I) Analysis of Radio Telemetry

Radio telemetry data obtained with homing or triangulation methods can be used to estimate home range, resource selection or survival rates. Radio telemetry data allows managers and researchers to determine "precise" (depends) location for an individual animal over time, observe behavioral characteristics such as movement and space use, and to identify cause and time of death. Let's examine the design issues, data collection, and analysis for home range estimation.

II) Data – Radio telemetry data allows researcher to identify an animal's use of space over time

1) **Home range** is considered the "area traversed by the individual animal in its normal activities of food gathering, mating, and caring for young" (Burt 1943). The home range is believed to contain many of the essential requirements for an animal, such as food, cover, and water. A **territory**, in contrast, is usually defined as the defended part of the home range.
2) **Core Area Use** - internal use of the home range showing the area of concentrated activity, sometimes considered the non-random use of space within the home range.
3) **Utilization Distribution** – probability density function of locations used to assess an animal's probability of occurrence at each point in space (Worton 1987). Used to evaluate home range as well as intensity of use within the home range.

III) **Data and Design Issues for Home Range estimation using radiotelemetry data**

1) Home range estimation using telemetry involves two levels of experimental units – individual animals and measurement of each animal's movement over time. This leads to a two-stage sampling process: 1) select a random sample of animals from the population of interest for capture and "tagging" with a radiotransmitter, and 2) sample each radio-marked animal at some regular frequency, allowing for temporal and spatial independence among subsequent telemetry locations.
2) Spatial data (based on telemetry) used for home range estimation are 3-dimensional – they have attributes of latitude (x-coordinate), longitude (y-coordinate), and time. Locations are given by x_i, y_i coordinates (they are bivariate) where *i* represents time.
3) Because of the time-dependence in area traversed, home range is only a meaningful concept when referenced to a particular time period (e.g., home range during the breeding season; annual home range).
4) Home range estimators are sensitive to sample sizes used to construct estimates. Important to assess required sample size so that results of study can be attributed to biological differences, not the sample size used. General rule for most home range estimators is >50 independent locations recorded per individual in order to be reliable, though this is quite variable. Can use area-observation curve to assess sample size to determine at which point additional locations do not result in increase estimate of home range size (Odum and Kuenzler 1955). Area-observation curves can be created by sequentially removing (or adding) animal locations to see how sample size affects home range size.

IV) Assumptions of Radiotelemetry data

1) **The effect of transmitter on animals is negligible**
   - Assume that by placing transmitter on (or in) an animal, that the behavior, risk of predation, and physiological demands on that animal is not different from non-tagged animals.

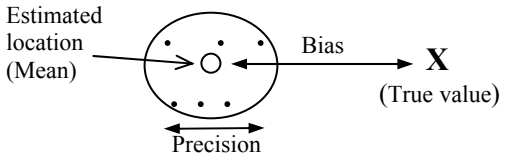
- Effects of transmitters can include hair or feather loss, entanglement, impaired movement, impaired foraging, disruption of breeding behavior, increased metabolic costs, increased risk of predation.
- Complete telemetry studies should include an assessment of effects of transmitters on subjects. Difficult to test because transmitters usually used to make observations that are difficult or impossible to make otherwise. One approach is to compare behavior of tagged individual to untagged mate. Another approach is to compare behavior of tagged bird at nest versus untagged bird at nest as has been done with Prairie Falcons where saw no effects on behavior for nest attendance, prey delivery, or prey catching (Vekasy et al. 1996).
- General recommendations to decrease effects of transmitters on animals: use smallest transmitter possible (3% rule ratio of transmitter to body mass for birds and small mammals), allow time for acclimation, avoid tagging during breeding season, accurately fit harness.

2) Locations are temporally independent

- Definition: location of individual animal at time t is independent of its location at time t+1.
- Temporal independence requires that subsequent observations be spaced in time. If radio telemetry locations too close together in time, called dependent or autocorrelated (data is redundant).
- Temporally dependent data may cause the daily distance traveled, as well as the home range, to be underestimated.
- Decrease autocorrelation by increasing the time between locations. Conceptually, as the time between locations increases, the degree of autocorrelation decreases.
- Theoretically, there is a time interval when successive observations are not correlated. Assess minimum "time to independence" by randomly selecting a few animals for continuous monitoring to evaluate how long takes to cross largest part of home range, then space relocations at intervals sufficient to allow the animal to traverse its entire home range.
- Problem: restricting sampling effort to ensure statistical independence may sacrifice biological significance. For example, it may not be possible to get enough relocation data to achieve temporal statistical independence and still be able to make biological conclusion. If the study is infeasible, important to know this before start the study. Generally need to balance the importance of temporal independence with the study objectives.
- Generally good idea to use systematic sampling for relocations (some specific time interval such as once per day) to try to achieve biological significance as well as eliminate temporal bias.
- This assumption can sometimes be relaxed as methods do exist to handle autocorrelation. Why? Because we are often interested in the dependence of the locations, i.e., we'd like to no what an animal does sequentially. It might be important from a behavior point of view or to adequately delineate an animal's home range.
  (i) These methods often focus on each animal as the experimental unit or a replicate and the series of movements of each animals are then considered to be independent of other animals.

3) **Locations are spatially independent**
   - Definition: one individual animal's position does not influence another individual's position.
   - Problems can arise when movements and habitat use of one animal affects the movements and habitat use of another animal, e.g., a mother with young, mated pair, herding animals, or territorial animals. Spatial independence is violated whenever two radio-tagged animals are together at the same time and space.
   - When assessing spatial dependence, try to evaluate whether individuals are inherently reliant on each other for survival, or whether animals may occur together due to favorable habitat conditions.
   - Spatial independence requires that you use (analyze) only one randomly selected observation from a dependent group, such as only one individual from a family group or mated pair whenever possible. For example, some studies only radio 1 individual of a family group. This may reduce sample size. Try to distribute transmitters in a random, yet biologically independent manner (not just statistical independence, biological independence also important).

4) **Location estimates are unbiased and precise.**
   - To evaluate bias and precision use a "beacon" study. Get estimates of transmitters in known locations (Estimated locations are dots, while the true location is the circle at the center. The average of the dots ideally is unbiased and precise.):



   - Bias: distance between estimated location to true location (requires a beacon test).
   - Precision: Bearing error defines confidence intervals around location estimates.
   - Precision defined by "error polygon": intersection of two 95% CI's around estimated bearings, each representing 1.96 (SE) of bearing.
   - Precision improves as increase the number of receiver sites. Big increase in precision from 2 to 3 sites. Important to optimally allocate receiver sites.

References:

Bookhout, T. A. (editor) pages in: Research and management techniques for wildlife and habitats, 5th edition. The Wildlife Society, Bethesda, Maryland.

Burt, W. H. 1943. Territoriality and home range concepts as applied to mammals. Journal of Mammology 24:346-352.

Odum, E. P., and E. J. Kuenzler. 1955. Measurement of territory and home range size in birds. Auk 72:128-137.

Vekasy, Marzluff, Kochert, Lehman, and Steenhof. 1996. Influence of radio transmitters on Prairie Falcons. Journal of Field Ornithology 67:680-690.

White, G. C., and R. A. Garrott. 1990. Analysis of wildlife radio-tracking data. Academic Press, London.

Worton, B. J. 1987. A review of models of home range for animal movements. Ecological Modelling 38:277-298.