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TELEMETRY IN STUDIES OF PREDATION, DISPERSAL AND DEMOGRAPHY

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General structure of a radio-telemetry study can be divided into four stages:

Stage 1—acquiring equipment
Stage 2—capturing and marking animals
Stage 3—developing field techniques
Stage 4—analysis

Each stage should be considered before starting a project, as each affects the others. Many projects fail from lack of adequate field techniques. Reliable equipment and transmitter attachment are essential (see Mark Fuller's summary in these proceedings). Care taken in selecting equipment and in hiring personnel will yield better data. Personnel comfort, especially at night or under extreme conditions, improves resulting data and lengthens lifespan of field workers. Be sure you can capture enough of your animals and that you can follow them adequately. A good road net or dependable aircraft to decrease travel time is necessary when following many animals. A large travel budget will also be needed. A pilot study is very helpful, especially to estimate costs: it is painfully easy to underestimate travel costs, forcing curtailment or premature termination of the study when funds run out.

The role of experience in telemetry studies cannot be overestimated. It is obvious that new personnel must be given time to learn to track animals, but it is less obvious that tracking large numbers of animals for dispersal and survival studies requires different skills from those used in studies of individual behavior or predation. Telemetry studies tend to evolve as they continue, and there must be time for this evolution. Data collection is seldom satisfactory until the second or third study season. Flexibility of study design is advisable as you gain experience in field techniques and refine your study questions. Analyze your data as you progress, and discuss results, so that changes in data gathering can be made as new ideas and questions arise. The final ingredient, luck, is unfortunately stochastic and difficult to obtain on short notice. But it does help.

Predation Studies. Predator-prey interactions can be studied by marking either the predator or the prey. If behavior and predation of one predator is of interest, or if many fresh kills must be examined (e.g., for selection effects), marking the predator is indicated. If a guild of predators is of interest then it may be best to mark prey. Recording each kill adequately will be more difficult, and kills may be attributed to a scavenger rather than the real predator.

In studying Goshawk (*Accipiter gentilis*) predation on Wood Pigeons (*Columba palumbus*) it was easiest to mark the Goshawks. Following individual hawks gave data on time spent in various habitats, detailed movement along search paths, types of prey taken and kill rate. Analyzing fresh kills for selection effects showed that Goshawks tended to take pigeons with below average weight, except when prey were taken completely by surprise (Kenward 1976).

After discovering that Goshawks remained for long periods at or near large kills, and learning radio signal cues which indicated a kill, several hawks could be monitored concurrently when studying predation on pheasants (*Phasianus colchicus*) in Sweden; most kills of 250 g or larger could be recorded by checking each hawk at one hr intervals. Fewer behavioral data were obtained than when following individual hawks but larger samples of kills and of predation rates were obtained from different hawks. Radio transmitters were also used to estimate hawk density, since the number of transmittered hawks in the area was known, and each hawk seen could be checked for the presence of a radio much more easily than for a visual marker. Combining average kill rates with hawk numbers gave an estimate of predation impact on censused Pheasant populations in several different areas. Diet differences between hawk sexes, and differential prey selection were also studied, most recently with the aid of a radio tag that indicates when a hawk is feeding (Kenward et al. 1981a,b.).

Sociality and Range Use. When recording ranges to estimate habitat use or sociality, minimizing number of fixes required to estimate range size or structure saves much work. If range size is plotted after each consecutive fix for a number of individuals, the area will first show a rapid observation-based increase as the animal is recorded throughout its normal range. A plot then reaches "sampling saturation," after which recorded range size increases represent continuing small increases in area covered by an individual animal. For grid-cell-based analyses it often takes 200-300 fixes to reach sampling saturation, but studies of three species [Goshawk, Badger (*Meles meles*) and Grey Squirrel (*Sciurus carolinensis*)] have shown saturation for outline ranges (convex polygons) in 30-40 fixes.

Convex polygon areas can be dramatically increased by occasional excursions outside normal core areas. Nonparameteric clustering or isoline techniques give a better fit to fixes and make fewer assumptions about spatial distribution than earlier bivariate parametric techniques for estimating probabilistic core areas (e.g., probability circles and ellipses) (see Vicky Meretsky's summary in these proceedings). Core areas can be found by inspecting for a drop in variance coefficient as size decreases along a multi-range utilization distribution; the core includes percentage of fixes which give greater similarity between individual ranges than at larger range sizes.

A sampling regime of three daytime locations plus a roost gives saturation in 10 d for Goshawk maximum convex polygon winter ranges. Contrary to popular opinion, hawks showed little territoriality in winter and gathered with their core areas overlapping at Pheasant farms and other sites with local prey abundance.

Dispersal and Demography. For dispersal and mortality studies, it is essential that transmitters are reliable and do not adversely affect their carriers. After five years of predation studies, Goshawk transmitters had evolved to 1500 mA Li/CuO_2 cells powering single-stage transmitters for 9-12 mo. Tail-mounted tags gave 3-5 km working ranges across flat ground and 10-20 km from high vantage points or aircraft. Recapture rates and weights had been similar between radio-tagged and banded birds (Kenward 1978). Unfortunately, tags could not be tail-mounted on nestlings. Nestlings were equipped with leg-tags and caught 10-20 d post-fledging for tail-tagging, all of which involved development of satisfactory leg tags (which were very prone to antenna breakage) and capture techniques near the nest (Kenward 1985).

My study was done on the 30 000 km^2 Baltic island of Gotland, which has little emigration or immigration of hawks. Location and survival of 30 juvenile hawks and 20-30 adults tagged each year were checked mainly at night, because live hawks were then in trees and thus unlikely to be overlooked due to poor signals while feeding on the ground. When several hawks had been lost, the island was searched from the air.

Dispersal date was linked to hawk sex and local food abundance. Hawks tended to remain the least time around nests where and when food was scarce, especially the males, but remained longer at such nests than elsewhere when artificially fed. Dispersing juveniles quite frequently parasitized other fledged broods, especially in prey-rich areas and in years when prey elsewhere was scarce. Mortality was surprisingly low the first autumn, and much less than suggested by banding studies, with a peak of juvenile and adult mortality at the end of winter. Movements have been linked to local abundance of rabbits, an important prey on the island (Kenward, Marestrom and Karlbom, in prep.).

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