USE OF RADIOTRACKING TO STUDY FORAGING IN SMALL TERRESTRIAL BIRDS

PAMELA L. WILLIAMS

Abstract. Radiotracking can be used to study foraging of small birds (approximately 30 g and larger), often allowing a more accurate description of behavior than can be obtained by visual observation. I describe methods used to study foraging of Northern Orioles (*Icterus galbula bullockii*) during the breeding season and compare them with methods used in other radiotracking studies of small terrestrial birds. Transmitters revealed that nesting orioles foraged as far as 1 km from their nests, returning repeatedly to foraging sites 200–850 m away. Individuals from different nests within the same valley used foraging sites within the same general area and in some cases were found within the same patch of trees, sometimes simultaneously. These distant foraging sites, and this consistent overlap in foraging activity, were not discovered until transmitters were attached to birds.

Key Words: Radiotracking; Northern Oriole; *Icterus galbula bullockii*; foraging behavior.

Radiotracking is useful for studying the spatial and temporal distributions of the activities of individual animals because: (1) it allows studies of animals where detection might be difficult; (2) it can locate foraging sites that are distant from a central place (nest vicinity or roost); (3) it allows continuous observation of an individual to determine its use of different parts of its home range. Thus, it allows calibration of the amount of observational time at different sites so that it is proportional to the actual use at that site, and thus is less biased than observational methods.

Sampling of behaviors, as well as locations, may be improved by radiotracking. The ability to continuously follow and identify an individual avoids biasing observations toward conspicuous individuals or behaviors, a common problem (Altmann 1974). With radiotracking, an observer can detect with higher confidence differences between sex and age classes in foraging sites, substrates, and distances (see Grubb and Woodrey this volume), or follow the behavior of nonterritorial as well as the more obvious territorial individuals. The option to stay farther away from an individual also allows testing of the observer's effects on behavior and site use at different distances. Radiotracking can also directly detect simple changes in behavior. If a bird is not moving, the signal transmitted is constant, whereas when the bird moves the signal varies. Additional activities and orientations can be monitored by using simple radio circuits with variable resistors (Kenward 1987:39–43).

Reduction in the size and weight of the electronic components of transmitters and batteries in the last 20 years has allowed radiotracking of birds weighing as little as 29 g (e.g., Great Tits [*Parus major*; East and Hofer 1986], *Catharus* thrushes [Cochran et al. 1967, Cochran and Kjos 1985], and Brown-headed Cowbirds [*Molothrus ater*; Raim 1978, Dufty 1982, Rothstein et al.

1984, Teather and Robertson 1985]). The greater horseshoe bat (*Rhinolophus ferrumequinum*), which ranges in weight from 17–27 g, is one of the smallest species that has been radiotracked (Stebbings 1982).

I radiotracked the foraging activities of nesting Northern Orioles (*Icterus galbula bullockii*) at Hastings Reservation, Monterey Co., California. While many authors have described Northern Orioles as nesting and feeding on all-purpose territories (Grinnell and Storer 1924, Miller 1931, Bent 1958), I observed considerable overlap in space use among individuals of different pairs. For example, in a case where two pairs nested in the same tree, I observed at least nine individuals perching, foraging, and even singing there, although the nonresidents were not usually present at the same time as the resident pairs. Spacing of nests within a 100-m radius circle varied from solitary pairs with no neighbors to clusters of up to 13 pairs (Williams 1988), and I suspected that although the former pairs might have all-purpose territories, the latter did not. I used radiotracking to compare distances of foraging trips from the nest and the amount of overlap in foraging areas, if any, in relation to the density of nesting conspecifics. The technique was used because I could not otherwise locate an individual's foraging areas or determine if individuals overlapped on foraging sites. Using my data and a brief literature review I report here on data obtained by radiotracking that could not have been discovered by traditional observational methods.

METHODS

Equipment

The transmitter package was a Cochran design (Cochran et al. 1967, Wilkinson and Bradbury 1988) with a single-stage transmitter, battery (zinc-air, mercury 312, or silver oxide), and a stainless steel fishing-trace whip antenna. Transmitters were supplied by Bio-

track, Wareham, Dorset, England BH20 5AJ and AVM Instrument Co. Ltd., Dublin, CA 94566. Dental acrylic was used as potting to seal out moisture. A thin piece of cloth with a finished edge (seam binding) extending 2–3 mm beyond the transmitter was attached. This created a larger surface area for attachment of the transmitter to the bird. The joint between the antenna and the transmitter was covered by the manufacturer with heat-shrunk tubing, and I constructed a cone of silicone glue around the joint to further protect it from breaking. The transmitters came with 15-cm antennae, which I trimmed to extend 2–3 cm beyond the tail. Weight at attachment for transmitters from Kenward averaged 2.1 g (N = 9, range = 1.8–2.3 g); those from AVM averaged 2.7 g (N = 3, range = 2.4–3.0 g). Weights of the birds before transmitters were attached averaged 34.8 g (N = 12, range = 29–39 g), and the transmitters averaged 6% of body weight (range = 4.9–7.7%).

After I soldered the battery lead to the transmitter and completed potting over the solder joint, I located the frequency of the strongest signal and any weaker signals from the transmitter on each receiver. (Weaker signals may result from problems in transmitter construction; knowledge of them may be useful later in locating the signal if it shifts with time or temperature.) When possible, batteries were activated 24 hours before needed because early battery failures often occurred within that time and because shifts in signal frequency sometimes occurred soon after activation. I used three receivers of model CE-12 from Custom Electronics (the same as the LA-12 model from AVM). I located the signal on all receivers, because slight differences in fine tuning occurred between receivers.

Attachment

I attached the transmitter while an assistant restrained the bird; placing the toe of a baby's sock over the bird's head calmed most individuals. I weighed the bird and the transmitter before attachment to closely monitor the effects of the relationship between transmitter weight and individual behavior. The transmitter was then placed anterior to the articulation of the humeri, as high on the back as possible without interfering with the movement of the head (see illustrations in Cochran et al. 1967, Raim 1978, Perry et al. 1981). Transmitters were attached to six birds with contact cement and to 11 birds with cyanoacrylate glue. Feathers in an area slightly larger than the transmitter were trimmed to a length of 1–2 mm and the area was cleaned with acetone or alcohol. Trimming the feathers rather than removing them prevented stimulation of the growth of new feathers that would push the transmitter off. Before releasing the bird I again located the signal on the receiver to confirm that the frequency had not shifted during attachment.

Following the bird

Immediately after release, many newly radioed Northern Orioles flew to a nearby hillside and foraged there for several hours. All birds had resumed normal behavior patterns after 3–4 hours and showed no difficulty in flying or other activities. Although I usually followed the birds immediately after release, only data collected at least three hours after release were analyzed. By that time I was aware of no differences in behavior due to the transmitter. I followed individuals

on foot, carrying a receiver and three-element Yagi antenna (see Mech 1983 for details on methods of following animals).

RESULTS

SUCCESS OF METHOD FOR NORTHERN ORIOLES

The five radio-tagged, nesting females I followed in 1984 returned in 1985 and four of these again nested on the study area. I recaptured two about a week after they had lost their transmitters. They had lost the feather quills where the transmitter was attached but the skin appeared healthy. I recaptured one of these birds in 1985, and she showed no evidence of the previous year's transmitter attachment. Four of the five nesting females tracked in 1984 and six of nine nesting females tracked in 1985 successfully fledged young, while the average nest success in these years for the study population was 62% (N = 42) and 68% (N = 34), respectively (Williams 1988). I did not monitor the return of individuals in 1986, but I believe these results indicate that the transmitters did not adversely affect survival and reproduction.

I placed transmitters on 17 females and gathered sufficient data to analyze movement patterns of 13. I was able to follow birds an average of 9 days (range = 3–15 days; SD = 4 days) before either the battery failed or the transmitter fell off.

The average life of batteries active for more than 24 hours was 11.9 days (N = 13, SD = 8.0 days). One transmitter retrieved after 13 days was monitored until the battery failed after 35 days. The zinc-air batteries had a higher failure rate than the mercury batteries within the first 24 hours after being activated.

It was not always possible to tell if a female was still carrying a transmitter after it stopped working, because it was preened into the feathers, with only the antenna remaining visible. Five transmitters attached with contact cement remained attached for 14 ± 8 days SD, whereas 10 attached with cyanoacrylate glue stayed attached for 16 ± 18 days SD. Two (one attached with each type of glue) that fell off after two days were recovered and re-attached to the same individuals for 13 and 14 days. In most cases the attachment lasted longer than the battery. This was especially true using cyanoacrylate glue, with two females carrying their transmitters a minimum of 42 and 55 days.

Using hand-held equipment, I was able to detect line-of-sight distances up to 1 km. The signal from a bird on the ground could be detected from about 300 m.

DISTRIBUTION OF FORAGING SITES

Assuming that the movements of nesting females were primarily influenced by food avail-

ability, and that females would minimize the distance traveled from their nests, I compared the spatial distribution of foraging sites of females to the density of conspecifics near their nest site. Observations along yielded little information. I located dispersed pairs readily when they were near the nest, but only rarely after they left the area. Where nests were clustered, it was easier to locate a foraging individual, but it was not possible to follow a particular individual or relocate it on enough occasions to adequately describe its foraging area. Soon after departing the nest individuals usually disappeared into dense foliage or over a hill, occasionally flying directly out of sight. Given that I was often unable to locate birds foraging, I could not know whether they were present and camouflaged or had left the nest area. Although I observed birds from different pairs foraging sequentially in the same tree, and sometimes even simultaneously with a minimum of aggressive interactions, it was not possible to determine whether these were rare or common occurrences.

Using transmitters I discovered that individuals sometimes foraged undetected in the canopy of a tree for as long as an hour and that they could enter or leave a tree undetected. They sometimes appeared to move only to the next tree or over a small hill but were located next at sites up to 1 km from their nests. I found no consistent association between the direction they departed from the nest and the direction of their destination. In the first month after their arrival in the spring, I discovered that the orioles abandoned their nesting areas during cold or rainy weather and spent whole days on nearby hillsides, sometimes with other individuals in the same tree, as well as occasionally making trips of several hours duration to sites at least as far as 1 km from their nests. Only by using transmitters was I able to determine the proportion of time females spent foraging at different sites, the distance traveled from the nest to foraging sites, or whether there was overlap in foraging areas among different females either sequentially or simultaneously.

During incubation I followed seven females, two in 1984 and five in 1985, for varying numbers of days. I used three 3-hour samples from different days to compare foraging by these females. Because of considerable individual variation in movement patterns, even among females nesting at the same density, I have presented data for each female separately (Fig. 1). Each female spent on average 2 hours of a 3-hour watch in her nest tree ($\bar{X}$ = 128 min, SD = 13 min). Females foraged farther than 200 m from their nests between 10% and 92% of the time. Four of the seven females spent more than 50% of their foraging time at these distant sites.
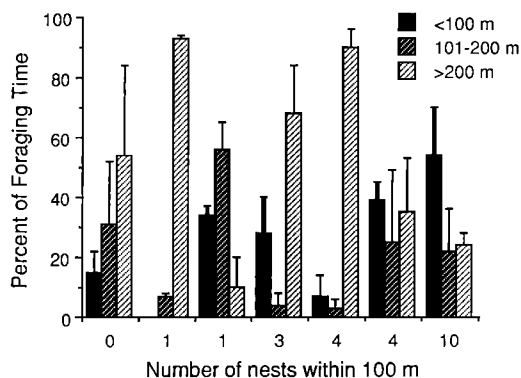

FIGURE 1. The relationship between nest density and proportion of foraging time spent at increasing distances from the nest for incubating female Northern Orioles at Hastings Reservation during 1984–1985. Each set of three bars represents the mean and standard error from three 3-hour observations of one female, with the density of nests within a 100 m radius around her nest on the X axis below the data for each female. The first of two females nesting with one nest within 100 m is represented by only two bars because she was not observed foraging less than 100 m from her nest.

Of the three females that spent less than 50% of their time at distant sites, one spent 58% foraging 100–200 m from her nest, whereas the other two did almost half of their foraging (40% and 54%) within 100 m of the nest. The two females with only one other pair nesting within 100 m spent 92% and 10% of their time foraging more than 200 m from their nests. A similar contrast was noted between the two females with four neighboring pairs, who spent 90% and 35% of their time at distances more than 200 m from the nest. The variation in distance to foraging sites between females nesting at the same density, and the lack of correlation between foraging distance and nest density, suggest that density of conspecifics near the nest was not an important determinant of foraging patterns. Although this conclusion is only tentative because of the small sample size, the fact remains that I would not have known about foraging sites beyond 100 m from the nest without the use of telemetry. This would have eliminated more than 53%, on average, of the foraging time of these females.

Between 5 and 23 May 1985, I tracked six females, each for a varying number of days. Four were incubating, one nest building, and one laying. This revealed extensive overlap in foraging sites among five females nesting in a valley within 0.5 km of each other, but solitary foraging by the sixth female nesting on a ridge over 0.5 km from the nearest nest in the valley (Fig. 2). This female, nesting 230 m from her nearest neighbor, did more than two-thirds of her foraging 200–
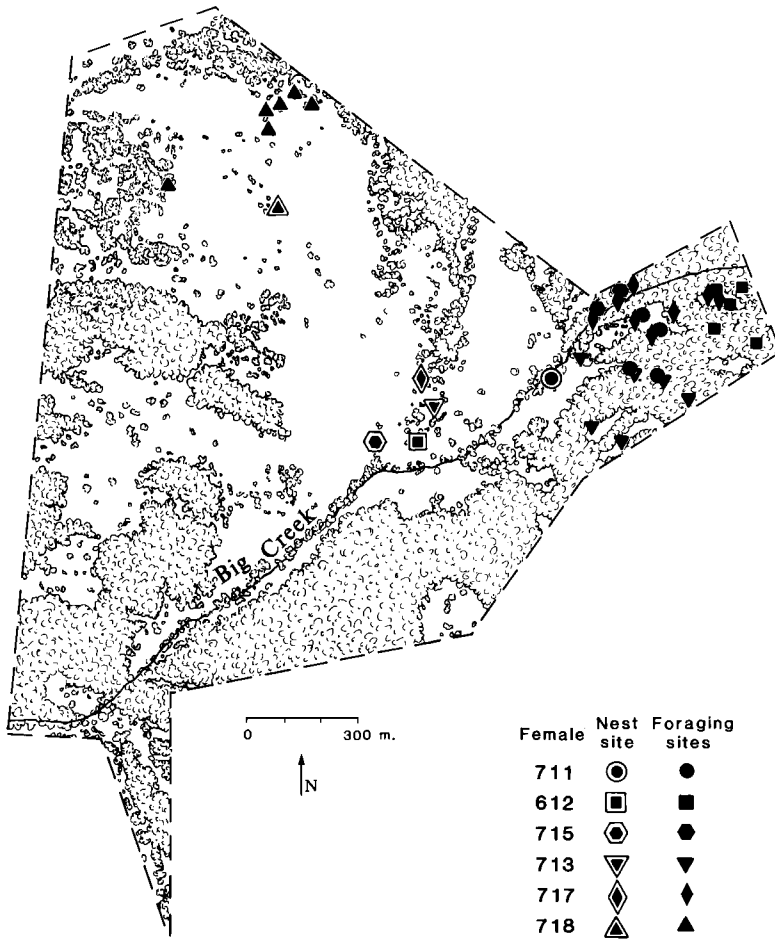
FIGURE 2. The study area at the Hastings Reservation showing nest sites and foraging sites of six female Northern Orioles tracked for different numbers of days each between 5 and 23 May 1985. Nest sites of additional orioles present in the same season are not shown. Big Creek runs through a lowland area with terrain rising both to south and north as well as along the creek east of nest site 711.

320 m from her nest, by herself or with her mate. In contrast, the females nesting in the valley overlapped considerably in foraging areas. They did the majority of their foraging at sites on Buckeye Hill and in neighboring ravines at the north end of the valley, flying 200–850 m from their nests to these sites. While these five birds overlapped in general foraging area, they also sometimes overlapped in exact foraging sites. Thus, females 711 and 713 foraged near each other in neighboring trees on one occasion, and female 612 left a foraging site just before female 717 arrived at that site. It was more common to detect sequential overlap in foraging sites, as evidenced by other observations of these same females. Additionally, female 717 was observed overlapping sequentially with females 715 and 711. While at these foraging sites, I could usually see or hear a number of other Northern Orioles, either on the sites or flying overhead up and down the hillside or ravine. In a few cases I could identify banded individuals in addition to the birds with transmitters. The only way I could monitor the females at this time was by following their signal and seeing them fly in and out of an area. They left their nests in a variety of directions, giving no visual cues of their final destinations. While foraging they were hidden from view in the canopy. Without the use of radiotracking I would never have discovered this considerable overlap in foraging areas.

DISCUSSION

Contrary to the prevailing view regarding spacing in breeding populations of orioles (e.g., Lowther 1975, Orians 1985a), Northern Orioles

in this study were not consistently territorial. This is shown by clustered nests and by radiotracking data, which showed (1) significant overlap in foraging areas of breeding birds, and (2) recurrent use by the same individuals from one breeding area of a localized foraging area. The latter suggests some form of communication among these individuals. Their nesting dispersion and feeding overlap remind one of other icterids such as the Brewer's Blackbird (*Euphagus cyanocephalus,* Horn 1968).

The occurrence of dispersed as well as clustered nesting in the Northern Oriole may vary geographically (see Pleasants 1979, Williams 1988). A contributing factor in central California is the seasonal summer drying and local uncertainties in insect food levels. Thus, overlap in foraging is not surprising.

OTHER SPECIES

Radiotracking has been used mainly to determine home-range size and to follow social behavior (e.g., Bradbury 1977, MacDonald 1978, Marquiss and Newton 1981, Pruett-Jones 1985, Wilkinson 1985, Wood 1986), but is now being used increasingly for foraging studies to obtain information that is not available by observation alone.

East and Hofer (1986) found that Great Tits foraged intensively at small patches interspersed among similar-sized areas of low use. This confirms laboratory studies showing that Great Tits concentrate foraging in areas with high food density while continuing to appraise food availability elsewhere. The two territorial males they followed ranged over substantial areas outside their territorial boundaries, foraging on the territories of other males. The single nonterritorial bird also ranged over a large area. "Radio signals suggested that Great Tits spent a large percentage of their time during the late morning and afternoon foraging near the ground in dense vegetation, explaining why Great Tits are so difficult to observe after an active period following dawn" (East and Hofer 1986).

The Woodcock (*Scolopax rusticola*) is an elusive and secretive species. Using radiotracking, Hirons and Owen (1982) established that in winter and early spring birds foraged mainly in pastures at night, returning to woodlands during the day. As nights got shorter, the birds switched to feeding in woodland during the day and roosting at night. As with Great Tits, individual Woodcocks used intensively only small patches within preferred habitat, and these were areas where earthworm densities were highest. Hirons and Johnson (1987) found no evidence that Woodcocks preferred swampy patches, as described by other authors, e.g., Cramp and Simmons (1982).

Nesbitt et al. (1978) found a consistent pattern of foraging movements for three groups of Red-cockaded Woodpeckers. By placing a transmitter on one bird they followed the daily movements of all clan members along a 1.9-km foraging path. Each clan began moving and feeding soon after leaving the roost hole in the morning and moved quickly until late morning or early afternoon, reaching the farthest distance from the roost, 0.72 km on average, early in the afternoon; they returned in the late afternoon, sometimes in one direct flight.

Radiotracking of two species of brood parasites, Brown-headed Cowbirds and the Common (or European) Cuckoo (*Cuculus canorus*) supported qualitative information that these birds have separate breeding and feeding ranges. Wyllie (1981:96) found that cuckoos moved 4 km between breeding areas in reed beds and feeding areas in orchards and scrublands. Several males and females used the same feeding areas, although foraging was usually solitary. Rothstein et al. (1984) found that Brown-headed Cowbirds spent the early mornings on breeding areas, and in late mornings and afternoons flocked at favored feeding areas. Females visited fewer feeding sites, traveled shorter distances between sites, and spent more time at feeding sites than males. Some males commuted between disjunct breeding and feeding sites; others stayed at feeding sites all day.

Common Grackles (*Quiscalus quiscula*) at three roosts in Oklahoma foraged on successive days at sites an average of 11.9 km apart, and did not always return to the same roost (Bray et al. 1979). European Starlings (*Sturnus vulgaris*) wintering in Oregon also foraged at different sites each day, although they returned to the same roost each night. The average distance between sites used on succeeding days was 4.8 km (Bray et al. 1975). In contrast, in New Jersey this species used several roosts, with individuals using up to five during the 4-month study, while each bird returned regularly to the same diurnal activity center (Morrison and Caccamise 1985). Multiple roost sites may have been used to exploit rich sources of supplemental food near those roosts, while maintaining foraging territories in areas of persistent food abundance.

CONCLUSIONS

Radiotracking allows the gathering of important qualitative and quantitative information on the foraging activities of individuals that could not be discovered otherwise. Large amounts of data can be accumulated, albeit on a small number of individuals. However, the procedure is both expensive and time-intensive, and equipment failures are not uncommon. Using auto-

matic monitoring equipment can save considerable time, but at great initial expense and loss of direct observations of behavioral details, and the procedure is not appropriate for all studies. Despite these problems, radiotracking is an important component of thorough modern studies of resource use in avian populations.