Radio-Tracking the Movements of a Young Male Raccoon

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ABSTRACT — Movements of a young male raccoon (Procyon lotor) were studied for four months in 1965 through the use of an automatic radio-tracking system. Data for 135 days were collected, and 2,065 locations were recorded. The study animal usually rested throughout the day at different sites. Nightly activity usually began within an hour before or after sunset and ceased within an hour before or after sunrise; the mean duration of the active period was 9 hours and 5 minutes (S.E. = 19 minutes). Nightly movements varied both in extent and areas visited. The raccoon visited a certain cornfield on 87 per cent of the nights, but shifted the density of his use of various areas and continued to try new areas through most of the four-month study period. The greatest length of two-week activity ranges varied from 4,620 to 8,514 feet, and that of the total range was 9,240 feet.

Knowledge about the life history of the raccoon is incomplete at present because of inadequate methods of studying movements and activity of this species. Studies based on capture-recapture methods, such as those of Steuwer (1943) and Butterfield (1944), have provided limited information. Even Ellis (1964), using portable radio-tracking equipment, obtained relatively scant location data. With development of an automatic radio-tracking system (Cochran et al., 1965), detailed movement information is now available on individual animals in a population (Mech and Tester, 1965). Analysis of hundreds of thousands of locations, or “fixes,” for many individuals must await improvement of the techniques for analysis.

Tester and Siniiff (1965) using the automatic-tracking system, studied 521 locations for a raccoon but limited their analysis to statistical problems. Mech et al. (1966b) investigated only the autumn daytime resting sites of raccoons.

The present study, based on 2,065 locations obtained by the automatic radio-tracking system, attempts to develop analytical methods and to add new information on raccoon movements and activity. It features an analysis of the movements of a young male raccoon, No. 616, from April to August, 1965, plus consideration of a few movements during colder weather.

The Study Area

The study was conducted 30 miles north of Minneapolis, Minnesota, on part (Fig. 1) of the Cedar Creek Natural History Area in Anoka and Isanti Counties. The site has been described in detail by Pierce (1954).

Temperatures during the study period varied from −29°F on 24 March to 90°F on 12 August. During the first half of the period, monthly highs averaged 65°F and lows 6°F; while during the second half high average was 88°F and low 40°F. Accumulations of snow varied from a few inches on the level in late February to about 40 inches in late March. By mid-April most of the snow was gone from open areas. Total rainfall from 15 April to 15 August was 13.28 inches. All weather data were recorded at the U. S. Weather Bureau Station on the Cedar Creek Natural History Area.

The Monitoring System

The study animal was captured by hand while feeding in a cornfield; recaptures were by live traps. The animal was anesthetized with ether (Balser and Kinsey, 1962), and a radio transmitter (Cochran and Lord, 1963) was molded in an acrylic collar which was attached around the raccoon’s neck (Mech et al., 1965). Total weight of the apparatus was 100 grams. After each capture, the raccoon was released at the capture point.

The automatic tracking system consists of two elevated, continually-rotating yagi antennas 0.5 mile apart, a pair of receivers and visual signal-display tubes for each study animal, and continually operating 16 mm motion picture cameras. Antennas rotate at 1 1/2 rpm, so ideally, signals from each animal are recorded every 45 seconds, as are the time and the direction in which each antenna is pointing (in terms of angular bearings in whole degrees). The investigators attempted, however, to sample fixes at intervals of approximately 15 minutes throughout the animal’s activity period (primarily at night). Raccoons are usually resting during the day (Mech et al., 1966b), so only two fixes per day were used to represent the resting locations.

The precise time of onset and cessation of activity also was sought, in much the same manner as reported by Mech et al. (1966a) for cottontail rabbits (Sylvilagus floridanus) and snowshoe hares (Lepus americanus).

The most important errors of the tracking system were discussed by Sargeant et al. (1965) and Heezen (1965). These result mainly from a slight misreading of the microfilm, so that recorded bearings may be inaccurate by
1 degree. Sargeant *et al.* (1965, Fig 1) outlined zones in which a 1-degree error would amount to a certain maximum distance. Since 85 per cent of the fixes of the study fell in error zones in which the average error was 148 feet or less (Table 1), and since conclusions did not require more precise data, the authors do not believe that such errors constitute a serious limitation.

For each location, the time, date, and bearing from each antenna was processed by a computer using programs described by Sini (1966). These calculate distances between successive locations, the geometric center of a given number of points (Hayne's, 1949, "center of activity"), the activity radii or distances between each point, and the geometric center (Dix and Clark's, 1953, "recapture radii"), and the number of points falling in each 6.4-acre square of a grid system covering the study area.

Results and Discussion

During the study period, 17 February to 12 August 1965, raccoon 616 was captured five times. Including 616, four raccoons of similar size were caught in a certain cornfield (Fig. 1, Area 1) from 5 to 28 February. Because of their unusually small size and the fact that each was often found with at least one of the others, they probably were litter mates. At least three adult males and two adult females also used all or part of 616's range at times.

The study animal weighed 5.5 lb. in February, and gradually increased to 8 lb. when last handled, on 22 June. A non-extrusible penis indicated that he was a young of the previous year (Sanderson, 1961). On 13 April, all his canine teeth were broken, probably from biting the trap. No. 616 and the other individuals in his group were in very poor condition in February, and only 616 survived the exceptionally severe late winter of that year.

The animal was radio-tagged three times. During the 177-day study, data were collected for 135 days, mostly between 12 April and 12 August. The 2,065 fixes were obtained at a rate averaging about 15 per day. Resting sites were determined for 108 days, and times of onset and cessation of nightly activity were determined within 15 minutes for 55 and 68 days respectively.

Resting Habits

Mech *et al.* (1966 b) demonstrated that in autumn, raccoons (1) spend most of the day resting, (2) generally rest on the ground in lowland, and (3) seldom use the same resting site on two consecutive days. The resting habits of 616 followed this pattern. After 12 April, this raccoon usually rested in lowland throughout most of the day, presumably on the ground. Of the 83 approximate resting sites that could be classified as definitely in either lowland or in a complex of fields and hedgerows, 62 (75 per cent) occurred in lowlands (usually in a cedar swamp).

General shifts in the proportion of different habitats used for resting occurred twice. Before 1 May, all resting sites classifiable by habitat occurred in lowland, mainly in the cedar swamp. From 1 May to 15 July, 41 per cent of the classifiable resting sites occurred in the field-hedgerow environment. After 15 July, all classifiable resting sites were again in lowland.

The greatest straight-line distance between consecutive daily resting sites was 4,917 feet, and the mean was 1,745 feet. The mean activity radius for the 108 resting sites was 1,484 feet. All these figures are in the same order of magnitude as those reported by Mech *et al.* (1966 b). Raccoon 616's daily resting sites generally were distributed throughout his entire activity range. The geometric center of resting sites is only 396 feet from the center of all the 2,065 locations recorded during the animal's nightly activity. The mean activity radius for the resting sites (1,484 feet) is about the same as that for the activity locations (1,328 feet).

Onset and Cessation of Activity

The study animal began nightly activity within an hour before or after sunset on 84 per cent of the 55 days for which data are available, with after-sunset starts on 78 per cent of the days. Activity ceased from an hour before to an hour after sunrise during 53 per cent of 68 days for which there is data. In 75 per cent of the days, movement did not stop until after sunrise. After 1 July, cessation occurred after sunrise on 96 per cent of the days. Average duration of nightly activity was 9 hours and 5 minutes (S.E. = 19 minutes), based on 42 nights when both starting and stopping time were known to within 15 minutes.

![Figure 2](https://example.com/fig2.png)

*Figure 2. Nightly travel route, 21-22 April. Triangle represents the geometric center of the points.*


**Table 1.** Percentage of total number of fixes of Raccoon 616 falling in maximum 1° error zones, and average error in each zone (Sargeant et al., 1965: Fig. 1, Table IV).

<table>
<thead>
<tr>
<th>Zone</th>
<th>Percentages of fixes used in present study</th>
<th>Average error (Feet)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0–200 foot</td>
<td>17</td>
<td>82</td>
</tr>
<tr>
<td>200–400 foot</td>
<td>68</td>
<td>148</td>
</tr>
<tr>
<td>400–600 foot</td>
<td>14</td>
<td>422</td>
</tr>
<tr>
<td>600–800 foot</td>
<td>1</td>
<td>335</td>
</tr>
</tbody>
</table>

**Nightly Activity**

A subjective appraisal of the 135 maps of 616's nightly travel shows great variation. During some nights the animal traveled extensively most of the night, each 15-minute fix being far from the previous one along a definite line, e.g., 21-22 April (Fig. 2). On other nights the average distance of movements was greatly restricted, but location was changed frequently.

By using nights when the study animal did little zigzagging, accurate minimum figures for distance traveled can be derived. The only 2 nights for which we are confident that the minimum figures approached the actual were 21-22 April (Fig. 2), when the minimum total-distance traveled for 672 minutes was 17,429 feet, and 26-27 April, when it was 14,742 feet for 575 minutes.

Although extent of nightly travel is an important aspect of animal movement, consideration of the areas visited is probably more significant. Such an analysis, however, is hindered by difficulties in quantifying routes and sequences of nightly travel. To compensate for this, a quasi-objective approach was employed. After examination of all 135 maps of 616's nightly travel, the total activity range was divided into regions or entities that were considered important to the animal, regardless of their relative size. The number and sequence of visits to these areas for each of 76 nights in which there were at least 10 fixes has been summarized.

**Locational Patterns**

Descriptions and patterns of use of each area follow (Fig. 1).

**CORNFIELD**

This field, containing 18 acres of unharvested corn, was the only cornfield in 616's range and was the area used most. It was bordered on three sides by hedgerows and on the fourth side by an open oak woodlot and a cedar swamp, where 616 often rested for the day. During 42 per cent of the nights, the raccoon visited this field first after leaving his daytime resting site. He made at least one trip to this field during 87 per cent of the nights, and returned to it three times some nights. On 34 per cent of the nights, the cornfield also was the last place 616 visited before going to a daytime resting site.

**CEDAR SWAMP**

This dense lowland, in the north-central section of the animal's range, contained about 110 acres of white cedar and was bordered on the west by cultivated fields. It was the only cedar swamp in 616's range after 30 April. On 59 per cent of the 76 days recorded in this analysis, 616 bedded in this swamp. He visited it at least once during the active part of 29 per cent of the nights.

**SOUTH FIELDS**

The raccoon visited these fields almost as often as the cornfield, perhaps at times en route to the cornfield. They were either uncultivated or planted to soy beans or alfalfa in May. A dirt road and a few hedgerows are in the complex. Before 19 July, the south fields were used only sporadically. Later they were visited more frequently, sometimes three times per night. During 22 of 76 nights, these fields were visited first.

**WEST FIELDS**

In May, these were planted with alfalfa, corn, soybeans, or rye. Many are separated by hedgerows. From 13 April to 31 May, 616 used these fields on 16 to 38 days; and from 1 June to 11 August, on 30 or 38 days.

**EAST FIELDS**

The east fields are bordered by the south fields, the cedar swamp, a creek, and two oak woodlots. They consisted of a small pasture, an alfalfa field, a fallow field, and an uncultivated field. Movements through the east fields were well distributed throughout the night, so these may have been main routes to other areas.

**CEDAR CREEK**

This is a slow-moving creek, 15 to 25 feet wide, bordered by lowland vegetation such as cedar, alder, red osier, and willow. It is on one edge of the area used by 616. From 13 to 28 April, the animal visited the creek on 9 of 13 nights. From 29 April to 20 June, he visited it on only 9 of 42 nights. After that, he did not use it at all. On most visits to the creek, 616 crossed it, doing so on three occasions while on the way to Cedar Bog Lake.

**OAK WOODS**

The only large oak woodlots in 616's activity area were used sporadically, and the study animal rested in them only one day, as far as known.

**EAST OF CREEK**

Most of this area consists of cedar and alder swamps. It was visited primarily during the early part of the study, and 616 usually spent only a few hours in this area, then returned to the west-of-creek areas.

**DUCK-PEN FIELD**

Two enclosures of wild ducks were the most prominent features in this field. The first eggs were laid on 10 May, and hatched in early June. The study animal visited this field on 20-21 and 21-22 May and on 9-10 and 10-11 June. No sign of predatory activity was found, however.

**CEDAR BOG LAKE**

This 3.2-acre lake on the easternmost edge of 616's activity area is surrounded by cedar swamp. It was visited three times, the last on 26 April.
Shifts in Travel Patterns

The most striking shifts in nightly activity occurred early in the study. Only 4 nights of data were available before 13 April. These were 25 February to 1 March, and 616 visited the cornfield each night. This habit persisted until 21-22 April, when the raccoon crossed the creek and went to Cedar Bog Lake for the first time (Fig. 2). He remained east of the creek the next evening and again visited the lake. At 2300 hr, he recrossed the creek and was caught in a live-trap. He stayed west of the creek until 26-27 April, when he made his last trip to Cedar Bog Lake; then he returned to the cornfield. Nightly travels were the most extensive during that period, 21-27 April.

Because 616's nightly travel routes varied considerably, the data has been grouped into two-week periods to determine the extent of the animal's travel over longer time spans (Table 2).

Shifts in areas used during these periods can be seen in Fig. 3. In general, the boundaries and two-week geometric centers of each period from 1 May to 15 July remained the same. The deviant periods were 15-30 April, when the cedar swamp, creek, and area east of the creek were visited; and 16 July to 12 August, when the cedar swamp received more use. Ellis (1964: 367) also noted shifting in the ranges used by two raccoons which he studied.

From 16-30 April, 616 traveled more extensively than during any other part of the study. The mean activity radius was about 40 per cent greater than that of any other two-week period. There was a general decrease in this parameter for May and June, and then an increase until the end of the study. Generally, as the extent of the daily range increased, so did the extent of the two-week range. The two ranges did not increase proportionally, however, as illustrated by the increasing ratio of the mean daily activity radii to the mean two-week activity radius (Table 2).

Size of Range

The methods of measuring and expressing home range are extremely diverse, and no single standard applicable to these data was found. Brown (1962) and Sanderson (1966) have reviewed this problem also. Because the term “home range” has various meanings, the term “activity range” is preferred in this report. It covers all the locations at which an animal is found during a specified period.

We believe that in most cases area figures are misleading because they do not consider areas of no use bounded by areas of use (Fig. 2). However, there may be some merit in calculating the area of an activity range for an extended period based on many locations.

![Figure 3. Distribution of daily geometric centers, extent of 2-week activity ranges, and intensity of use of each range. Numbers represent the percentage of the total number of fixes occurring in each square. Empty squares enclose less than 1% each.](image)

<table>
<thead>
<tr>
<th>Table 2. Extensiveness of 2-week and total activity ranges.</th>
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<tbody>
<tr>
<td><strong>Period</strong></td>
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<tr>
<td>-------------</td>
</tr>
<tr>
<td>Apr 16-30</td>
</tr>
<tr>
<td>May 1-15</td>
</tr>
<tr>
<td>May 16-31</td>
</tr>
<tr>
<td>Jun 1-15</td>
</tr>
<tr>
<td>Jun 16-30</td>
</tr>
<tr>
<td>Jul 1-15</td>
</tr>
<tr>
<td>Jul 16-31</td>
</tr>
<tr>
<td>Aug 1-12</td>
</tr>
<tr>
<td>Unweighted mean</td>
</tr>
</tbody>
</table>

1 Includes 105 fixes from 6 nights between 25 February and 15 April.
2 From 25 February to 15 April, 34 squares were used.

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if an objective method can be devised. We have derived maximum area figures by using a grid system in which the number of 6.4-acre squares containing at least one fix are summed (Siniff, 1966). This method usually yields acreages that are too large, so when such a figure is presented, it should be accompanied by one derived by totaling those squares which contain at least 1 per cent each of the total fixes for a period. Table 2 gives both figures for the two-week periods, and Fig. 3 illustrates them. The mean activity range of at least 1 per cent use for two-week periods was 153 acres, between extremes of 122 and 192 acres. Maximum activity ranges for the same periods varied from 147 to 352 acres, and averaged 254 acres.

The number of new 6.4-acre squares used by 616 during each two-week period generally decreased; during latter July only one square was new and during early August there were no new squares (Table 2). Thus 616 did not use the full extent of his range until more than five months had elapsed.

The maximum size of the composite activity range (Fig. 4) from 25 February to 12 August, based on 2,065 fixes was 608 acres, with the area in which each 6.4-acre square received at least 1 per cent of the use encompassing 154 acres. These figures consider only the amount of time spent during the nightly activity periods.

Intensity of Use

Location data were usually taken at equal intervals throughout the nightly activity periods, so if 10 per cent of all fixes fell in a certain field, it is assumed the animal spent 10 per cent of his active time in that field. The 2,065 fixes were analyzed on this basis for their distribution throughout the study area. The 6.4-acre grid system was applied, and the number of fixes falling in each square was tallied by computer.

The fixes fell in 95 contiguous squares (Fig. 4) averaging 21.7 per square, with a range of from 1 to 217 per square. The square with the highest use (11 per cent) was completely within the cornfield. Most of the squares with the next highest intensity of use either were near the cornfield or partly in it. Fifty-nine per cent of all the fixes occurred in a rectangle two by six squares, including part of the west fields, the cornfield, and the cedar swamp east of the cornfield.

Variations in intensity of use (Fig. 3) generally followed those in daily activity patterns. The square within the cornfield received from 5 to 16 per cent of the use during the eight two-week periods. Areas adjacent to this field also were utilized heavily during all periods. The cedar swamp was used much more intensively from 16 to 30 April and from 15 July to 12 August than during any other periods. From 1 to 15 May, it was hardly utilized.

Use of both the two-week activity ranges and the total activity range was distributed unevenly, with most squares being lightly used, and a few receiving very intensive use. For instance, 80 per cent of the use occurred in 37 per cent of the squares; while if the activity area were used with equal intensity throughout, 80 per cent of the squares would have received 80 per cent of the use. Curves of such relationships between area and intensity of use might be useful to characterize differences among individuals or species in manner of use of the range.

Acknowledgments

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References

ELLIS, R. J. 1964. J. Wildl. Mgmt. 28:363-68.