TELEMETRY AS A TECHNIQUE IN THE STUDY OF PREDATION[1]

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Abstract: Eight snowshoe hares (*Lepus americanus*) and five cottontail rabbits (*Sylvilagus floridanus*) were radio-tagged and tracked by an automatic system. Three of the hares, injured upon capture, lived an average of 2.3 days before being killed by predators. The remaining five survived for an average of at least 28.2 days. Of two uninjured rabbits killed, one was preyed upon within an hour after being disturbed; the other evaded predators for 24 days. Red foxes (*Vulpes fulva*) and owls probably were the main predators. Accounts of each instance of predation are given, including one in which both predator and prey were radio-tagged. The potential of telemetry for predation studies is emphasized, and suggestions are made for setting up such studies.

The use of radio transmitters attached to animals for studies of movements and behavior is now a standard procedure (Lemunyan et al. 1959, Marshall et al. 1962, Cochran and Lord 1963, Cochran et al. 1965). However, little use has been made of this technique for investigating predation and other mortality factors, although mention has been made of its potential in this regard by Marshall and Kupa (1963). These authors were able to locate four predator-killed grouse (*Bonasa umbellus*) and determine the type of predation in three cases. Recently McEwen and Brown (1966) used telemetry to study reactions of sharp-tailed grouse (*Pedioecetes phasianellus*) to insecticides. Through this technique they learned that at least three of their treated birds succumbed to predation.

This paper emphasizes the potential of telemetry for predation studies and presents predation information obtained via the technique. Data were obtained from January through March, 1964, incidental to investigations of snowshoe hares and cottontail rabbits. Information on a night's movements of a red fox were contributed by Alan B. Sargeant. Besides foxes, other predators probably involved were barred owls (*Strix varia*), great horned owls (*Bubo virginianus*), and large hawks. The study was conducted in cedar (*Thuja occidentalis*) and alder (*Alnus rugosa*) swamps on the Cedar Creek Natural History Area, 30 miles north of Minneapolis, Minnesota. A snow cover of several inches existed throughout the study. W. W. Cochran designed and built the transmitters and automatic tracking system.

METHODS

Rabbits and hares were captured in wire live traps, and tagged with radio transmitters of the Cochran and Lord (1963) circuitry embedded in a collar of dental acrylic (Mech et al. 1965). They were released where captured. Movements of the rabbits, hares, and foxes were monitored by the automatic tracking system using triangulation (Cochran et al. 1965). The average error found by Sargeant et al. (1965) where this study was carried out was 82 ft.

Data were recorded on movie film, and the film read in a microfilm reader several months later. A device allowing instantaneous display of data provided day-to-day information on the resting locations of rabbits and hares. When an animal had the same bearing intersect, or "fix," for several days, mortality was suspected, and field checks were made with a portable receiver

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to locate the individual precisely. Thus predation was not always detected immediately. When predation was discovered, I examined the sign in the snow to identify the predator, and then read the movement data on the film for the prey animal. In one instance the film data were also used to plot a fox's movements.

RESULTS

Ten snowshoe hares and six cottontail rabbits were radio-tagged, and data were received for eight hares and five rabbits. Information on the animals' presence in the population was obtained for 148 hare days and 102 rabbit days. Predators killed three snowshoe hares and two cottontails.

Snowshoe 207, a 3.5-lb male, was released on March 12 at 11:50 AM in an alder swamp. He had scraped much skin off his flanks, shoulders, and forehead while in the trap. On March 18, his skeleton, intestines, and much fur were found about 150 yards from the release point. "Whitewash" indicated that the predator was avian. The tracking system showed that the hare was dead by the evening of March 13.

Snowshoe 209 was a 2.6-lb male released in a cedar swamp at 11:11 AM on March 19. In the live trap, he had scraped fur off his flanks and forehead. Upon release, he ran about 340 ft away and remained there until 2:38 PM, when he began to move for the night. From 3:07 PM to 5:53 the next morning he remained in one location, about 1,000 ft from the release point. At 5:59 he reached the spot where we later found his tail and 12 square ft of fox tracks. From 6:47 to 6:49 AM, the transmitter moved about 120 ft away and remained there until we found it on March 25. Fox tracks connected these two points, so probably the fox took the transmitter-collar to its final location after having eaten most of the hare between 5:59 and 6:47 AM.

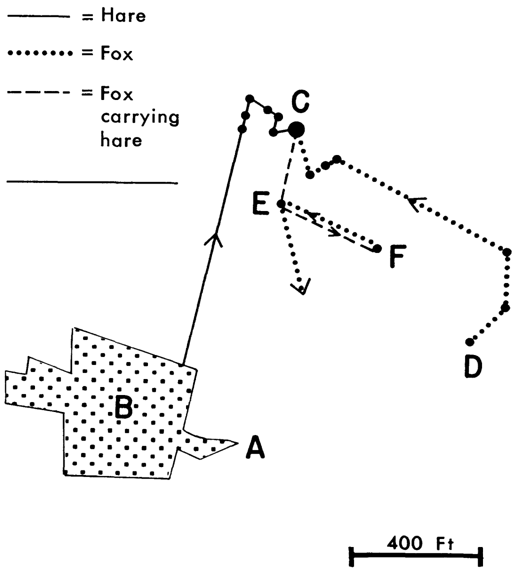

Fig. 1. Movements of a radio-tagged fox preying upon radio-tagged snowshoe hare 203. Large dots represent known locations; lines merely show sequence. (A) Hare captured and released here. (B) Area where hare stayed for next 4 days and nights. (C) Point where hare rested and was killed. (D) Point where fox was resting when he headed for hare. (E) Where fox took hare a few minutes after killing it, and remained several hours. (F) Where fox buried part of hare. Fox returned to (E), then left area.

Snowshoe 203, a 3.4-lb male, was captured, radio-tagged, and released on March 3 (Fig. 1-A). He had skinned his forehead in the live trap. The night of his release, the hare moved about 600 ft, and for the next 2 nights also restricted his movements (compared with unpublished data from other hares). On March 6 a field check showed that the animal had been foraging around a blown-down tree under which he was staying. On March 7 at 8:00 PM, the hare moved from where he had spent the previous 4 days (Fig. 1-B). He stopped for the night (Fig. 1-C) at 3:00 AM, on March 8, much earlier than hares usually do (Mech et al. 1966). Meanwhile, fox 2060 had been traveling in another area, but by 8:00 AM was resting approximately 1,000 ft from the hare (Fig. 1-D). At 10:48 AM, the fox

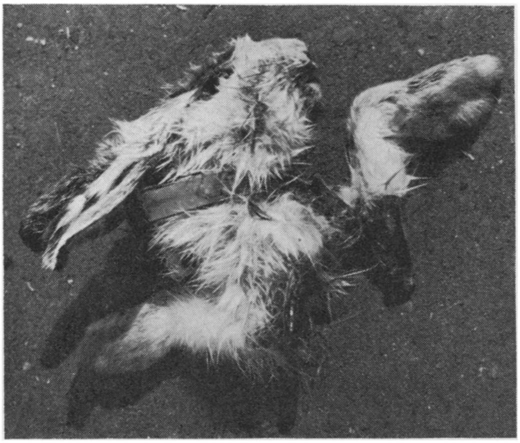

Fig. 2. Portion of hare buried by fox at point (F) in Fig. 1. Note radio collar.

headed toward the hare, and at about 11:02 caught it and probably killed it where caught, since photographed signals of both hare and fox were broken similarly—as though both radios were being shaken in a similar manner. By 11:06, the fox had carried the hare about 300 ft away (Fig. 1-E). Entrails and a small amount of rabbit hair were later found at the new spot. The fox rested there from 11:06 AM to 2:31 PM and then became active for the next 16 minutes at or near the spot. At 2:47 the fox carried part of the hare and transmitter (Fig. 2) about 400 ft away and buried it beneath 10 inches of snow at 2:52 (Fig. 1-F). At 2:56 the fox was back where the entrails were later found. He left the area at 3:01. The fox either ate the hare between 11:02 and 11:06 AM or between 2:31 and 2:47 PM, or at both times.

Cottontail 1 was a male weighing 2.8 lb, apparently in good condition. He was released on December 31, 1963, and was killed by a fox on January 23, 1964. The rabbit had spent the night moving around an area that he visited often. About 3:00 AM he reached the approximate location where his remains were later discovered. The last movement or activity of the transmitter-collar was at 4:53, so the fox must have killed the animal between these times. Tracks later showed that the fox had walked up to a sparse clump of alders, continued through the clump, and then killed the rabbit on the other side. There was no sign of a chase or intricate strategy by the fox. All that remained of the rabbit were cecal contents and a few hairs.

Cottontail 6, a male in good condition weighing 2.6 lb, was released on March 4, 1964. He traveled at least ¾ mile that night. The next day we jumped him from his form at 10:50 AM. The film record is unreadable for the next hour, but at 11:56 the rabbit was 400 ft away and was either being eaten by an avian predator or was about to be. By 1:51 PM, the transmitter-collar was lying still in the same location in which it was later found. The rabbit's fur and cleanly picked bones, when discovered, were scattered about in three areas 15 to 20 ft apart in an alder swamp. "Whitewash" was found on the bones and the snow.

DISCUSSION

The tracking system was still being developed when these incomplete data were obtained, but some information can be extracted from them. One striking point is that each of the three hares killed had sustained serious trap injury, whereas only one of the five surviving hares had been injured. All in this group survived for a minimum of 10 to 44 days. A second significant point is that the injured hares were killed so soon after their release. The three succumbing to predation lived an average of 2.3 days, whereas the surviving hares lived for an average of at least 28.2 days. Similar results were reported by McEwen and Brown (1966). They lost three sharp-tailed grouse to predators within a few days after the birds were treated with levels of insecticides which the authors believed might not have affected their survival under pen conditions.

The information presented above supports the concept that predators often take weakened prey, whereas healthy prey can survive for long periods in the same area.

With the cottontails the situation is less clear. Two of the three surviving individuals were in good condition, but the other had scraped his forehead in the live trap. All survived for a minimum of 14 to 36 days. Both cottontails that were killed also seemed to be in good condition. However, we had jumped one from his form only about an hour before he was killed, which may have put him at a critical disadvantage. The other did evade predators for 24 days.

Because relatively few individuals were involved in this study, no other generalizations can be made. However, it is apparent that a well-planned predation study using an automatic tracking system could yield much valuable information such as distribution of time of day prey is killed, cover types in which predation occurs, mortality rates, relative loss to various species of predators, and relative mortality to predation.

Comparing predation losses of individuals that have been experimentally impaired versus those of unimpaired individuals would be especially valuable. Impairment could be psychological, physiological (including ingestion of pesticides), pathological, or physical (including irradiation).

Most of the above information could be obtained by manual tracking systems such as those of Marshall et al. (1962) and Cochran and Lord (1963) if the study were planned correctly. The main considerations for such an investigation would be (1) radio-tagging a large number of a single prey species, (2) maximizing the life of each transmitter, (3) minimizing weight and hindrance of the transmitter and attachment, (4) monitoring the location of each individual every 12 hours, and (5) promptly investigating all suspected mortality.

A prudent choice of study area and species would facilitate the first consideration. Use of low-current-drain batteries would help maximize transmitter life (Kuechle 1967), as would pulsing rather than continuous-signal output. The weight and hindrance of the transmitter package could be minimized by further experimentation with existing attachment techniques.

To monitor a large number of animals every 12 hours, one could establish a system of receiving antennas throughout his study area, preferably on high towers. Since movement data are of secondary interest in a predation study, all that need be determined is whether each animal has changed position from the previous fixes. When an individual remained in the same position longer than usual, a prompt field check would be made.

Personnel of the Illinois Natural History Survey have suggested the development of a transmitter whose signal would change when an animal died, perhaps by monitoring changes in the animal's body temperature. Such a transmitter would greatly facilitate a predation study.

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QUANTIFIED ESTIMATES OF PREDATION BY A GOLDEN EAGLE POPULATION[1]

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Abstract: In south-central Montana, 702 prey items were recorded during a 3-year survey of 17–19 nesting pairs of golden eagles (*Aquila chrysaëtos*) on a 1,260-square-mile area. One pair of eagles brought an estimated 490 g of edible food mass per eagle per day to one nest during a 39-day period. An estimated 40–49 prey individuals were taken per eagle over a 100-day period for an average of 19–27 prey individuals taken per 10 square miles per 100 days by the total eagle population. The most important species were white-tailed jackrabbits (*Lepus townsendii*) and cottontails (*Sylvilagus audubonii* and *S. nuttallii*).

The purpose of this paper is to describe the food habits of a nesting population of golden eagles by giving a quantitative estimate of the number of each prey species taken during a definite period.

Early natural historians made the first attempts to quantify feeding and predation by golden eagles. In California, Finley (1906) estimated that one pair of eagles with two young would consume at least six ground squirrels a day and concluded they would kill 540 ground squirrels during a 3-month period. Cameron (1908) calculated that a pair of nesting eagles in eastern Montana could kill 636 prairie dogs within 4 months. Recently, more precise data on feeding have been gathered. Fevold and Craighead (1958) obtained values for the minimum food mass required to maintain the body weight of three captive golden eagles.

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