Cave where six years ago the percentage was 68 percent."

Place of hibernation: Like Myotis keenii septentrionalis, this species has been discovered in both natural and sandstone caves but is always found where high temperatures prevail and where the relative humidity is between 90% and 100%.

Spring dispersal: The earliest spring records of this species for Minnesota are those recorded by Bailey (1929, p. 155) who observed them in Sherburne County on April 29, 1922 and April 27 and 30, 1923.

Hvoslef writes in his journal under the date May 9, 1882 for the region of Lanesboro, Fillmore County, "There have been bats caught at Iverson's the past few days. Vespertilio subulatus." A diagram of the dentition accompanied the notation to substantiate the species.

Guthrie (1933, p. 17) noted at Rocheport and Hunter's Caves, Booth County, Missoui that "Indications of movement were noted on February 28 at Rocheport by the occurrence of M. lucifugus in a new location nearer the entrance; and on the same day at Hunter's a specimen was

taken from the entrance passage. Young ones were now defintely more numerous. Throughout March this species was present, but early in April the numbers were noticeably reduced and the last ones were taken on April 16;...."

Sherman (1929, pp. 320-321) at National, Iowa found the median date of arrival at the summer roost to be May 13; while the earliest date was May 2, and the latest May 30. It was interesting to note that on three separate years, the bats arrived on May 2.

On May 18, 1941 a house at Brownsville, Minnesota was visited. A great number of Myotis l. lucifugus were found inhabiting the attic. All but one of the captured individuals were females. When the attic was entered, many bats were flying about, while others were found concealed beneath the insulation of the roof. The favorite roosts were indicated by the larger dung piles beneath them.

Young: Bailey (1929, p. 155) writes that the earliest record of embryos in this species in Sherburne County is May 30, 1925, when three females were collected and two contained embryos. He further notes, "Many specimens have been examined between June 27 and July 10, all of which were at the time nursing, or had recently nursed, young."

One of the two females collected at Brownsville, Minnesota on May 18, 1941 contained a single embryo in the left horn. This embryo measured 10 mm. from crown to rump in its natural uterine position and weighed 0.32 gram with attached placenta.

Mohr (1933, p. 52) made several observations upon the young of this species in Pennsylvania. On July 17, two captives gave birth to one young each. At birth, these young weighed 1.45 and 1.55 grams respectively.

During parturition one of the females rested upon a horizontal screening; another female hung from a vertical screen, head up. The young were partially supported by the pouched interfemoral membrane and partly by the umbilical cord which was not severed but remained attached to the placenta when it was shed. The placenta dried and apparently broke off on the second day.

Mohr (1933, p. 52) reported that at no time did he find females carrying young on leaving the summer roosts.

On July 18 he collected 35 male and 33 female bats in the region and supplied the following note, "The immature bats were easily distinguished from the adults by the darker coloration, a sooty gray above, lacking the yellowish tinge below; by the thicker finger bones and swollen epiphyses; and upon closer examination by the milk dentition and the lighter weight, which on that date ranged from 4.7 to 5.4 grams. In summer the adults range in weight from 6 to 7.5 grams."

Feeding habits: H. H. Pittman (1924, pp. 231-232) kept several captive Myotis lucifugus and made some interesting observations upon their feeding mannerisms. When a moth had been captured, the bat would settle right-side-up on a near object. The body, wings, and interfemoral membrane were brought into position to form a pouch into which the insect was placed after it had been rubbed down the animal's chest several times. Burying its head in the pouch, the bat would viciously bite the insect a couple of times and then bring it forth to eat it head first, rejecting the wings which would fall to the ground.

This same manner of feeding was observed in the large brown bats which were kept as pets by the author. It is perhaps the common manner of feeding among the cave bats when large insects are captured.

Enemies

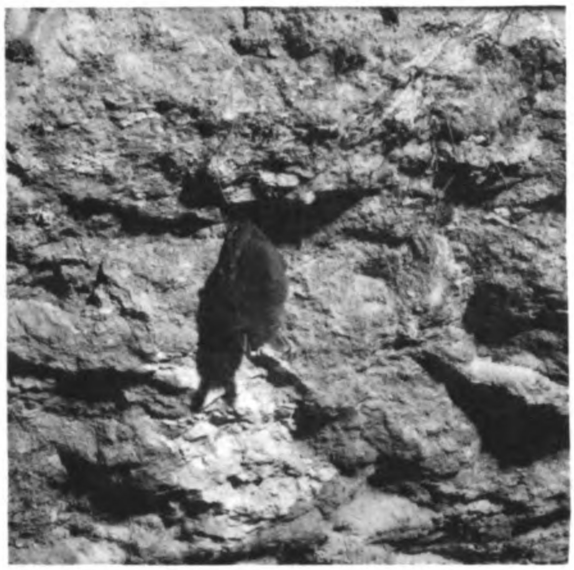
Vertebrate enemies: No specific predation has been noted, but it is likely that the same factors of predation as found with the large brown bat operate against this species.

Invertebrate enemies: Several times the mite, Spinturnix americana, has been removed from the wing membranes of this bat. The parasite has not been listed for Myotis l. lucifugus (Stiles and Nolan, 1931, p. 708). Two fleas, Myodopsylla insignis, were taken from a female little brown bat captured at Brownsville, Minnesota on May 18, 1941. This parasite has been previously recorded for Myotis lucifugus from Ontario(Stiles and Nolan, 1931, p. 708).

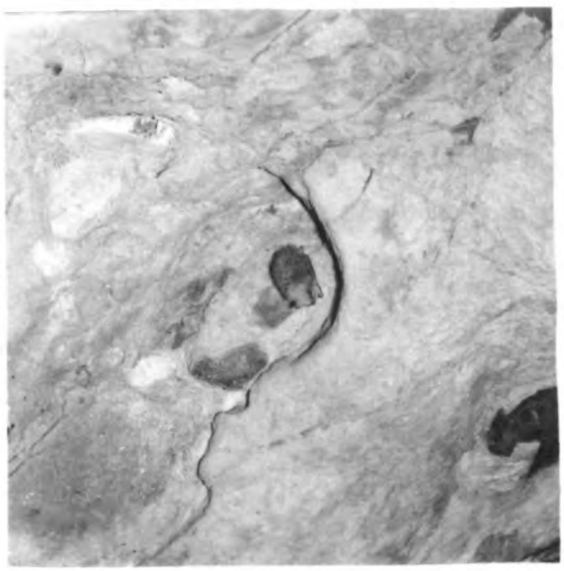
Distribution

Minnesota distribution: The little brown bat is well distributed over the entire state during the summer months. In winter, as already mentioned, it is rare. The distributional map shows both summer and winter distribution as now known from specimens in collections and reliable field records.

PLATE VI.



1. Myotis keenii septentrionalis hanging singly in cave at St. Peter, Minnesota



2. Pipistrellus subflavus obscurus customarily hangs alone in warm and moist chambers

3. Only cluster of Georgian bats ever encountered. This group disbanded a few days later, thereafter hanging in solitary manner

4. When covered by droplets of condensed moisture, Georgian bats appear white

Genus Pipistrellus Kaup

This genus is represented through the greater part of the Eastern Hemisphere, and throughout the southern half of North America, the exact distributional limits being unknown. Two species, Pipistrellus hesperus and Pipistrellus subflavus, are found in the United States.

DUSKY GEORGIAN BAT

Pipistrellus subflavus obscurus Miller

Description

Dental formula: I-2/2; C-1/1; P-2/2; M-3/3---34.

General characters: Size small, total length, 84 to 86 mm.; tail, 37 to 41 mm.; forearm, 34 to 36 mm.; ear, 10 ,,.; hind foot, 8 mm.; ear, and wing membranes thin and delicate; fur color blackish slate at base, middle band of back dull, pale, wood brown, tips of hair dusky brown above, below uniform isabella color and lacking yellowish brown of true subflavus; fur extends on base of ears and interfemoral membrane and on the wings to mid-forearm anteriorly and knee joint posteriorly.

Ears: Reach just to tip of nostril when laid forward or sometimes a bit beyond nostrils. Sprinkling of fine hairs on inner surface; basal lobe small; tragus half length of ear, bluntly rounded tip turned slightly backward, basal lobe well developed.

Skull: Measures about 5 mm. in zygomatic breadth and 8 mm. in occipital length. Muzzle narrow and arched, lateral concavities nearly obsolete.

The pipistrelle bat is the smallest of the species found in our state, occurring in limited numbers in the caves, both natural and artificial, during the winter season. So far as known, it has never been encountered in Minnesota in summer.

Up until 1934, the presence of this bat in Minnesota was not known. On February 12, 1934, Dr. G. A. Swanson, Dr. Charles Evans, and Dr. W. J. Breckenridge visited the caves at St. Peter, Minnesota and discovered 15 individuals of this species to establish the first state record. At a later date, Mr. Richard Daggy and H. T. Peters found the pipistrelle bat in a Wabasha County cave.

During the course of this study, the following counties have been added to the distributional record of this species: Fillmore, Scott, Goodhue, and Washington Counties.

D. M. Hatfield (1940) designated our pipistrelle bat as Pipistrellus subflavus subflavus. In examining the specimens in our collection and the live bats in the caves, it became apparent that our forms did not match the description of the subspecies subflavus. As a matter of verification, all specimens of Pipistrellus were forwarded to Dr. Glover M. Allen who pronounced them to be, without exception, Pipistrellus subflavus obscurus, the northern form known commonly as the Dusky Georgian Bat. Even among our few specimens here, there exists some individual variation; but all of our specimens definitely fall into this northern darker group.

Hibernation

Migration to the caves: This species had already reached the caves of St. Peter, Minnesota and Jordon, Minnesota when they were first visit-

ed on October 24, 1940; so that no exact dates of arrival are available.

Griffin (1940, p. 237) has banded and traced the migrations of a number of species of bats in the East, and he has recovered Pipistrellus subflavus 85 miles from the point where banded, showing that even this diminuitive species is capable of migrating considerable distances.

Correlated with the migratory habit is the homing ability of the smaller species of cave bats. They return year after year to the same summer roosts and wintering caves. In 1916, Allen (1921, pp. 53-54) banded four female pipistrelle bats at a summer roost at Ithaca, New York. Three years later three of the four were retaken at the same roost.

As has been shown by several workers, if bats are removed from the summer or winter quarters and released at some distance, a great proportion of them return to the same spot. On October 24, 1940 I caught a pipistrelle bat at St. Peter, Minnesota. It was banded and released the following day at Minneapolis, Minnesota. When the cave was again visited on February 2, 1941, this individual was recovered at the same cave and very nearly at the same spot from which it was originally taken. To return, this individual had to travel at least 80 miles. As was previously reported (p.9), the fall season was mild, permitting the bat to migrate at this late date.

Place of hibernation: The pipistrelle bat selects the warm and humid quarters in the natural and artificial caves. In no instance has this species been found where the temperature was lower than 45° F., and usually the temperature of the chambers in which they were found varied between 48° and 50° F. The relative humidity of the hibernating quarters usually ranged above 95%. Refer to Table I.

Although this species is reported as social with others of its kind

during the summer season, but in winter while in the caves it is the most solitary of all the species of cave bats in the state. Only once have I ever found a cluster of pipistrelles in a cave. This group consisted of five individuals hanging side by side and a sixth near by but somewhat removed from the main group. This cluster was found at the Jordon Cave and photographed. (See Plate VI, figure 3) In less than a week this group had disbanded, and thereafter the individuals were found hanging singly.

The pipistrelle bats, in the winter caves, remain inactive for longer periods of time than the other species; but they periodically arouse and move about the cave. During the time they remain inactive, their bodies become clothed in droplets of condensed moisture; and in torch light they appear almost pure white. Whenever I have traced the reports of white bats in caves, I have found either this species or the little brown bat which are given the white appearance by the light reflected from these water droplets. Plate VI, figure 4 shows a pipistrelle bat covered with moisture and photographed with a flash bulb. The result is a picture of what appears to be an albino bat.

In Mystery Cave, Spring Valley, Minnesota, I observed a Pipistrellus arouse from a state of torpidity. It first showed movement by an occasional shiver; then opened its eyes and peered about with upraised head. The ears, which during the period of resting were somewhat curled, were spread open to full size and twitched sensitively; and the wings were exercised. Before taking flight, the bat spent some moments licking the droplets of moisture from its fur, then carefully cleaned itself, scratching its fur and drawing portions of the wing membrane through its mouth.

Spring dispersal: On April 11, 1941 the cave at Jordon, Minnesota was visited. At this date the Eptesicus had already departed, but all the pipistrelle bats which had passed the winter there were found in residence. It was impossible to return to the cave again until June 2, 1941 at which time no bats were to be found.

Guthrie (1933, p. 8) stated that "...males are resident in the caves for a considerable period after the females have left."

Inasmuch as no summer specimens from the state are known, an effort has been made this spring to locate a summer colony. Numerous buildings have been examined, but only little brown bats have been found inhabiting them. Allen (1921) reports that in New York this species is found in clusters in attics, cupolas, and similar situations. These clusters are usually composed entirely of pregnant females. It has been stated by Black (1937, p. 148) that in Kansas this species is found sleeping in rock crevices in summer. If this is true, those individuals so found may be males which are segregated from the females during the summer season.

Enemies

Vertebrate enemies: Nothing is known at the present time concerning the vertebrate enemies of this species. It is likely that they are less subject to predation than some of the other species which winter in more accessible situations.

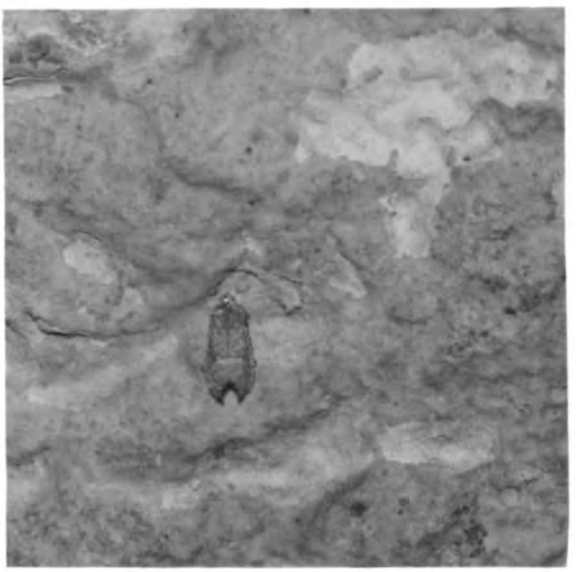
Invertebrate enemies: A considerable number of Georgian bats have been examined for ectoparasites, but none has been found thus far.

It appears as though they are less heavily infested than some of the other cave bats.

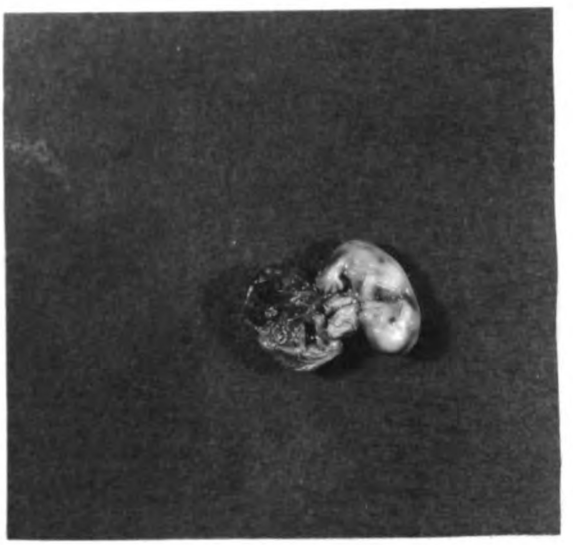
Distribution

Hatfield (1940) states that this species is found as far north in the state as St. Peter, Minnesota. Specimens have now been taken from six counties in the state as as far northward as Washington County. It is likely that during the summer months this species is found to the northern limits of the state, but there is no available data at the present time upon summer range.

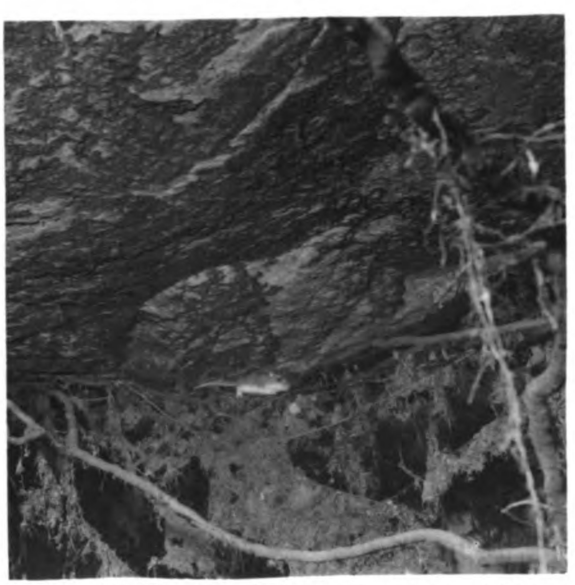
PLATE VII.



1. A common moth wintering in many of the caves was this Scoliopteryx libatrix



2. Embryo removed from Myotis lucifugus taken May 18, 1941 at Brownsville, Minnesota. Length, 10 mm. from crown to posterior end in natural uterine position



3. White-footed mouse encountered in Jordon Cave, Jordon, Minnesota in mid-winter

4. Marked long-eared little brown bat showing placement of band on the leg

POSSIBLE ADDITIONS TO THE STATE

There are a number of species of cave bats which have not been recorded for the state but which are found in adjacent areas and may now reside in the state but have been overlooked, or others which may invade the state during coming years.

Myotis californicus ciliolabrum (Merriam). This species is rare and but few specimens are in existence. It is known from Trego County, Kansas and central South Dakota.

Nycticeius humeralis Rafinesque. This species is found distributed through the Austral zone of the United States west at least as far as Arkansas. Specimens have been taken in Kalamazoo County, Michigan (Burt, 1939, p. 103) and in Illinois (Cory, 1912, p. 477).

Myotis volans interior Miller. One specimen taken at Bull Springs, Custer County, South Dakota (Moulthrop, 1936, pp. 413-414). This is an extension of its range by 150 miles to the northwest.

Myotis thysanodes Miller. Two specimens were taken from Jewel Cave, Custer County, South Dakota (Bole, 1935, pp. 147-148).

Nyctinomus depressus Ward. This bat, Tacubaya free-tailed bat, has been recorded twice for the state of Iowa, once from Marshalltown and once from Cedar Rapids (Gabrielson, 1916, pp. 85-86), both having been taken during the summer season.

OTHER ANIMAL FORMS FOUND IN THE CAVES

Other animal forms are frequently found in the caves inhabited by bats. In several of the caves, surface waters enter the openings after heavy rains. Evaporation is slow in the caves, and certain amphibian forms find suitable conditions on the moist floors. Not infrequently toads (Bufo americanus), frogs (Rana pipiens), and the tiger salamanders (Ambystoma tigrinum) have been encountered, using the caves as temporary retreats.

Rats (Rattus norvegicus) have been seen several times, and their tracks are numerous on the cave floors, especially when the caves are situated near human habitations. Mice (Peromyscus sp.) have been observed in the Jordon Cave, and a photograph of one of these appears on Plate VII, figure 3.

Rabbit (Sylvilagus floridanus) tracks are frequently seen leading into the caves, and on one occasion the tracks of a skunk (Mephitis mephitis) were discovered at the entrance of a cave. Cats frequent the caves, probably in search of prey; but caves may well serve stray cats as shelters from inclement weather conditions.

Great horned owl (Bubo virginianus) pellets indicate that these birds sometimes resort to caves for shelter; one pellet was gathered from the St. Peter cave. Phoebes (Sayornis phoebe) often build nests on the ledges just inside the entrance ways.

Insect forms of many types are to be seen passing the winter in the caves, and these furnish food for the bats during their periods of activity. Cave-crickets (Ceuthophilus sp.) inhabit many of the caves.

Mosquitoes (Anopheles maculipennis), several other diptera, Rhymosia sp., Drosophila sp., and Helomyza sp. are also to be found. There were many moths (Scoloptery*x* libatrix) illustrated on Plate VII, figure 1, and others of an undetermined group. Spiders were found in great numbers, but no effort has been made to identify them as yet.

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KEY TO THE BATS OF MINNESOTA

1. Membrane enveloping tail hairy above, naked below.....2.

1a. Membrane enveloping tail entirely or mainly naked above and below.. .....4.

2. Total length more than 4 3/4 inches; wing spread about 16 inches; fur color light grey over yellowish brown..... Hoary Bat (Lasiurus cinereus)

Description. Size large, total length 5 to 5 3/4 inches; general fur color Seal Brown and Buff generously overwashed with white, the throat band extending to each ear Naples Yellow, sides of face black and furred; wing membranes thick and leathery, medium to dark brown and heavily furred on anterior half of ventral surface; ears short, oval, furred on inner and outer surfaces, Naples Yellow outlined with black, basal lobe large; tragus short, blunt, slightly furred, and incurved.

2a. Total length less than 4 3/4 inches.....3.

3. Wing spread about 13 inches; fur yellowish with overlayer of rich reddish brown modified to varying degrees by ashy tips of hair... Red Bat (Lasiurus borealis).

Description. Size large, total length 3 3/4 to 4 1/4 inches; fur color siffers with sex, ♂: general color yellowish with heavy overlay of Kaiser Brown, lower belly much paler, ♀: with Russet wash modified by ashy hair tips; wing membranes medium to dark brown, relatively thick and leathery, and furred heavily on anterior half of ventral surface; ears short, oval, Naples Yellow, basal lobe is prominent; tragus medium length, blunt, basal lobe moderate.

3a. Wing spread about 12 inches; fur dark chocolate brown with frosty tips.....Silver-haired Bat (Lasionycteris noctivagans).

Description. Size large, total length 3½ to 4¼ inches; fur color deep Blackish Brown tipped sparingly with silvery white; wing membranes medium to dark brown, thick and leathery; ears short, oval, inner surface naked, outer surface furred on basal half, dark brown, basal lobe prominent; tragus medium length, blunt, basal lobe slightly developed.

4. Total length more than 4 1/8 inches; wing spread about 13 inches; fur color wood brown above, paler below..... Large Brown Bat (Eptesicus fuscus).

Description. Size large, total length 4 1/4 to 4 3/4 inches; general fur color dark Van Dyke Brown above, paler and more yellowish below; wing membranes dark brown, appear thick, leathery, naked, and outer surface furred on basal half, basal lobe moderate; tragus is straight, blunt, basal lobe large.

4a. Total length less than 4 1/8 inches.....5.

5. Ears extending noticeably beyond tip of nose when laid forward; tragus long and tapering.....
Long-eared Little Brown Bat (Myotis keenii septentrionalis).

Description. Size medium, total length 3 1/8 to 3 ½ inches, general fur color Snuff Brown over Blackish Slate above, paler and more yellowish below; wing membranes dark brown, thick and leathery, appear to be naked; ears long and extending 2 to 5 mm. beyond tip of nose when laid forward, light brown, basal lobe moderate; tragus long, narrowed toward backward directed apex, basal lobe moderate.

5a. Ears extending just to tip of nose when laid forward; tragus medium length and nearly equal width throughout.....6.

6. Color dark brown; forearm more than 1 3/8 inches.....
Little Brown Bat (Myotis l. lucifugus).

Description. Size medium, total length 3 to 3½ inches; fur color is the same as that of Myotis keenii septentrionalis in every respect; wing membranes thick and leathery, dark brown, appear naked; ears are medium length reaching just to tip of nose when laid forward, light brown, basal lobe prominent; tragus medium, blunt, directed forward, basal lobe moderate.

6a. Color yellowish brown; forearm less than 1 3/8 inches.....
Pipistrelle Bat (Pipistrellus subflavus).

Description. Size small, total length 3 to 3 3/8 inches; fur color Blackish Slate at base overlayed by Tilleul-Buff and tipped with light Wood Brown above, somewhat paler below; wing membranes thin, delicate, appear naked, dark brown; ears moderate length, directed forward, light brown, basal lobe small; tragus medium, blunt, basal lobe prominent.

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