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EXPERIMENTAL DESIGN OF TELEMETRY PROJECTS

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In its short life radio telemetry has progressed from a "fascination" stage characterized by small studies of poor design based on unrealistic expectation to a stage of more sober reassessment. At present we are seeing studies of possible problems involved with telemetry, composite studies which test telemetry against other techniques and a general atmosphere of more cautious expectation. In the future we can hope to work with telemetry as a thoroughly researched tool with known strengths and weaknesses for which accompanying texts and sound analysis techniques are widely available.

Telemetry studies are generally costly and therefore tend to be multipurpose so that many questions can be addressed from one data set. This in turn leads to tradeoffs among sample size, accuracy of location, frequency of location, etc.

In developing telemetry studies four points should be addressed to help ensure that the results are meaningful and may be analyzed as intended.

1) **Define the experimental unit.** Some studies will seek to analyze bird-days of observation, others will be concerned simply with the number of birds. The former contains a degree of ambiguity as one bird followed for 20 d, 20 birds followed for one d or five birds followed for four d will all yield 20 bird-days, although there are important differences in conclusions made from each data set. Defining the experimental unit as one bird avoids ambiguity.
2) **Attempt to insure that study animals are randomly selected from the population to which you wish to make inferences.** Basically, the trapping technique should be unbiased as to age, sex, size, habitat type, etc., within the chosen population.
3) **Try to estimate the replication the study will require** (see pilot study in QUESTIONS).
4) **Determine what, if any, type of stratification you will employ** (see pilot study in QUESTIONS).

Inappropriate or insufficient experimental designs can be difficult to detect or remedy, but a number of them can be found in the literature. Mortality studies are often characterized by inadequate sample size and questionable experimental units. Customarily, survival on any given day is assumed to be independent of survival on any other day, although this assumption is not tested. Similarly, home-range studies also suffer from inadequate sample sizes, both of animals and of animal-locations. If a study is designed to produce inferences for all age/sex classes, it must have adequate representation of each of those classes. Home-range estimates are dependent on the time frame of the study and on sampling intensity. If either time frame or sampling intensity is increased, estimated home-range size will also increase. In general researchers seem to have an insufficient understanding of the concept of home-range and of how the picture of home-range changes depending on the study framework. Hopefully, continued work on this problem will lead to a better definition of home-range.

As a brief experiment in study design tradeoffs, let us look first at a mortality study designed to quantify overwintering survival. In order to cover all age/sex classes you probably need 50–100 animals even to consider beginning the study. The good news is that you probably only need to locate the animals once each day, or with long-lived species perhaps once each week. Even with the decreased observation intensity, such a study may be impractical for many species.

Now let us look at an activity study designed to quantify activity patterns between and within days Initially we have several options, three of which are listed below.

Design 1: one bird followed for 40 d with 16 locations/d.
Design 2: 40 birds followed for one d each with 16 locations/d.
Design 3: 10 birds followed for eight d each with 16 locations/d.

The first two designs are extreme and inappropriate. Design 1 looks only at one bird, so there will be no way to estimate the variance of activity patterns among birds. If you study an abnormal bird, you could generate an array of misleading information, and if you study a normal bird you will still have no way of estimating the range of normal behavior.

Design 2 looks at each bird for only one day, so there will be no way to estimate the variance of activity patterns between days. You can estimate the variance between birds and between days (assuming you did not follow all 40 on the same day) together, but you cannot estimate the effect of only bird-to-bird differences or of only day-to-day differences. Design 3 is one possible compromise: an intermediate number of birds, days and locations which would permit estimates of all variances of interest. However, optimal balance among birds, days and locations is complex and can only be determined using a good pilot study.

Costs will invariably affect study design, as will time needed to switch between animals and many other nonstatistical concerns. So even for a fairly straightforward question, such as the activity pattern experiment above, determining the best design can be difficult.

As the previous examples illustrate, some study designs will be incompatible with each other. We could not run a mortality study and an activity study simultaneously without going to very great expense: one requires many animals with few observations/animal/time, the other requires few animals but more observations/animal/time. Two additional problems occur with activity studies. Missing values can require increased complexity in the analysis, so it is best to develop a regular sampling framework which is always achievable. Secondly, the interdependence of locations which are close in time is a statistical problem only now being addressed. Many home-range analyses assume that all animal locations are independent of each other, although many study designs produce dependent locations. Pantula and Pollock (1985) presented a time-series approach to this problem.

One plea here from the statisticians: please do not overvalue lots of data on few animals. Many times a good design will be too costly to achieve and the biologist will continue anyway in the hopes of gaining at least some useful information. While this is certainly not a waste of time, writers should acknowledge limitations of their results and avoid making far-reaching statements from scanty data. To date statisticians have been only occasionally involved in telemetry analyses. Telemetry lends itself to tailored analysis techniques due to its specific problems and approaches. More statisticians should become involved so that analyses can become effective and available.

QUESTIONS

Re continuous monitoring of animals vs. distinct locations at known time intervals: in general too much data is generated from too few animals. Often no additional information is gained by much additional observation. However, in specific cases it may certainly be appropriate to monitor continuously, as when the exact duration of a given activity/movement is of interest.

Re the effect on mortality estimates of bird/day units vs. bird units: estimates of mortality made using bird/day units will be unbiased, but the estimate of the variance will be too small.

Re the gathering of lots of information/bird: if the goal is to describe the activity of one or a few animals without making inference to a population, then small numbers of animals are not problematical. But if your goal is statistical inference from a sample to a population, then fewer data on more animals is better. Of course lots of data on many animals is best of all but seldom practical.

Re pilot studies: the problem of adequate sample size is best addressed by a good pilot study which can provide an estimate of variability of variables of interest. Pilot studies also permit estimates of cost, time, personnel needs, etc., and can save time and money in the final study.

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