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BASIC TECHNIQUES FOR ANALYZING MOVEMENT AND HOME-RANGE DATA

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Circular Statistics for Movement, Migration and Dispersal Data. Data collected using radio telemetry may comprise daily flight lines of a migrating bird, overall dispersal lines of a cohort of juvenile animals from natal locations to their locations at some later time or some other collection of line segments. Important qualities of data are direction and distance of movement, which are represented as vectors. Often, one may wish to analyze vector length separately from vector direction. Movement distance may be related to age, sex, weight, weather, etc., while direction may be related to guiding lines, prevailing winds, latitude, etc. (Heintzelman 1975). Distance (length) can be analyzed using standard statistical techniques. Direction, however, often cannot. Consider two dispersing individuals, one on a heading of 359°, the other on a heading of 1°. Intuitively, the average is 0° (i.e., due north), but standard math tells us the average is 180°. Likewise consider 0°, 120° and 240°, which divide a circle into thirds. Their average is 120°, which is nonsensical. Further, if we call those same lines 120°, 240° and 360°, the average becomes 240°, although we are still analyzing the same lines. These anomalies are characteristic of attempts to analyze data for which no true zero point exists.

Circular statistics are designed to permit analysis of angular data. One can calculate an average angle of dispersal separately from average distance, or average angle of a day's migration path separately from average daily travel. Analogs to familiar *t*-Test, Chi-square Test and many other parametric and nonparametric tests exist which permit one to test for differences in direction of two populations (e.g., differences in dispersal direction of two cohorts or differences between migration paths and available guiding lines). Circular statistics can also be used to determine whether path directions are randomly distributed or show a significant tendency toward a given direction. The reference section lists some excellent texts dealing with circular statistics.

Techniques for Analyzing Home-range Data. Home range and core area sizes are frequently cited by resource managers as a quantitative basis for resource protection. Several methods can be used to calculate home ranges or land-use patterns, and no single figure can accurately reflect an animal's use of its surroundings. I will review some of the commoner analyses, then focus on two recent computer-generated models of home-range/use patterns. I will not address the problems associated with collecting accurate location data with telemetry (see Grainger Hunt's summary for references).

Home-range data usually consist of a series of points collected over some period, hopefully at regular intervals. The simplest method of representing observations is to plot them on a map, which may be sufficient for many uses, but often you will need or want to estimate area used by study subjects or to indicate high-use or core areas. We will assume for the following discussion that in addition to the map, you have devised some sort of a grid coordinate system so that each observation point can be indicated by a pair of X,Y values.

For many years the standard method of estimating size of home range was the minimum convex polygon, constructed by connecting the outermost observation points. The technique tends to be overly generous including many unused areas and is sample size dependent but requires no computers.

A quick approach to finding core areas is simply to locate the area of the map which contains the highest density of observations and perhaps a nest, den or roost tree as well. However, the urge to generate numbers may drive you to attempt an "average" location by averaging the X and Y values of your observations, often producing a location that the animal never uses. For example "average" location of a creature which hunts around the edge of a pond is very apt to be in the pond. While this example is extreme, it points to a problem with straight averages—the animal has no knowledge of your X,Y grid and no reason to order its movements around the average. Despite this fact, one widely-used technique of home-range analysis relies on the arithmetic mean location to construct a series of probability ellipses or circles. A 95% probability ellipse would be assumed to enclose 95% of the range Just as animals are generally ignorant of arithmetic means, they are not generally disposed to move in

Table 4. Home-range computer programs.

FEATURES	DETAILS		
Source	Dr. Edward O. Garton Fish and Wildlife Dept. Univ. of Idaho Moscow, Idaho 83843	Ms. Laura Beery Conservation and Research Center Nat'l Zoological Park Smithsonian Institution Front Royal, VA 22630	Ms. Blair Jones Dept. of Fisheries and Wildlife Science Virginia Polytechnic Institute Blacksburg, VA 24061
Use	Home Range: mainframe FORTRAN, IV or 77, Calcomp plotter	McPAAL: TURBO PASCAL for IBM-PC, -XT, compatibles, Epson or IBM graphics printers, in future for Summagraphics and H P plotters	TELEM: for IBM 370, IBM-PC, -AT. Tektronix and H P plotters
Graphics	Polygons, ellipses, weighted ellipses, harmonic mean, Fourier transforms, tests for distribution types, tests for independence of observations	Convex, concave polygons, ellipses, harmonic mean Fourier transform	Convex, concave polygons, polygms, ellipses
Cost	$250.00 includes updates	$15.00 includes updates	$15.00

ellipses or circles; thus, we will dispense with further discussions of probability ellipses on the grounds that they are unrealistic and that better techniques exist.

To return to the problem of centers and cores there are many different measures of the "center" of a distribution of points (e.g., arithmetic mean, geometric mean, mode, median, harmonic mean, etc.) each with different properties. The harmonic mean is the basis for one of the newer home-range techniques. A harmonic mean, which can be defined for any point on a map, not just the center, is basically a measure of the average distance from a given point to all observation points. A point that is near the center of a dense cluster of observations will have a small average distance to observations, while a point on the perimeter will have a larger average distance and hence a larger harmonic mean.

The point with the smallest harmonic mean is the point that is as close as possible to as many observations as possible and is called the harmonic mean center. Note the harmonic mean center must always occur in an area of high use, never in an area the animal never uses, since the harmonic mean center is defined by animal locations. Since you can measure a harmonic mean anywhere on a map, you can calculate a harmonic mean for all intersections of an X,Y grid (or every quadrant of each square, or whatever) and use the values to create isolines (contours) (Dixon and Chapman 1980).

Points that are the same average distance from observations will have the same harmonic mean; peaks will occur at high-use areas and valleys in low-use areas. By plotting isolines over observation points, one can calculate area of the isoline that encloses 50% of locations, which can be considered an estimate of 50% use-area. Similarly a 95% or 99% isoline can be considered an estimate of home-range. One assumption about mathematical properties of data has been made: each observation is independent of all others. The independence assumption is a major problem that we are ignoring for lack of time (but see the summary of Ken Pollock's discussion and references hereafter). The animal defines the shape of the map and we have made no assumptions about shape or distribution of home-range.

Anderson (1982) takes a different approach to the home-range problem. Think of the X,Y grid overlaying the map as a checkerboard. Every time an observation occurs in a square, put a checker in that square. Soon, we have a stacked-up checkerboard with big stacks in core areas and no checkers where the animal has not been seen. We have created a three-dimensional histogram, with frequency of occurrence graphed as the third dimension. A measure of use can be obtained by looking at volume of checkers over land area of interest. We could leave it here, at the checker stage, but the results are rough, and do not permit inferences about presence of travel ridors (which are notoriously difficult for obtaining data) between high-use areas, etc. Anderson's (1982) technique uses the method of Fourier transforms to smooth out the peaks and valleys a bit, put saddles between close peaks and valleys between distant peaks. By looking at volume under the landscape, one can define use areas by the isoline that encloses a given percentage of the volume—perhaps 10% use area for cores or 90% use area for an estimate of total home-range size.

My summaries of home-range techniques are meant to be brief introductions and mention none of the shortcomings or underlying mathematics. I feel the techniques are promising and worthy of attention, but not perfect; researchers should read the supporting papers thoroughly before employing programs. Both Dixon and Chapman's (1980) harmonic mean technique and Anderson's (1982) Fourier technique are published with references for programs to generate area figures. However, several individuals and institutions have computer packages that execute these and other techniques of home-range analysis. Table 4 lists some available packages, addresses and abilities.

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