RACCOON MOVEMENTS IN A SOUTHERN MICHIGAN AGRICULTURAL UPLAND

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ABSTRACT

RACCOON MOVEMENTS IN A SOUTHERN
MICHIGAN AGRICULTURAL UPLAND

By

Kenneth Lee Stromborg

This study was undertaken to evaluate raccoon movements and cover type use in an agricultural environment containing small hardwood woodlots.

Live-trapping was carried on for 16 continuous months. Seventeen per cent of the retrapped raccoons were found to have shifted their centers of activity between woodlots. The number of raccoons captured per unit of effort was highest during the breeding season and during the summer and fall when the animals were presumably most active.

A low-cost Citizen's Band telemetric transmitter was developed to allow a detailed study of raccoon movements. Using these transmitters and a portable hand-held receiving system, 4 animals were tracked for a total of 21 nights in the late summer and fall. Movements of these animals were found to be regular and predictable. Periods

of relatively rapid movement were found to be interspersed with periods when the animals remained in a localized area.

Woodlots and areas containing corn, either as a crop or as animal feed, were found to be most frequently used. The major, although infrequent, use of pastures and grassy areas was for travel lanes. Little evidence was found of raccoons utilizing permanent standing water.

Raccoons moved from 1,000 to 7,000 feet per night (mean, 3,194) at rates from 160 to 1,320 feet per hour (mean, 733). The home ranges of the four animals, based on radio-locations, ranged from 19.8 to 83.2 acres.

I conclude that trapping is an efficient technique for evaluating inter-woodlot movements and seasonal activity. Cover type use can be evaluated by telemetric monitoring. Some portions of home ranges were unused and I conclude that home range descriptions should take this into account.

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Kenneth Lee Stromborg

A THESIS

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INTRODUCTION

Knowledge of the movements of an animal species provides perhaps the best basis for inferences regarding its ecology aside from direct observation. With the advent of radio-location telemetry in the early 1960's, detailed study of many species' movements was made possible.

Nocturnal species are particularly difficult to study by visual means. The raccoon (*Procyon lotor*) is one such species which has been studied mainly by indirect methods. Prior to the use of telemetric devices, its movements were determined primarily from tracks (Stuewer, 1943 and Stains, 1956). Berner (1965) used an automatic event recorder set along raccoon runways to evaluate movements between cover types.

These methods show the presence of animals, however, they fail to indicate the time spent in various cover types or the movements within types. Telemetric studies offer this potential, but have been largely limited to studies of resting sites (Mech, Tester, and Warner, 1966) and the size, shape, and shifts of home range (Ellis, 1964 and Tester and Siniff, 1965). One study which dealt with use of cover types (Turkowski and Mech, 1968) was limited to one animal from February to August.

This study was carried on from July, 1968 until November, 1969 with the objectives of determining raccoon movements and their relationship to habitat and home range. To meet these objectives, it became clear that a low-cost telemetric system would have to be developed and used in conjunction with live-trapping.

STUDY AREA

Location

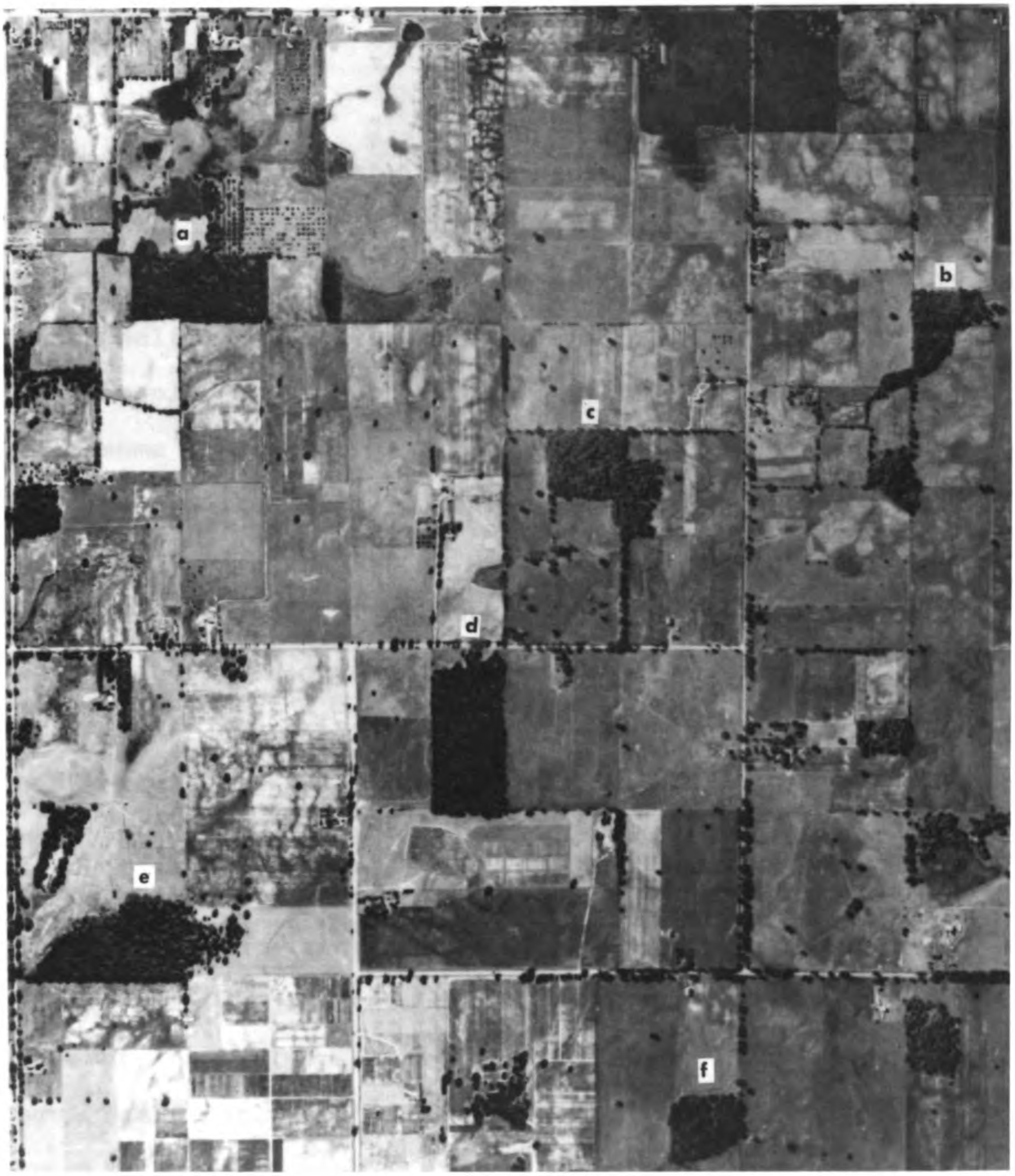
The study area, on Michigan State University property, included all or parts of sections 30 and 31, R1W, T4N and sections 25 and 36, R2W, T4N, Ingham County, Michigan.

Physiography

Since one objective of this study was to evaluate raccoon movements, precise restrictions were not placed on the size of the area. However, Berner's (1965) limits were generally followed giving an area of 2.5 square miles with a width of 1.7 miles and a length of 1.5 miles (Fig. 1). The primary use of this study area is intensive agricultural research.

The soil type of the fields north of Bennett Road is predominantly well-drained Hillsdale fine sandy loam of moderate fertility. South of Bennett Road, various well-drained loams are interspersed with small pockets of imperfectly-drained loam soils. The predominant soil type in the woodlots is Hillsdale sandy loam. Grazed Woodlot, however, is in an area of Miami loam and both Hudson and Toumey Woodlots contain extensive areas of Spinks loamy fine sand. All of these areas are well-drained and low to

Fig. 1.--The general study area on the University farms. a, Maple Woodlot; b, Bee Woods; c, Grazed Woodlot; d, Hudson Woodlot; e, Toumey Woodlot; f, Minnis Woodlot.


a
b
c
d
e
f

moderate in fertility. The extreme southern portion of Hudson Woodlot contains an area of imperfectly-drained Locke sandy loam.

Vegetation

The area of most intense study is centered around Hudson Woodlot. This woodlot is 19 acres in extent and consists of two almost equal-sized communities. The northern half is a mature hardwood stand of predominantly sugar maple (*Acer saccharum*) and beech (*Fagus grandifolia*) with some black cherry (*Prunus serotina*) and basswood (*Tilia americana*) irregularly interspersed. The dominants are roughly 14 to 25 inches in diameter and form a dense canopy with few openings. The southern half consists of an even-aged stand which developed after clear-cutting about 35 years ago. The principal species are sugar maple, beech, and white ash (*Fraxinus americana*) in the 6 to 8 inch diameter size class. This stand is closed and contains only a few scattered larger trees left during the cutting.

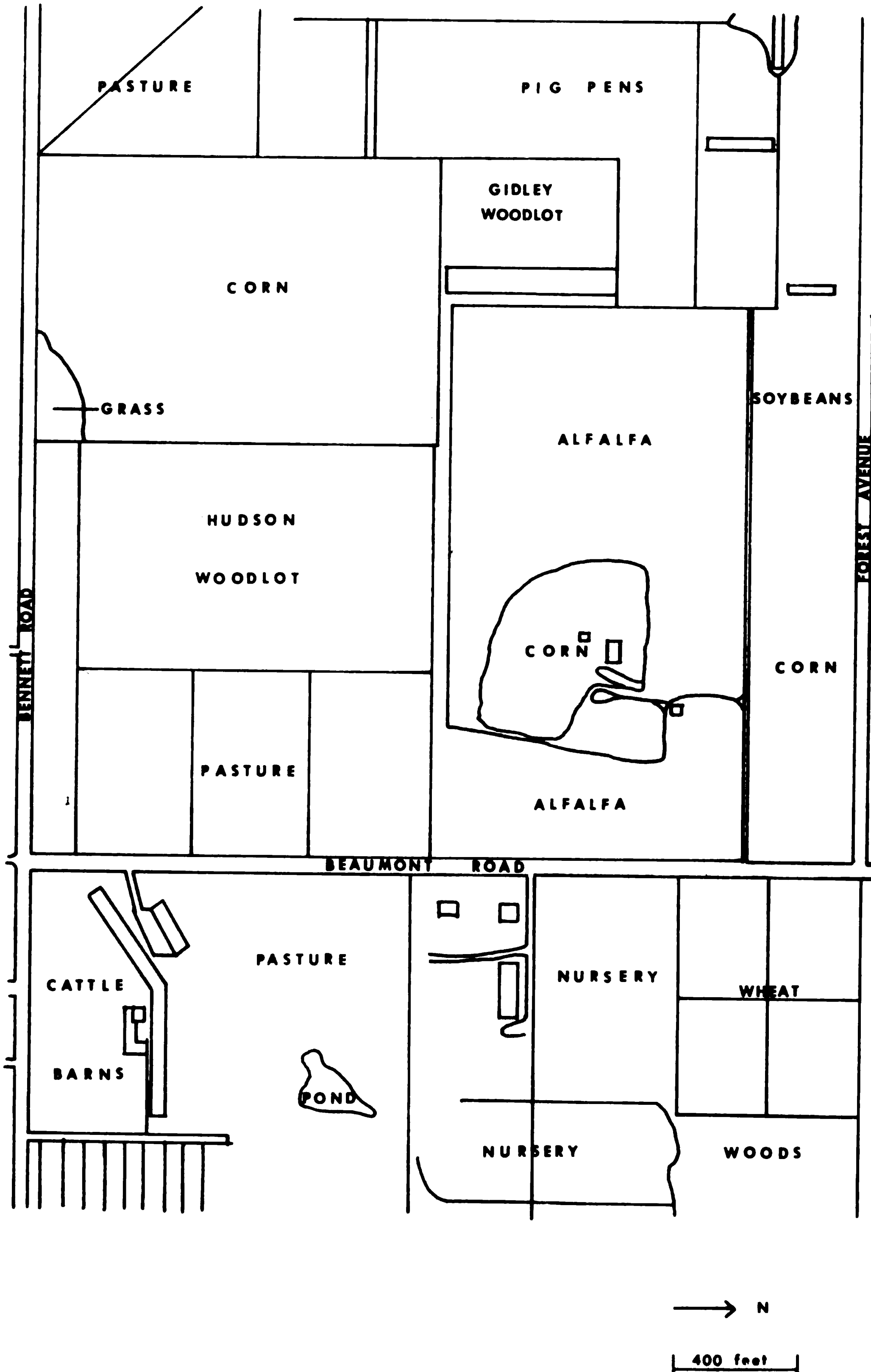
Herbaceous and shrubby foods available to raccoons within this woodlot were quite diffuse. It was noted, however, that clumps of red-berried elder (*Sambucus pubens*) bore fruit early in the summer, and this fruit disappeared quickly upon ripening. Also, gooseberry (*Ribes cynosbati*) was scattered throughout the woodlot. May apples (*Podophyllum peltatum*) were quite abundant early in the summer, but the fruit disappeared within a short time after ripening. On the northern border of the woods, near the center, a large clump of pokeweed (*Phytolacca decandra*) bore fruit, and these berries did not disappear until near the end of the winter, and then only slowly.

Surrounding Hudson Woodlot are agricultural lands (Fig. 2). To the north, an alfalfa field was cropped both years. Approximately 200 feet north of the woods, in the middle of this extensive hay field, and also to the west of the woodlot, corn was planted both years. Cattle pastures occupied the land to the east and south of the woodlot. Barns and feeding troughs were southeast and pig pens northwest of the woodlot.

Beyond the adjacent corn fields on the west were goat pastures. On the north of the alfalfa field, corn and soybeans were planted. On the far northeast, wheat was grown, and southeast of this planting, there was a nursery which provided ornamental plants for the campus and contained some fruit-producing trees, particularly crabapples (*Malus* sp.). Beyond the area described were scattered woodlots, pastures, and fields (Fig. 1).

Stock tanks at the cattle barns, pig pens, and in the pastures directly east of the woods, and a small 0.7 acre permanent pond in the pasture east of Beaumont Road were the only permanent sources of water near the woodlot. Temporary vernal pools in the woods and fields were the only other sources of water near the woodlot.

Fig. 2.--Hudson Woodlot and the surrounding agricultural areas.


PASTURE
PIG PENS
GIDLEY
WOODLOT
CORN
GRASS
SOYBEANS
ALFALFA
HUDSON
WOODLOT
FOREST AVENUE
BENNETT ROAD
CORN
CORN
PASTURE
ALFALFA
BEAUMONT ROAD
PASTURE
CATTLE
BARNS
NURSERY
WHEAT
POND
NURSERY
WOODS
N
400 feet

METHODS

Trapping

Live-trapping and tagging of animals were carried out from July, 1968 through October, 1969. The traps used were National Wire Company live-traps and live-traps of the same design and dimensions as those used by Stuewer (1943).

In Hudson Woodlot, traps were initially set on a grid of four lines, seven traps in length. The distance between traps was paced off and marked in a uniform pattern 170 feet in each direction. During August, 1968, 16 traps were removed from Hudson Woodlot when recaptures indicated that the majority of the raccoons there had been captured at least once. This removal left three lines of four traps each with 340 feet between each trap.

The remainder of the larger study area was also trapped. During the summer of 1968, four traps were set in each of the six outlying woodlots on the area. One trap was placed as near as possible to the center of each of the four borders of each woodlot to get some indications of movements between woodlots. As telemetric data later verified, raccoons used the borders of woodlots for travel, and hence, placing traps on the borders seemed to be a more efficient trapping strategy than placing traps in the interior of woodlots.

The number of traps in outlying woodlots varied from a high of 21 during the first 3 months of the study to a low of 4 at the end. Traps were also set along the borders of the fields north and west of Hudson Woodlot when the corn was ripe. During the summer of 1968, additional traps were set in the pastures surrounding Hudson Woodlot. Traps were set a minimum of two nights per week during the 16 months of the study. This procedure resulted in a total of 4,133 trap nights.

When captured, an animal was weighed, sexed, and aged as to adult or young of the year. Then it was tagged in each ear for later identification and released. A chicken wire cone as described by Stuewer (1943) was used for handling animals.

Telemetry

The development of a suitable telemetric system constituted a major portion of this study. The critical component of this system was the transmitter. When this study was begun, I felt that with slight modification, a design which Dr. Rollin Sparrowe (pers. comm.) had attempted to use with hawks would serve my purposes even though it had not proved adequate for his. The history of this design was obscure although it appeared to have been evolved from circuits developed by Southern (1963). With technical advice from Mr. Richard Thomas of the university radio station, WKAR, the circuit shown in Fig. 3 was developed.

The components shown were assembled and sealed in silicon rubber (Dow Corning Silastic), then coated with cold-cure dental acrylic (Perm by Hygenic Dental Manufacturing Company). It was possible to reopen the component package by dissolving the potting materials in chloroform. This permitted repair or tuning of the circuit.

During the summer of 1968, four transmitters were built and attached to different raccoons. Of the four transmitters tested, only the first operated for more than two days. All were subsequently recovered and it was determined that they were neither waterproof nor resistant to damage by raccoons.

On the basis of this evidence, I decided that the initial design was inadequate in several respects. First, although the use of silicon rubber permitted repair of a faulty transmitter, it did not seem to form a waterproof seal around the copper antenna wire. Second, the antenna seemed to be subject to considerable movement in the interior of the component package, and was also easily deformed by the animal. This deformation changed its electrical properties and resulted in a loss of the emitted signal.

To overcome these deficiencies, I decided to sacrifice the repair capability inherent in the original design.

Fig. 3.--Circuit diagram of the transmitter. T, transistor (2N-708); R_1, resistor (2,200Ω); R_2, resistor (180 KΩ); B, battery (Eveready E133); X, crystal (channel 8); C_1, capacitor (300 pF); C_2, capacitor (5 mF); L, antenna (25 cm aluminum strip).

Fig. 4--Circuit diagram of the loop antenna. C, capacitor (7-45 pF); L, antenna loop (2 10" diameter turns of 3/8" copper tubing).

Instead of using silicon rubber as a potting compound, epoxy resin was used on all transmitters built during 1969. There were several advantages to using this compound: epoxy completely immobilized and waterproofed the components of the package and was easy to shape using plaster of paris molds. Molding the epoxy resulted in a much smaller package than was possible with the silicon rubber.

Since the epoxy precluded opening the component package after potting, it was necessary to have some adjustment in antenna length to fine tune the transmitter to the frequency in use. I also considered it important to be able to remove the transmitter easily in the field. To meet these conditions, the copper antenna was replaced by a thin one inch wide strip of aluminum. Two short pieces of aluminum were potted in the epoxy to serve as leads for the connection of another strip to complete and tune the circuit. This strip was attached with two bolts on each end after determining the optimum length to use.

As Ellis (1964) pointed out, epoxy is not resistant to damage by raccoons, so the completed component package and battery pack were coated with dental acrylic. The battery was coated only with dental acrylic, so when it lost power, I was able to expose and change it by dissolving the acrylic in chloroform.

This design was found to be waterproof and resistant to damage by the animals. It was also extremely easy to attach to an anesthetized animal using only the antenna as a collar. In the field, the transmitter could be removed by cutting the replacable strip of aluminum. One transmitter was recovered and reused after changing the battery. This transmitter functioned well despite having been partially opened to replace the battery and then resealed. I did not feel that the transmitter caused any significant abnormalities in the animals' movements.

The receiver used initially was a Lafayette model HA450. It was a crystal controlled Citizen's Band unit. The only modification of this receiver was the inclusion of a beat frequency oscillator which imparted a tone to the signal making it easier to distinguish weak transmitter signals from static.

This receiver was stolen on September 19, 1969, necessitating the use of another unit. The only alternative receiver readily available was a Heathkit Mohican. This receiver was inferior to the first in several respects. First, it covered a wide range of frequencies. This necessitated the inclusion of more parts and consequently was a bulkier and heavier unit. Second, although portable, it was not designed for hand-held operation and had to be set down for operation. Its biggest disadvantage was that it was not crystal controlled. Tuning was not precise enough to allow setting a frequency with assurance that it was close enough to the transmitter's frequency to detect a signal. This caused considerable wasted effort in scanning the band trying to pick up a signal from a transmitter which might or might not have been in range.

These disadvantages severely hampered locating the animals at the beginning of tracking periods. However, it was quite easy to maintain contact once the animal had been located and the operating frequency of the receiver fixed.

The antenna used for location was built from the circuit design shown in Fig. 4. It was a portable hand-held directional loop with an accuracy of approximately five degrees when line of sight fixes were used. The original antenna was lost with the first receiver and I built another to the same specifications which seemed to function as well as the original.

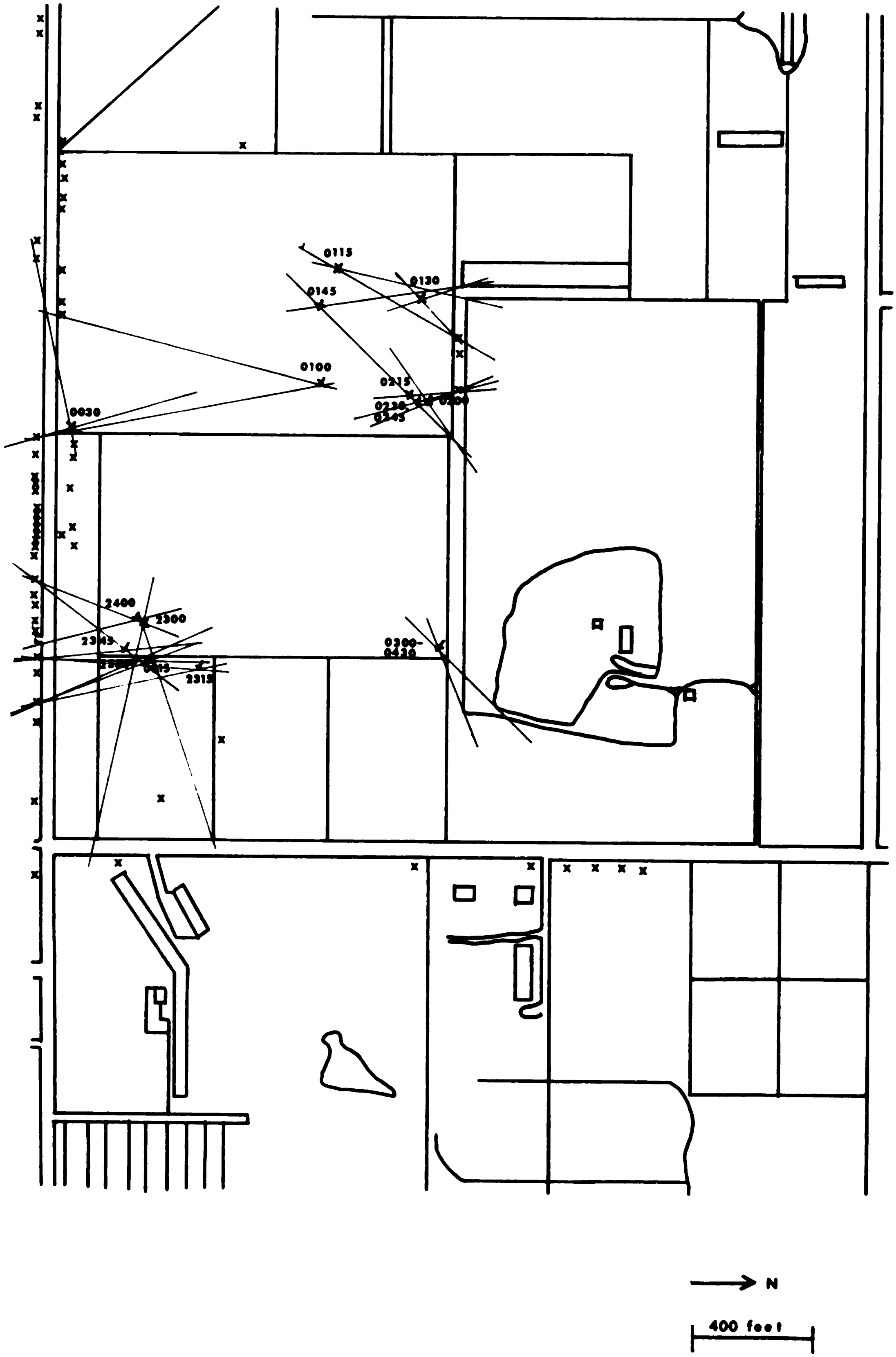
The tracking system just described was adequate for this study. Its range was between one-quarter and one-half mile depending on weather conditions, intervening cover types, other transmissions on the frequency in use, and transmitter power. The Lafayette receiver had slightly better range, but the Heathkit allowed better tuning to eliminate extraneous noise. In the final analysis, I felt that the two systems had comparable useful ranges. The biggest advantage of using the crystal controlled Lafayette unit was that, unlike the Heathkit, it allowed me to conclude with some degree of assurance that the animal was not within range if no signal was received.

Animals were usually tracked for two nights per week, although at times it was possible to include more tracking nights in a week. On several occasions, rain precluded use of the equipment so a total of 21 tracking nights was obtained over the 12 weeks of the telemetric study. The animals were usually followed from shortly after dark until it was felt that they had become inactive for the day. The average length of nightly contact after the initial location, excluding three nights on which rain or equipment failure cut short tracking, was 6 hours 45 minutes.

Field records were kept on mimeographed maps of the area. A sample field sheet with bearings and fixes from one night is shown in Fig. 5. Fixes were taken approximately 15 minutes apart from convenient landmarks. When the animal was on the boundary of cover types, a fix coincident with the boundary was taken to determine which type it was in. This feature of a portable system was a major advantage over a large fixed antenna system in this study because locations with respect to environmental variables were of more interest than geometric locations.

From the field sheets, the locations and times were transferred to clean maps of the same type used for field records. This permitted easier evaluation of results since extraneous marks and lines were not present, and the times were recorded in a legible ordered manner.

Fig.5--A field sheet showing the movements of raccoon 1 on the night of August 8, 1969.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RESULTS AND DISCUSSION

Movements Revealed By Trapping

The trapping program was intended to measure large-scale movements by the raccoon population. Of 36 animals caught more than once during the 16 months of trapping, 9 were caught in or near more than one woodlot (Table 1). Of these nine, three were caught in traps set in the fields around Hudson Woodlot.

During the telemetric studies, animals were found to approach woodlots other than the one in which they resided, although there were no instances in which they actually entered a second woodlot. Therefore, the capture of an animal in more than one woodlot probably indicated a shift in its center of activity from one woodlot to another, while a capture near, but not within a second woodlot would not indicate such a shift. By this criterion, animals caught in Hudson Woodlot and later in adjacent fields or by the pond were not considered as having shifted centers of activity. Likewise, animals caught in fields adjacent to Hudson Woodlot and later caught in another woodlot were discounted as not actually having entered Hudson Woodlot.

TABLE 1.--Raccoons that were captured in or near more than one woodlot.

Tag Number	Location of Successive Captures				
	Original	Second	Third	Fourth	Fifth
544	Hudson	Bee Woods			
513	SW Hudson*	Grazed	Grazed	Grazed	
503	Hudson	Grazed			
518	Hudson	Grazed	Grazed		
512	Hudson	Maple			
534	NW Hudson	Minnis	Minnis		
11	Grazed	SW Hudson			
85	Grazed	Maple			
170	Toumey	Hudson	Hudson	Hudson	NE Hudson

*Abbreviated directions signify direction from the center of the woodlot to traps located in adjacent fields.

Using these criteria, 3 animals were deleted from the 9 which might have shifted their centers of activity from one woodlot to another during the course of this study, leaving 6 out of 36 (17 per cent) which might have shifted activity centers. Of these six, four moved from Hudson to other woodlots in the general study area, one moved from Toumey to Hudson, and one moved from Grazed to Maple. The net outward movement from Hudson might indicate that more animals were produced there than the woodlot could support.

The number of traps set and the frequency of recapture were not sufficient to delineate home ranges of trapped animals. The movements of the two animals which were most frequently caught, numbers 514 and 559, could be inferred, within the boundaries of the woodlot, to be mostly in the eastern half and the western half, respectively (Table 2). The recaptures of these animals outside the woodlot also followed this pattern with number 514 caught east of Hudson at the pond and number 559 west of Hudson in the corn. The eight captures of number 514 were confined to July and August of 1968 while number 559 was captured six times from July, 1968 to February, 1969, and finally in July, 1969. The recapture records of other animals were more difficult to evaluate. Of the six other animals which were caught at least three times within Hudson Woodlot and once outside of it, all captures were made from late June until early October of 1968 or 1969. In addition, all except number 119 followed a pattern in

TABLE 2.--Animals caught at least three times inside Hudson Woodlot and once outside it during the course of the study.

Tag Number	Location of Successive Captures							
	1	2	3	4	5	6	7	8
514	SE1/4*	NE1/4	NW1/4	SE1/4	NE1/4	NE1/4	E**	E
521	SW1/4	SE1/4	SW	SW1/4				
559	NW1/4	W	SW1/4	NW1/4	NW1/4	SW1/4	SW1/4	
119	NE1/4	NW1/4	NW1/4	SW				
114	SW1/4	NW1/4	SW1/4	NW				
136	SW1/4	SE1/4	SW	SW1/4				
142	SW1/4	SE1/4	W	SE1/4				
132	NE1/4	NW1/4	NE1/4	NW1/4	NW			

*Directions followed by 1/4 indicate quarters of the woodlot.

**Abbreviated directions signify directions from the center of Hudson Woodlot to traps located in adjacent fields.

which their captures were confined to one-half of the woodlot and the fields adjacent to that half. Number 119 was exceptional in that it was caught in the northern half of the woodlot, but in the southern half of the cornfield west of Hudson Woodlot when recaptured outside of the woodlot.

During the telemetric portion of the study, raccoons were found to use the borders of Hudson Woodlot more than the interior. To ascertain whether this use was reflected by the trapping data, captures of raccoons from August 1, 1968 to July 30, 1969 were analyzed. During this one year period, 12 traps were utilized with 10 set in peripheral locations and 2 in central locations. Assuming each trap to be equally efficient, the number of captures in a trap should have reflected the relative use of that trap's segment of the woodlot. Therefore, if the interior of the woodlot was used proportionally as frequently as the borders, the ratio of captures in the central traps to those in the peripheral traps should have been 1:5. Of the 32 captures in Hudson Woodlot, 2 were in central traps and 30 in peripheral traps: a ratio of 1:15. A chi-square test gave a value of 2.497 with one degree of freedom. This value had a probability of being exceeded by chance of slightly more than 10%. Although the results were not significant at the 5% level, the small sample size would require a ratio of at least 1:31 to attain significance and I feel that there is a strong possibility that a larger number of captures would have showed a significant difference.

From these results, it is apparent that both frequency of capture and the limited distribution of traps mitigate against obtaining an accurate evaluation of the movement patterns of raccoons. If capture in more than one woodlot is truly indicative of a shift in the center of an animal's activity between woodlots, then this gross aspect of raccoon movements can be determined by trapping.

Raccoon activity by season might also be indicated by trapping data. Fig. 6 shows the number of raccoons caught per trap-night by months. The rates of capture in January, March, April, October, November, and December were roughly the same while the capture rates were considerably higher during the summer months of May through September. The sharp peak in February corresponded roughly to the breeding season of raccoons in this area (Stuewer, 1943) when increased activity would be expected.

Telemetric Findings

The most intensive aspect of this study was the telemetric monitoring of raccoon movements. One behavioral characteristic of the animals followed was the regularity of their nightly pattern of movements. While following animal number 1 before detailed data collection began, I was impressed by the extremely small variation in the

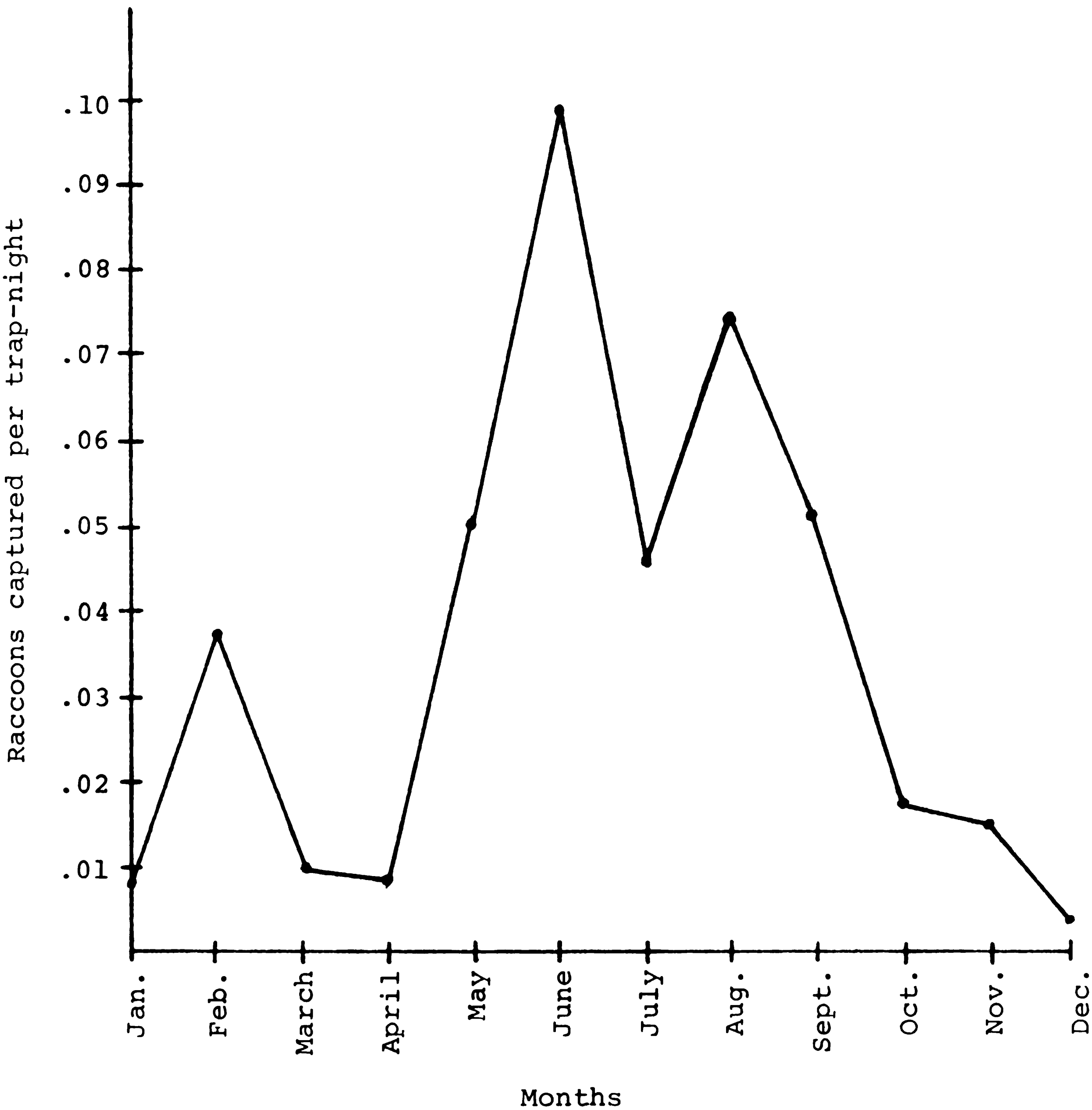


Fig.6--The number of raccoons captured per trap-night by month.

animal's itinerary during the several hours after sunset. When I began to collect data for longer periods, this pattern was found to continue throughout the night. With two exceptions, animal number 1 followed the same general pattern, moving along the eastern and southern borders of Hudson Woodlot, into the cornfield on the west side, and finally returning along the northern or southern and eastern edges of the woods (Fig. 5). The exceptions were two nights when this animal moved east to the nursery and pasture east of Beaumont Road.

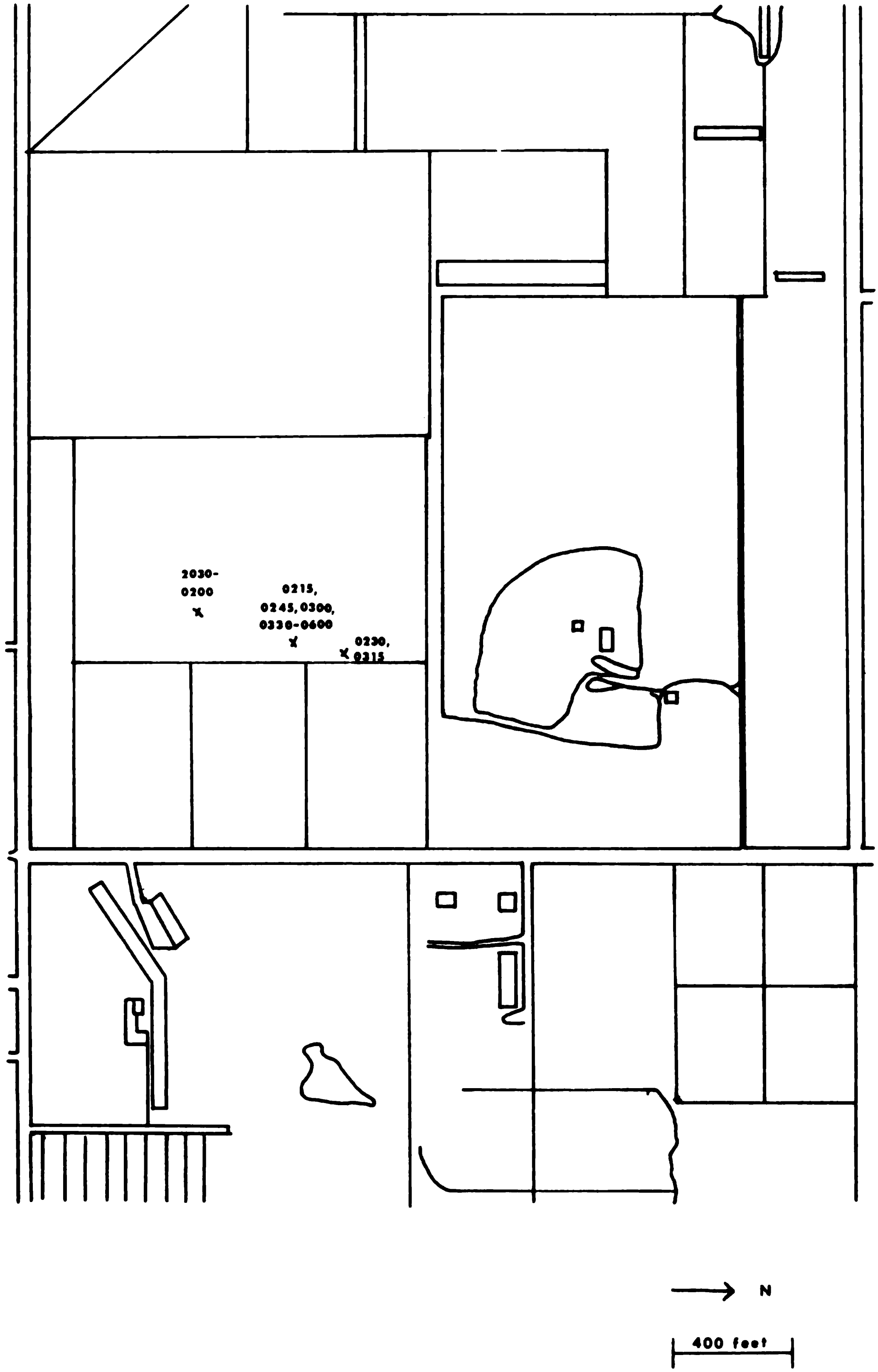
While not as many data were collected on the other three animals, they also followed a somewhat regular pattern in their movements. As a result of this regularity, I was able to begin tracking several hours after dark merely by using prior knowledge of the animal's habits for the initial location.

Animal number 2 exhibited some variability over the three nights it was followed, but generally, its main activity centered on the pasture east of Beaumont Road. It visited this pasture on all three nights. On one of the nights, it was initially located in the southern half of the cornfield west of Hudson rather than the pasture. From the cornfield, it moved along the southern border of the woodlot, stopped for one hour in the brushy area on the very edge of the woodlot, then moved relatively directly to the pasture east of Beaumont Road.

Animal number 3 usually moved counterclockwise around the pig pens immediately adjacent to Gidley Woodlot, in which it denned, and then either returned to the vicinity of the den for all or part of the remainder of the night or moved southeast into the adjacent cornfield. On two nights, the animal moved only through the pig pen area, not into adjacent fields.

The movements of animal number 4 were less regular and more difficult to follow than the others. A large part of the difficulty was due to the animal's remaining in the woods and the problem of my negotiating passage with fragile, bulky equipment through the heavy underbrush after dark. On three nights, this animal moved north along the eastern border of Hudson Woodlot. On one of those nights, the animal moved further north and into the cornfield just north of the woodlot. On another night, the same pattern was probably followed although contact was lost and the cornfield position not verified. On the third night, it remained stationary and presumably denned along the eastern border of the woods (Fig. 7). On one of the nights when this pattern was not followed, the animal moved slowly, with frequent stops, from the center of the northern half of the woods south through the middle of the woodlot stopping just inside the southern border of the woods. From there, this animal made a brief excursion into the pasture on the south of the woodlot, then back, presumably denning at the place where it had previously

Fig. 7.--The movements of raccoon 4 on the night of October 24, 1969.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stopped. On the last night this animal was located, it moved from east to west through the woodlot and into the cornfield on the west of the woods where the signal was lost. This transmitter had by then been operating for three weeks and probably went dead at that time.

Another striking feature of the nighttime movements of these animals was that periods of movement alternated with periods during which the animal remained in essentially the same location during the tracking period. In summarizing the data, periods of movements were defined to include series of fixes which occurred singly (Table 3). Localized activity included fixes occurring in a series at a single location. The first fix of such a series was, however, included in the preceeding period of movement as I felt that the time from the last single fix to the first of a series of stationary fixes should be included as movement to give a conservative estimate of the amount of time the animals remained stationary. Also excluded from localized activity were series at the beginning or end of a tracking night since these probably represented den site activity and were not indicative of activity patterns away from the den site. The average number of consecutive fixes of each type of activity was calculated for each animal and for the four animals considered together (Table 3). These average numbers were then converted to time by multiplying by 15 minutes. On the

TABLE 3.--Average duration and nightly frequency of periods of movement and stationary activity.

Animal	Movement Activity		Localized Activity	
	Duration (minutes)	Number per night	Duration (minutes)	Number per night
1	54	3.6	39	3.3
2	51	3.7	36	3.3
3	45	3.2	29	2.2
4	36	3.2	42	2.6
Weighted Average	48	3.4	38	2.9

average, the duration of these patterns was about the same: 48 minutes of movement and 38 minutes of localized activity.

The pattern of alternating periods of movement and localized activity is shown by the average number of periods of each type of behavior per night. An underestimate of the frequency of localized activity periods is shown by the consistently higher number of movement periods per night caused by the exclusion of localized periods at the beginning and end of tracking nights. If the animals had always been followed only from the onset of movement until after movement ceased in the morning, the number of movement and localized periods would be equal due to the definition of the two types of activity. The number of periods of each type per night is an indication that these animals were not continuously moving, rather their behavior consisted of movements and localized activity distributed in blocks of time greater than the 15 minute tracking intervals. In the field, during tracking operations, this two-phase pattern was even more noticeable since the receiver was not turned off between fixes.

To facilitate evaluation of raccoon use of cover types, the area was subdivided on the basis of available resources rather than on geographical criteria (Fig. 2). Therefore, the two areas of woods were included in the same subdivision although they were not geographically continuous. Likewise, the two cornfields were considered together as were the pig pens, cattle barns, and the pasture east of Beaumont Road. This pasture contained loose corn dumped with manure from the cattle barns and thus, animal feed was available there in much the same manner as at the livestock feeding areas. The remaining pastures formed the fourth subdivision. Alfalfa fields and grassy areas were grouped into the fifth subdivision and the nursery comprised the sixth. The southeast corner of the cornfield west of Hudson Woodlot was included in the alfalfa-grass subdivision because it was wet and contained high grass rather than corn.

Several general conclusions were evident from the summarized data (Table 4). As might be expected, these animals spent a considerable proportion of their time in wooded areas. Three out of the four animals spent more than 50 per cent of the time they were tracked in wooded areas. The fourth spent only 11 per cent there; however, this animal was only followed for roughly one-half as long as any of the others and there may have been insufficient data to detect the animal's true behavior pattern.

Another general observation was evident from the summary. On most nights, these animals visited areas where corn, either in the form of crops or feed, was present. On 4 of the 21 total nights this visitation did not occur, but of these 4 exceptions, 2 were nights when fewer than 12 fixes were obtained. The remaining two nights were apparently nights when the animal did not visit an area which contained corn.

TABLE 4.--Summarized nightly use of cover types by raccoons.

Animal	Date	Number of Fixes	Percentage of Fixes in the Listed Cover Type					
			Woods	Cornfields	Livestock Areas	Pasture	Hay and Grass	Orchard
1	7/30	25	60	16		20	4	
	8/1	25	68	32				
	8/4	33			100			
	8/6	22	59	36		5		
	8/7	20	65	10		20	5	
	8/11	21	71	29				
	8/12	22	32		18			50
	Total	195	52	12	19	10	1	6
2	9/2	17	6		12	76		6
	9/3	21			90	5		
	9/9	24	25	33	33	9		
	Total	62	11	13	47	26		3
3	9/15	29	76	24				
	9/17	26	31	42	19		8	
	9/18	18	50		44		6	
	9/28	10	100					
	10/3	24	71	29				
	Total	108	62	23	12		3	
4	10/11	32	97			3		
	10/17	11	100					
	10/18	27	63	7		4	26	
	10/24	18	100					
	10/25	5	40	60				
	Total	93	85	5		2	8	

This observation points up the importance of corn to the ecology of the animals in and around Hudson Woodlot, particularly during the late summer and fall. Berner (1965) noted a great number of movements between woodlots and cornfields, and a large percentage of corn in the raccoon scat he examined. During the present study, I qualitatively examined 31 scats located during trapping operations and the contents of 2 stomachs from road-kills. Only one scat and one stomach were not predominantly corn. Both of these exceptions were composed entirely of black cherry and were found in August, one in each year. One scat was found which contained fairly direct evidence of feed corn. This scat was found in April and contained corn and pieces of the black plastic used to cover various materials at the livestock areas.

The last general conclusion about cover types which was drawn from the summarized data was that alfalfa and dense, tall grassy areas were relatively infrequently used by raccoons. The highest percentage of use of this type of area by an animal on a night was 26 per cent. These fixes were all obtained at the end of the tracking period when the animal moved to the north of the northern cornfield, entered a culvert there and remained until tracking was discontinued after dawn. The other fixes of animals in this type of cover were contributed by animals moving through these areas rather than spending extended periods of time there.

Another aspect of raccoon movements which was ascertained from these data was the distance moved and area covered by an animal (Table 5). The total distance covered by the animal during the tracking period, as shown in the third column of Table 5, must be regarded as a minimum figure since short movements were not detectable, and often, either the initial or final movements of a night were not recorded. The fourth column shows the hours the animal was tracked on the night in question, and the fifth column is the quotient of the third divided by the fourth, i. e., the average distance covered per hour of tracking. The sixth column shows the time during which the animal was active either after leaving the den, before returning to it, or both. This column was included because on many occasions, the animal was inactive for a period at the beginning or end of the tracking period and I did not feel that this time should be included in a measure of rate of travel since the animal was presumably at the den site and inactive. The seventh column is similar to the fifth in that it is a rate of movement calculated from the distance traveled and the time of tracking less those periods which were excluded from the beginning or end of the tracking period.

From this table, it can be seen that the mean distance covered varied from 1,000 to 7,000 feet with a mean of 3,194 feet and a standard deviation of 1,800 feet. The average rate of travel was 564 feet per hour or 733 feet

TABLE 5.--Distances and rates of movement.

Animal	Date	Distance (feet)	Total Hours	Rate (feet/hour)	Adjusted* Hours	Adjusted** Rate (feet/hour)
	7/30	5,600	7.5	760	6.5	880
	8/1	3,120	6.25	520	6.0	520
	8/4	1,440	8.25	160	6.5	200
1	8/6	5,040	5.5	920	4.0	1,240
	8/7	4,280	4.75	880	3.25	1,320
	8/11	5,000	6.25	800	3.75	1,320
	8/12	5,800	6.0	960	5.5	1,040
	8/13	4,400	6.75	640	4.75	920
	9/2	3,120	4.5	680	4.5	680
2	9/3	2,280	5.25	440	5.25	440
	9/9	4,600	6.5	720	6.5	720
	9/15	2,400	7.0	320	1.75	1,320
	9/17	7,000	6.75	1,040	6.5	1,080
3	9/18	2,040	4.5	440	2.5	800
	9/28	1,000	2.25	440	2.25	440
	10/3	2,360	5.75	400	4.25	560
	10/11	2,040	8.5	240	5.75	360
	10/17	1,640	2.75	600	2.5	640
4	10/18	1,800	11.75	160	10.25	160
	10/24	1,040	9.5	120	7.0	160
	10/25	1,040	1.75	600	1.75	600
Means		3,194		564		733
Standard Deviations		1,800		275		382

*Total hours less hours before the onset of nightly activity and hours after it was felt the animal had become inactive for the day.

**Based on adjusted rather than total hours.

per hour based on entire tracking periods or adjusted time periods, respectively. The corresponding standard deviations were 275 and 382 feet per hour. The precision of all these estimates is low indicating considerable variation in nightly activity.

Inspection of the raw data led me to believe that much of this variation was due to differences in the movement patterns of individuals on different nights. On most nights, the animals ranged widely at a relatively high average rate. However, on a few nights, the animals remained in essentially the same location for the entire night leading to low distances covered and low rates of travel.

To quantify this subjective evaluation, the rates of movements of the four animals were grouped by increments of 100 feet per hour (Table 6). This distribution suggested that animals were moving at quite different average rates on different nights. On the raw data sheets, the pattern of movements on nights at the extremes of rates for an animal were consistently far-ranging and low-ranging, respectively. On the nights in the middle of the range, the pattern of movement was intermediate between the two types. In these cases, the animals moved at a fairly rapid rate for a short period but then remained relatively motionless for the remainder of the night, lowering the nightly average to an intermediate value. The cause of this divergent behavior pattern was not clear but might

TABLE 6.--Number of nights with a given average rate of movement.

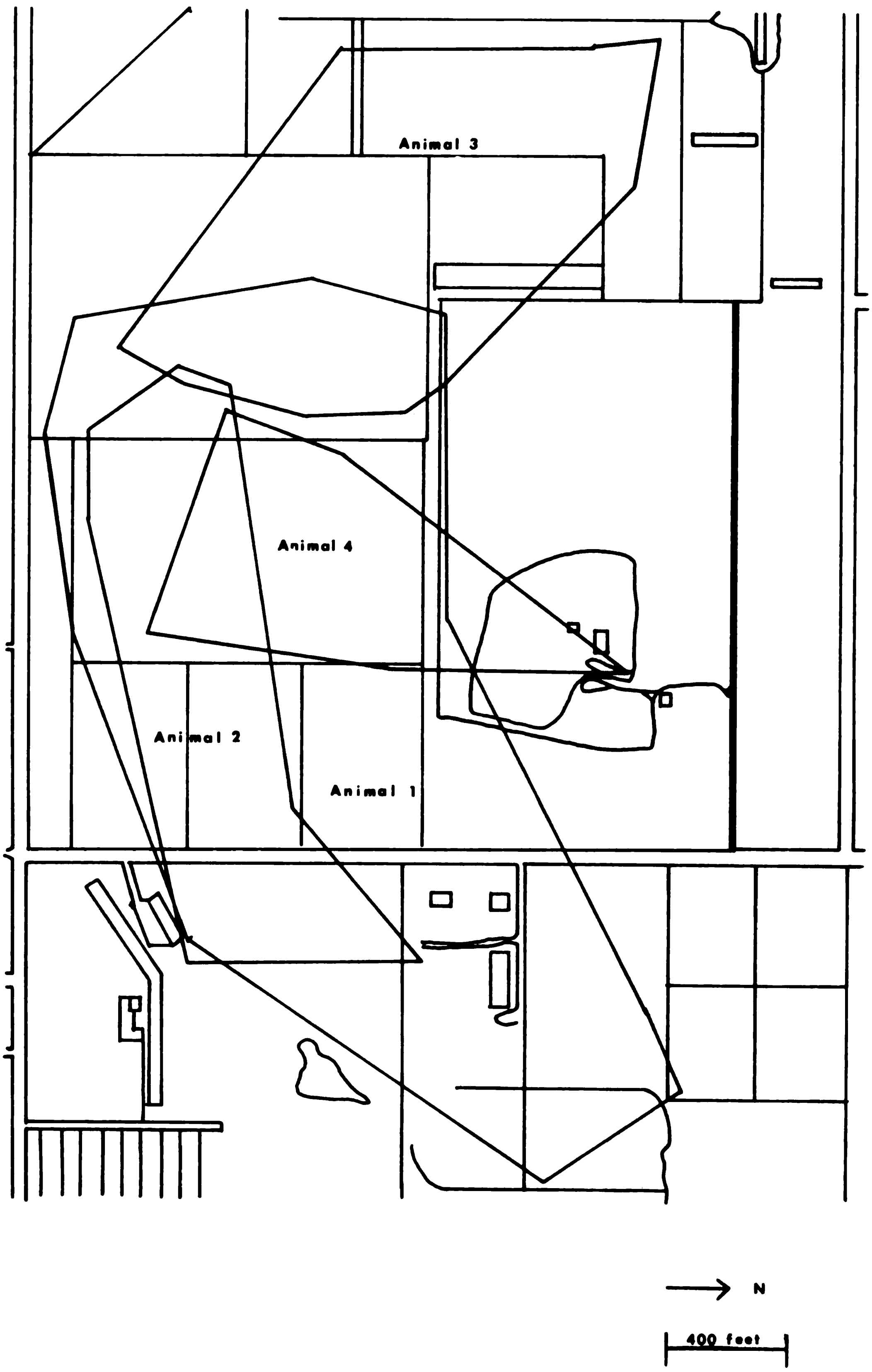
Animal	Rates (feet/hour) 100-200	200-300	300-400	400-500	500-600	600-700	700-800	800-900	900-1,000	1,000-1,100	1,100-1,200	1,200-1,300	1,300-1,400
1		1			1			1	1	1		1	2
2				1		1	1						
3				1	1			1			1		1
4	2		1			2							

have been related to an unrecorded variable such as a meteorological change. Examples of these two types of movements are presented in Figs. 5 and 7.

Too few recaptures were made by live-trapping to describe home ranges, so the peripheral radio-locations were used as the limits of home ranges for each of the four animals (Fig. 8). Home ranges for the periods during which they were tracked were found to be 83.2, 33.2, 19.8, and 24.4 acres. These areas represented short-term observations and were not measures of the total area which would be included if the same procedure was applied on a yearly basis. Weather might also influence raccoon movements, however, data were not gathered over a range of meteorological conditions and represent only nights with no rain and moderate temperatures.

Shifts in the home ranges of the animals as described by Ellis (1964) and Turkowski and Mech (1968) would make yearly home ranges much larger. In fact, the large home range of the first-monitored animal was probably due to such an effect. This animal usually confined its activities to the woodlot and fields west of it. On two occasions, however, extensive movements east of the woodlot to the pasture containing corn and the nursery were made. These movements very nearly doubled the area included in this animal's range.

Fig. 8.--Home ranges of the four radio-tracked animals based on radio-locations.


Animal 3
Animal 4
Animal 2
Animal 1
N
400 feet

The home ranges of the other three animals were based on more consistent movement patterns. The second animal moved both to the east and west of the woodlot in one night leading to an extension of its range similar to that observed for the first animal but smaller in magnitude. The movements of the other two animals did not exhibit this pattern, however, and probably represented the movements typically exhibited during the normal activities of these animals within a period of time short enough that the animals did not shift areas of activity.

These patterns illustrate what I feel to be the major short-coming of evaluating home range as merely the area enclosed by the most distant points which an animal reaches during its movements. The area so enclosed is easy to describe, but it may not accurately reflect the area of actual significance to the animal. There may be large areas in the home range which have no significance for the animal and which it does not visit. A good example of this discrepancy is the range of the first animal as depicted in Fig. 8. The home range included all of Hudson Woodlot, yet the animal never moved through the interior of the woodlot; only on the eastern, southern, and northern edges of it. This led to a gross over-estimate of the actual area of direct significance to the animal as indicated by the radio-locations.

The home ranges of the other three animals more accurately reflected the areas which they visited, but if tracking had been extended for a longer time, the same type of distortion might very well have occurred. It is apparent from this illustration that home ranges as usually presented should be critically evaluated and not interpreted as necessarily representing the area which an animal utilizes uniformly or completely.

One short-coming of home ranges as determined by live-trapping became evident during this study. In the case of large animals such as the raccoon, home ranges are large and consequently, a very large number of traps are necessary to cover an area completely. During this study, few traps were set in fields and hence, these areas would not have been considered had home ranges been constructed from trapping data. This would have led to an incomplete picture of the home ranges of animals in this area.

The final ecological variable of interest in this study was the availability of water. Little standing water was present on this study area and the location of all sources was known. During tracking operations, raccoons were rarely located at any of these sources and never for a period long enough to be included as more than one fix. On several occasions, a monitored animal passed close to the stock tanks east of the woodlot or was in the general vicinity of water at the pig pens, but any use of these sources must have been extremely brief and was not accompanied by resting at these sources.

SUMMARY AND CONCLUSIONS

The movement patterns of raccoons living in the hardwood woodlots of an upland agricultural area were studied from July, 1968 through October, 1969 using live-trapping and radio-location telemetry. Movements between woodlots were monitored by live-trapping for the entire 16 months and detailed movements were telemetrically monitored during a 12-week period in the fall of 1969.

The results of 4,133 trap-nights revealed that 9 of the 36 animals recaptured were caught in or near more than one woodlot. Three of these animals probably did not enter a second woodlot leaving six which probably changed woodlots during the course of the study. This 17 per cent of the recaptured animals probably represented the proportion of raccoons on this area which left the woodlot in which they were born to take up residence in another woodlot at some time during their lives.

Using radio transmitters which were developed for this study, the detailed movements of raccoons were monitored on a nightly basis. These transmitters fulfilled the requirements of being cheap, durable, and having sufficient range and life to be useful in tracking raccoons.

A crystal controlled receiver was found to be more convenient than a tunable receiver although the range of the two designs was comparable. It seemed that a portable hand-held system should be superior to a fixed arrangement for quantifying cover type use because of the greater flexibility of the portable system in removing uncertainties about the cover types being occupied.

Using this system, four animals were monitored for a total of 21 nights over a 12-week period. During this period, animals frequently spent a considerable portion of their time on the borders of woodlots. Other cover types used frequently were cornfields and livestock areas containing feed corn. Grassy areas and alfalfa fields were used infrequently and only as travel lanes.

The movement patterns of the monitored raccoons were found to be quite consistent and predictable. These patterns consisted of rapid movements between locations at which the animals often remained relatively stationary for long periods of time.

The distance an animal covered during a night ranged from 1,000 to 7,000 feet with a mean of 3,194 and standard deviation of 1,800 feet. The nightly rate of travel ranged from 160 to 1,320 feet per hour with a mean of 733 and standard deviation of 382 feet per hour.

Two types of movement patterns were identified. On most nights, the animals ranged widely and moved at a relatively rapid average rate. On some nights, however, the animals remained in a restricted area and the average rate of movement was low.

Home ranges during the period each animal was tracked were constructed for each of the animals from the radio-locations. These home ranges varied from 19.8 to 83.2 acres. Longer-term tracking of the same animals would probably result in larger home ranges due to the animals shifting their areas of activity.

No direct evidence of raccoon use of permanent standing water was obtained.

A large portion of the area included in the home range calculations was not actually used by the monitored animals. The traditional concept of home range may be convenient, but this limitation of the concept should be taken into account when considering the ecology of an animal species.

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