MOVEMENTS OF RACCOONS IN SMALL UPLAND WOODLOTS DEVOID OF WATER

Thesis for the Degree of M. S.

MICHIGAN STATE UNIVERSITY

LYNN ELLEN FISHER

1977

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By

Lynn Ellen Fisher

AN ABSTRACT OF A THESIS

Submitted to
Michigan State University
in partial fulfillment of the requirements
for the degree of

MASTER OF SCIENCE

Department of Fisheries and Wildlife

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ABSTRACT

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Radiotelemetric methods were employed in a study concerning raccoon movement patterns and cover type use in small upland farm woodlots in southern Michigan. Ten animals living in two upland woodlots devoid of permanent natural water sources were monitored from May through August, 1976.

Approximately three-quarters of the fixes were recorded within the 8 ha encompassing the woodlots. Home ranges, averaging 55.17 ha overlapped considerably. Raccoons inhabiting Grazed woodlot spent significantly more time within the woodlot and had smaller home ranges than those of Hudson woodlot.

Minimum home ranges, including only those areas containing at least 1% of the total fixes to exclude occasional sallies, averaged 36.52 ha. The effect of seasonal foods on home range was apparent in the shift to the orchard in July. The increased concentration of movements around the woodlots in August may be attributed to adjacent corn fields.

Distances moved per night averaged 524.3 m; the mean rate was 115.17 m/hr. Activity began within an hour or more after sunset and ended within an hour after sunrise; the mean duration was 8.6 hours. As

indicated by distances and rates of movement, the activity increased steadily to peak between 0100 and 0400. Daytime activity was rare; resting sites were most often tree dens.

Available water sources, in the form of small ponds and metal stock tanks, were visited rarely, if at all.

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ACKNOWLEDGMENTS

I am indebted to professor Leslie W. Gysel under whose guidance this research was conducted. I also wish to thank Rollin Baker and John King for their suggestions and for editing the manuscript.

Special thanks go to Marvin Siegel for his invaluable assistance in the refining and troubleshooting of the telemetric system and to Cal BuBrock, Lynn Mazo and Fred Hampel for their help in gathering data.

Finally, to Greg Maddex, my gratitude is immeasurable for his unfailing understanding and encouragement.

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INTRODUCTION

Movement patterns are established and regulated by the density of the species, food supply, reproductive activity, the quality and physiographic arrangement of the habitat and no doubt many other factors (Sanderson 1966). Prior to 1940 low raccoon populations were related to the lack of available den trees (Scott 1937, Steuwer 1943) and reported movements were restricted to watercourses (Giles 1942, Seton 1929). In the following years, a continent-wide population explosion (Sanderson 1951, Stains 1956, Llewelyn et al. 1960) was associated with the raccoons' extension of range (Sowls 1949, Peterson 1966). Coinciding with this extension was a movement into upland areas, often far from natural water (Findley et al. 1975, Fitch 1958, Stains 1956). Movements toward good food supplies (i.e., corn) and acceptable den trees may have induced raccoon populations to remain in the uplands (Sonenshine et al. 1972, Schoonover et al. 1951). Previous investigations of raccoon ecology however, have centered upon lowland areas adjacent to streams, ponds, swamps and marshes (Steuwer 1943, Turkowski et al. 1968, Urban 1970, Llewelyn et al. 1960, Dorney 1954, Mech et al. 1966, Frampton 1973, Ellis 1964, Giles 1943, 1944).

"Home range" typically represents the area within the perimeter of capture points or telemetric fixes. All points obtained are usually included in the calculation of home ranges. Varying from 36 ha (Ellis 1964) to 154 ha (Steuwer 1943), home ranges for raccoons seem to vary

with experimental technique, age, sex, population density and available food and cover. Within the home range some areas are used more frequently and intensively than others, while some are avoided altogether. The avoidance of open fields and utilization of seasonal food sources, croplands and livestock areas were mentioned by Ellis (1964), Turkowski et al. (1968) and Fitch (1958).

Grinnell et al. (1937) claim ready access to a good supply of water is the chief requirement for the presence of raccoons in an area. As a means of satisfying the drinking requirement and as a source of food, a permanent natural water supply has long been associated with the raccoon. Natural water supplies were considered a necessity in the raccoons' habitat by Dorney (1954), Seton (1929) and Steuwer (1943). Butterfield (1944), Frampton (1973), Winslow et al. (1971) and Giles (1943, 1944) also documented the close association of raccoons with a permanent water supply. In the past, the proximity of water has all but been a prerequisite to the study of raccoons.

Populations of raccoons are know to prosper in upland woodlots with little or no known permanent water supplies. Berner (1965) and Stromborg (1970) could find no direct evidence of use of neighboring water sources by raccoons inhabiting upland woodlots in southern Michigan.

Throughout the summer, 1976, radiotelemetric methods were employed in the investigation of raccoons residing in small upland woodlots. Over 3000 locations were utilized in the determination of raccoon movements and activity.

STUDY AREA

Location

The study area is part of the Michigan State University farm property south of the campus in East Lansing, Ingham County, Michigan. All of parts of sections 30 and 31, R1W, T4N and sections 25 and 36, R2W, T4N were included.

Physiography

The nature of this study precludes the restriction of the size of the study area. The general study site is 3.2 km long and 2.6 km wide, covering an area of 619 ha (Fig. 1, 2). Characterized by gently rolling farmland, the primary use of the area is intensive agricultural research.

Well-drained Hillsdale fine sandy loam of moderate fertility predominates the fields and woods. Extensive areas of Spinks loamy fine sand are found in Hudson woodlot. Well-drained, these areas are low to moderate in fertility. The extreme southern portion of Hudson woodlot contains an area of poorly-drained Locke sandy loam. Miami loam characterizes Maple and Grazed woodlots.

Vegetation

Selection of intensive study areas was resolved by the proximity of natural water sources. The lack of adjacent surface water is most conspicuous in Hudson and Grazed woodlots.

Figure 1.--Aerial photograph of the general study area.

Figure 2.--Aerial photograph of the intensive study area.

Hudson woodlot is a sugar maple (Acer saccharum)-beech (Fagus grandifolia) stand of 7.69 ha. Divided into two nearly equal-sized communities, the unmanaged northern half is a mature stand of irregularly interspersed beech and sugar maple in the 18 to 30 inch diameter size class (.46 to .76 m). Developing after clearcutting 45 years ago, the southern half consists of an even-aged stand of sugar maple, beech and white ash (Fraxinus americana) in the 8 to 14 inch diameter size class (.2 to .36 m).

Grazed woodlot is a 5.63 ha stand of mature sugar maple, beech, basswood (Tilia americana), white ash and ironwood (Ostrya virginiana) in the 10 to 25 inch diameter size class (.25 to .64 m). A complete lack of woody ground cover in the west and northwest 1.9 ha of the woodlot has resulted from cattle grazing. Fencing has protected the remaining 3.7 ha from grazing for the past 10-15 years. Sugar maple saplings comprise 85% of the dense understory.

Agricultural lands surround these woodlots (Fig. 3, 4). A description of the major plant communities found in the study area is contained in Table 1. A 0.3 ha pond in the pasture east of Beaumont Road and a muddy 0.16 ha pond 3.1 meters north of Grazed woodlot are the only nearby permanent sources of water. Metal stock tanks are located at the cattle barns, pig pens and in the pastures northeast of Grazed and east of Hudson woodlots. The only other sources of water near the woodlots are temporary vernal ponds in the woods and fields.

Climate

Based on records for the 1941-1970 period, the average yearly temperature was 8.6°C, mean maximum 14°C, and mean minimum 3.2°C. The average annual precipitation for this 30-year period was 30.39 inches.

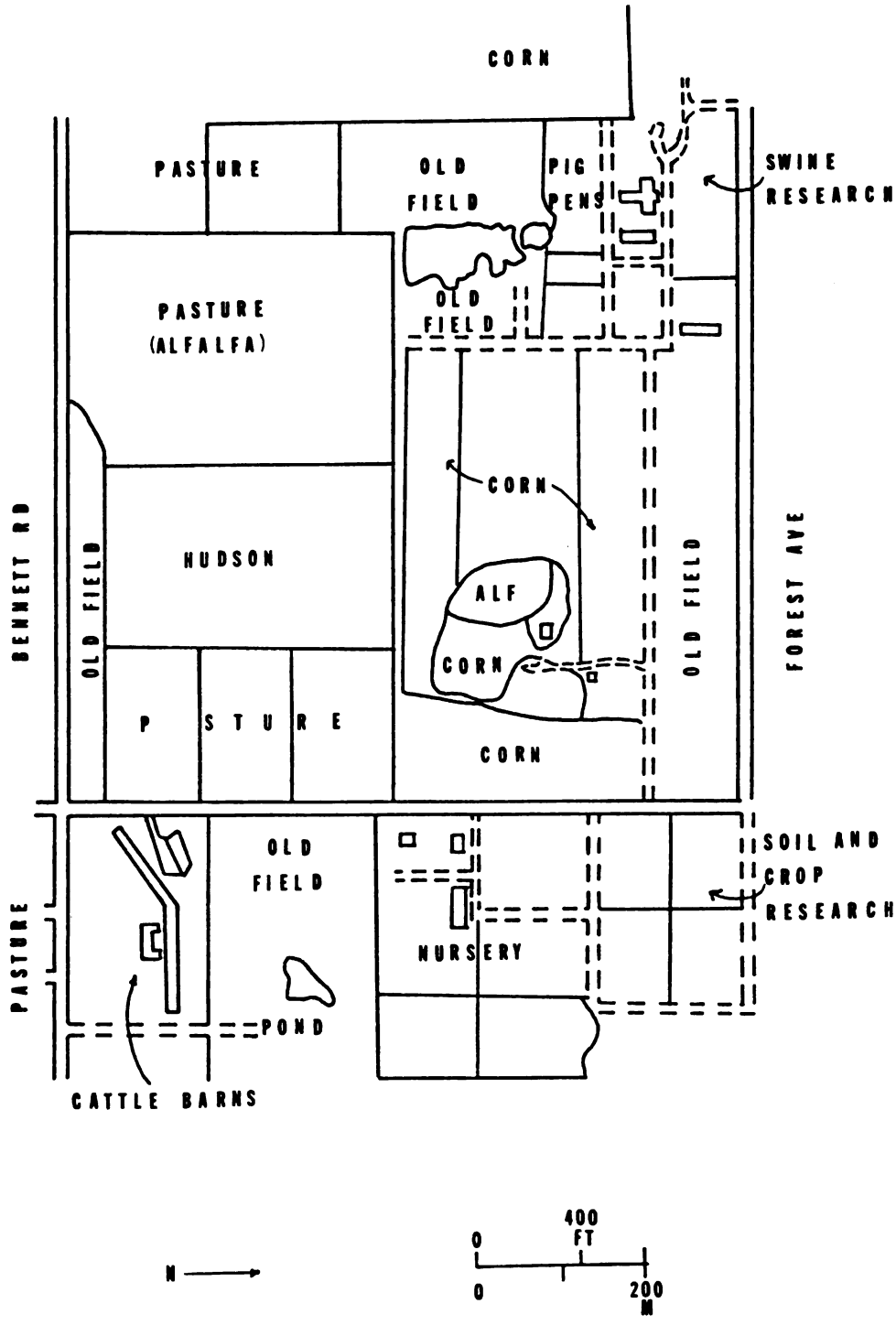

FIGURE 3. HUDSON WOODLOT AND SURROUNDING COMMUNITY.

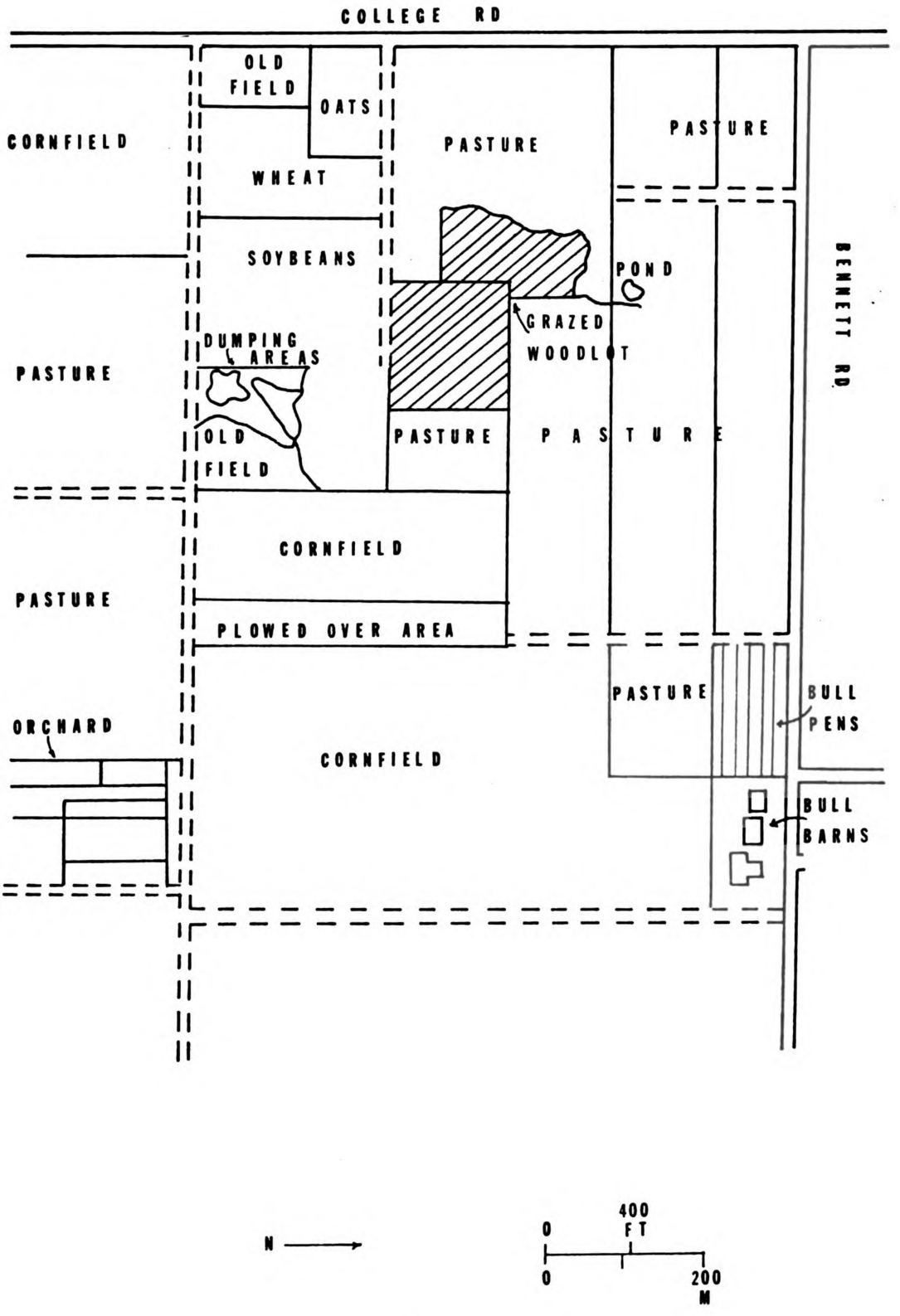

FIGURE 4. GRAZED WOODLOT AND SURROUNDING COMMUNITY.

Table 1.--Description of major communities.

Community	Overstory cover (%)	Major species
Woodlot		
Hudson	90-100	Acer saccharum, Fagus gradifolia, Fraxinus americana, Tilia americana, Prunus serotina, Rubus sp., Sambucus sp., Ribes cynosbati, Ulmus americana, Cornus florida.
Tree Clump (NW of Hudson)	20-30	Acer saccharum, Fraxinus americana, Quercus rubra, Tilia americana, Quercus alba, Plantanus occidentalis.
Grazed	75-95	Acer saccharum, Tilia americana, Fraxinus americana, Fagus grandifolia, Ulmus americana, Ostrya virginiana, Prunus sp., Sambucus sp., Ribes cynosbati.
Agricultural Lands	50-100	Medicago sativa, Grasses, Corn, Oats, Wheat, Soybeans.
Orchard and Nursery	10-70	Peach, Apple, Cherry, Pear, Grape, Vaccinium sp., Ribes sp., Quercus sp., Malus sp., Populus sp., Pinus sp., Viburnum sp., Acer sp., Salix sp., Cornus sp., Crategus sp., Ulmus sp., Tilia sp., Picea sp., Lonicera sp., Fraxinus sp., Prunus sp., Berberis sp., Magnolia sp., Taxus sp., Euonymus sp., Carya sp., Lirodendron sp., Syringa sp., Althaca sp., Ginko sp.
Pasture	80-100	Grasses, Medicago sativa, Trifolium sp., Daucus carota, Taraxacum sp., Cirsium sp., Amaranthus sp., Linaria vulgaris, Meliotus sp., Mentha piperita, other annual herbs.
Old Field	90-100	Grasses, Cirsium sp., Daucus carota, Amaranthus sp., Silene sp., Chenopodium sp., Arctium sp., Polygonum sp., Brassica sp., Crategus sp., Quercus alba, Fraxinus americana.

Temperatures during the study period varied from -.6°C in May to 33°C in July. Monthly highs averaged 27°C and lows averaged 13.5°C for June through August. The average high of 17.6°C in May and the average low of 11.9°C in August were approximately 3°C lower than those reported for the 30-year period. The remainder of the monthly averages were within 2°C of the standards. The total rainfall of 11.43 inches for these four months was an inch below the normal. Only 0.49 inches of rain were reported for August, whereas the normal is 2.79 inches. Weather data were provided by the United States Weather Bureau at Lansing, Michigan.

METHODS

Trapping

A three-week period of prebaiting to increase trapping success began on 14 April 1976 in Hudson woodlot. Twenty-two live-traps were set along the perimeter and five on the north-south midline of the woodlot. The heavy concentration of edge trapping was prompted by Stromborg's (1970) previous experience in this area. A mixture of dogfood and sardines was initially used for bait. Later, mackerel was substituted for monetary reasons.

By 8 May the majority of the vernal ponds and other surface water had dried up and trapping began. Location of capture, relative age (adult-juvenile), sex and weight were noted for each individual. Juveniles were color-dyed with Nyanzol A for later identification and released. (The use of a standard-sized collar precluded radio-tracking juveniles.)

Adults were anesthetized using ether in a variable-sized anesthetizing chamber (Balsar and Kinsey 1962). The raccoons were ear-tagged and a transmitter was attached around the neck.

Unfortunately, the remaining transmitters were not completed until the end of June. Trapping in Grazed woodlot thus began on 2 July. Prebaiting was omitted because of the high trapping success in Hudson woodlot and the lack of time. All raccoon captures in Hudson woodlot were along the edge. Thus the trapline in Grazed woodlot was comprised of ten traps along the perimeter of the ungrazed portion and three traps

within the grazed portion of the woodlot. The trapping procedure was consistent with that explained earlier.

At the conclusion of the study, the traplines were reset in both woodlots. The local fish market provided unlimited fish scraps for use as bait. This 3-week long attempt to recover some of the transmitters was not successful.

Radiotelemetry Equipment

Transmitters were slightly revised versions of those described by Cochran and Lord (1963). The copper collar served as a transmitting (loop) antenna for eight of the transmitters. The remaining three used a wire (whip) antenna (Fig. 5, 6). This modification was designed to increase the transmitting range. Unfortunately, the whip antenna is more susceptible to damage by breaking, as it extends 6 inches (15.2 cm) from the collar. All three of these transmitters were apparently damaged within a few weeks of their wearer's release. The initial two-fold increase in range was reduced by a factor of 10 or more.

Once constructed and field-tested, the transmitters were potted in a dental acrylic to prevent damage from teeth or water. The total weight of these units was 100 g; range varied from one-eighth to three-quarters of a mile.

A lightweight harness was improvised from nylon straps for holding the portable, twelve-channeled receiver. The three-element Yagi antenna was hand-held. Extraneous noise was reduced by using headphones.

Fieldwork

Tracking usually commenced 60 minutes before sunset and continued until 60 minutes after sunrise. Position sightings were taken at 15

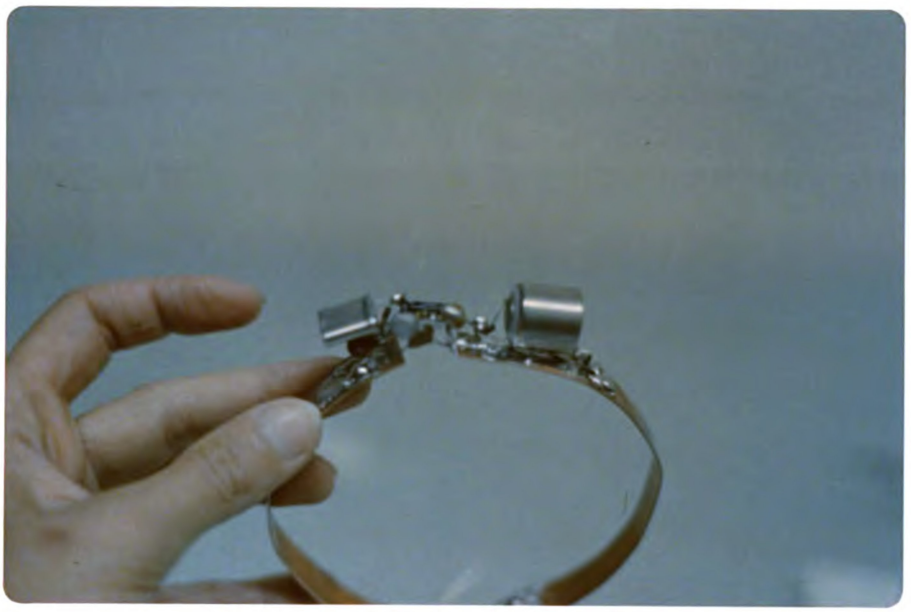

Figure 5.--Photograph of completed radio transmitters.

Figure 6.--Photograph of "whip" antenna transmitters.

minute intervals. Triangulation was relied upon for accurate location data. Throughout the summer, intermittent daytime sightings were used to pinpoint den locations and to ascertain any daytime movements. Over the 4-month period, 3527 separate fixes were obtained.

The identification of food sources and cover type use was aided by the qualitative examination of scats. A total of 257 scats in Hudson and Grazed woodlots were inspected between 11 May and 15 August.

RESULTS AND DISCUSSION

There were ten raccoons captured during 150 trapnights within Hudson woodlot in May 1976. In July, 130 trapnights yielded 19 animals in Grazed woodlot. Based on ranges determined by telemetry, population densities were approximately 1/11 acres (4.44 ha). In comparison with wetland area estimates (Steuwer 1943, Urban 1970), this upland area supports a relatively high population of raccoons.

Four female and two male raccoons were captured and collared in Hudson woodlot between 9-27 May (Table 2). Female number 5 removed her collar within 2 weeks. The remaining 5 animals were radio-tracked for 9 to 14 weeks. These 5 averaged 260 fixes per night for 23 nights of tracking or 11 per night per animal.

Between 3-13 July, 3 males and 2 females in Grazed woodlot were trapped and collared (Table 2). In the 6 to 7 week tracking period, there averaged 384 fixes for 24 nights, or 16 per night per animal.

A mean weight of 12.6 pounds was recorded, males averaging 1 pound more than females. Although heavier than Sonenshine's (1972) Virginia raccoons (average June weight of 7 pounds), these findings are consistent with weights recorded for Michigan raccoons (Steuwer 1943, average spring-summer weight of 12.6 pounds).

Cover Type Use and Home Ranges

Burt (1940) described home range as the area about its established home that is transversed by the animal in its normal activities. One

Table 2.--General trapping and radiotracking information.

Raccoon number	Sex	Weight (lbs)	Area	Trap date	Antenna type	Tracking period	No. nights tracked	No. of fixes
1	Female	11.5	Hudson	9 May	Collar	9 May - 18 Aug	31	361
2	Male	10.0	Hudson	8 May	Collar	11 May - 25 Aug	31	434
5	Female	8.0	Hudson	9 May	Collar	9 May - 20 May	4	10
3	Female	14.0	Hudson	24 May	Whip	25 May - 25 Aug	20	192
6	Female	12.0	Hudson	27 May	Whip	1 June - 4 Aug	11	81
4	Male	17.0	Hudson	27 May	Whip	1 June - 18 Aug	21	233
10	Male	14.5	Grazed	3 July	Collar	3 July - 23 Aug	26	365
9	Male	13.5	Grazed	3 July	Collar	4 July - 24 Aug	19	240
11	Male	12.0	Grazed	5 July	Collar	5 July - 25 Aug	31	563
7	Female	12.5	Grazed	11 July	Collar	11 July - 24 Aug	19	171
8	Female	13.0	Grazed	13 July	Collar	13 July - 25 Aug	26	580
	MEAN	12.6					22	294
	TOTAL						239	3230

factor determining the size of the home range is the distribution of suitable habitat.

Using a grid system comprised of 6.4 acre (2.6 ha) squares (Turkowski et al. 1968), the percentage of fixes falling in each square was tallied. As the location data were usually taken at equal intervals throughout the nightly activity period, the percentage of fixes in an area should represent the percentage of time an animal spent in that area.

An exception to this premise was the corn fields. Corn comprised 67% of the scats (Table 8) collected in August, yet no fixes were recorded for corn fields this month (Fig. 11). The percentage of corn field fixes actually decreased as the corn ripened.

This phenomena was caused by the interruption of radio signals by dew on the corn plants. On most evenings, dew point was reached soon after raccoon activity began. As the corn field height approached 2.5 m, the interruption of the signals became more severe. (Receiving antenna height was typically 1.2 to 1.5 m.) The absence of a comparable height and density in the other cover types limited the problem to the corn fields.

The remaining cover types occupied varying amounts of time for different animals (Table 3). The percentage of fixes recorded for the woodlots ranged from 59.6 to 96.6%. Grazed woodlot raccoons averaged 20% more time inside the woodlot than those of Hudson.

Urban (1970) reported female raccoons occupied wooded areas more than males. The reverse was true in this study; 5.2% more fixes were recorded in the woodlots for the males.

Table 3.--Summarized use of cover types by raccoons.

Raccoon number	Number of fixes	Percentage of fixes in the listed cover type						
		Woods	Corn field[a]	Pasture	Old field	Orchard	Livestock areas	Crops
1	361	59.6	6.4	23.2	3.9	0	6.4	0
2	434	55.1	3.5	28.6	7.8	0	4.8	0
3	192	60.4	6.8	13.0	2.1	0	17.7	0
4	233	71.7	7.7	8.1	4.7	0	7.7	0
6	81	69.1	12.3	13.6	1.2	3.7	0	0
7	171	66.7	1.8	12.9	12.9	2.9	0	2.9
8	580	96.6	0	2.2	0.2	0	0	1.0
9	240	84.6	1.2	9.8	3.3	0	0	2.1
10	365	80.5	0	11.0	1.9	0.5	0	6.0
11	563	86.7	0.7	11.2	0.4	0.5	0	0.4
Males	1835	75.7	2.6	13.5	3.6	0.2	2.5	1.7
Females	1385	70.5	5.5	13.0	4.1	1.3	4.8	0.8
Hudson	1301	63.2	7.3	17.3	4.0	0.7	7.3	0
Grazed	1919	83.0	0.7	9.2	3.7	0.8	0	2.5
Total	3220	73.1	4.0	13.3	3.8	0.8	3.7	1.3

[a]Actual time spent in corn field is greater than represented. This distortion was caused by dew on the plants interrupting the radio signals.

Occasional sallies outside the area, perhaps exploratory in nature, should not be considered as part of the home range (Burt 1940). A maximum area "activity range" was calculated by summing the number of 2.6 ha squares containing at least one fix. Since this method tends to overestimate the real home range, an additional figure was derived by totalling those squares containing at least 1% each of the total fixes (Turkoswki et al. 1968).

The 'maximum activity range' for these raccoons varied from 41.44 ha to 64.75 ha, averaging 55.17 ha (Table 4). Previous estimates derived from radiotelemetry were comparable (61.9 ha, Mech et al. 1966; 48.4 ha, Urban 1970; 36.5 ha, Ellis 1964). Hudson woodlot raccoons had maximum home ranges which were significantly larger than Grazed woodlot animals ($F = 29.74^{**}$). The home range averages of 58.01 ha and 52.32 ha, respectively, are probably due to the provision of requirements in a smaller area (Sanderson 1966).

Ellis (1964), Giles (1943) and Urban (1970) noted a smaller home range for female raccoons. In this study, the average maximum range was slightly higher for females. According to the more realistic range of 1% use, however, the range of female raccoons was 1.75 ha less than males. The 1% use range varied from 10.36 ha to 46.6 ha, averaging 36.52 ha.

The orchard provided an additional food source with the ripening of fruit in July. Found in 20% of the scats analyzed (Table 8), cherries lured three of the raccoons from Grazed woodlot 490 m to the orchard between 15 July and 15 August (Fig. 8, 11). Raccoon number 6 from Hudson woodlot was the sole visitor to the nursery across Beaumont Road, 245 m from the woods (Fig. 7).

Table 4.--Movement patterns and activity ranges.

Raccoon number	Distance[a]	Mean distance per night (m)	Rate (m/hr)[b]	Adjusted rate[c] (m/hr)	Maximum activity range (ha)	Range of 1% use (ha)
1	40.31	469.48	110.67	125.76	64.75	46.62
2	50.11	701.53	152.61	125.06	64.75	38.85
3	48.58	466.34	110.25	88.79	54.39	36.26
4	54.68	606.70	142.83	141.15	62.16	41.44
6	47.79	351.89	110.92	108.20	44.03	44.03
7	46.61	419.50	114.64	126.28	56.98	38.85
8	29.43	656.48	97.60	98.54	41.44	10.36
9	36.08	455.76	101.35	114.54	46.62	38.85
10	37.08	520.51	102.50	101.59	59.57	44.03
11	32.81	594.85	108.30	93.97	51.98	25.90
Males	40.96	524.90	115.14	108.67	54.39	38.33
Females	37.76	523.70	115.20	116.10	55.94	36.58
Hudson	48.29	519.20	125.46	117.79	58.01	41.44
Grazed	36.40	529.62	104.88	106.98	52.32	31.60
Total	39.58	524.30	115.17	112.39	55.17	36.52

[a]Mean distance moved since last fix (in meters).

[b]Mean rate = total distance ÷ total number of hours moving.

[c]Adjusted rate is the calculation of mean rate excluding data for movement periods of less than five consecutive hours.

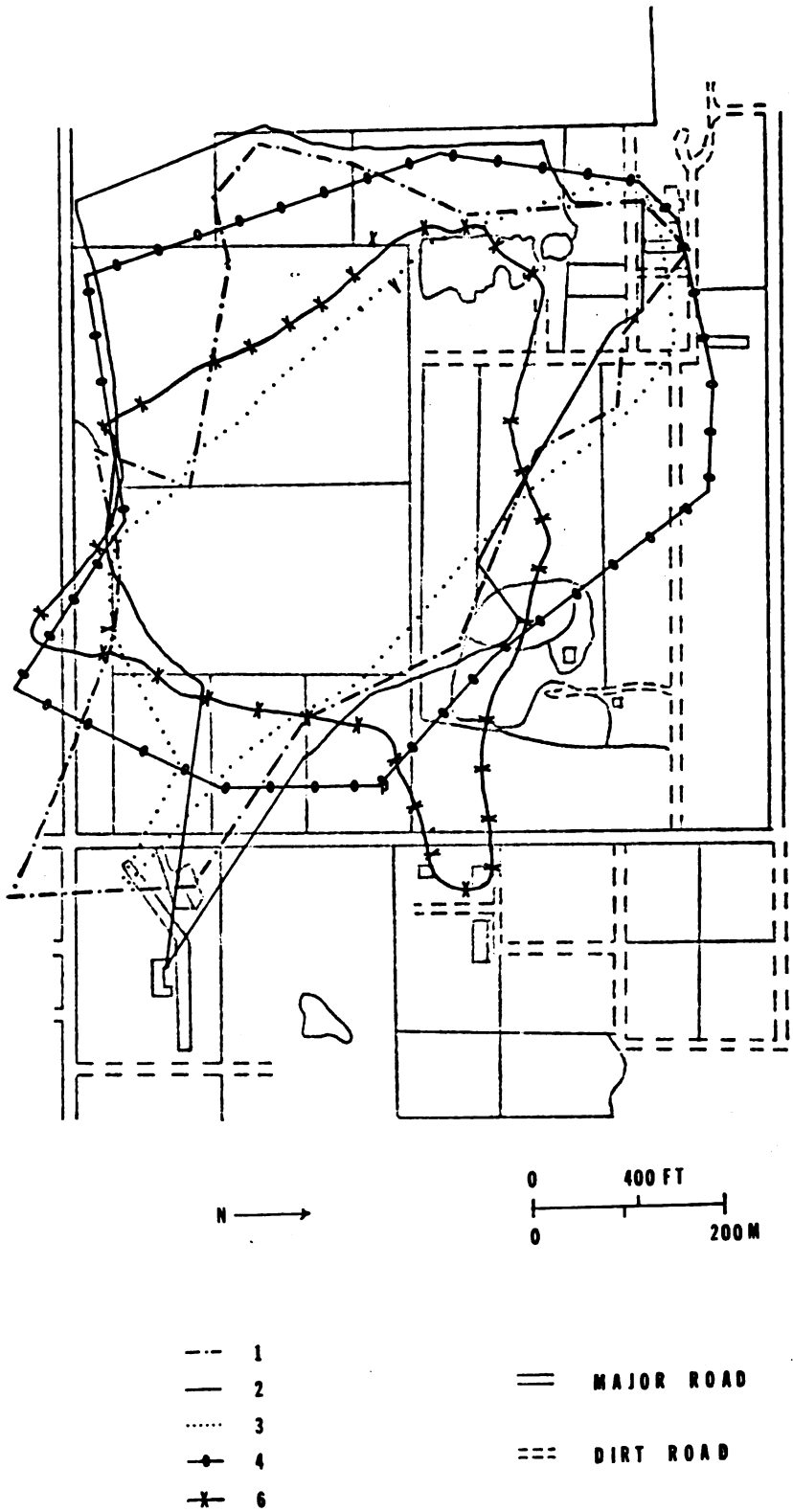

FIGURE 7. MAXIMUM ACTIVITY RANGES IN HUDSON WOODLOT

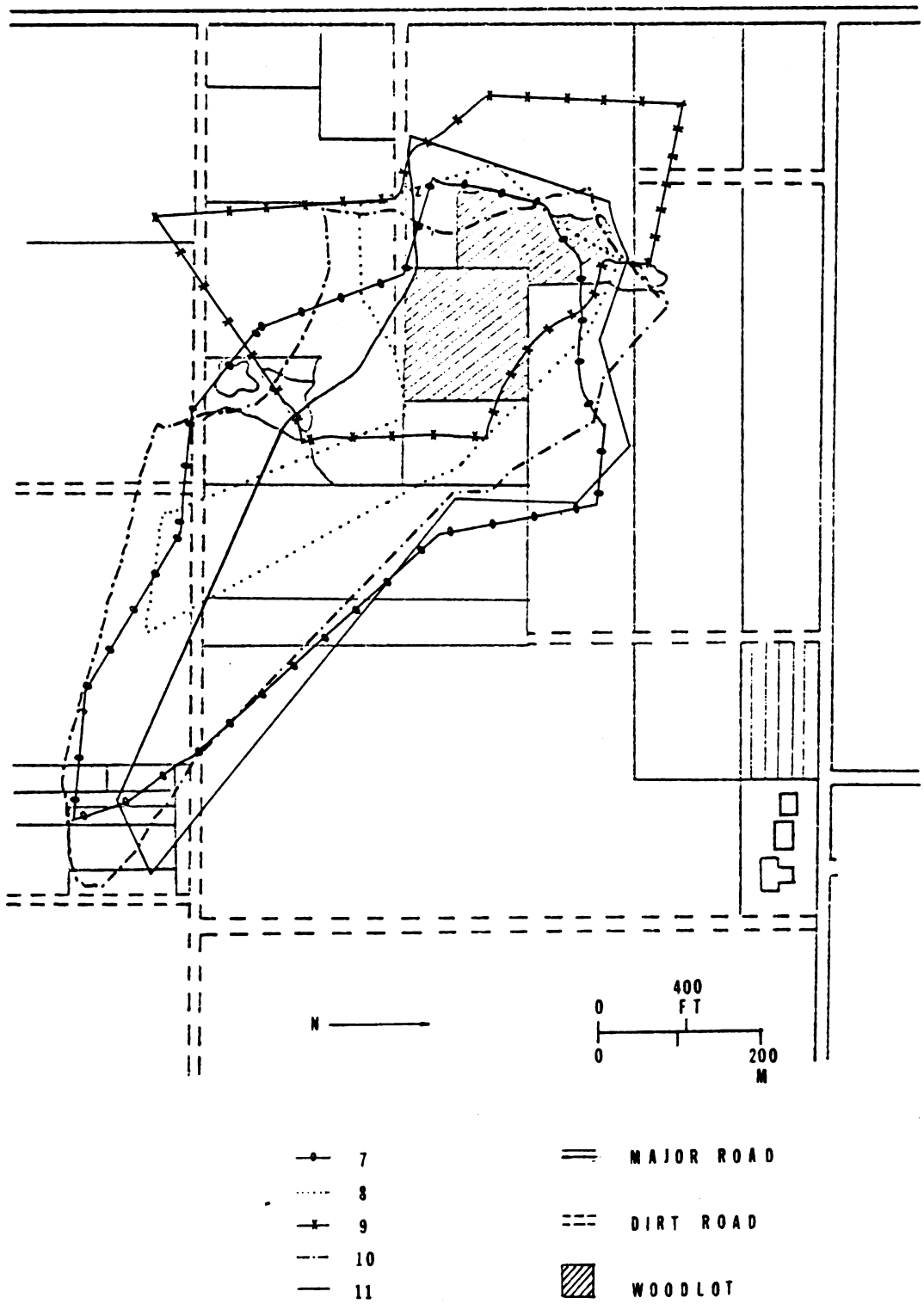

FIGURE 8 MAXIMUM ACTIVITY RANGES IN GRAZED WOODLOT.

Possible inhibition of movement by Beaumont Road may explain the nonuse of the nursery, cropland and pond by the Hudson raccoons.

Although the number of fixes was lower than expected, corn fields north of Hudson woodlot were included in the 1% range of all the raccoons (Fig. 9). The corn field east of Grazed woodlot was frequented by raccoon number 9; while the others utilized corn east of the woodlot (Fig. 10). Ellis (1964), Turkowski et al. (1968) and Fitch (1958) also noted the influence of nearby corn fields on movement patterns.

Aside from corn, soybeans covered the most common and frequently used cropland near Grazed woodlot. The fields south of the woodlot were traversed and/or utilized by all of these raccoons (Fig. 8, 10). The use of the wheat field by raccoons 8 and 9 occurred during the latter half of July (Table 3).

Utilization of livestock areas varied considerably among the Hudson woodlot raccoons (Table 3). The swine barn area was found within the minimum home range of four of the five animals (Fig. 9). Ground shelled corn and bone meal in the barns and in feeders within each pen were 'pilfered' often by raccoons (J. Strittmatter, pers. comm.).

Activity near the cattle barns across Beaumont Road was less frequent. The occasional use by raccoons 1, 2 and 3 occurred during June and early July (Fig. 7). Further use may have been inhibited by the road.

No feed was provided for the cattle pastured east of Hudson woodlot during the study period. Permanent stock tanks were furnished with a float arrangement. Corks found in the bottom of the tanks were occasionally removed by raccoons (P. Sweeney, pers. comm.).

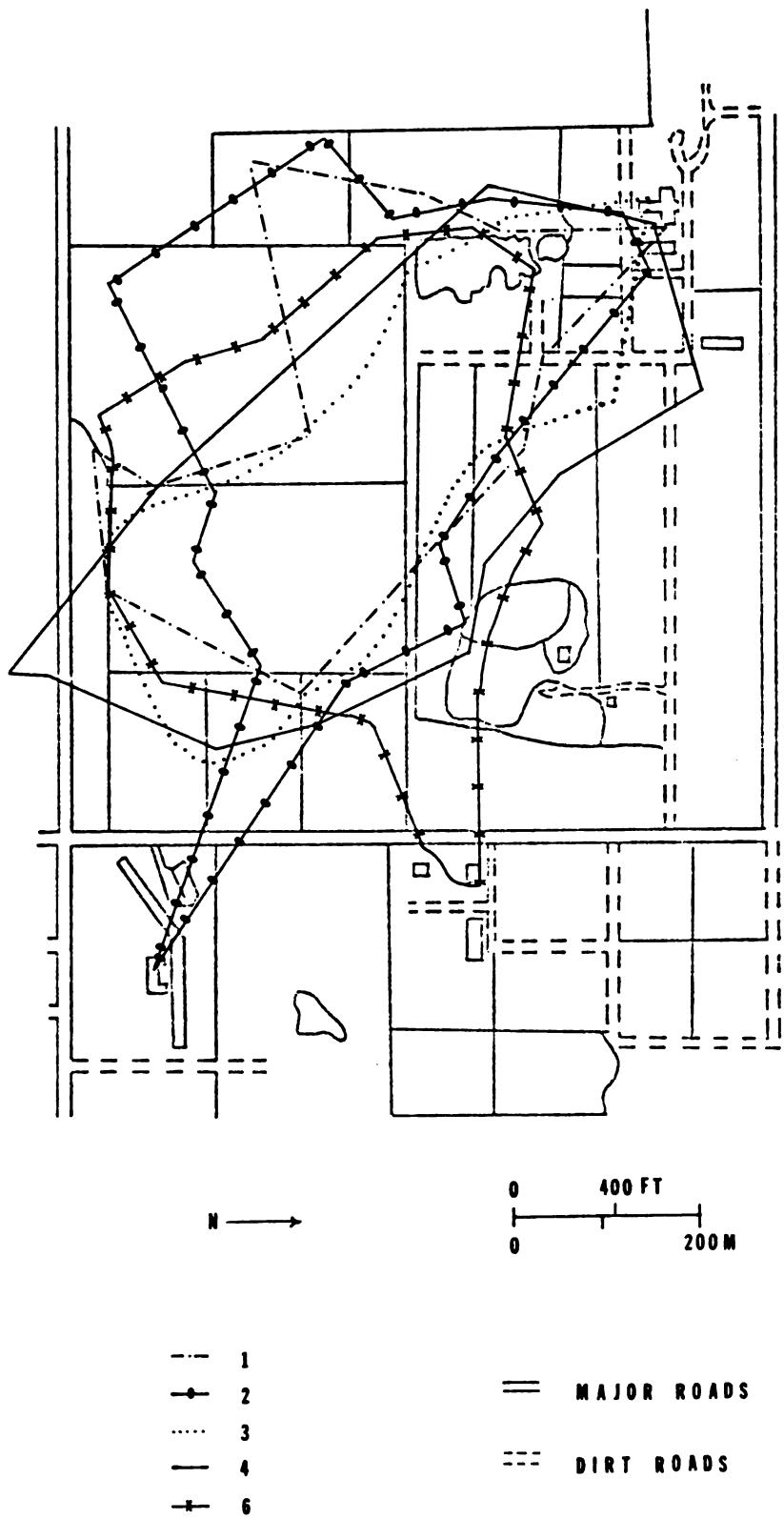

FIGURE 9. RANGES OF 1% USE IN HUDSON WOODLOT.

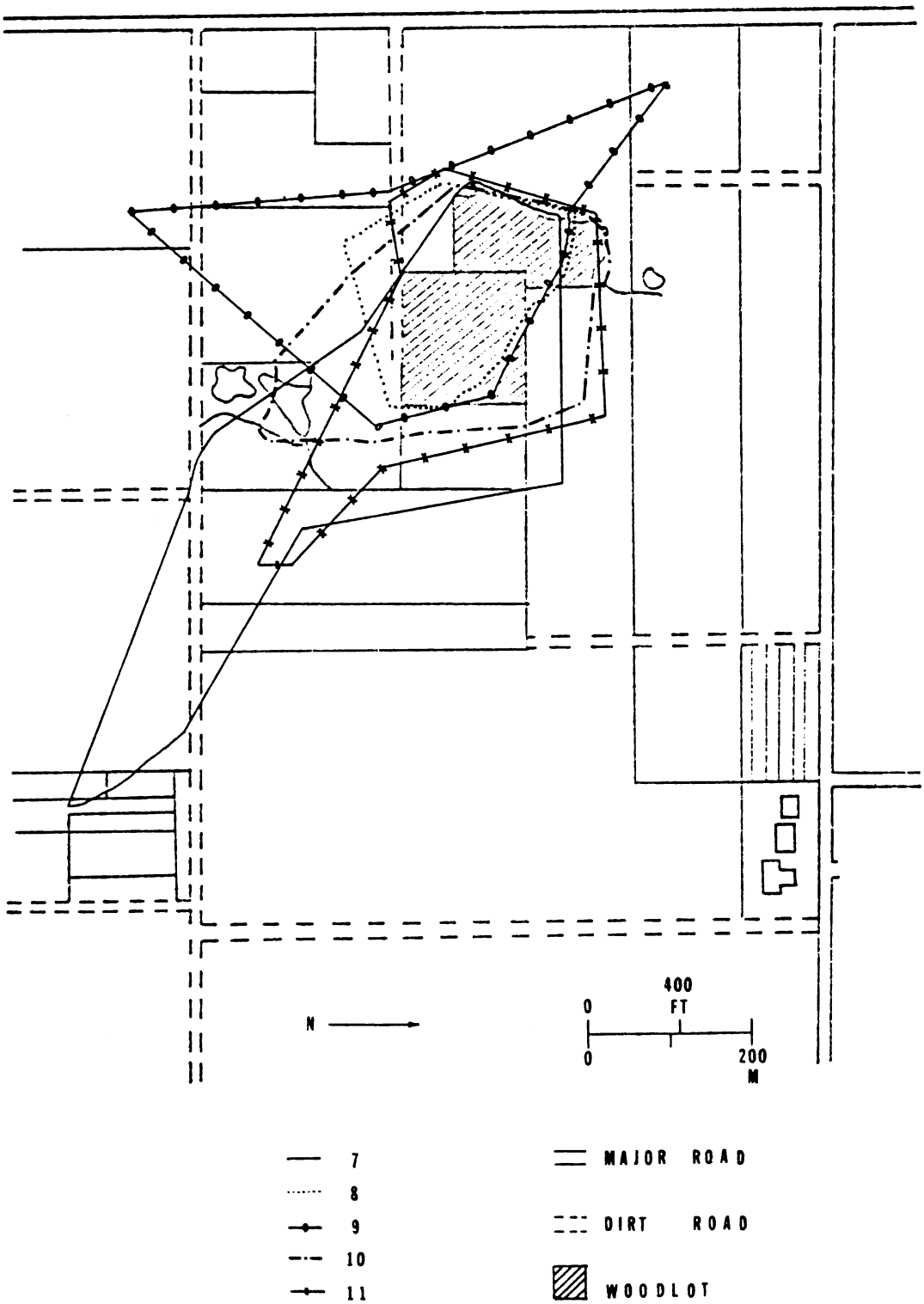

FIGURE 10. RANGES OF 1% USE IN GRAZED WOODLOT.

Grazed woodlot animals were never located near livestock barns, the closest of which was over 600 m from the woodlot. Corn silage and shelled corn were fed to cattle pastured to the north and west of Grazed woodlot. An uncollared raccoon was observed inside the feed trough in this pasture on 10 July at 0535. This trough and its neighboring waterer were within the maximum home range of raccoons 9, 10 and 11 (Fig. 8). Only raccoon number 9 included them in his 1% range of use (Fig. 10).

The remainder of the home range was occupied by pastures and old fields. The alfalfa pasture west of Hudson woodlot was included in the 1% range of all raccoons. Other pastures located east and south of the woodlot, were used with varying intensity.

Grazed woodlot raccoons were also located often in alfalfa fields. The field south of the woodlot was used by raccoons 7 and 10 with 7 including it in his 1% range. Number 9 was found in the alfalfa field northeast of the woodlot. The overgrown old field south of Grazed woodlot was included in the minimum home ranges of four of the raccoons. Varying use was made of the pastures circumventing three sides of the woodlot (Fig. 8, 10, 11).

Use of Water Sources

Water appeared to have minimal effect on the movement or use of cover types by these raccoons. There were no fixes located at the pond across Beaumont Road and only one in the vicinity of the pond north of Grazed woodlot (Raccoon number 10, Fig. 8). The previously mentioned mischief at metal stock tanks may insinuate their use by raccoons; however, raccoons 6, 7 and 8 were never located near any of the known

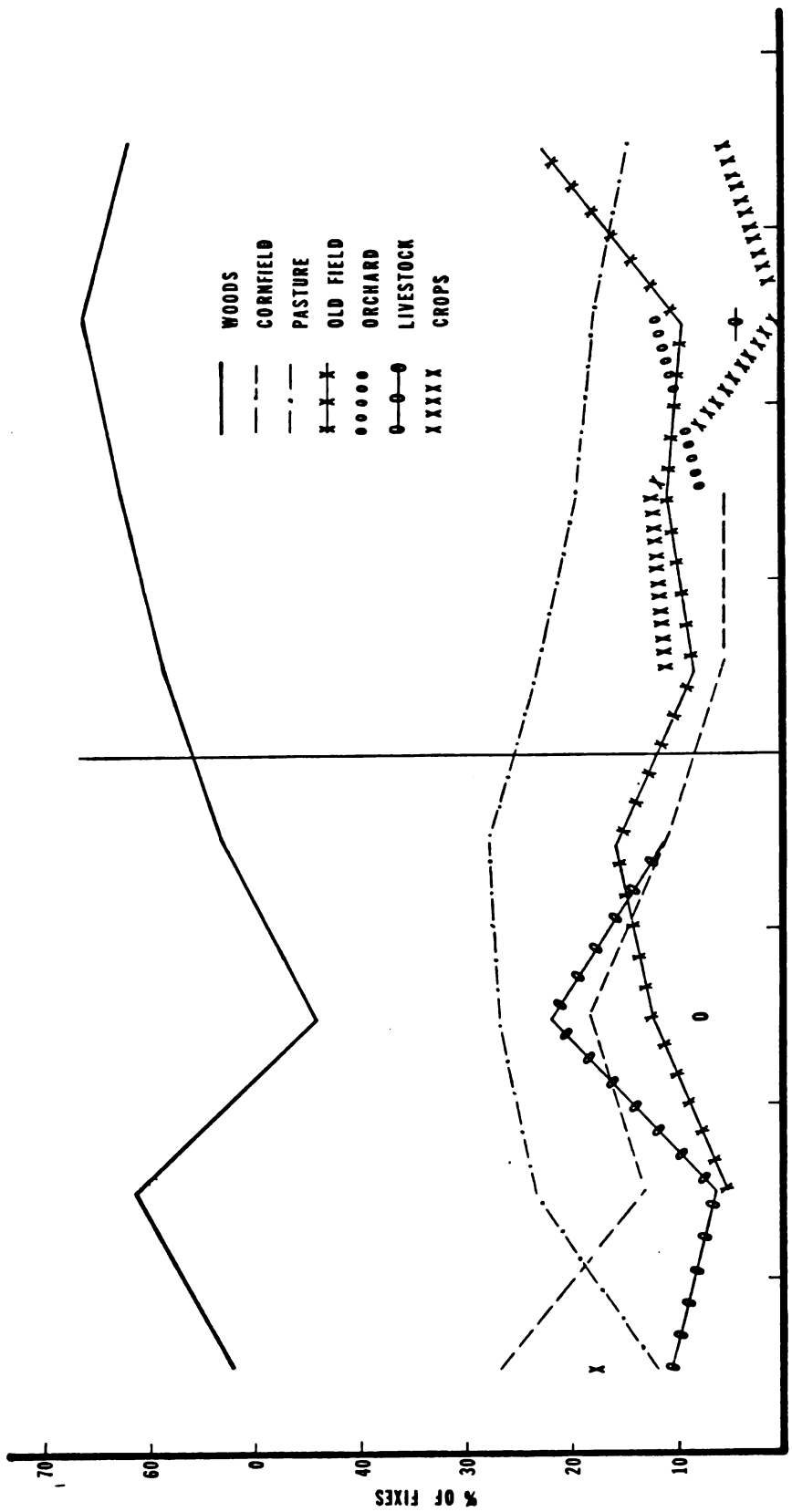

FIGURE 11. BIWEEKLY HABITAT USE (ARCSINE TRANSFORMATION)

sources of water. Metal stock tanks northwest of Grazed woodlot were included in the 1% range of only one raccoon (Fig. 10). The 'necessity' of permanent water sources was not upheld in this study.

Travel Pattern Shifts Over Time

Ellis (1964), Turkowski et al. (1968) and Tester and Siniff (1965) noted a slight shift in home range or center of activity over time. Fig. 11 depicts the shift in cover type use over the course of this study. A major shift from Hudson woodlot to the small group of trees northwest of the woodlot took place in the latter half of May and June. This area is somewhat lower than the woodlot, vernal ponds remaining until 20 June. Although movement was first attributed to this water, the coincidental sojourns to the swine barns and later evidence indicate food to be the more likely attraction. The return to Hudson woodlot in late July and August was indicated by denning sites and nightly movements. Ripening of corn and improved shade may have contributed to this return.

The shift in movement patterns to encompass the cherry orchard in late July and early August was anticipated. Grinnell et al. (1937) and Steuwer (1943) reported extended treks to orchards in the summer.

On the whole, movements seemed to be more scattered over the home range early in the summer and concentrated around the woodlots in August. Bider et al. (1968) found the reverse to be true, as activity increased in forested areas from early May through mid-July and subsequently rose in open fields until September. Food availability and population density may contribute to the shift and decrease in home range size. A population increase, with the dispersal of spring-born raccoons, may result in home range decreases (Sanderson 1966, Steuwer 1943, Ellis 1964, Urban 1970).

Fitch (1958), Bider et al. (1968), Ellis (1964) and Cauley (1974) noted the influence of food sources on raccoon activities and home range. Corn fields located within 125 m of both woodlots as well as plentiful fruits and insects adjacent to and within woodlots indicate smaller home ranges.

Movement Patterns: Distances and Rates

The mean distance moved per night, 524.3 m, was similar for the sexes (Table 4). Distance moved per night varied from 351.89 m to 701.53 m.

The sum of the distances traveled each night was divided by the number of hours tracked for the computation of rates of movement. Cessation of radiotracking during the night was precipitated by receiver malfunctionings, battery problems, lightning and rain. A period of less than five continuous hours may not be representative of the rate of movement for the entire night. An adjusted rate, excluding data for periods of less than 5 hours, was thus computed (Table 4).

The overall rates of travel and adjusted rates were quite similar (115.17 m/hr and 112.39 m/hr, respectively). Individual raccoons varied from 97.6 m/hr to 152.61 m/hr for average and 88.79 m/hr to 141.15 m/hr for adjusted rates. Although comparable, these rates are slightly lower than those reported previously (161.54 m/hr, Urban 1970; 118.87 m/hr, Ellis 1964). The rates of travel averaged 20.58 m/hr greater for Hudson area raccoons ($F = 4.55^{*}$).

Rate of movement depends on type of activity, travel conditions (including cover type), weather, presence of other animals and season (Sanderson 1966). Beyond the resolution of actual movement, the type of

activity was not discernible. Cover type does appear to influence the rate of travel. Foraging decreased rates in croplands, woodlots and livestock areas, whereas lack of cover may have increased rates in pastures and old fields. Although Sharp (1956) and Berner and Gysel (1967) relate raccoon activity to temperature and wind, this study showed no correlations.

Activity Periods

Nightly activity usually commenced an hour or more after sunset and ceased within an hour after sunrise (Table 6). The average duration of the nightly excursion was 8.6 hours. Previous studies indicate similar trends; activity beginning within an hour before or after sunrise (Berner and Gysel 1967, Urban 1970, Turkowski et al. 1968). Turkowski et al. (1968) also noted a high incidence of after sunset starts and after sunrise ends.

Sharp (1956) and Bider et al. (1968) reported the differential utilization of different areas of the same habitat at different times. The movement toward known food sources in the early evening was characterized by the cropland, where nearly 40% of the activity prior to 2200 took place.

Activity peaks, indicated by distances and rates of movement occurred between 0100 and 0400 (Table 5, Fig. 12). This peak was 2 to 5 hours later than those observed by Bider et al. (1968) and Urban (1970).

Resting Habits and Denning Sites

Although Ellis (1964) reported raccoon movement during 74% of the daylight period, Urban (1970), Berner and Gysel (1967), Bider et al. (1968), Mech et al. (1966) and Turkowski et al. (1968) noted very little

Table 5.--Movement patterns for time intervals.

Time interval	Average distance moved during time inverval						Average rate moved during time interval		
	Hudson		Grazed		Total		Hudson	Grazed	Total
	m	%	m	%	m	%	m/hr	m/hr	m/hr
0700-1100	0	0	0	0	0	0	0	0	0
1100-1500	0	0	2.34	0.44	1.19	0.23	0	0	0
1500-1900	0	0	0	0	0	0	0	0	0
1900-2200	53.17	10.24	44.73	8.45	48.73	9.32	141.60	131.7	136.8
2200-0100	173.05	33.33	120.20	22.70	146.12	27.87	276.35	194.6	235.7
0100-0400	190.20	36.63	187.81	35.46	188.92	36.03	345.20	276.5	306.8
0400-0700	102.80	19.80	174.54	32.96	139.19	26.55	267.70	276.8	272.3

Table 6.--Activity periods.

Raccoon number	Onset of activity (minutes after sunset) Mean	Range	n	Termination of activity (minutes after sunrise) Mean	Range	n	Duration (hours)
1	88	25 -173	13	51	31**-151	6	8.38
2	70	30 -173	17	51	4**-151	7	8.68
3	60	16 - 90	7	54	16 -101	3	8.90
4	68	20*-100	10	43	11 - 77	4	8.58
7	73	58 - 93	5	51	37 - 64	3	8.63
8	59	11*-102	12	39	25**- 87	16	8.66
9	63	2 -112	8	36	5**- 61	7	8.56
10	70	15 -112	8	44	9**- 96	12	8.57
11	61	1 -125	14	44	56**- 91	21	8.72
Males	66	20*-173	57	44	56**-151	51	8.622
Females	70	11*-173	37	49	31**-151	28	8.643
Hudson	71	20*-173	47	50	31**-151	20	8.636
Grazed	65	11*-123	47	43	56**- 96	59	8.628
Total	68	20*-173	94	46	56**-151	79	8.63

*Activity began before sunset. (# minutes)

**Activity ended before sunrise. (# minutes)

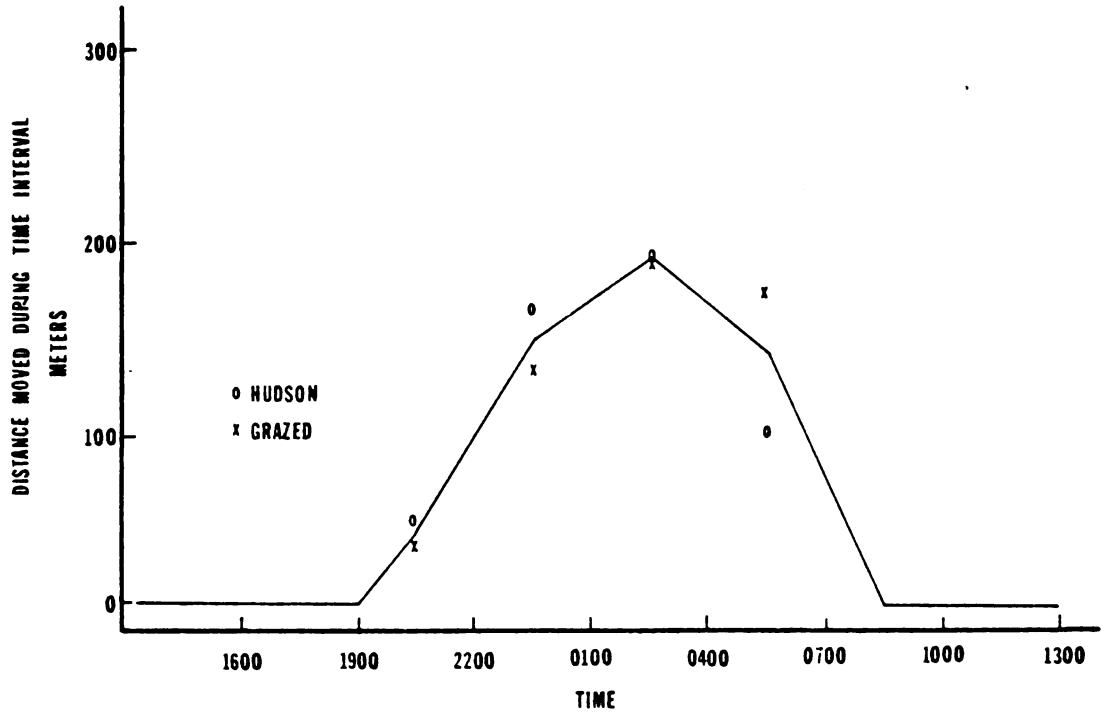

FIGURE 12. MOVEMENT PATTERNS FOR TIME INTERVAL A

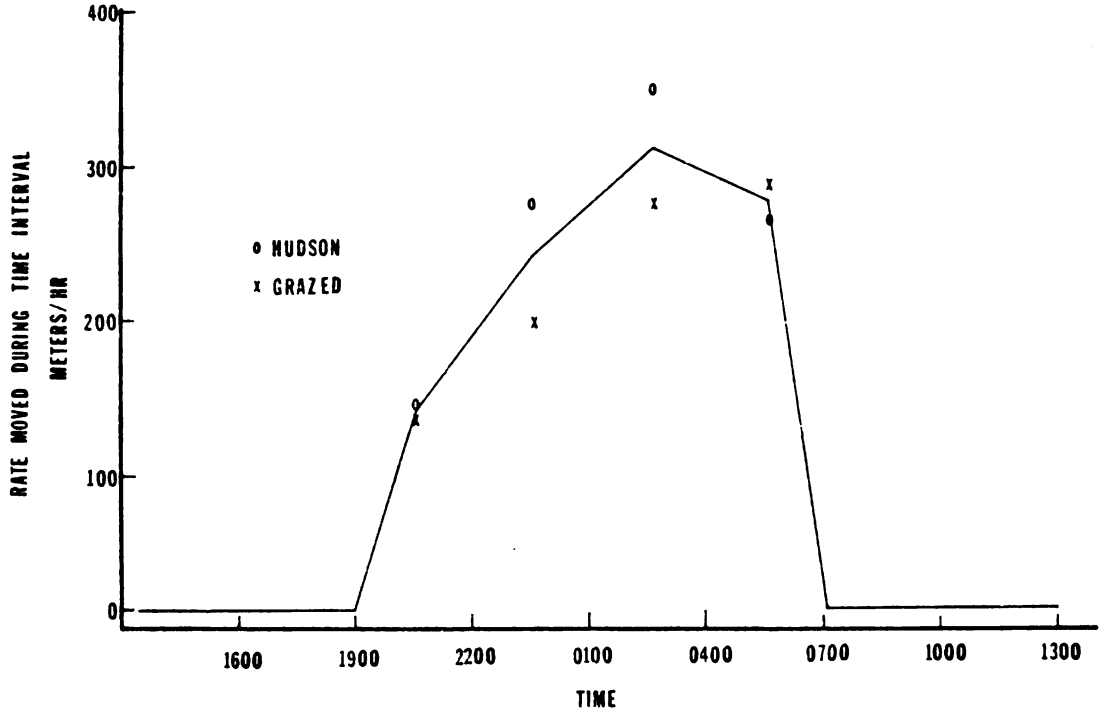

FIGURE 12. MOVEMENT PATTERNS FOR TIME INTERVAL B

movement during the day. Only one instance of daytime movement was noted during this study (Table 5).

From daytime fixes, 16 raccoon dens were located; 14 tree dens and 2 ground dens. Steuwer (1943) and Berner (1965) agreed the majority of dens were tree dens. Both ground dens were located in or nearby Hudson woodlot (Table 7). Four different dens were pinpointed for raccoon 1, three for raccoons 8 and 11 and two for raccoons 4, 7 and 9. Shifting of daytime resting sites was also noted by Mech et al. (1966) and Turkowski et al. (1968).

Foods as Indicated by Scats

The variety of the diet of raccoons has been well-documented (Baker et al. 1945, Steuwer 1943, Stains 1956, Sonenshine et al. 1972). Between 11 May and 15 August corn, mice, insects, oats, soybeans, fruit, seeds, grass and hay were identified in 257 scats (Table 8).

Although plant foods exceeded animal foods by 30 to 40% throughout the summer, insects amounted to 20 to 25% of the monthly totals. The shift to seasonally available foods was evident in both the scats and movement patterns. In May, insects, hay and seeds comprised 83.4% of the scats. By August, these three food items were only 21.3% of the total. Animal foods, primarily insects, decreased considerably in August, as corn ripened. Corn increased from 5.5% in May to 16.25% in July to 67.2% in August. The influence of corn on raccoon movements has been mentioned.

Throughout the summer, fruits and crops assumed varying importance. Preference for sour cherries ripening toward the end of July was exhibited through location data and scat analyses. Baker et al. (1945), Dorney (1954), Steuwer (1943) and Stains (1956) mentioned the

Table 7.--Denning information.

Area	Date	Raccoon Number	Location (in woodlot)	Tree species with den	dbh in	
					inches	(cm)
Hudson	5/10	1	SW	Maple	40	(101.6)
Hudson	5/12	1	NW	Ground	-	-
Hudson	6/04	2	SW	Not pinpointed	-	-
Hudson	6/04	4	Field[a]	Ground	-	-
Hudson	6/04	1	N in trees[b]	White Oak	23	(58.42)
Hudson	8/03	4	W	White Ash	Unknown	-
Hudson	8/04	1	W	Maple	30	(76.20)
Grazed	7/04	9	NW	Elm	25	(63.50)
Grazed	7/10	11	NW	Elm	25	(63.50)
Grazed	7/13	7	W	Beech	Unknown	-
Grazed	7/17	8	SW	Basswood	22	(55.88)
Grazed	7/17	9	SW	Basswood	20	(50.80)
Grazed	7/25	7	SW	Basswood	22	(55.88)
Grazed	8/06	11	NE	Maple	24	(60.96)
Grazed	8/20	11	NW	Beech	18	(45.72)
Grazed	8/20	10	NW[c]	Maple	24	(60.96)
Grazed	8/20	8	NW[c]	Maple	30	(76.20)

[a]In pasture 10 m west of woodlot.

[b]In small group of trees NW of woodlot.

[c]In grazed portion of woodlot.

Table 8.--Raccoon foods as indicated by 257 scats.

Food	May		June		July		August	
	Number of scats	%[a]	Number of scats	%[a]	Number of scats	%[a]	Number of scats	%[a]
Corn	1	5.5	5	13.5	13	16.25	82	67.2
Mouse	1	5.5	4	10.8	7	8.75	8	6.6
Insects	5	27.8	9	24.3	21	26.25	25	20.5
Grasshopper	-	-	3	8.1	4	5.00	19	15.6
Beetles	-	-	3	8.1	8	10.00	5	4.1
Misc.	5	27.8	3	8.1	9	11.25	1	0.8
Soybeans, oats, grains	1	5.5	4	10.8	5	6.25	-	-
Fruit	-	-	3	8.1	17	21.25	1	0.8
Elderberries	-	-	3	8.1	1	1.25	-	-
Cherries	-	-	-	-	16	20.00	1	0.8
Seeds	5	27.8	7	18.9	1	1.25	-	-
Grass	-	-	2	5.4	11	13.75	5	4.1
Hay	5	27.8	3	8.1	5	6.25	1	0.8
Total	18		37		80		122	

[a]% of scats based on monthly total.

importance of seasonal fruits. Whereas hay was found most often in May, soybeans, oats and other grains were more common in June.

From this analysis it appears as though corn and fruit, when available, and insects are the more preferable raccoon foods.

SUMMARY AND CONCLUSIONS

During a 15 week period in the summer of 1976, ten raccoons living in two small upland woodlots were telemetrically monitored to determine movement patterns. Over 3000 locations were recorded. The study area, located on Michigan State University farm property south of East Lansing, Michigan is extensively cultivated. A lack of permanent natural water sources distinguishes the two woodlots.

Although the intensity of use of the different cover types varied, home ranges overlapped considerably. Averaging 55.17 ha (S.E. = 8.49), a significant difference was found between the 'maximum' activity ranges of raccoons from the two woodlots ($F = 11.7^{**}$). Home range size is directly related to the location of a good food source. Frequent forays to livestock areas by raccoons living in Hudson woodlot were likely in search of food.

A minimum home range was also calculated, including only those areas where at least 1% of the total fixes occurred. Omitting the occasional excursions outside the area, home ranges averaged 36.52 ha (S.E. = 10.8). Shifts in home range coincided with seasonal food sources. Importance of livestock areas declined as fruits and corn ripened. Cherries enticed 3 of the Grazed woodlot raccoons to expand their ranges. On the whole, movements scattered over the range early in the summer became more concentrated around the woodlots in August. Population increases and the proximity of ripe corn may have contributed to the decreased range size.

The average distance moved per night varied from 351.9 m to 701.53 m, averaging 524.3 m. Overall rates of movement, averaging 115.17 m/hr (S.E. = 18.06), were significantly greater for Hudson area raccoons.

Nightly activity usually began an hour or more after sunset and ended within an hour after sunrise; the mean duration of activity was 8.6 hours. Activity, indicated by distances and rates of movement, generally increased steadily, peaking between 0100 and 0400 hours.

Only one instance was reported of daytime movements. Changing sites often, 87.5% of the daytime resting locations were tree dens.

A qualitative examination of 257 scats throughout the study period identified corn, insects, seeds, hay and fruit as the most important foods. Plants exceeded animals in the scats and many seasonal foods were highly preferred.

Cover type use, home range size, distances and rates of travel, activity periods, resting habits and foods are comparable to those reported previously for raccoons inhabiting lowland areas. The only significant difference appears to be the relationship to permanent sources of water. Whereas in the past, a water source was considered indispensable for raccoon habitat, in this instance, sufficient water appears to be obtained through foods and dew.

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