ECOLOGICAL EVALUATION OF LARGE TREE CAVITIES AND GROUND BURROWS AND THEIR USE BY RACCOONS

Thesis for the Degree of M. S.
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ABSTRACT

ECOLOGICAL EVALUATION OF LARGE TREE CAVITIES AND GROUND BURROWS AND THEIR USE BY RACCOONS

by Alfred Berner

This ecological study was undertaken to describe the cavities and burrows used by racoons, to determine the amount and time of use and the microclimates of tree cavities and ground burrows, and to evaluate the relationship of environmental factors to the use of cavities and burrows by raccoons.

All the tree cavities and ground burrows located in the study area were examined and measured. Microclimates of some of the dens were studied by the use of temperature recorders and direct observations. Den use was monitored by using wire-metal tube switches and an Esterline Angus event recorder.

Of the 13 dens located in the study area, ten were tree trunk cavities, two were tree base cavities, and one was a ground burrow. These 13 dens were monitored for 180 days. The natural ground burrow had the most raccoon activity, and also the most stable microclimate; the average daily temperature fluctuation was 1.5°F. The most used tree

cavity was usually warmer than the ground burrow, and had an average daily temperature fluctuation of 8.7°F. Most of the raccoon activity occurred from one hour before sunset to two hours after sunrise. Raccoons were active around dens during the daylight hours, but in most instances, this was due to raccoons sunning themselves at the entrances.

Raccoon den use was found to be influenced by the sunrise-sunset times, the construction and microclimate of the cavity or burrow, and by the external temperature fluctuation. The raccoon den activity appear to be regulated more by the sunset than by the sunrise. The size and how well a den sheltered the raccoon from adverse weather conditions appeared to have a direct influence on den use. Also, the construction of the den may have influenced the microclimate. It was indicated by differential use, that in most cases microclimate was the most important factor regulating the type of raccoon use; investigational and rest. The external temperature fluctuations above 35°F affected den activity in the following manner. An increase in temperature brought about a general decrease in activity while a decrease in temperature brought about an increase in activity. Below 35°F this trend was reversed. Also, above 40°F the predominant type of den use was investigational and below 40°F it was rest use.

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By

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INTRODUCTION

Tree cavities and ground burrows have long been known to be important forms of shelter used by many species of mammals. Despite this fact, little is known of the true ecological picture and importance of these two types of shelter.

Data, collected on the denning habits of raccoon (*Procyon lotor*), indicate that tree cavities and ground burrows are the principal den types used (Steuwer, 1943, Butterfield, 1954 and Dorney, 1954). These data also point out the possibility that a lack of available shelter, particularly of the types mentioned, has a definite regulatory effect on raccoon population. In spite of the apparent importance of dens in the ecology of the raccoon, very few detailed studies have been made to determine the characteristics of suitable raccoon dens. There is even less information on the amount of daily and seasonal use and on the environmental factors influencing the time and amount of use.

This study was initiated in June of 1964 and carried on through December of 1964 in an attempt to accomplish the following objectives: (1) To describe tree cavities and ground burrows utilized by raccoon; (2) to determine the amount and time of raccoon use; (3) to determine the microclimates of tree cavities and ground burrows; and (4) to indicate and evaluate environmental factors influencing the use of cavities and burrows by raccoons.

STUDY AREA

LOCATION

The land selected as the study area is part of the Michigan State University farm property south of the campus at East Lansing, Ingham County, Michigan.

PHYSIOGRAPHY

The general study site* has a surface area of 2.39 square miles (1,529 acres) and is two miles long and 1.62 miles wide (Fig. 1). The topography of the area is gently rolling farmland. It is extensively cultivated. This is demonstrated by the fact that only 6.5 percent of the total acreage is in woodlots, while the remaining 93.5 percent is being used for agricultural purposes (Figs. 2, 3, 4 and 5).

*The size of the general study area was determined by circumscribing a circle, a mile in diameter, around each of the four woodlots and consolidating all the land within the circles into one tract.

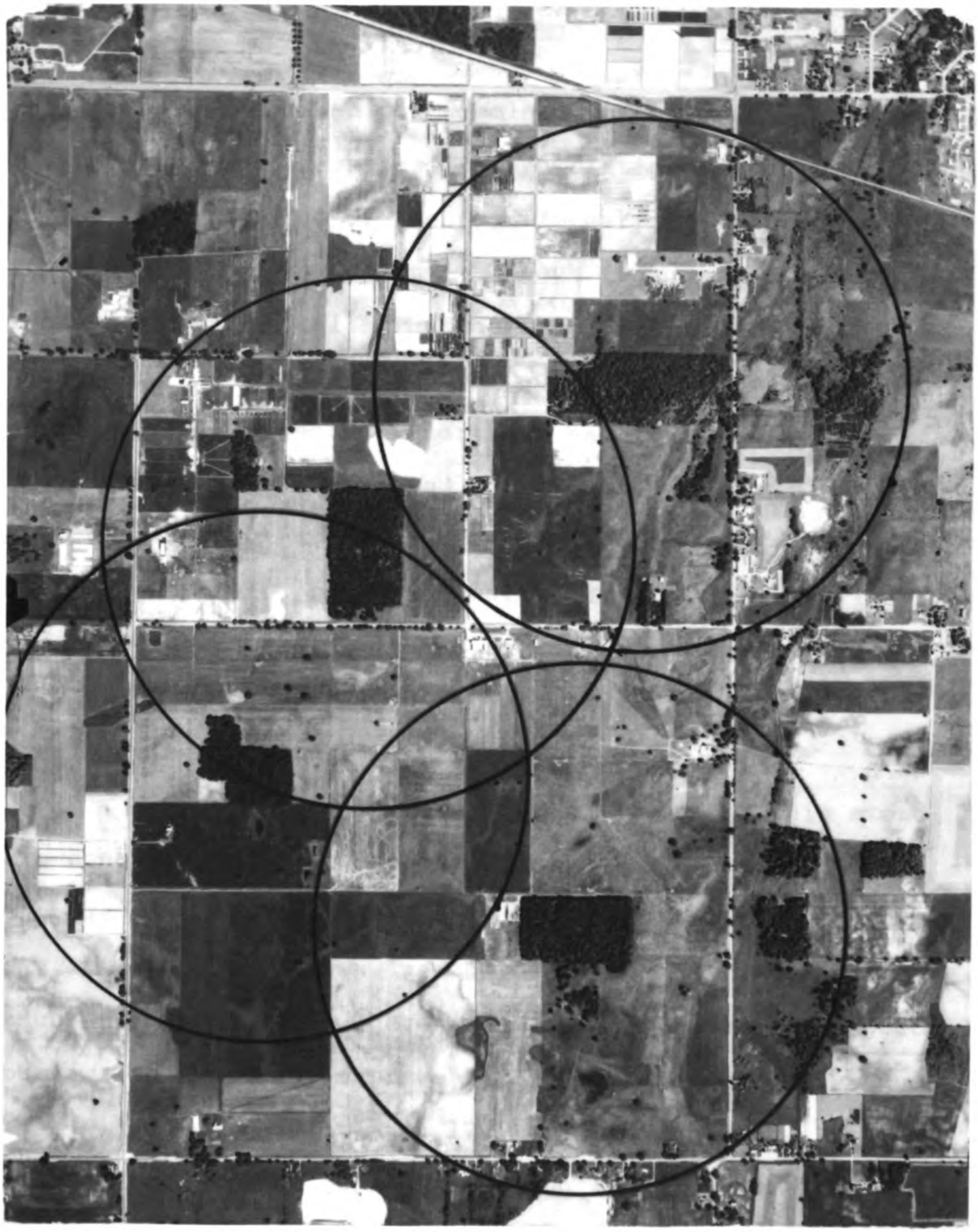

Figure 1: The general study area on the University farm property.

FOREST COMMUNITIES

The four principal woodlots on the study area are all similar, yet, each has its own distinguishing characteristics. The largest of the four forest communities is a sugar maple (_Acer saccharum_) - beech (_Fagus grandifolia_) stand of 19 acres called Hudson woodlot (Fig. 2). The 19 acre stand is divided into two, approximately equal, sections. The unmanaged, northern half contains trees of all ages and is well stocked with mature sugar maples and beeches. The cut south section is an even-aged stand of young sugar maple, beech and white ash (_Fraxinus americana_). The even-age condition is due to cuttings made in 1925 and 1930 which removed the good growing, mature stock of the tree species previously mentioned (Gysel, 1961).

Almost all the tree cavities present in this stand are concentrated in the northern section. This is due to the age of the trees present and to the large amount of decay in the boles, crowns and bases of the mature trees, particularly the beech. There is also a large number of ground burrows in the sandy surface soil of the Spinks loamy sand.

Toumey woodlot is a 17.5 acre, old-growth, unmanaged stand (Fig. 3). It is uncut and ungrazed. It is well stocked with sugar maple, beech and basswood (_Tilia americana_) of all ages. The trees range in size from seedlings up to 40 inches in d.b.h. (Gysel, 1961).

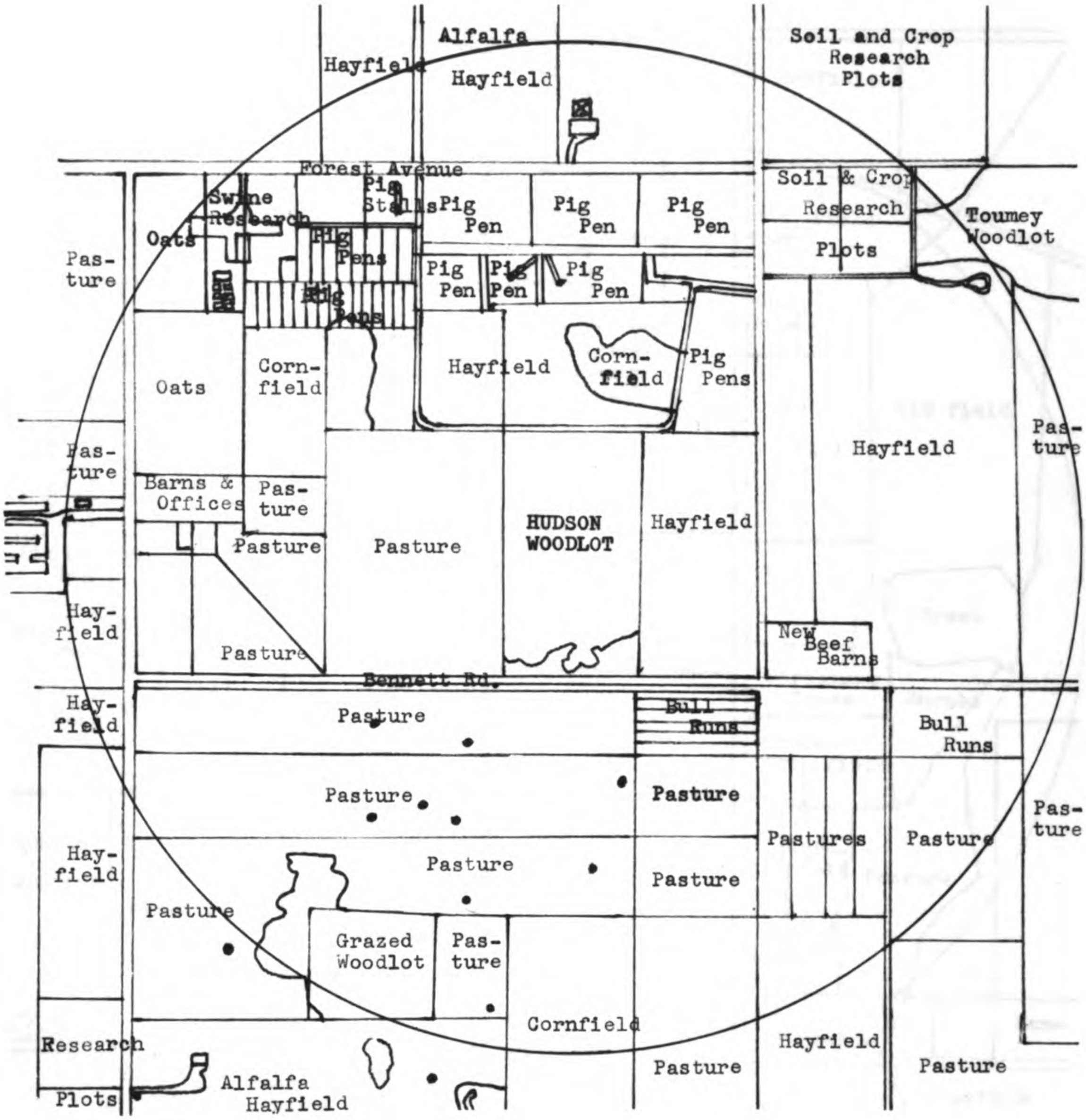

Figure 2: Hudson woodlot and surrounding communities.

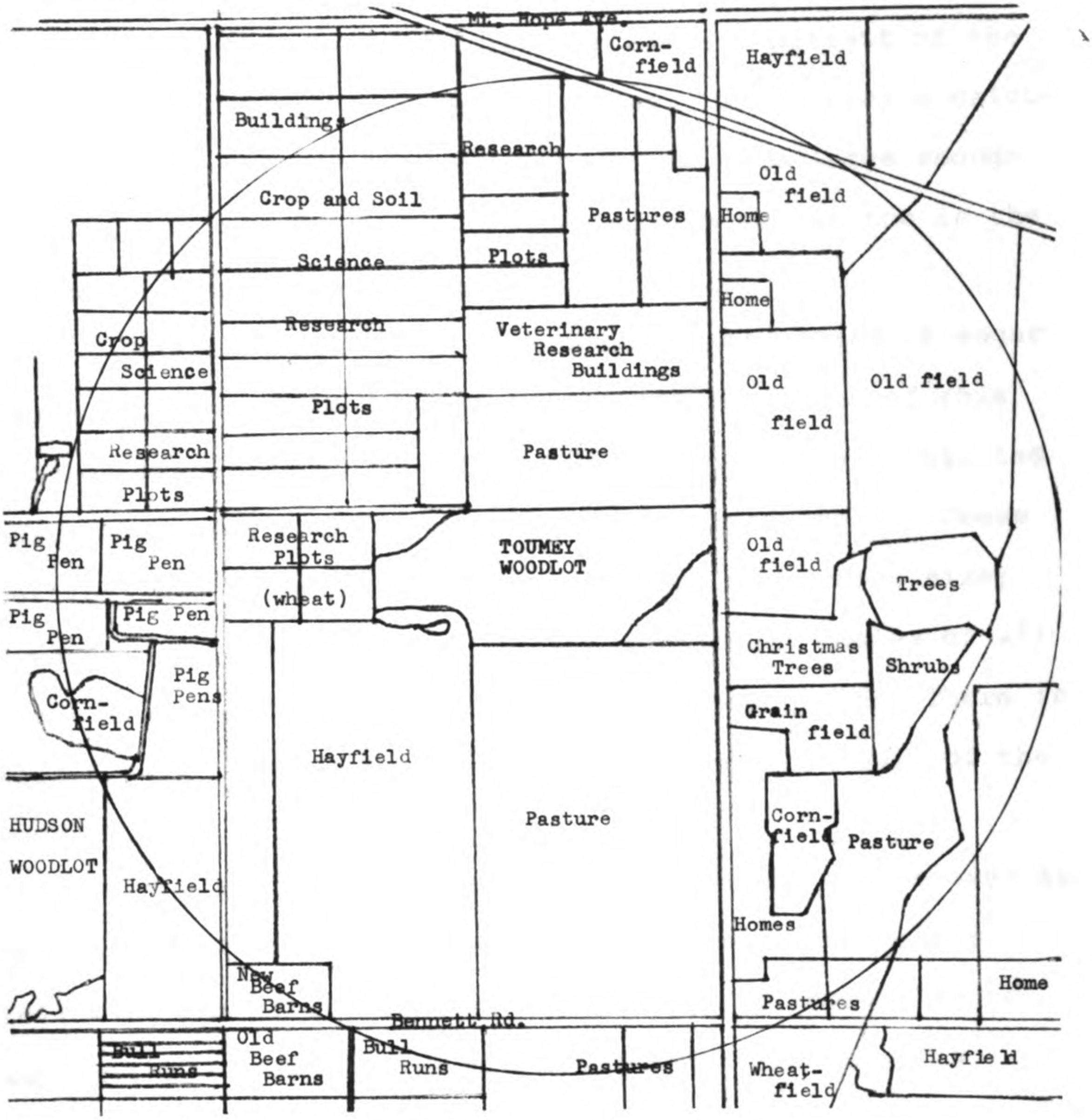

Figure 3: Toumey woodlot and surrounding communities.

There are a large number of tree cavities, most of which are in the mature and over-mature trees. Gysel (1961) found an average of 34 cavities per acre; 3 percent of the 34 had entrances of 4 inches or larger. This gives a calculated density of one to two cavities per acre large enough for possible raccoon use. Ground burrows are scarce in the Hillsdale sandy loam of the woodlot.

Maple woodlot is a 16.1 acre managed stand of sugar maple (Fig. 4). The present homogenous condition of this woodlot was produced by selective cuttings which eliminated most other tree species and poor sugar maple stock. These cuttings also removed many tree cavities of raccoon size; however, the stand is well stocked with sugar maples of all sizes from seedlings to ones with 26 inches d.b.h. There is also a lack of ground burrows in the Miami loam soil of the woodlot.

The smallest of the woodlots, Grazed, was choosen as the intensive study area; this was because it possesses the following specific characteristics: (1) It appears to be supporting a sizeable raccoon population; (2) there is present a sufficient number of tree cavities and ground burrows of raccoon size; and (3) these cavities and burrows are all located within a 1,000 foot radius of the center of the woodlot.

Besides the specific characteristics just mentioned, Grazed woodlot possesses 13.9 acres of mature sugar maple,

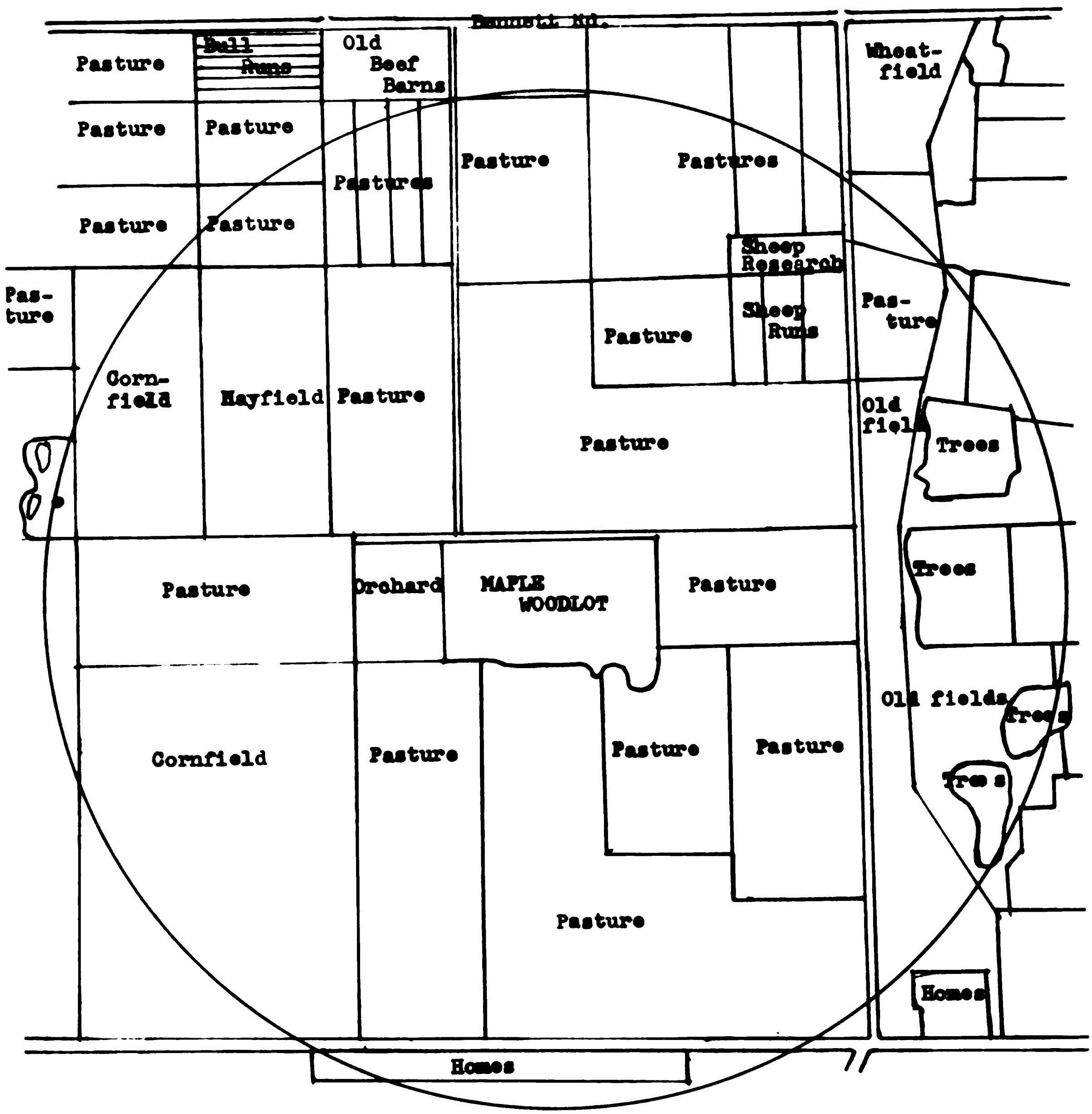

Figure 4: Maple woodlot and surrounding communities.

beech, basswood, white ash, and American elm (<u>Ulmus americana</u>). A complete list of the stand's woody species can be found in Table 1. The west and northwest 3.4 acres are grazed by cattle. The grazing has produced a complete lack of woody ground cover in that portion of the woodlot (Fig. 6). The remaining 10.5 acres have not been grazed for at least five years. This lack of disturbance has allowed a tremendous number of seedlings to grow (Fig. 5). Sugar maple comprises over 90 percent of the seedlings present. When the leaves are out, the seedlings produce a thick, three to four foot high, ground cover on 95 percent of the 10.5 acres. The soil type for Grazed woodlot is the same as that for Maple, Miami loam.

The area surrounding Grazed woodlot, included in the intensive sutdy area, is being used for various agricultural purposes (Fig. 7). The principal foraging areas, as determined by scat analysis, for raccoon are located in cornfields and the orchard and around the stock feeders.

In other ecological studies on raccoon (Stuewer, 1943, Cabalka, 1952, Dorney, 1954, and Stains, 1956), natural water supplies, such as streams and lakes, were always considered a necessary part of the raccoon's habitat and, therefore were always included in the immediate environment being observed. The lack of adjacent surface water distinguishes my study area from those of the above authors. The nearest permanent natural water is a pond 1.06 miles south-southwest

Table 1: A list of the woody plant species identified in Grazed woodlot.

TREES	SHRUBS, SMALL TREES AND VINES
Black maple (*Acer nigrum*)	Dutchman's pipe (*Aristolochia diorior*)
Sugar maple (*Acer saccharum*)	Barberry (*Berberis vulgaris*)
American hornbeam (*Carpinus carolinana*)	Running strawberry bush (*Evonymus obovata*)
Shagbark hickory (*Carya ovata*)	Tartarian honeysuckle (*Lonicer tataria*)
Hawthorn (*Crataegus* sp.)	American fly honeysuckle (*Lonicer canadensis*)
Beech (*Fagus grandifolia*)	Virginia creeper (*Parthenocissus-quinquafolia*)
White ash (*Faxinus americana*)	Choke cherry (*Prunus virginiana*)
Hop hornbeam (*Ostrya virginiana*)	Gooseberry (*Ribes cynosbati*)
Black cherry (*Prunus serotina*)	Red raspberry (*Rubus ideaus*)
Cherry (*Prunus* sp.)	Black raspberry (*Rubus occidentalis*)
Apple (*Pyrus* sp.)	Blue berried elder (*Sambucus canadensis*)
White oak (*Quercus alba*)	Red berried elder (*Sambucus ramemosa*)
Smooth sumac (*Rhus glabra*)	Greenbrier (*Smilax hispidus*)
Basswood (*Tilia americana*)	European bittersweet (*Solanum dulcamara*)
American elm (*Ulmus americana*)	Poison ivy (*Toxicodendron radicans*)
	Pigeon grape (*Vitis aestivalis*)
	Prickly ash (*Zanthoxylum americana*)

Figure 5: Ungrazed portion of Grazed woodlot with Cavity 13 in the foreground.

Figure 6: Grazed portion of Grazed woodlot with Cavity 11 in the foreground.

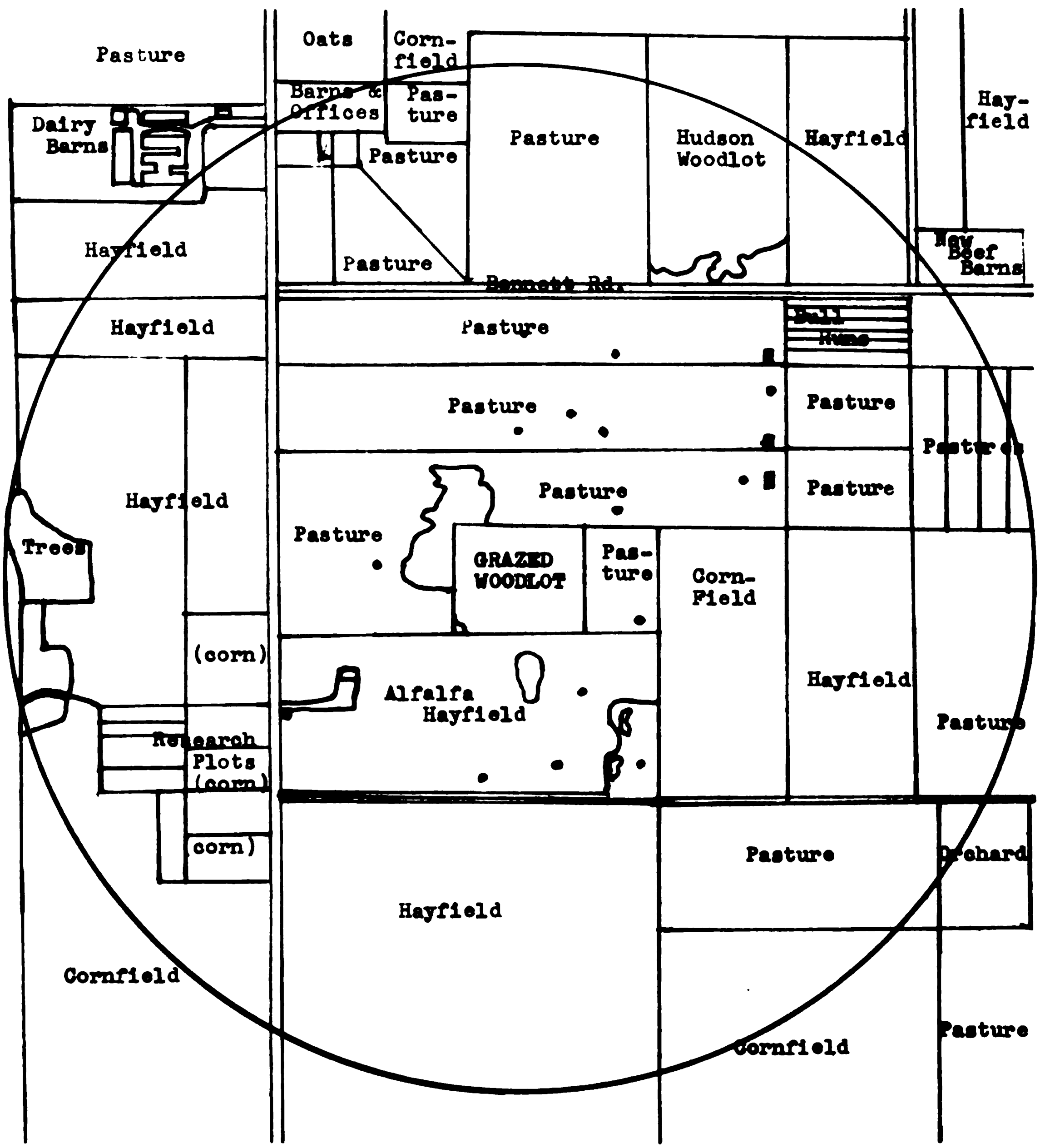

Figure 7: Intensive study area, Grazed woodlot, and surrounding communities.

of Grazed woodlot. The closest permanent water is at three metal stock tanks located about 1,500 feet northeast of Grazed woodlot (Fig. 7).

SEASONAL CLIMATIC CONDITIONS

The climatological standard normals obtained from the United States Weather Bureau at Lansing, Michigan were calculated from data recorded for the years of 1931-1960. The average yearly temperature for this 30-year period was 47.6°F., mean maximum 51.1°F., and mean minimum 38.2°F. The average annual precipitation for the same period of time was 30.62 inches.

The seasonal standard normals for the same 30 year period were calculated per three month periods and were determined as follows: Winter, January-March, had an average temperature of 26.9°F., a mean maximum of 34.6°F., and a mean minimum of 19.3°F. The average precipitation was 6.3 inches. The spring months of April-June had an average temperature of 56.7°F., a mean maximum of 67.5°F., and a mean minimum of 45.9°F. The average precipitation for these months was 9.93 inches. The summer months of July-September had the highest average temperature which was 68.0°F., mean maximum 79.3°F., and mean minimum 56.6°F. Average rainfall was calculated to be 8.22 inches. Fall, October-December, had an average temperature of 38.9°F., a mean maximum of

49.9°F., a mean minimum of 30.9°F., and an average precipitation of 6.69 inches.

METHODS

LOCATING AND MEASURING DENS

Locating tree cavities and ground burrows used by raccoons was accomplished by the following means: (1) By reviewing the data gathered in a previous study on cavities and burrows (Gysel, 1961); (2) with the aid of binoculars; and (3) by the use of ladders designed especially for tree climbing.

Once a den of sufficient size (entrance four inches or more in diameter and inner dimensions nine inches or more in diameter) was located, it was examined and measured. The types of measurements and observations made are presented in figures 8 and 9. Measurements were made with the aid of a six foot, flexible metal tape-measure and a 25 foot, flexible probe. The probe was used primarily to measure the depth of the cavities and burrows. A periscope device and a six volt spotlight were employed to observe the bottom in the deep cavities. Due to the depth of some of the cavities, it was impossible to obtain accurate measurements of the cavity bottoms. Trees, too risky to be climbed, and deep natural burrows were not measured.

Figure 8: This is an example of the cards used in collecting data on tree cavities.

Den No.__Date Located______Locality__________________________

County_____Township_______Forest type________________________

Topography____

DEN TREE: Species_______Height_______Diameter_______________

Distance to water: Natural_____Artificial_____Location_____

CAVITY: Height____Exposure____Dia. of entrance____Depth to

the nest____Inside dimensions____Nest material_______________

Additional Notes:	<u>Diagram</u>

Figure 9: This is an example of the cards used in collecting data on ground burrows.

Den No.__Date Located______Locality__________________________

County____Township_______Forest type_________________________

Topography____

Burrow: Distance to water: Natural_______Artificial_______

Location______Exposure_____Dia. of entrance_____Total Horiz.

Depth______Horiz. Depth to nest_____Vert. Depth to nest_____

Inside Dimensions______________Nest materials_______________

Additional Notes:	<u>Diagram</u>

USE DETERMINATION

The question, which tree cavities and ground burrows were being frequented by raccoons, was answered by the use of one or more of three methods. Direct observation of raccoon signs or the presence of raccoons in the den was used most often in this determination. If there were no apparent signs of use, hair catchers or automatic photographic units, placed at the entrances to the dens, were employed to obtain this necessary information.

ANALYSIS OF MICROCLIMATES

Recording thermometers were employed to obtain the temperature inside selected cavities and burrows. Stains (1961), using a similar bulb-type recorder, had placed the bulb element directly on the cavity bottom where it was constantly being influenced by the presence of the raccoons. In order to eliminate this problem, I suspended the bulb element approximately 18 to 24 inches above the cavity bottom along the cavity wall. In this study the Bararach bulb-type Tempscribe, model SDC, was used. The daily maximum and minimum temperatures were calculated from the recording charts and compared to the external temperature readings obtained from a weather station located approximately 1½ miles due north of Grazed woodlot. In order to determine other aspects of the microclimates of the cavities and burrows, direct observations were made periodically. These observations were made particularly after there had been precipitation of any type.

ANALYSIS OF THE MACROCLIMATE

Climatic data were obtained from a weather station located east of Baker woodlot on the Michigan State University campus. From the data, I was able to obtain the minimum-maximum temperatures, amount, time, and duration of precipitation, and cumulative wind counts from an open area. The daily sunrise and sunset times were taken from a calculated sunrise-sunset table. Additional weather information was obtained from my own observations and from the United States Weather Bureau at Lansing, Michigan.

ANALYSIS OF DEN USE

In order to determine the time, amount and type of raccoon use, the cavities and burrows were monitored with the aid of wire-metal tube switches and an Esterline Angus Twenty-Pen Event Recorder.

The wire-metal tube switches used to activate the pens were modifications of the type described by Lawrence and Sherman (1963). These were modified by using a 2-inch piece of 3/8ths-inch-diameter copper tubing and a .025 inch stainless steel wire, 5 inches long, which passed through a glass capillary rod 1¼ inches long. These switches were stapled to the entrances of dens in such a position, that any raccoon passing through the opening would complete a circuit by bending the wire and touching it against the tubing (Fig. 10). Some of the switches were modified even further by making them directional (Fig. 10). This was accomplished by insulating the copper tubing so that the contact could be made only in the desired direction. In addition to these switches, a special one was devised in order to monitor the cavity located in the top of a rotten beech, which was too risky to be climbed. This switch was constructed in such a manner that it would be activated as the raccoon made its way up or down the tree trunk.

In determining the validity of the data obtained by the Esterline Angus recorder, I made direct observations. Also, automatic photographic units were sometimes used to verify the raccoon use recorded for the ground burrows. Two types of photographic units were utilized: One was a single shot unit devised by Gysel and Davis (1956) and the other was a unit with an automatic camera and strobe unit.

RECORDED USE INTERPRETATION

In interpreting the activity indicated on the recorder charts, I made the following assumptions: (1) Any activity recorded between sunset and sunrise was attributed to raccoons unless proven otherwise; (2) any activity between sunrise and sunset was attributed to squirrels (*Sciurus niger*)

Figure 10: Directional switches installed at the entrance to Cavity 2.

unless proven to be raccoons by direct observations; (3) if activity was recorded at a den before sunrise and again at the same den after sunset of the same day, it was assumed that the cavity or burrow had been used as a place of rest by a raccoon; (4) during cold spells of several days duration, the third assumption was expanded to include activity that indicated the use of a den as a rest place by a raccoon during the period of the low temperatures. It was assumed that a den was used for the duration of the cold spell, if activity was recorded before sunrise just prior to or at the onset of the cold spell and not resumed until after sunset and/or rising temperatures.

In summarizing the activity, two units were devised to define the types of raccoon use. The term "rest unit" was used for any activity that indicated that the raccoon had used the cavity or burrow for any period of time over three hours in duration. "Investigational unit" was used to define any activity that was less than three hours in duration.

MOVEMENT ANALYSIS

Several different methods were employed in obtaining an indication of raccoon abundance and the direction and amount of movement between the different plant communities in the general and intensive study areas. The principal method used in determining the relative abundance and movement was live trapping and tagging. There were five traplines in the general study area. The first trapline consisted of 36 wire-box traps placed in a 600 by 600 foot grid pattern, in the ungrazed section of Grazed woodlot. The second trapline consisted of 32 traps, of which 11 were placed along the fence 100 yards north of Grazed woodlot, 15 along the fence 100 yards east of the woodlot, and 6, 100 feet south of the woodlot. All traps were spaced at 100 foot intervals. The three remaining traplines were in Maple, Hudson, and Toumey woodlots and all consisted of 36 traps which were set 100 feet apart in the same grid pattern as the one described for Grazed woodlot.

Movement from Grazed woodlot to the cornfield 100 yards east of the woodlot was monitored by five counters. These counters were tripped by lines stretched across runways under or through the fence. The counters gave only an indication of numbers and not time or direction of movement.

The last method employed to determine general movement was observation of the composition and location of scat. The scat composition confirmed, in some instances, exactly where the raccoon had eaten, and the location confirmed the presence of the raccoon.

RESULTS

INDICATION OF THE NUMBER OF RACCOON

Intensive trapping was used to determine whether the population was of sufficient size for the study, and the relative numbers in the forest communities surrounding Grazed woodlot. A total of 47 different raccoons were captured, tagged and released during 2,500 trapnights* (Table 2). When these figures were compared with trapping data of previous years on the study area, there was an indication of a rise in the raccoon population.

In analyzing the raccoons handled, as to age and sex, I found that there were 21 adults (11 males and 10 females), and 26 juveniles (7 males and 19 females). This gave an age ratio of 1.21 juveniles per adult and a sex ratio of 1 male per 1.61 females. This sex ratio is quite different from the ones obtained by Stuewer (1943), 1.08 males per female, and Stains (1956), 1.1 males per female. If the ratio I calculated is not valid, then the only explanation for the error would be a bias in trapping juvenile females; however, this conclusion is not born out by the data. The ratio of recaptures to total captures in both the female and male juvenile classes was 6 recaptures per 10 total captures. Therefore, it does not appear that there is a bias in trapping of juvenile females.

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*A trapnight is one trap in operation for a 24 hour period.

Table 2: The number of raccoons trapped in the five trap-lines and the total trapnights for each.

Trapline	Trapnights	New Raccoons	Retrapped Raccoons	Total Captured
1. Grazed	940	15	33	48
2. Vicinity	304	4	10	14
3. Maple	425	2	0	2
4. Hudson	417	14	6	20
5. Toumey	414	12	2	14
Totals	2,500	47	51	98

GENERAL MOVEMENT PATTERNS

Table 3 lists the raccoons that were retrapped in more than one trapline. The information obtained from the movement of the first four raccoons listed indicated that there was substantial travel between Grazed and Hudson woodlot. This was expected because Hudson woodlot is less than one-half mile from Grazed woodlot, which, according to Stuewer's (1943), Stains' (1956), and Tester and Siniff's (1965) estimates of one mile in diameter home range for raccoon, placed it within the limits of the normal home range of a raccoon.

The retrap records of the second set of four raccoons listed in Table 3 indicated that these particular juveniles appeared to have been summer residents of Grazed woodlot, and the cornfield east of the woodlot was their main source of food.

Number 681, trapped in Grazed, was found on October 30, 1964 dead on College Road 400 yards southwest of Grazed woodlot. A possible explanation for this raccoon's being there was that its usual food supply had been harvested and the only other close supply of corn was the cornfields west of Grazed woodlot.

Number 720 was found dead on February 16, 1965, with three juvenile females, two juvenile males and one yearling male, in a field southeast of the Hagedorn-Bennett crossroads.

Table 3: Raccoons that were captured in more than one trapline.

			Traplines						
Age	Sex	Tag No.	Grazed	Vicinity	Maple	Hudson	Toumey	Deaths
A	M	700	2R**			0*		
A	M	15		1R		0		
J	F	671	1R	0				D***
J	M	693		0		2R		
J	F	661	0	4R				
J	F	665	0	3R				
J	M	660	0	1R				
J	F	669	0	1R				
J	F	681	0					D
J	F	720					0	D

*"0" represents the trapline of original capture.

**"R" represents the trapline in which the raccoon was recaptured.

***"D" notes that the raccoon was recovered dead.

They had been using a 14 inch drainage tile for a den but were flooded out by an early thaw and died of drowning and exposure.

Despite the intensive trapping, only 20 out of the 47 raccoons were ever recaptured; of the 20 recaptured, only 11 were captured more than once and only 8 more than twice. This indicated that either trap shyness, or emigration or immigration or mortality or any combination of these factors must have influenced the recapture rates. The recapture ratio of adults was noticeably different than that of juveniles. The juveniles had 6 recaptures to 10 total captures ratio while the adults had a 2.4 recaptures to 10 total captures ratio. This did indicate a trap shyness factor among adults.

The five counters, along the fence 100 yards east of Grazed woodlot, were in operation for the months of August and September. In the month of August, there were 62 tallies in 30 days giving an average of 2.07 counts per day. In September, there were 56 counts in 31 days for an average of 1.8 per day. The possible explanation for the decrease in the number of counts from August to September was the increase in the number of additional openings in the fence.

Scat examined in Grazed woodlot, during the last week of June 1964 and the first two weeks of July 1964, contained large numbers of sour cherry pits. The only source of sour cherries in the immediate vicinity of the woodlot was the University orchard west of Maple woodlot. Upon examination of the cherry trees, I found extensive branch damage, particularly on the young trees.

As the corn began to ripen in mid-July, it became increasingly more important in the scat composition analysis. By the end of July 1964, almost 100 percent of the scat found consisted of corn. The high percentage of corn in the scat continued into October, by which time all the corn had been harvested. The presence of corn in the scat indicated that they were frequenting the cornfields but due to the large number of accessible cornfields present, it could not be determined with any reliability, which cornfields were being visited by which raccoons.

Apricots were found in the scat along the fence west of the cornfield between Grazed and Maple woodlot. This, like the cherries, indicated a use of the orchard as a source of food. Further examination of the orchard proved that raccoons also were feeding on the grapes; but, no scat containing grapes was found outside the boundaries of the orchard.

DENS LOCATED

Types

Using the methods described previously, 13 raccoon dens were located, examined, classified and measured in

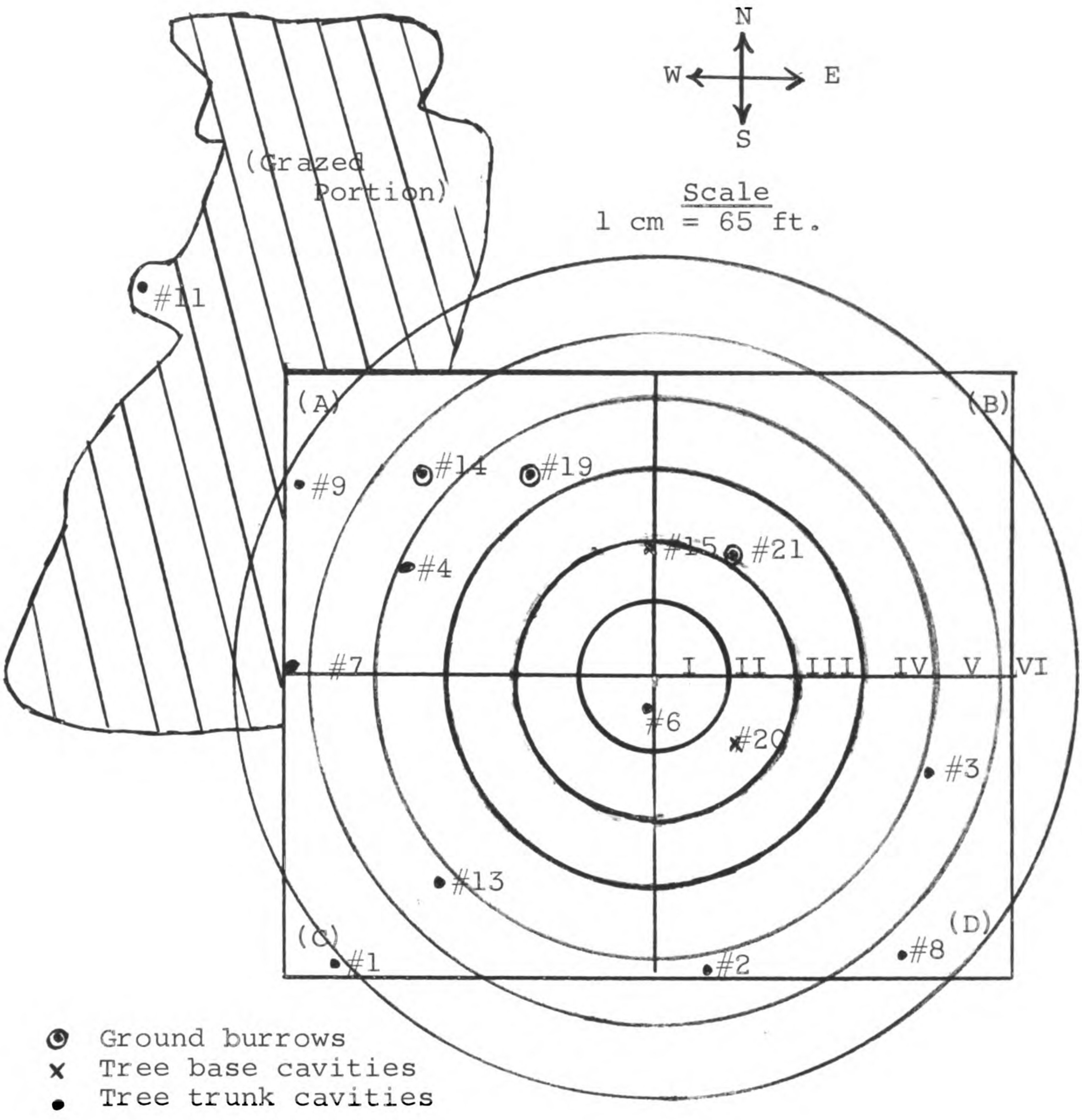
Grazed woodlot. The tree cavities were divided into two groups; tree trunk cavities and tree base cavities. Ten of the 13 dens located were of the tree trunk type; the remaining consisted of two tree base cavities and one ground burrow. In addition to the 13 natural dens located, two artificial ground dens were constructed, when it was noted that the only natural ground burrow had tremendous amounts of raccoon activity.

Locations

The locations of the 15 dens in Grazed woodlot are pin-pointed in Figure 11. This figure, when combined with Figure 7, illustrates the position of each den in relationship to each other and to the plant communities surrounding the woodlot.

In attempting to relate location to differential use of dens, I first divided the ungrazed portion of the woodlot into four equal parts and then constructed circles from the center of the woodlot in 65 foot intervals (Fig. 11). I then tried to make comparisons by contrasting the activity that had occurred at each den to the activity of the other dens located in the same quadrant and circle interval. (For example: comparing activity at cavities 2 and 3.) I also tried to compare individual den activity of the different dens in the same quadrant regardless of its circle interval location and vice versa.

Figure 11: Location of the tree cavities and ground burrows in Grazed woodlot.



The roman numeral is the circle interval location and the letters in the corners are the quadrant initials.

Descriptions

A verbal description of a den's characteristics would be of little value, due to the difficulty in making comparisons with such a description; therefore, in order to eliminate some of this difficulty, the descriptions were made in the form of measurements (Tables 4, 5, and 6). In an attempt to make better comparisons of the tree trunk cavities certain distinguishing characteristics were used to place the nine cavities into three groups.

The first category consisted of Cavities 2, 3, 8 and 11. Their similarities, which placed them together, were: entrance dimensions (5-7.5 inches in diameter); entrance exposure (horizontal); inner dimensions (11-15 inches in diameter); and the distance to the cavity bottom from the entrance (56 inches plus). This group of cavities could be classified as ones with the maximum entrance size for maximum protection and medium to large inner dimensions and depth.

The second category consisted of Cavities 1 and 4. The characteristics of these two cavities were very similar to the ones just mentioned for group 1 but with one exception, the vertical entrance exposure. As pointed out later, however, the vertical entrance exposure does truly place them in a class by themselves.

The last group consisted of Cavities 7, 9, and 13, and had the most similarities of the three categories.

Table 4: Measurements taken of nine tree trunk cavities and the raccoon activity recorded for ten tree trunk cavities. (Also there is the averages for this study and Stuewer's (1943).

1	2	3	4	5	6**	7	8	9	10	11	12
Basswood	1	31.2	9.7	7.5 X 7.0	WV	24.5 X 23.0	3.7	62	25.0	25.0	0.0
Maple	2	35.0	8.0	8.5 X 6.5	SH	16.4 X 13.4	10.0	56	22.0	8.0	14.0
Basswood	3	21.0	15.5	5.3 X 5.3	NWH	14.2 X 9.7	3.7	95	20.0	17.0	3.0
Basswood	4	28.0	6.0	8.0 X 6.0	NV	12.3 X 9.3	9.0	56	11.0	9.0	2.0
Beech	6*	----	----	---- - ---		---- - ----	----	--	12.0	9.0	3.0
Elm	7	17.8	17.5	11.5 X 3.5	WH	10.0 X 10.0	2.0	7	5.0	4.0	1.0
Basswood	8	24.8	15.0	6.5 X 5.5	EH	18.0 X 13.0	4.3	72	16.0	12.0	4.0
Elm	9	25.0	9.0	19.0 X 3.5	WH	10.0 X 10.0	7.0	1	23.0	21.0	2.0
Basswood	11	22.6	21.2	6.0 X 4.5	SH	13.0 X 8.5	2.7	66	45.0	14.0	31.0
Beech	13	21.0	11.0	42.0 X 3.0	WH	10.5 X 10.0	4.7	0	8.0	8.0	0.0
Totals		226.4	112.9	114.3 X 44.8		129.4 X 106.9	47.1	415	187.0	127.0	60.0
Averages		25.1	12.4	12.7 X 4.98		14.4 X 11.9	5.2	46	18.7	12.7	6.0
Stuewer (1943)		28.3	27.5	12.4 X 5.96		13.8 X 11.7		38.6			

*This tree was too risky to be climbed.

**The "V" stands for vertical and the "H" for horizontal.

1. Tree species
2. Cavity number
3. Tree diameter (inches)
4. Height to entrance (feet)
5. Entrance dimensions (inches)
6. Direction and exposure of entrance
7. Inner dimensions (inches)
8. Insulation (inches)
9. Distance to cavity bottom from entrance (inches)
10. Total activity in 180 days
11. Investigational activity in 180 days
12. Rest activity in 180 days

Table 5: Measurements taken of two tree base cavities and the raccoon activity recorded at them.

1	2	3	4	5	6	7	8	9
Maple	15	24.0	5.0 X 3.5	NH	14.0 X 13.0	18	17	1
Beech	20	29.9	27.5 X 5.5	SH	16.5 X 10.5	25	25	0

1. Tree species
2. Cavity number
3. Tree diameter (inches)
4. Entrance dimensions (inches)
5. Direction and exposure of entrance
6. Inner dimensions (inches)
7. Total activity in 180 days
8. Investigational activity in 180 days
9. Rest activity in 180 days

Table 6: Measurements taken of the three ground burrows and the raccoon activity recorded for each.

1	2	3	4	5	6	7	8	9	10
Natural	14	9.5 X 6.5	WH	300+	-- - -- - --	70	66	24	42
Artificial	19	6.5 X 6.5	SH	50	24 X 14 X 10	24	14	10	4
Artificial	21	7.0 X 7.0	SH	22	24 X 14 X 10	22	12	12	0

1. Ground burrow type
2. Burrow number
3. Entrance dimensions (inches)
4. Direction and exposure of entrance
5. Horizontal depth to nest (inches)
6. Nest dimensions
7. Vertical depth to nest
8. Total activity in 180 days
9. Investigational activity in 180 days
10. Rest activity in 180 days

Their characteristics of entrance direction (west) and exposure (horizontal), and their inner dimensions (10 inches in diameter) were all identical. Also, all their entrance dimensions were much longer than wide and all had very little or no vertical depth from the entrance to the cavity bottom (Table 4). This group could be described as having large sized entrances causing minimum protection, poor entrance direction (because most rain comes from westerly directions), small cavity dimensions and no depth.

Only a few studies had information on raccoon den measurements. Stuewer (1943) had measurements for 34 tree trunk cavities used by raccoons. In comparing the averages he obtained in his study, to nine measured for this study, I found a very close comparison (Table 4).

The remaining five dens, because they could not be compared to each other or to previously gathered data, were described by the use of verbal descriptions as well as by their measurements listed in Tables 5 and 6.

The natural ground burrow, Number 14, was a large den dug by foxes. Its entrance faced west and was surrounded by two feet of excavated dirt. The total horizontal length of the tunnel and the distance to the chamber or chambers could not be measured because the distance was longer than the 25 foot probe available. The greatest vertical depth measured was 70 inches; however, it is very possible that it was not the deepest portion of the burrow.

Tree base cavity, Number 15, was in the base of a sugar maple. The 5 by 3.5 inch elliptical entrance opened into a room-like cavity 14 by 13 inches in diameter and 10 inches in height. There was rotting wood material on the floor of the cavity.

Number 20, the other tree base cavity, was located in the base of a mature beech; its 27.5 by 5.5 inch entrance left the bottom of the cavity exposed to the weather. The cavity extended 50 inches upward inside the trunk beyond the entrance on the outside.

Artificial burrows, Numbers 19 and 21, were both constructed of a piece of rectangular metal duct 24 inches long, 14 inches wide and 10 inches high, as the chamber, and connected to the surface by a piece of stove pipe six to seven inches in diameter and 26 inches or more in length laid horizontally at a 20 to 30 degree upward angle.

The bottom of all the tree cavities, both trunk and base, contained rotten organic material and/or sawdust. No cavities used by raccoons had any material in them that resembled the makings of a nest of any type.

Surroundings

Grazed woodlot is surrounded on the west, north and east by pastures which were being grazed throughout the summer and early fall by beef cattle. The grass in these pastures was usually between four and six inches high, which in most cases offered little in the way of cover for a raccoon. An alfalfa hayfield to the south of the woodlot offered much more cover, except when it was mowed (this occurred twice during the study period). When the alfalfa was over 12 inches high, it gave good cover to any raccoon traveling in a southeast, south or southwest direction (Fig. 7). The only permanent cover connected with the woodlot was a narrow strip of high grass along the fences running east and west from the southeast and southwest woodlot corners.

Cavity 1, located in the southwest corner on the south boundary, was flanked to the south by the alfalfa hayfield and to the west, north and east by woods with dense ground cover. The description of the surroundings of Number 1 also describes the conditions existing around Cavity 2 and 8 which were also located on the south border, only east of Cavity 1.

Cavity 3 was located approximately 80 feet from the east fence and encompassed by the same type of woody ground cover that was present throughout the woodlot. This cavity was located closest to the cornfield (Table 7).

Cavity 13 was located about 80 feet from the south fence and was also surrounded by the three to four foot high woody ground cover (Fig. 5). These same ground cover conditions existed also around cavities 4, 6, 15 and 20, and burrows 14, 19 and 21.

Table 7: Number of feet from den to important constituents of the surrounding communities.

*1	2	3	4	5
1	5,280	1,848	1,008	2,561
2	5,280	1,848	657	2,229
3	5,515	1,155	549	2,229
4	5,445	1,555	950	2,640
6	5,636	1,500	709	2,395
7	5,285	1,745	1,040	2,723
8	5,280	1,320	478	2,145
9	5,515	1,640	1,040	2,805
11	5,940	1,815	1,203	3,052
13	5,280	1,718	904	2,561
14	5,430	1,609	923	2,723
15	5,528	1,418	715	2,475
19	5,528	1,500	826	2,640
20	5,445	1,364	631	2,320
21	5,610	1,412	631	2,400
Averages	5,466	1,563	818	2,527

*1. Den number
2. Distance to natural water
3. Distance to closest stock tank
4. Distance to nearest cornfield
5. Distance to the orchard

A unique set of surroundings existed around Cavity 7 and 9. These two cavities were the only ones located on the west fence which separated the grazed from the ungrazed portion of the woodlot (Fig. 11). The cavities were encompassed on three sides by the heavy woody ground cover of the ungrazed portion and on the west by no ground cover but by a 45 foot plus forest canopy cover.

The only cavity located in the grazed section of the woodlot was Number 11. It was located on the middle west edge which was adjacent to a pasture. The only cover available was the 45 foot plus forest canopy cover to the north, east and south of the cavity (Fig. 6).

Figure 11 combined with Figure 7 illustrates the position of each den in relationship to each other and to the land use communities surrounding the woodlot. The amount of activity at a den could have been affected by its distance to some important environmental constituent. Therefore, in an attempt to bring out a possible indication of such an affect, the shortest distances were measured from the dens to particular communities or environmental conditions believed to have possible importance to the welfare of the raccoon. The results of these measurements are listed in Table 7.

MICROCLIMATES

Using four bulb-type Tempscribes, the temperature conditions of tree trunk cavities 1, 8 and 11, and ground burrows 14 and 19 were monitored for various lengths of time. For the periods of time that the dens were not monitored, due to lack of instruments or malfunctioning of available ones, temperature averages were estimated. This was accomplished by calculating the usual daily temperature fluctuation inside the den and comparing it to the external temperature fluctuation (Table 8).

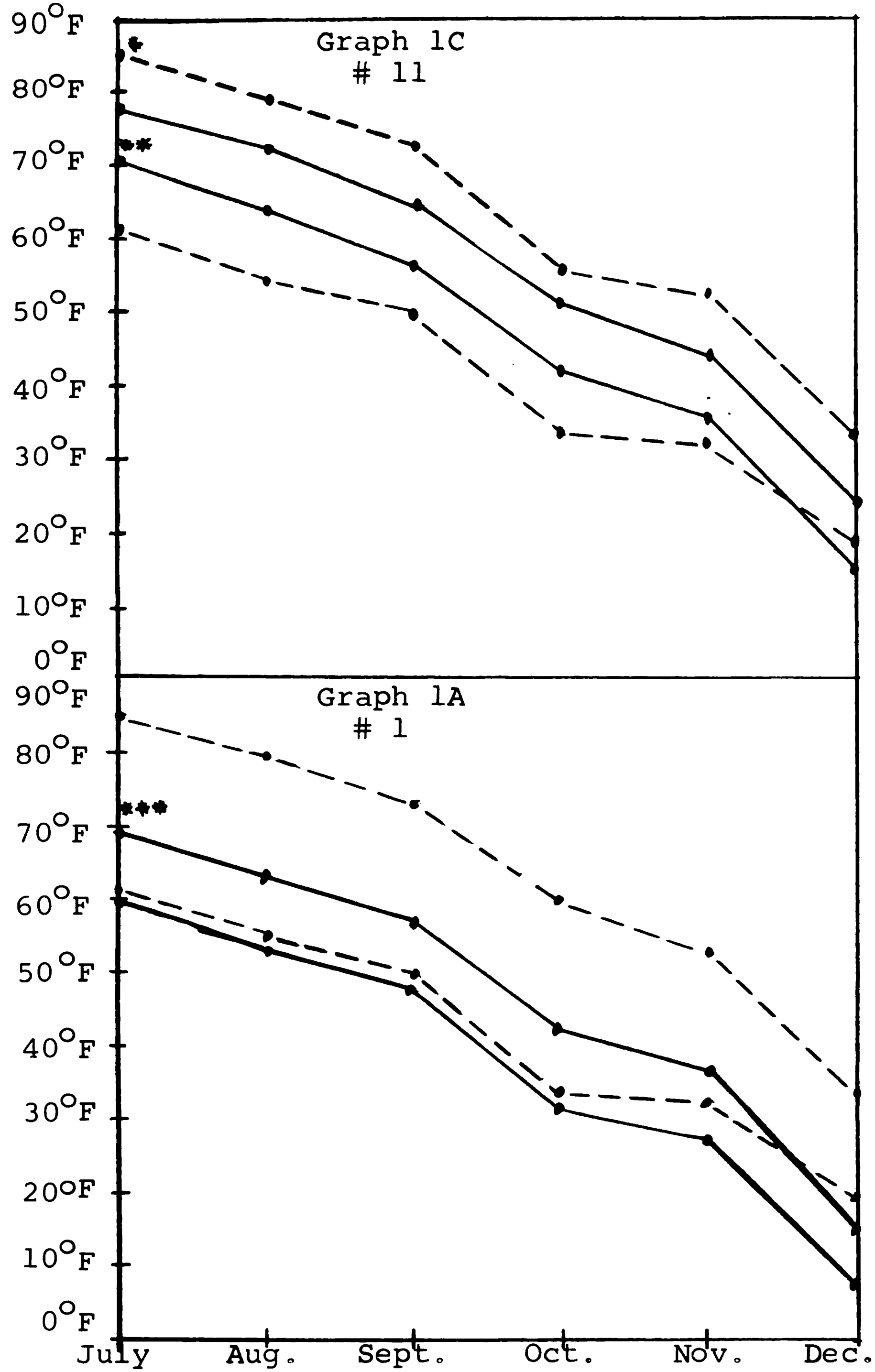
Cavity 1, a large tree trunk cavity located in the southwest corner of the woodlot, was monitored from September 2, 1964 to November 23, 1964. As shown in Graph 1A, the maximum and minimum averages inside the cavity were always below the corresponding external maximum and minimum averages.

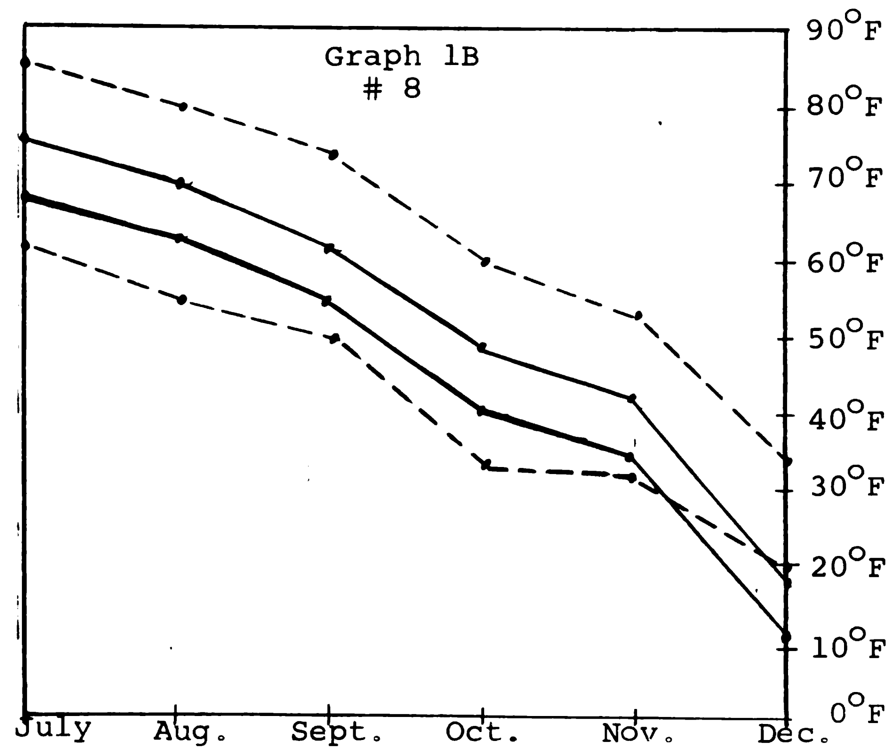
Cavity 8, described with the first group of tree trunk cavities, was equipped with the Tempscribe removed from Cavity 1 on November 23, 1964. It was monitored from that date until the end of the study December 31, 1964. Due to the lack of data, an accurate temperature pattern could not be determined; but, from a comparison of the data available I estimated the pattern to be somewhere between that for Number 1 and that of Number 11 (Graph 1B).

Table 8: The average daily temperature readings inside and outside the dens for the six months of the study. (Numbers in black are calculated averages from measurements; ones in parenthesis are estimated averages.)

		*1	2	3
External	July	85.1	61.2	23.9
	Den No.			
	1	(69)	(61.1)	(8.8)
	8	(75.3)	(68.4)	(7.3)
Internal	11	78	70.1	8.1
	14	(59.6)	(58.1)	(1.5)
	19	(60.4)	(58)	(2.4)
External	Aug.	79.3	54.2	25.1
	Den No.			
	1	(63.2)	(53.1)	(10)
	8	(69.7)	(62.3)	(7.5)
Internal	11	72.4	64	8.3
	14	57.6	56.1	1.5
	19	(58.6)	(56)	(2.5)
External	Sept.	73.0	49.8	23.2
	Den No.			
	1	57	48	8.7
	8	(61.4)	(54.4)	(7.4)
Internal	11	64.5	56.1	8.4
	14	56.2	54.8	1.4
	19	(57.3)	(54.8)	(2.4)
External	Oct.	59.6	33.2	26.4
	Den No.			
	1	41.4	31.4	11.5
	8	(48.5)	(40)	(8.5)
Internal	11	51.2	41.7	9.5
	14	45.8	44.2	1.6
	19	47.1	44.3	2.8
External	Nov.	52.8	31.8	21.0
	Den No.			
	1	36.2	27.1	9.0
	8	(42.2)	(33.9)	(8.3)
Internal	11	44.9	35.6	9.3
	14	42.8	41.2	1.5
	19	43.8	41.1	2.5
External	Dec.	33.2	18.5	14.7
	Den No.			
	1	(14.8)	(6.7)	(8.1)
	8	18	11	7.4
Internal	11	23.3	14.3	8.7
	14	31.1	29.4	1.3
	19	25.7	24.7	1.0

*1. Average daily maximum temperature (°F).
2. Average daily minimum temperature (°F).
3. Average difference between daily minimum and maximum temperatures.





Graph 1: Maximum and minimum monthly averages for tree trunk cavities 1, 8 and 11 for the six months of the study. (All temperatures are in degrees Fahrenheit.)

*The dotted lines are the minimum and maximum averages outside the cavity.

**The solid lines are the minimum and maximum averages inside the cavity.

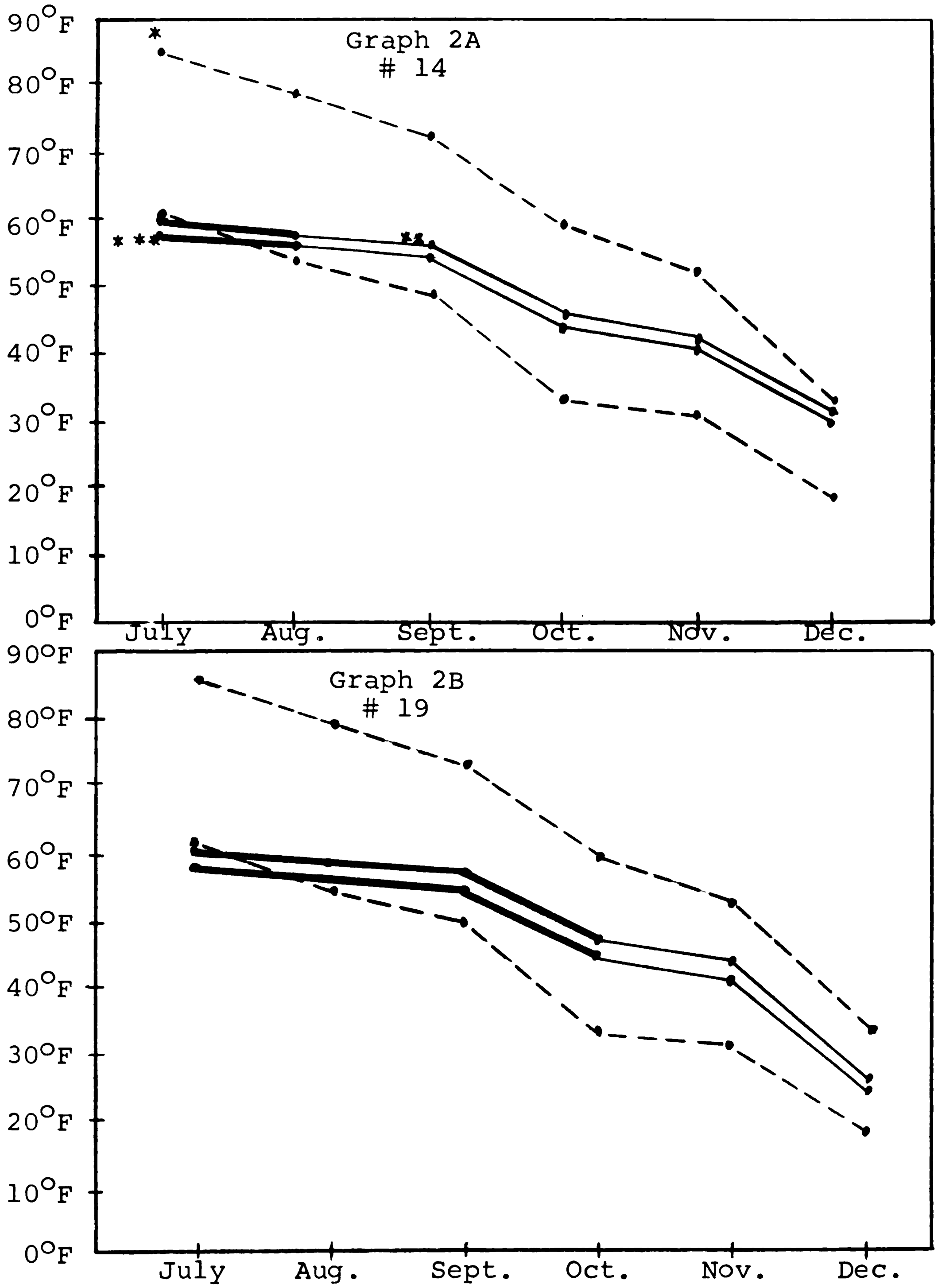
***The heavier solid lines are the estimated minimum and maximum averages inside the cavity.

A Tempscribe installed at Cavity 11, which was located in the grazed portion of the woodlot, was in operation from July 16, 1964 until December 23, 1964, at which time the time mechanism malfunctioned. The temperature pattern of this cavity indicated that this cavity was the warmest and the most stable of the three cavities monitored. The temperature pattern, in this case, instead of having the maximum and minimum averages on either side of the external minimum average, usually had both of them between the external maximum and minimum averages (Graph 1C).

Ground burrow 14 was equipped with a Tempscribe on August 24, 1964. The Tempscribe was in operation until September 20, 1964, at which time the clock mechanism failed. The mechanism was repaired and the Tempscribe reinstalled on October 7, 1964; and continued in operation until the termination of the study. The resulting temperature pattern obtained was completely different from the ones of the previously mentioned tree trunk cavities. The maximum and minimum monthly averages were usually only one or two degrees apart and the total slope of the graph was very gradual in comparison to those of the tree cavities (Graph 2A).

The last den to be monitored was artificial ground burrow 19. The Tempscribe was installed on October 26, 1964 and remained in operation until December 31, 1964. The temperature pattern obtained for this den was very similar

Graph 2: Maximun and minimum monthly averages for ground burrows 14 and 19 for the six months of the study. (All temperatures are in degrees Fahrenheit.)



*The dotted lines are the minimum and maximum averages outside the burrow.

**The solid lines are the minimum and maximum averages inside the burrow.

***The heavier solid lines are the estimated minimum and maximum averages inside the cavity.

to the one for Number 14. Its average fluctuation was usually around three degrees, which was slightly more than the average fluctuation for Number 14 (Graph 2B). I did not expect the close comparison of the two patterns due to the fact that the natural burrow was almost four feet deeper than the artificial one.

Cavity checks, after substantial precipitation, indicated that cavities 1 and 4 were always wet, that Number 8 was wet on occasion, depending on the storm direction, and that cavities 7, 9 and 13 were wet whenever the storm was from the northwest, west or southwest. These moist periods affected the temperature by lowering it as the water evaporated.

Table 9 shows the external weather conditions that existed during each of the six months of the study. Also illustrated by the table are the amount of departure from the expected normal temperatures, and amounts of precipitation taken from the averages calculated for the 30 year period from 1931-1960.

RECORDED ACTIVITY AT DEN ENTRANCES

The den activity indicated by the recorder charts, was first summarized as to date, den, time, and direction, if possible. The daily activity and the sunrise-sunset times were then plotted on a graph. After these had been plotted for each of the 180 days, daily activity was

Table 9: Monthly macroclimatic conditions for the six months of the study.

Month	Temperature				Precipitation			Wind	
	* A	B	C	D	** A	B	C	*** A	B
July	85.1	61.2	73.2	+1.5	3.07	1.32	+0.49	6.2	28
August	79.3	54.2	66.8	-3.4	3.95	1.24	+0.90	9.0	45
September	73.0	49.6	61.3	-0.7	1.90	.77	-0.70	8.8	34
October	59.6	33.2	46.4	-4.9	0.65	.33	-1.85	8.4	29
November	52.8	31.8	42.3	+4.4	1.92	1.07	-0.29	10.7	47
December	33.2	18.5	25.9	-1.6	1.62	.46	-0.37	11.3	32

Temperature (^{o}F)

*A. Average daily maximun
B. Average daily minimum
C. Observed daily average
D. Departure from the expected daily average

Precipitation (inches)

**A. Total for the month
B. Most in one day
C. Departure from the expected monthly total

Wind (mph)

*** A. Average daily speed
B. Fastest recorded

summarized by tallying all points on an hourly and weekly basis. In order to eliminate most squirrel activity, and also eliminate the interpretation as to type of activity, raccoon activity was considered only as the activity occurring from one hour before sunset to one hour after sunrise, although some day-time raccoon activity was observed. Also eliminated from the total activity was any activity caused by skunks (*Mephitis mephitis*), opossums (*Didelphis marsupialis*), and cottontail rabbits (*Sylvilagus floridanus*). This activity, however, proved to be minor, which had been expected because only one opossum and one cottontail rabbit were trapped in Grazed woodlot. The summary of the activity as to hourly and monthly categories is in Table 10.

Next raccoon activity was separated into two categories, investigational and rest units, and the units were summarized as to den and month (Table 11). The total units for each month, listed at the bottom of the table, are as they were taken from the data sheets. These totals, however, do not give a complete picture of the total den activity that could have occurred. This is due to the differences in the monthly functional day totals (Table 11). If all the monthly functional day totals were equal to December's 435 days, and the activity was proportional to the functional days, the grand total activity per month would probably have read: July, 47 instead of 33; August, 54 instead of 45; September, 63 instead of 62; and November, 60 instead of 57.

Table 10: Summarized amounts of uninterpreted daily activity.

Hours	Daily Activity						
	July	Aug.	Sept.	Oct.	Nov.	Dec.	Totals
PM 12- 1	2	1	1	0	3	1	8
1- 2	0	0	0	2	7	7	16
2- 3	1	0	0	0	5	2	8
3- 4	0	0	0	0	1	(6)	7
4- 5	2	1	0	(2	1)	4	10
5- 6	4	(2	2)	1	3	9	21
6- 7	(**2)	1	1	10	3	8	25
7- 8	6	5	2	9	4	4	30
8- 9	11	5	3	3	3	0	25
9-10	7	3	6	3	0	5	24
10-11	1	4	5	8	7	7	32
MN 11-12	3	5	5	4	1	8	26
AM 12- 1	3	7	8	10	1	6	35
1- 2	4	5	6	7	2	4	28
2- 3	0	4	6	9	6	4	29
3- 4	0	5	5	4	6	1	21
4- 5	7	8	4	3	6	5	33
5- 6	(3)	3	3	7	7	3	26
6- 7	5	(4	1)	5	1	2	18
7- 8	1	3	3	(2	5)	4	18
8- 9	1	1	2	6	8	(6)	24
9-10	0	1	2	2	5	1	11
10-11	0	0	1	1	1	4	7
MD 11-12	2	2	0	4	7	5	20
Totals	65	70	66	102	93	106	502
*Subtotals	45	59	59	87	53	74	377

*The numbers in these categories are the totals for raccoon activity from one hour before sunset to one hour after sunrise for each of the six months.

**The parenthesis are the average sunrise and sunset times for a month period.

Table 11: Summary of recorded investigational and rest activity.

**Functional days / den	Den	Investigational Activity July	Aug.	Sept.	Oct.	Nov.	Dec.	Totals
174	1	2	8	8	7	0	0	25
163	2	0	2	1	0	4	1	8
162	3	2	7	5	3	0	0	17
165	4	1	3	1	2	2	0	9
165	6	1	3	2	2	1	0	9
173	7	0	1	2	0	1	0	4
176	8	1	2	5	1	2	1	12
172	9	0	3	6	12	0	0	21
171	11	2	2	1	2	4	3	14
177	13	0	2	2	1	3	0	8
177	14	7	5	2	5	1	4	24
156	15	4	2	6	1	1	3	17
108	19	*(X)	(X)	2	3	1	1	7
109	20	(X)	(X)	5	7	2	0	14
41	21	(X)	(X)	(X)	(X)	0	4	4
2,289	Totals	20	40	48	46	22	17	193

	Den	Rest Activity July	Aug.	Sept.	Oct.	Nov.	Dec.	Totals
174	1	0	0	0	0	0	0	0
163	2	0	0	0	1	11	2	14
162	3	0	0	0	0	1	2	3
165	4	2	0	0	0	0	0	2
165	6	1	0	0	1	1	0	3
173	7	0	0	1	0	0	0	1
176	8	0	1	0	0	0	3	4
172	9	0	0	1	1	0	0	2
171	11	4	2	3	5	4	13	31
177	13	0	0	0	0	0	0	0
177	14	6	2	1	6	17	10	42
156	15	0	0	0	1	0	0	1
108	19	(X)	(X)	0	1	1	1	3
109	20	(X)	(X)	0	0	0	0	0
41	21	(X)	(X)	(X)	(X)	0	0	0
2,289	Totals	13	5	6	16	35	31	106
Grand Totals		33	45	54	62	57	48	299
Functional days/month		305	360	371	416	402	435	2,289

*The Xs in parentheses indicate that the dens were not monitored during those months.

**A functional day is defined as one den being monitored for a 24-hour period.

ENVIRONMENTAL FACTORS EFFECTING DEN USE

STRUCTURE AND MICROCLIMATE

The most important portion of this report is the analysis of environmental factors effecting the use of dens by raccoons. When the construction and the microclimates of different dens were compared, there were indications of differential use due to variations of these characteristics. To show comparisons between the individual den characteristics and use, each of the 15 dens will be discussed individually.

Cavity 1 had the largest inner dimensions of all the tree cavities; despite its size, it was never used as a rest place during the 174 days it was monitored. Possible explanations for the lack of rest use were indicated by the data. First, the entrance of the cavity was pointed west and its exposure was vertical which allowed snow and rain to enter without much difficulty. This was born out by my observations of snow on the bottom of the cavity and much rain running into the entrance. Secondly, in examining the microclimates of cavities 1 and 11, (Number 11 being the most used tree cavity), differences were clearly demonstrated by comparing Graphs 1A and 1C. The average daily fluctuation of Cavity 1 was 9.4°F while that of Number 11 was only 8.7°F (Table 8). Also, Cavity 1 was usually 10°F colder than Cavity 11.

Cavity 2, one of the three most active rest dens, had substantial use but only during the months of October, November and December. This fact produced several questions that had to be answered. These questions were: Why was the cavity used mainly during these months; and why was the principal type of use of the rest type?

Due to the lack of microclimatic information for this cavity, any direct relationship between the characteristics of the cavity and use by raccoon was difficult to prove; however, by comparing the information gathered from other cavities with the data collected for Cavity 2, I was able to formulate some possibilities.

First, Cavity 2 had better than average depth from entrance to the cavity bottom; average entrance dimensions, and inner dimensions; a horizontal exposure with a lip which aided in protecting the cavity from wind and other weather elements (Fig. 10); a south direction entrance; and ten inches of wood insulation. A comparison of measurements for Cavity 2 and 11 indicated the possibility that Cavity 2 was warmer and more stable than Number 11 (Table 4).

In re-examining the amounts and types of den use during the months of July, August and September, at which time Cavity 2 was used the least, it was noted that these were the warmest of the six months. Also noticed was the fact that the total rest units for all dens were at their minimum during these months. This gave an indication that the warmth of the cavities was uncomfortable for the raccoon. From these observations I speculated that the reason for the lack of use of Cavity 2 during the warm months was the uncomfortable microclimate existing in the cavity at these times. As to a reason for an increase of use during the colder months, I concluded that it was affected by the stable microclimate offered by Cavity 2 during the presence of adverse weather conditions.

The greatest distance from the entrance to the bottom of the cavity, 95 inches, occurred in Cavity 3. This measurement set it apart from all the other tree cavities. When first examined, this cavity possessed signs of extensive animal use; however, from the data collected by the event recorder, I determined that only about 60 percent of the total activity occurring at Number 3 could be attributed to raccoons. Also noted was the fact that, of the total raccoon activity, only 1/7th was of the rest unit type, which indicated the presence of some adverse factor or factors in the cavity itself. There was no microclimatic data for this cavity, so the only relationships had to be made on the physical construction comparison.

As previously mentioned, Number 3 was the deepest of the ten tree trunk cavities. From his observations, Stuewer (1943) concluded that depth did not apparently have an influence on use, however, the cavities that went to the base of the tree were usually wet. Since there was no accurate data on the differential use of cavities of various depths, I assumed, from the indications, that there was a good possibility that depth did have an adverse affect on use. Of course, there was the possibility that the depth was a secondary factor, in that, its influence was felt through the microclimatic conditions produced by the depth and the wetness conditions. A northwest entrance direction probably aided the possibility of a wetness factor since most storms came from westerly directions. In conclusion, I speculated that the principal affect was the microclimatic factor, but, the affect of depth may have been the cause for the unfavorable microclimatic conditions.

Number 4, like Number 1, had a vertical entrance exposure. Unlike Number 1, however, Number 4 was used twice as a resting place during the 165 days it was monitored. Also, I noted that the rest units occurred on warm sunny days. In analyzing the total amount of use of this cavity, I found that the cavity was used very little in comparison to the average amounts of use of all cavities (Table 4). I also found that microclimatic conditions similar to the ones for Number 1 existed in Number 4. On the same days that snow or other forms of precipitation were noticed in Cavity 1, they were also in Number 4 and usually in greater amounts. In fact, after an early winter thaw, Number 4 became frozen solid from the bottom of the cavity to within ten inches of the entrance. The data from Cavity 4 indicated that this cavity afforded very little protection for the raccoon at times when protection was needed most.

As previously mentioned, under den descriptions, cavities 7, 9 and 13 were very similar in construction. Despite their similarities, activity recorded varied from very little to slightly above average use. In order to determine possible reasons for the differential use, I examined all the characteristics and found the following differences.

Number 7, located in an American elm 17.8 inches in diameter, had the least use of any den in Grazed woodlot. This cavity was the highest from the ground, 17.5 feet, and the deepest, seven inches, of the three cavities.

Cavity 9 was used the most of the three cavities. It was located in a basswood only nine feet from the ground. Although it was shallower than Number 7, this cavity was sheltered from a west wind by a large limb directly in front of the entrance, extending from the bottom of the entrance (Fig. 12).

The last of the trio was located in a beech. The smooth tough bark of the tree was probably more difficult for raccoons to climb than the two previously mentioned trees. Also, this cavity was by far the least sheltered, due to its large entrance and lack of depth (Fig. 5). It was always wet from any type of precipitation.

From these observations I concluded the following: Due to their large entrances and shallow depths, their microclimates were probably very similar to existing external conditions. Also, their west entrance direction allowed all types of precipitation to enter from all westerly storms. These two observations could account for the fact that all three cavities combined were used only three times in 522 functional days as resting places by raccoons.

Raccoon activity was recorded only five times for Number 7. This indicated that there was some factor or factors of the appearance of the tree which had a negative affect on raccoons. The diameter of this tree may have given raccoons such a clue. The diameter of Number 7 was 3.2 inches smaller than the next smallest tree diameter, which was Number 3, and 7.3 inches smaller than the average diameter of all the nine trees (Table 4). Also, Number 7, 3 and 13 were the only cavities, whose entrances were over ten feet from the ground, that did not have a limb between the ground and the cavity entrance. And of these three only Number 3 had slightly above average use. In addition to the unsheltered entrance and lack of depth, the two observations just discussed could have all had a bearing on the lack of use of Number 7.

In comparison to cavities 7 and 13, Number 9 was much more accessible. The cavity was located only nine feet from the ground and a limb, with a ten-inch flattened surface, was

Figure 12: Limb sheltering the entrance to Cavity 9.

Figure 13: Two raccoons at the entrance to ground burrow Number 14.

directly in front of the entrance (Fig. 12). Raccoons have been known to use such limbs as resting places (Cabalka, 1952). The quality of accessibility could possibly explain the reason for the above average total activity but it would have little to do with dictating the type of use. Therefore, I believe that the data indicate that the accessibility factor was controlling the general activity of the cavity, but that the construction dictated the type of use.

As mentioned before, the bark of a beech tree is believed to be difficult for a raccoon to climb (Stuewer, 1943). Number 13 was the only tree in this study to possess this condition. If it is difficult for a raccoon to climb a smooth beech tree, then this factor could be an explanation for the below average amount of total use; however, like Number 9, I believe that it was the construction of the cavity itself that controlled the type of use.

When first examined, Cavity 8 appeared to be extensively used by raccoons. But data from later measurements indicated that this cavity had below average use (Table 4). Even after an analysis of its characteristics it appeared to be a good cavity. When the microclimates of Number 8 and Number 11 were compared, however, the possible cause for the lack of expected use was discovered (Graphs 1B and 1C). Further examination of the construction of the cavity uncovered a slit five inches long on the west side of the tree, just four inches above the cavity-bottom. This slit allowed wind and rain to enter from the west and had a definite controlling effect on the microclimate in the cavity.

Number 11, the most active of the ten tree cavities, was used extensively as a place of rest (Table 4). Due to the large amount of use incurred by Number 11, it was used as the primary example for comparisons. This cavity was located in a basswood 22.6 inches in diameter. The 6 by 4.5 inch entrance was 21.2 feet above the ground and had a south direction and horizontal exposure. The cavity extended 66 inches down inside of the trunk and was 13 by 8.5 inches in diameter. Despite the fact that it only had 2.7 inches of insulation, its microclimate was quite stable and warm. The average daily fluctuation between its minimum and maximum temperature was 8.7°F and the average daily temperature was usually one or two degrees cooler than the external daily average.

The natural ground burrow, Number 14, had the most stable temperature of all the dens. Its average fluctuation was 1.5°F and its temperature never went above 60°F or below 25°F during the five months that its temperatures were being recorded. This cavity had the largest amount of activity of any of the 15 dens and was used primarily as a place of rest (Table 6). Numerous photographs were taken of raccoons entering and leaving this burrow (Fig. 13).

Artificial burrow Number 19 was equipped with a temperature recorder so that the microclimate of this man-made den could be compared to the microclimate of the natural ground burrow. The microclimates proved to be very similar. The average temperature fluctuation for Number 19 was 2.3^{O}F as compared to the 1.5^{O}F for Number 14 (Table 8 and Graphs 2A and 2B). Despite the similarity between the two burrows' temperatures, there was little similarity as to the amount of use. During the 108 days the artificial burrow was monitored, there were only 10 units of activity (Table 11). In an attempt to determine the reasons for this difference, I continued to observe the burrow after the termination date. The extra observations indicated that Number 19 had poorer drainage than Number 14. During an early winter thaw, the burrow filled up with water and became frozen solid when the cold weather returned.

Number 21, the second artificial burrow, due to its identical construction, suffered the same fate as Number 19.

The last cavities to be analyzed were the two tree base cavities, Numbers 15 and 20. Number 15 possessed the smallest entrance dimensions of all the tree cavities. I observed a juvenile raccoon entering this cavity on June 25, 1964 and noticed that it had a tight fit. This fact could explain the lack of rest use recorded for this cavity; however, the total activity of 18 was almost average and the investigational units number of 17 was above average. Number 20 had 25 investigational units for the same period of time which indicated that this open cavity did not possess rest place qualities, but was very accessible to raccoon investigation.

It appears that once the dimensions of a den are sufficiently large enough to house a raccoon, the primary factor effecting the amount and type of den use is the microclimate of the burrow or cavity. The microclimate factor can be broken down into two components which seem to have approximately equal influence; temperature and wetness. The second one, of course, has the primary influence on days that precipitation occurs. The other factors discussed appear to be secondary except in specific cases, such as the smoothness of the beech bark making it difficult for raccoons to climb a beech tree. Factors such as den construction may be considered secondary in that they usually affect the raccoon through the microclimate. Dimensions of a cavity, however, do have an equal role with the microclimate during the time when young are in the den. The size must be adequate and the microclimate must be comfortable and sufficient to supply the young with the proper protection.

SURROUNDINGS

From scat analysis I determined that the cornfields and the University orchard were the principal sources of food. Table 7 contains the distances from each of the dens in Grazed woodlot to the closest cornfield and to the orchard and also to a natural and artificial water supply.

Using the distances and the method of location analysis described on page 26, I attempted to determine if there was any relationship between use and den location in respect to the location of the other dens in the woodlot, and between use and a den's location in respect to certain environmental consitituents. After I had made all the comparisons of the different dens in the different quadrants and circle intervals, I could not find any positive indication that there was any relationship between the amount of use and the location of the den in Grazed woodlot.

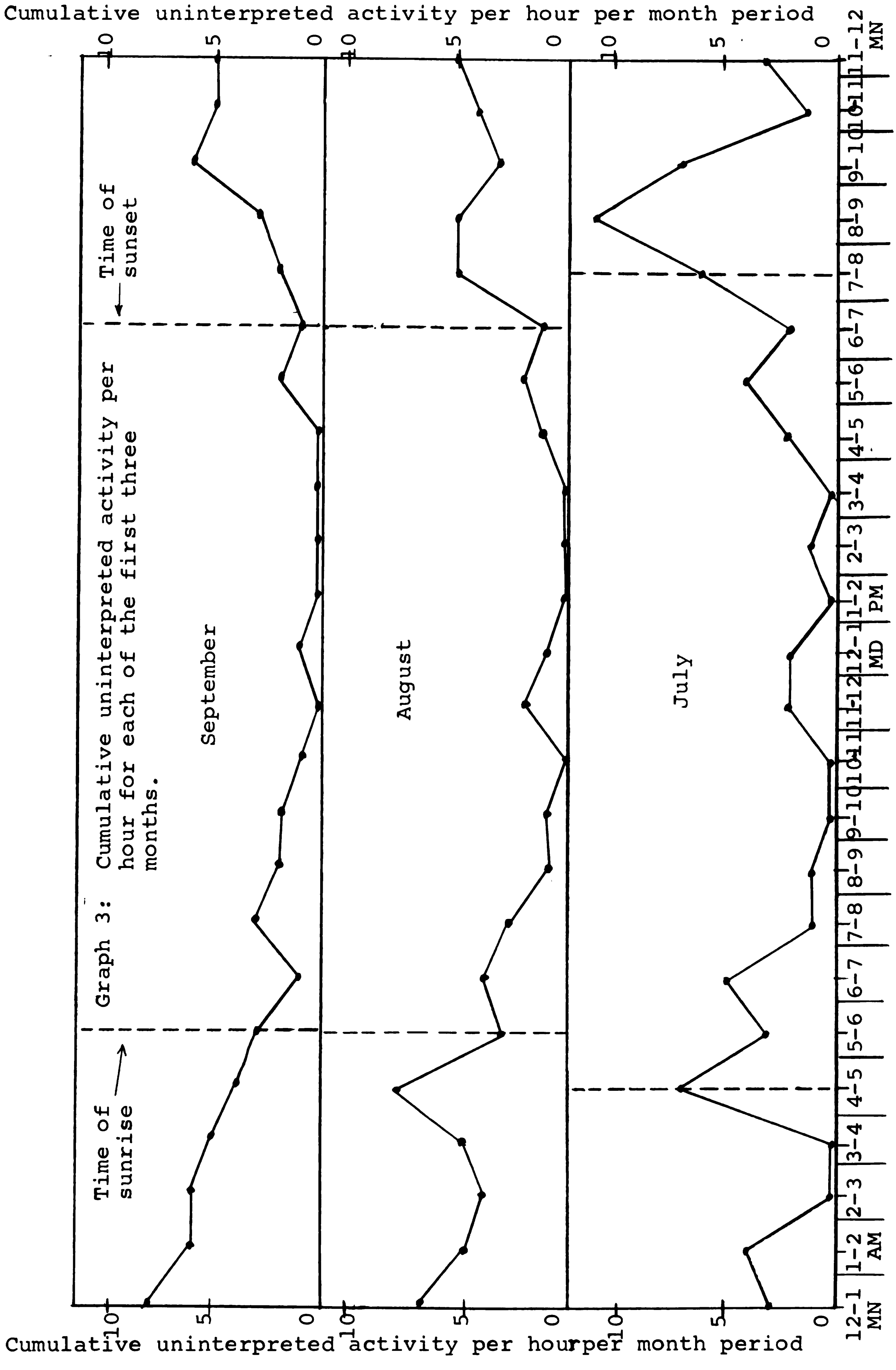
In analyzing the data in an attempt to answer the question of possible differential use due to location of a den in respect to particular environmental constituents, I found that during the months, particularly August and September, when food was most abundant in the cornfield and orchard, rest use of dens was at its minimum. But even then, Numbers 11 and 14 were used eight times as rest places. Of the cavities closer to the cornfield and orchard than Numbers 11 and 14, only Cavity 8 was used and that was only once in 61 days. During October when most of the food was being harvested and there was a decrease in temperature, there was an increase in rest den use. Even then, the cavities closest to the food supplies were not used as places of rest (Table 11).

In attempting to determine the possible influence that den location, in respect to its distance from water, had on the use of the individual dens, I examined both the natural water area and the stock tanks. There was evidence of raccoon use but I never observed any raccoons that had been tagged, around the pond or within one-half mile. Regular use of this area by raccoons inhabiting Grazed woodlot was not expected due to its distance from the woodlot. The stock tanks, which were much closer to the woodlot, were examined and found to be accessible to the raccoons due to a platform which would allow a raccoon to reach the water. I never observed any signs of raccoon use during the time of the study, but, this was due to the destruction of possible signs by the beef cattle using the stock tanks.

From these data, I concluded that there was no positive relationship between den use and the location of the den in respect to the particular surroundings discussed.

TIME OF SUNRISE AND SUNSET

Raccoons are generally considered to be nocturnal (Sharp, 1956). If this is true, then activities, particularly around dens, should be controlled by the sunrise and sunset. From the den use recorded by the Esterline Angus recorder, however, I found that raccoons could be active around dens at any hour of the day. But during July, August and September the chances of raccoon activity during daylight hours between two hours after sunrise and two hours before sunset were very slight (Table 10 and Graph 3). Recorded activity



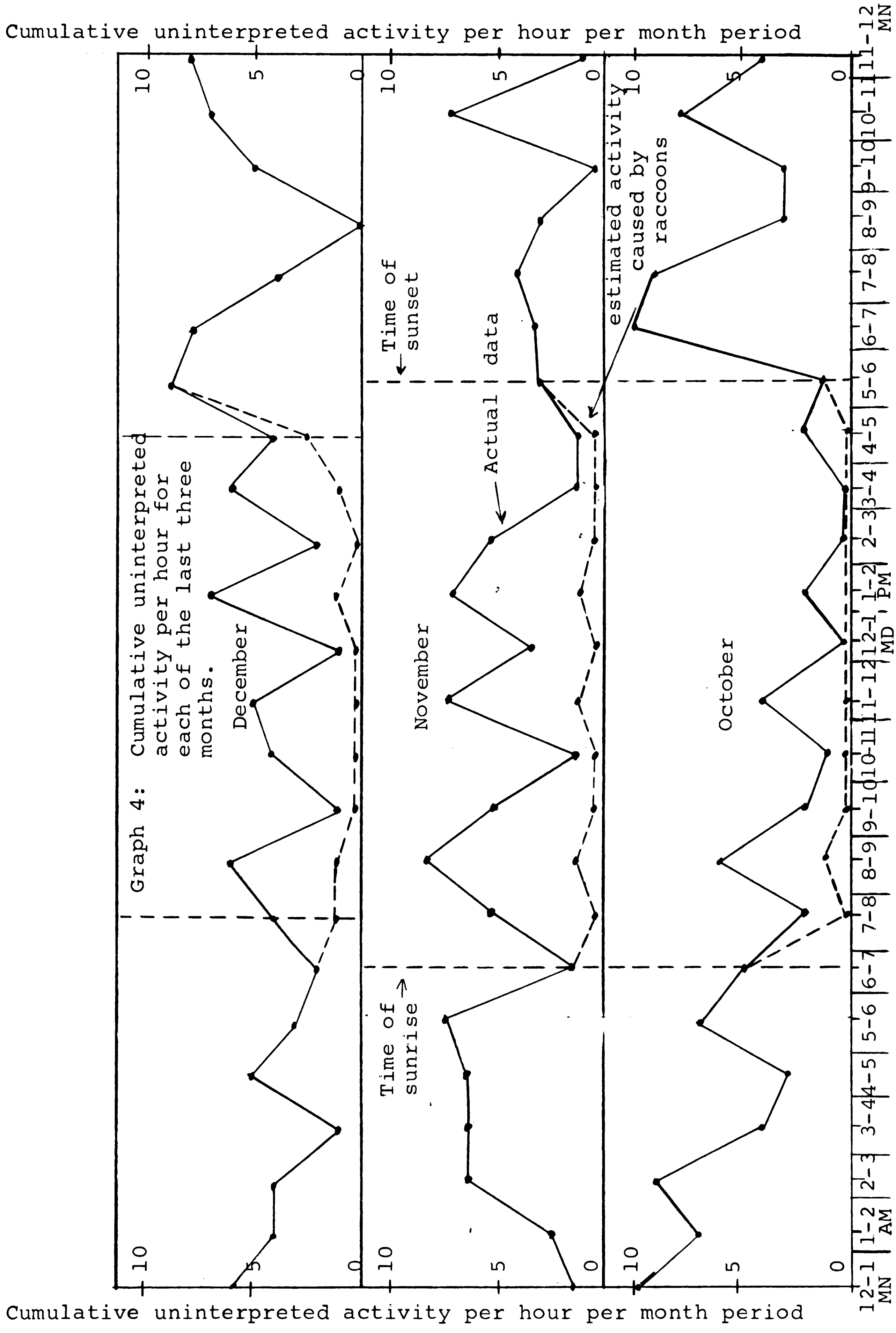
Graph 3: Cumulative uninterpreted activity per hour for each of the first three months.

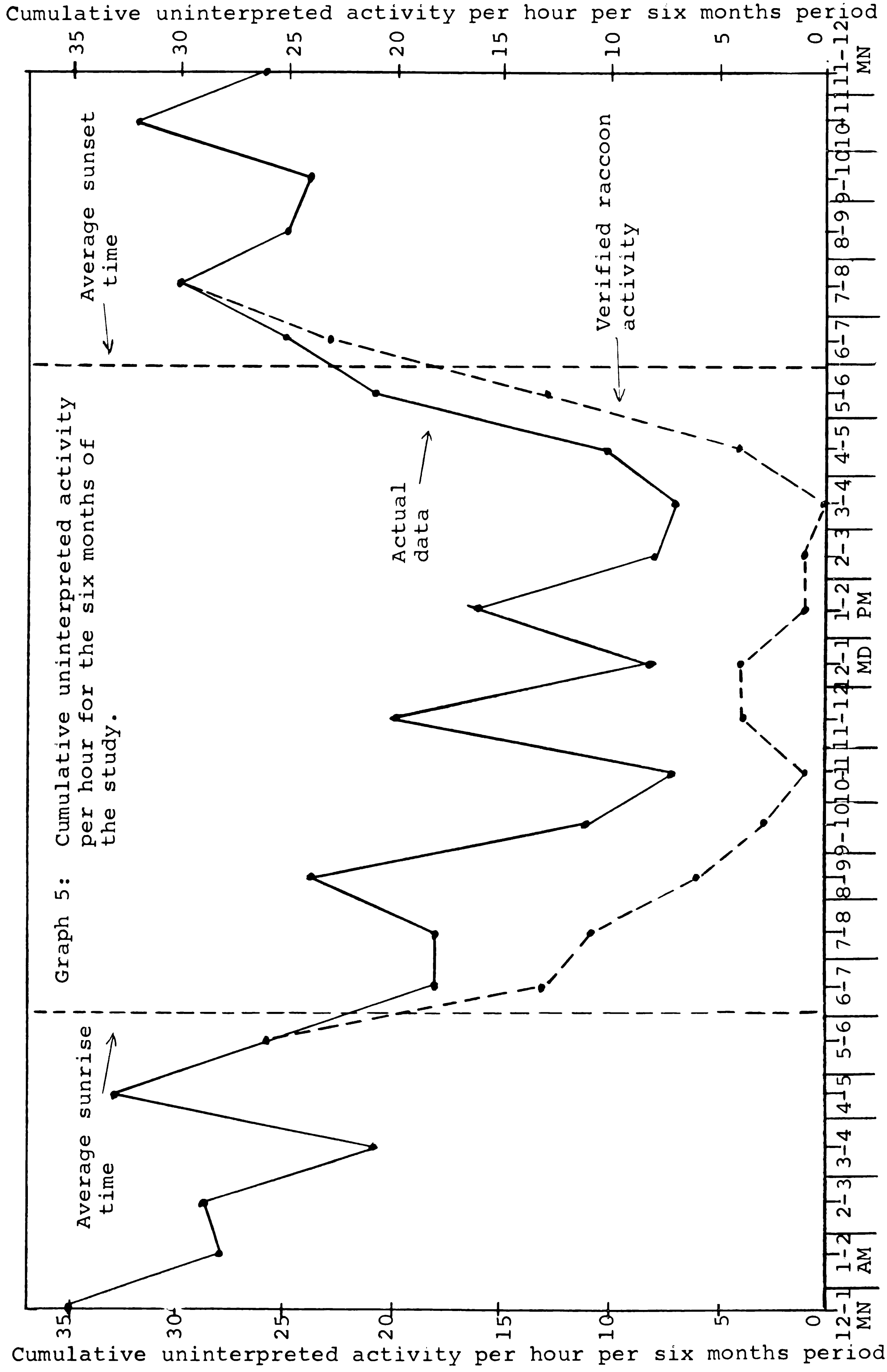
around cavities, during the daylight hours, increased during the months of October, November and December; however, the greatest percentage of this increased activity was verified to be caused by squirrels (Table 10 and Graph 4).

In comparing sunrise and sunset times with the increase and decrease in daily raccoon activity, I found that the time of sunset appeared to have more of a controlling effect on activity than did sunrise (Graphs 3 and 4). In order to illustrate this more clearly, activity was plotted against the time at which it occurred (Graph 5). Most of the raccoon activity during the daylight hours, particularly around 12 and 1 o'clock, was caused by raccoons sunning themselves at the entrance to the cavity.

CLIMATIC FACTORS

Factors effecting den use were not reported in the literature but some information was given concerning factors influencing movement. Stuewer (1943) stated, "it appeared that the coming of snow, rather than temperature, was the deciding factor which induced raccoons to cease outside activities." He concluded saying, "later in the winter when snow had been on the ground for a month or more, temperature seemed to have more influence." Cabalka (1952) concluded that the principal factor was the temperature and not the presence of snow. Stains (1956) came to the same conclusion.


Cumulative uninterpreted activity per hour per month period
Graph 4: Cumulative uninterpreted activity per hour for each of the last three months.
December
November
October
Time of sunset
Time of sunrise
Actual data
estimated activity caused by raccoons
10
5
0
12-1 MN
1-2 AM
2-3
3-4
4-5
5-6
6-7
7-8
8-9
9-10
10-11
11-12
12-1 MD
1-2 PM
2-3
3-4
4-5
5-6
6-7
7-8
8-9
9-10
10-11
11-12 MN
Cumulative uninterpreted activity per hour per month period

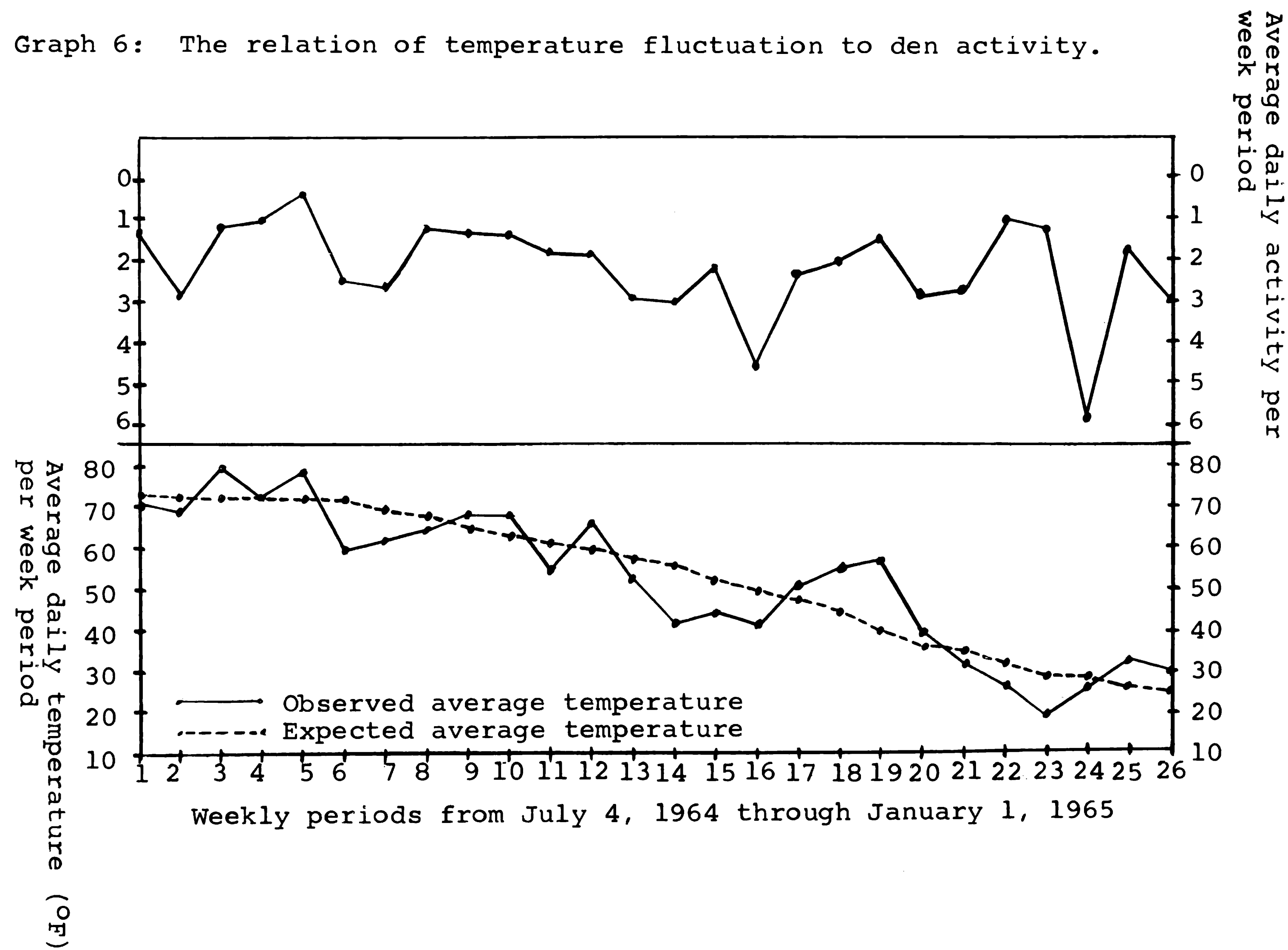

Graph 5: Cumulative uninterpreted activity per hour for the six months of the study.
Cumulative uninterpreted activity per hour per six months period
Average sunrise time
Average sunset time
Actual data
Verified raccoon activity
0
5
10
15
20
25
30
35
12-1 MN
1-2 AM
2-3
3-4
4-5
5-6
6-7
7-8
8-9
9-10
10-11
11-12
12-1 MD
1-2 PM
2-3
3-4
4-5
5-6
6-7
7-8
8-9
9-10
10-11
11-12 MN

Temperature

First, I graphed the average daily activity per week periods for the 26 weeks of the study. Next, I plotted all the average daily temperatures for the corresponding week periods. I then compared the resulting graphs (Graph 6). The activity was not broken down into the two units (investigational and rest) but was plotted as a daily unit of activity. This was to eliminate any possible bias that might have been caused by the interpretation of the activity as to type. A comparison of Graphs 6A and 6B indicated a relationship of temperature to activity. From this comparison, I found that when the average temperature went below 35°F and continued to decrease, activity likewise continued to decrease; however, if the average temperature was below 35°F but had increased over the previous week's temperature, there was a tremendous increase in activity (Graph 6, 24th week). The phenomenon just described was reversed when the average temperatures were above 35°F. In other words, if the average temperature was above 35°F and had decreased from that of the previous week, the activity was most likely to increase and just the opposite if the temperature increased (Graph 6, 6th week).

When closely analyzed, the complexity of this factor was indicated in Graph 6. The change in temperature appeared to be a controlling factor but the duration, direction and amount of change per unit time may also have had a direct

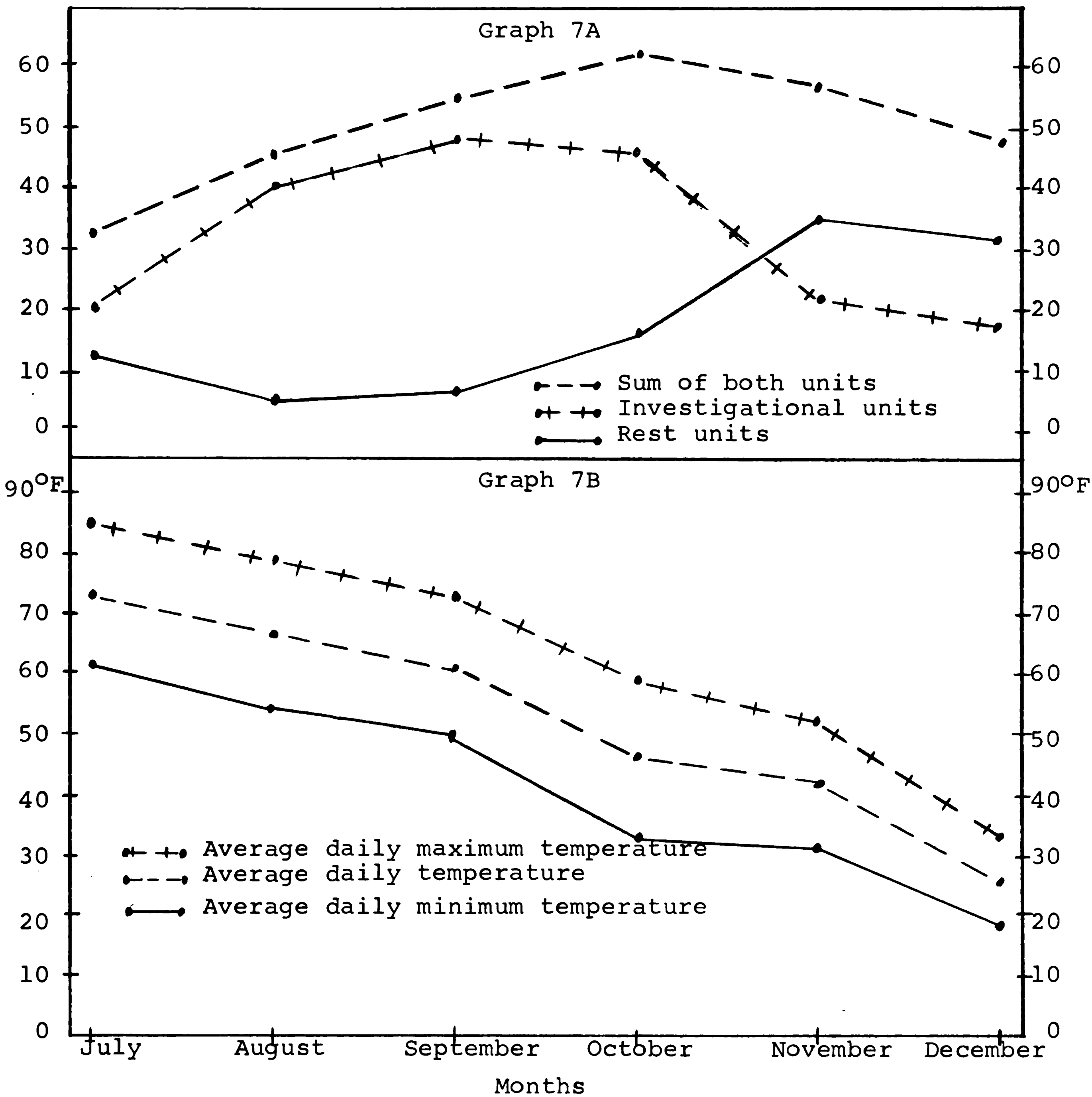
Graph 6: The relation of temperature fluctuation to den activity.



influence on the amount of den activity. For example, from the third to the fourth week there was a decrease of 6°F from 79°F to 73°F; however, there was also a decrease in activity. In all appearances, this disproved the above conclusion; but, when the week was broken down into days I found that during three of the seven days the average temperature was 67°F and during the remaining four days the average daily temperature was 78°F. When the activity was broken down into its components, I calculated that 7/8th of the total activity had occurred on the three days with the 67°F average daily temperature. Therefore, the above conclusion was not disproven.

The next step in this analysis was to determine the relationship of temperature to the two types of den use. The two types of use referred to are investigational and rest units. These units were arrived at by using the assumptions and methods of interpretation discussed on page 17. The units were summarized on an individual and monthly basis (Table 11). The monthly results were graphed and compared to the average monthly temperatures (Graph 7). The sum of the investigational and rest units varied slightly from month to month. But, when the units were graphed separately a definite trend took form (Graph 7A). It appeared that as the monthly average temperatures decreased from 70° to 60°F, investigational units increased and rest units remained constant at a low level (Graphs 7A and 7B). As the average

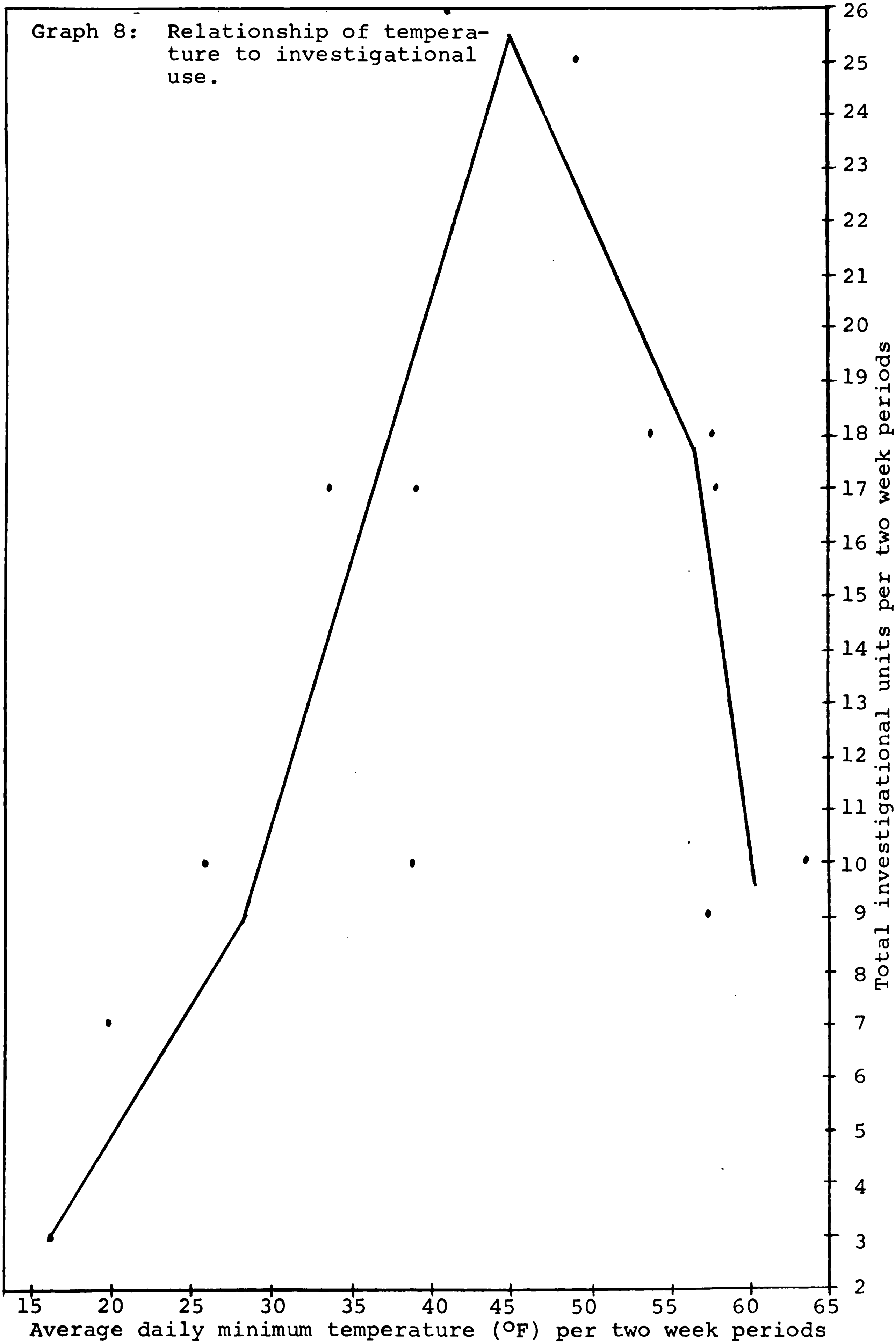
Graph 7: Relationship of temperature to the types of den use.



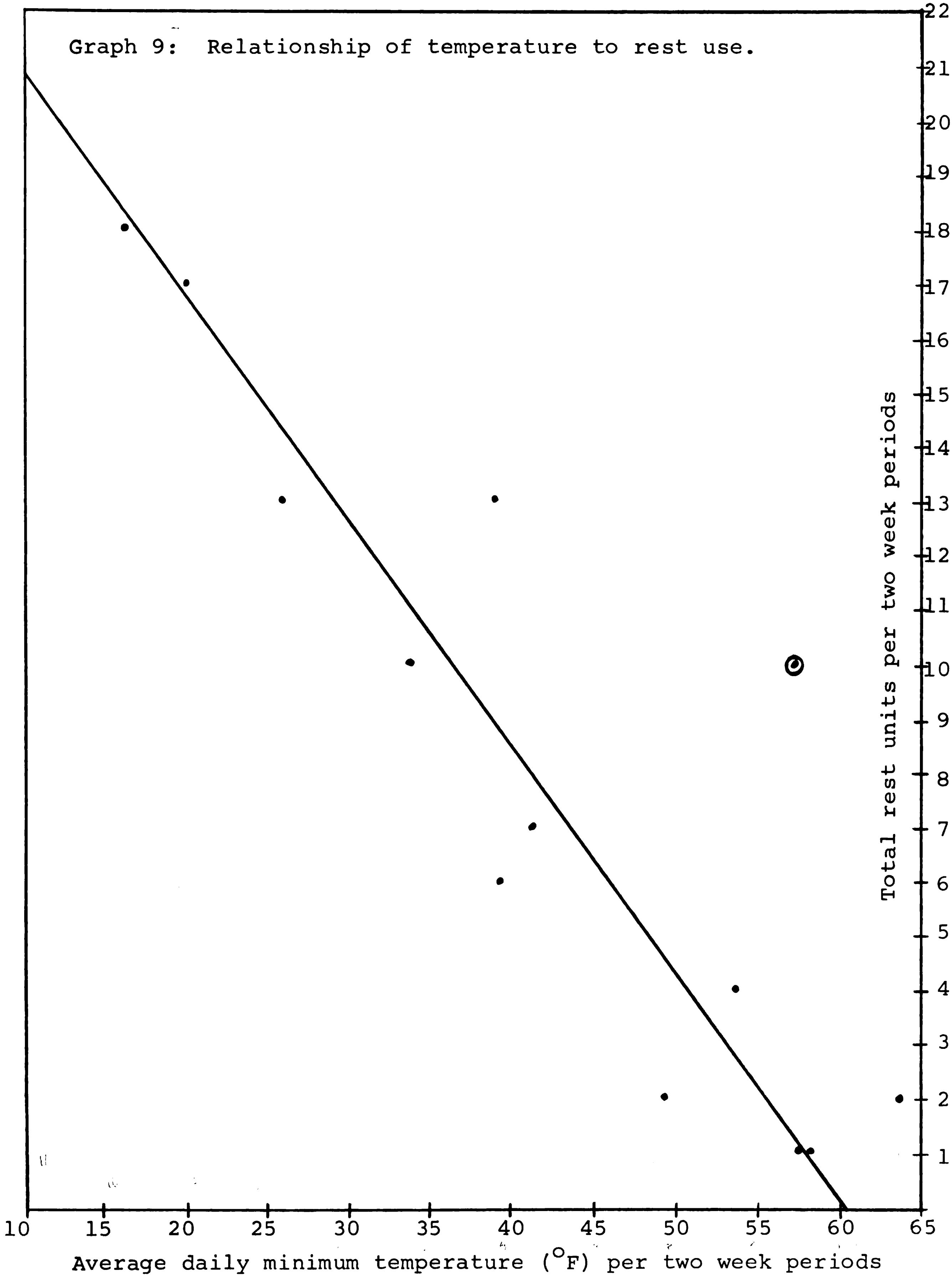
monthly temperatures continued to decrease from 60°F to 50°F, the investigational units decreased slightly and the rest units increased sufficiently to keep the total den use at a steady level (Graph 7A, October). And then, as the average temperatures dropped below 50°F the investigational units continued to decrease and the rest units continued to increase. At approximately 40°F rest units became the predominant type of den use. This trend continued as long as the temperatures remained below 40°F.

In analyzing den use further, I found that when the total investigational units per two week periods were plotted against the average minimum temperatures for the same corresponding periods, an inverted parabolic curve resulted (Graph 8). This curve showed that as the temperatures decreased to around 45°F the investigational units increased. Then, as the temperatures decreased below 45°F the investigational units also decreased.

Using the same method of analysis for the rest units, a straight line was produced (Graph 9). This meant that as the average minimum temperature decreased the rest units increased proportionally. Of all the points plotted only one did not follow this trend and that value is circled in red and was for the first two week period of the study. The only explanation for this departure from the normal trend was that the juvenile raccoons were still very young and there was a necessity for shelter despite the favorable temperatures.



Graph 8: Relationship of temperature to investigational use.
Total investigational units per two week periods
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
15
20
25
30
35
40
45
50
55
60
65
Average daily minimum temperature (°F) per two week periods

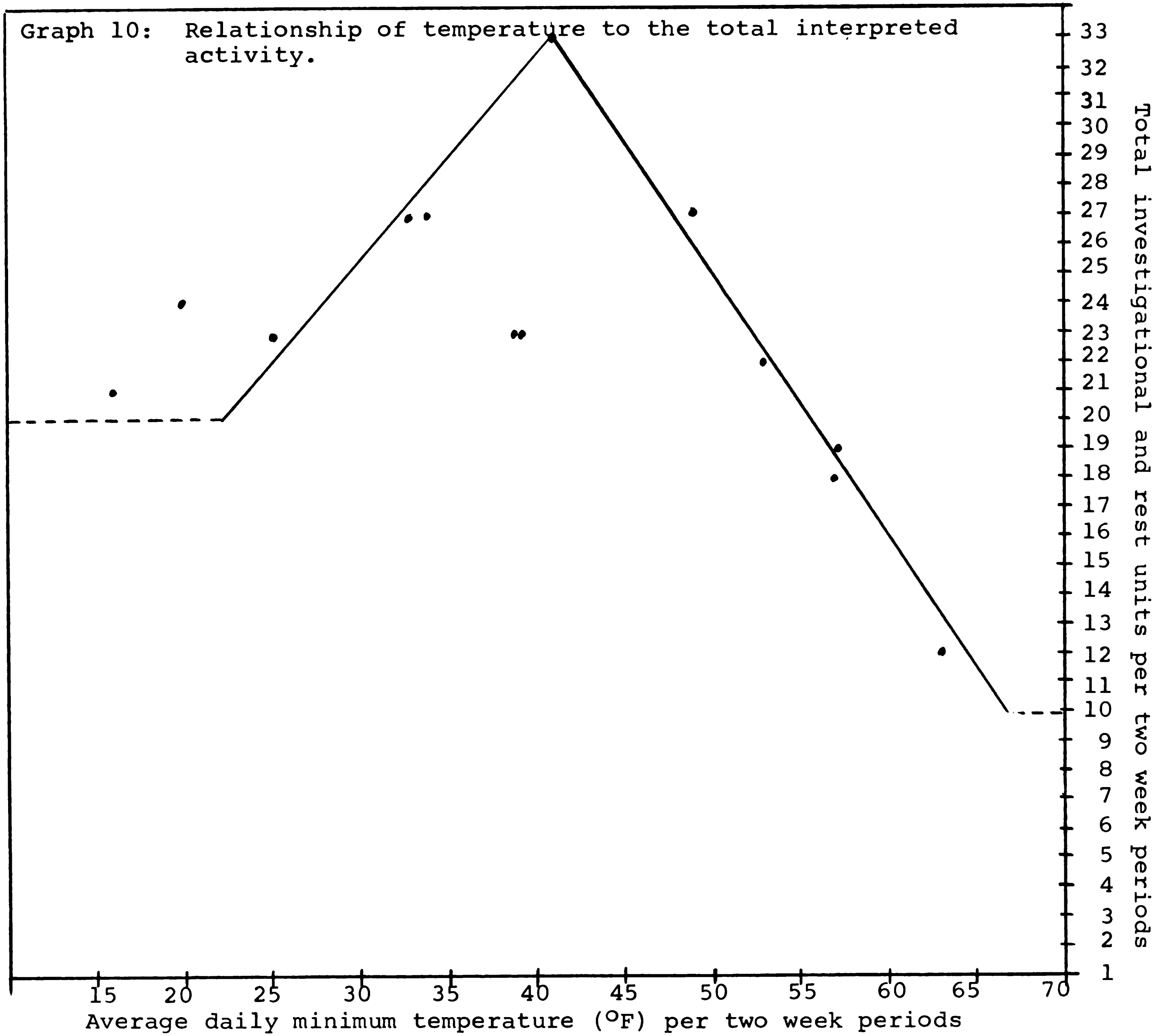

Graph 9: Relationship of temperature to rest use.
Total rest units per two week periods
22
21
20
19
18
17
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
10
15
20
25
30
35
40
45
50
55
60
65
Average daily minimum temperature (^{O}F) per two week periods

When the sum of the investigational and rest units per two week periods were plotted against the corresponding average minimum temperatures, the curve illustrated by Graph 10 resulted. The maximum den use was achieved when the average minimum temperature was at 41°F.

From this information, I have drawn the following conclusions as to the effects of temperature on the amount and types of den use. During the six months of the study, temperature was directly related to the amount and type of den use. Investigational use was the predominant type of use until the average minimum temperature went below 40°F, at which time rest use became dominant. As temperatures proceeded to increase, investigational use became minimum and rest use continued to increase until the carrying capacity of the useable dens was reached.

Precipitation

Another climatic factor believed to effect the behavior of raccoon is precipitation in the form of snow (Stuewer, 1943). However, after I had examined the data collected during the study, I could not find any relationship between the presence of snow and raccoon activity. The possible effects of snow were masked by the low temperatures which occurred at the times that snow was present. Since I had more data substantiating temperature as a controlling



Graph 10: Relationship of temperature to the total interpreted activity.

factor, I had to conclude that snow did not have any noticeable influence on raccoon activity.

Precipitation, in the form of rain, has not been considered in other studies as a factor effecting raccoon activity. In this study, however, there was some indication that rain did possibly effect raccoon activity. But, there was a lack of data because: First, most of the heavy rains occurred during the daylight hours, at which time there was very little raccoon activity; secondly, several times the rain ceased at approximately sunset which made it difficult to calculate which of these two factors had the most influence; and, lastly, on several occasions there was no activity recorded in Grazed woodlot for the entire day, which could have been taken as a positive or negative indication of the affect of the rain.

From the total picture indicated by the data, I believe that raccoons are affected by heavy rains (.10 inches or more per hour); however, the important factors to be considered are the time at which the rain occurred, how long it lasted and its hourly rate.

Wind

The last climatic factor to be considered was wind. I graphed daily cumulative wind counts taken in Grazed woodlot at six feet from the ground and daily cumulative wind counts obtained from the University weather station, which was in an open field at two and six feet, and compared them to the daily activity graphs. I could not find any direct relationship which showed any indication that wind affected raccoon activity. Wind, however, must be considered, at least, a secondary factor due to its influence on temperature.

SUMMARY AND CONCLUSIONS

Little is known about the ecology of tree cavities and ground burrows used by raccoons. This study was initiated in order to describe the cavities and burrows used by raccoons, to determine the amount and time of use and the microclimates of the cavities and burrows, and to evaluate the relationship of environmental factors to the use of the cavities and burrows by raccoons.

The study area, located on Michigan State University farm property, south of East Lansing, Michigan, is heavily cultivated and is characterized by small scattered mesic woodlots.

Field data were gathered from July 4, 1964 until December 31, 1964. Three tree cavities and two ground burrows were equipped with temperature recorders for varying lengths of time in order to determine their inside temperatures. These temperature patterns were then used to evaluate their microclimates. The natural dens located were monitored with the aid of wire-metal tube switches and an Esterline Angus event recorder, for a total of 180 functional days. The artificial burrows 19 and 21 were monitored for 113 and 43 possible functional days respectively.

Thirteen natural dens were located, examined and measured in Grazed woodlot; ten were tree trunk cavities, two were tree base cavities, and one was a natural ground burrow. Two artificial ground burrows were constructed after it was noticed that the natural ground burrow had much raccoon use. The average measurements of the nine tree trunk cavities were very similar to the ones calculated by Stuewer (1943) for 34 tree trunk cavities he examined. The averages I obtained were: tree diameter 25.1 inches; height to entrance 12.4 feet; entrance dimensions 12.7 by 4.98 inches; inner dimensions 14.4 by 11.9 inches; and distance from the entrance to the cavity bottom 46 inches.

The ground burrow had the most stable temperature. Its average daily temperature fluctuation was 1.5^{o}F. The most stable tree trunk cavity had a average daily fluctuation of 7.7^{o}F and usually averaged 3.8^{o}F below the external average temperature. The warmest of the tree trunk cavities averaged 1.3^{o}F below the outside average temperature and had an average daily fluctuation of 8.7^{o}F.

During the 2,289 functional days, 502 units of uninterpreted den activity were recorded. Of this figure, 377 units were attributed to raccoons. When the activity was interpreted, I calculated that there were 193 investigational units and 106 rest units of activity. The three dens with the most investigational activity were: Cavity 1 with 25, Cavity 9 with 21; and Burrow 14 with 24 units. The three dens with the most rest use were: Cavity 2 with 14; Cavity 11 with 31; and Burrow 14 with 42 units.

Four basic environmental factors were indicated by the data to influence the time, amount and type of den use. These factors were: sunrise and sunset, cavity size and microclimate, and the fluctuation of the external temperature. Sunset appeared to have more of a controlling effect on raccoons than did sunrise. The influence exerted by cavity size seemed to be minimized once the inner dimensions were over 10 inches in diameter, and the entrance dimensions over 4 inches in diameter. But, during the time the young were in the dens the minimum size probably increased to 11-12 inches in diameter. The data indicated that the microclimate was the most important controlling factor of the cavity which, in most cases, appeared to dictate the type of use. The general construction of the den, however, may have had a secondary controlling effect which was felt through the microclimate. The basic requirements of a good microclimate appeared to be a stable temperature located near the average daily external temperature, and a sheltered entrance which keeps the entrance of precipitation at a minimum. The external temperature fluctuations appeared also to dictate the types and amounts of den use. The average amount of daily activity at the dens per week increased as the average daily temperature per week decreased, and decreased as the temperature increased. This trend was followed so long as the average daily temperatures were above 35°F but was reversed when the temperatures were below 35°F. But, if there was an increase in the average daily temperature per week while the temperatures were below 35°F, there was a noticeable increase in the average daily activity per week. The predominant type of den use at temperatures above 40°F was investigational. Below 40°F rest use became the predominant type. The average weekly rest use, however, was limited to the dens that could furnish the necessary microclimate needed to protect the raccoon during existing adverse external weather conditions. The carrying capacity of the dens located in Grazed woodlot, under severe winter conditions as indicated by the data, was 21 rest units per week.

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