Animal Movement Analysis and Home Range Determination Package

H. S. Hill, *Experimental Statistics Unit, Clemson University, Clemson, SC 29631*

T. T. Fendley, *Department of Entomology, Fisheries and Wildlife, Clemson University, Clemson, SC 29631*

Abstract: A Statistical Analysis System (SAS) program has been developed for analysis of data gathered from radio-telemetry studies of animal movement. The program requires as input data from each observation (1) a pair of directional readings, one from each of 2 known reference points to an animal location, (2) animal identification number and (3) time of observation. From these inputs, x-y coordinates of each animal location are computed relative to a specified origin. A number of animal movement statistics are computed and displayed graphically. Boundary points for the home range (convex polygon method) are determined and plots of home range with or without interior locations are generated as well as a measure of the enclosed area. Any of these outputs may be displayed for an individual animal or for a group of animals by sex, age, season, or other subgrouping.

Proc. Annu. Conf. Southeast. Assoc. Fish and Wildl. Agencies 36:656–663

The desire to determine an animal's home range and characterize its movement within this area often leads to radio-telemetry studies (Garshelis and Pelton 1981, Eberhardt et al. 1982, Stevenson et al. 1982). Such studies usually result in a large amount of animal locational information collected at a specified fixed time interval. An animal's location at the time of observation is determined through triangulation. That is, from 2 known reference points, as nearly at right angles to each other as possible with respect to the animal's location, the direction of the animal is recorded in terms of azimuth degrees. The intersection of these 2 compass bearings gives the animal's location.

A number of packages have been described for handling data generated by radio-telemetry (Gilmer et al. 1973, Koeln 1980, Silvy et al. 1979, Gilmer et al. 1973, Siniff and Tester 1965). All of these have some limitations in terms of ease of use and scope of analysis. A primary hindrance to the use of these packages has been the need of the user to know a high-level programming language. Other shortcomings of these packages include such things as requiring that field compass bearings be converted to x-y values prior to input or only generating home range characteristics without movement analyses. A program should accommodate field bearings, convert these to x-y values, and compute home range and movement characteristics. In addition, a person without formal computer training should be able to utilize the procedures.

This manuscript reports on the use of the Statistical Analysis System (SAS) (Helwig and Council 1979) for analysis of radio-telemetry data. By translating a set of field compass bearings from known locations into x-y coordinates, a number of animal movement and locational characteristics can be described. The data subgrouping capabilities of SAS allow easy computation of these statistics by sex, age, season, or other subgroupings with minimal modification of program statements. Similarly, home range location, enclosed area of home range, and the geometric center of the observations for 1 or more animals can be computed and graphically displayed.

Translation to X-Y Coordinate System

The first segment of the program translates each pair of bearings into x-y coordinates of the point where the animal is located. These coordinates can be defined with respect to standard coordinate systems such as the Universal Transverse Mercator, or any user defined system with equal size horizontal and vertical units. First an origin must be chosen. This is usually a crossroads or other geographical landmark easily identifiable on a map of the study area. After placing the x-axis in an east-west direction and the y-axis in a north-south direction, and choosing a unit of distance, x-y coordinates are assigned to the fixed locations (receiving stations) from which compass bearings were taken. These fixed locations are specified to the program with a location identifier (receiving station number) as well as x-y coordinates. Once each set of compass bearings is input with location identifier, the animal location is computed in terms of x-y coordinates. This is accomplished through the use of basic trigonometric relationships, use of the pythagorean theorem to compute the distance between the 2 receiving stations, and a conversion of the 2 compass bearings to radian measures.

Animal Movement Analysis

The next segment of the program determines for each animal the distance moved between consecutive fixes. For a set of k fixes, this results in k-1 interval movements for which distances are calculated. For instance, observa-

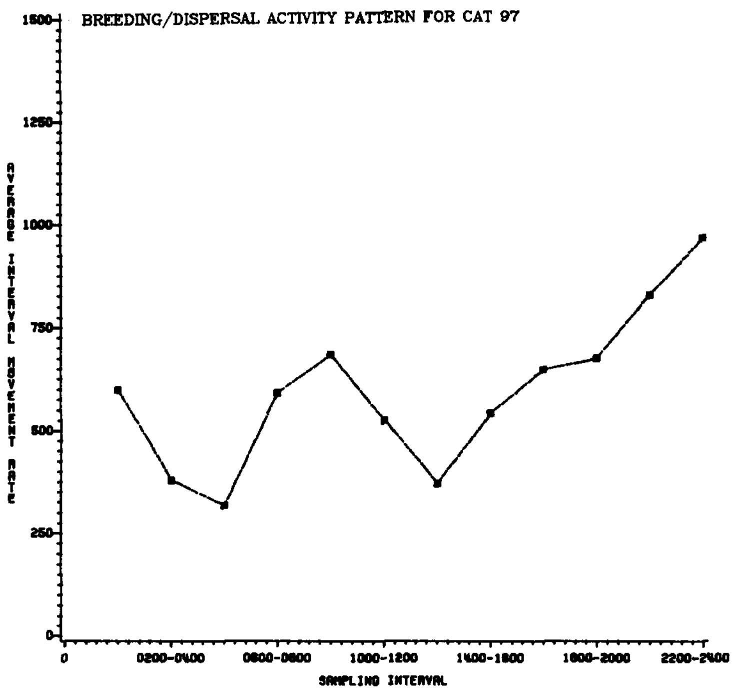

Figure 1. SAS plot of the average daily activity pattern during breeding season of an adult male bobcat radio tracked on the Savannah River Plant, South Carolina, August 1980 to August 1981.

tion of an animal once every 2 hours for 1 day (13 fixes) results in 12 interval movement distances. Interval movement distances are computed only for sequences of observations which are consecutive with respect to the user's chosen time interval.

Using the resulting SAS dataset containing interval movement information and the sorting and "by" grouping capabilities of SAS, the program can easily be tailored to the movement analysis needs of the user. For example, the average distance moved per time interval over all observations during the study allows comparison of movement behavior across intervals. Similarly, the computation of average distance moved per time interval during some subset of the total sampling period allows comparison of movement patterns between subperiods (Fig. 1). These subperiods might include seasons, day, or night. Adding each of the interval movements within a day gives minimum total distance moved per day (MTD) (Marchinton and Jeter 1966). Use of MTD values allows seasonal or other subperiod comparisons of daily animal movement. MTD values are computed only for those days which include a complete set of consecutive interval observations.

Analyses of the average movement behavior of groups of animals might also be desired. Average interval movement values by sex or age group over the entire study period, or by subperiod such as season, are easily computed at this point. Using interval movement rate as a response, an analysis of variance can be performed to determine the impact of subgroupings effects such as sex and season, and to determine presence of any interaction of these with each other or with the interval effect. With daily MTD values, average daily movement by sex or age group over the entire study period, or by subperiod such as season can be described.

Home Range Boundary and Area Determination

The third segment of the package is a SAS macro which determines from a set of animal fixes the boundary points forming the convex hull or Mohr's minimum home range (1947) and its enclosed area. This segment consists primarily of SAS matrix procedure statements, and uses the trapezoidal method of computing area (Husch 1963). Details of this boundary point determination and area calculation are given in Hill et al. (1981).

One useful application of the easy computation of enclosed area is in determining when the home range estimate has stabilized during an observational period (Odum and Kuenzler 1955). For example, if at intermediate points in a field study observations are gathered on a 2-hour time interval for a week, and these points are added to a current cumulative dataset, the immediate calculation of the area enclosed by the comprehensive home range on a weekly basis allows the researcher to determine when the home range estimate has stabilized.

Plotting Home Range

The final section of the package actually plots home range displays using the capabilities of SAS/GRAPH procedure GPLOT (Council and Helwig 1981), in conjunction with any one of numerous compatible graphic devices. Using the dataset containing all fixes in which boundary points have been marked, the polygon outlining the home range can be plotted with or without interior fixes (Fig. 2). The value of the enclosed area is printed out with the plot, which can be titled and axis-labeled as desired. Another home range descriptive characteristic, the geometric center of all fixes, is computed in this section of the package and can be displayed on home range plots if desired.

The subgrouping capabilities of SAS allow easy display of seasonal home ranges overlaid on the same plot (Fig. 3). Similarly, plots for each of several animals might be superimposed on the same plot. These multiple plots allow an analysis of seasonal changes in both location and size of home range.

By scaling the size of the plot to coincide with vegetation or topographic maps, researchers can determine the degree of animal utilization of specific areas. Placing a home range plot with all fixes over a habitat map aids in determining the percentage of fixes in a given habitat type. Unfortunately, this requires a counting by visual inspection of fixes by habitat types.

Plans for Future Enhancement

Presently, the biggest shortcoming in the application of this package is in comparing home range plots with a map showing topographical or vegetational characteristics of the study area. As mentioned, researchers fre-

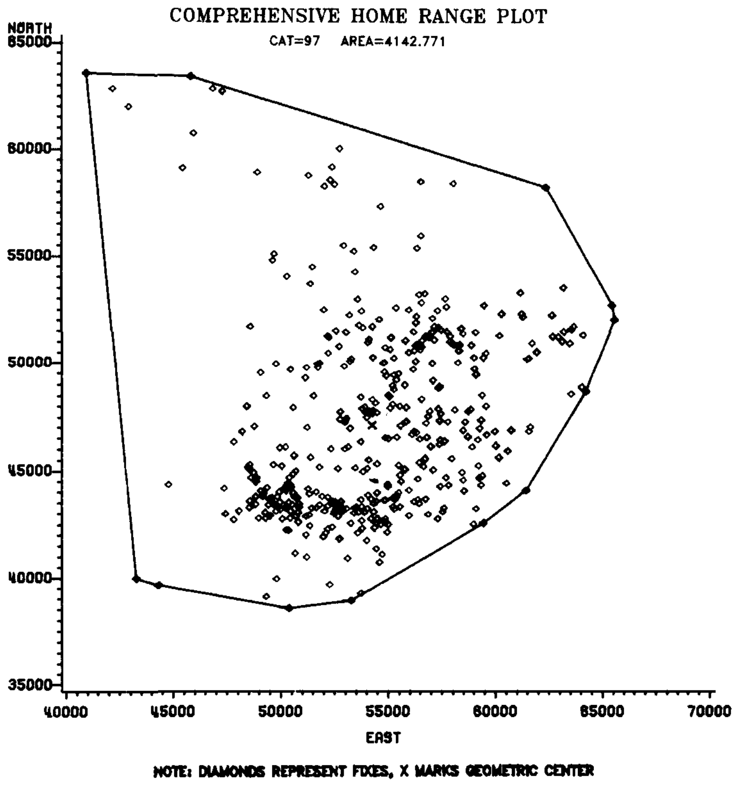

Figure 2. SAS plot of the comprehensive home range of an adult male bobcat radio tracked on the Savannah River Plant, South Carolina, August 1980 to August 1981.

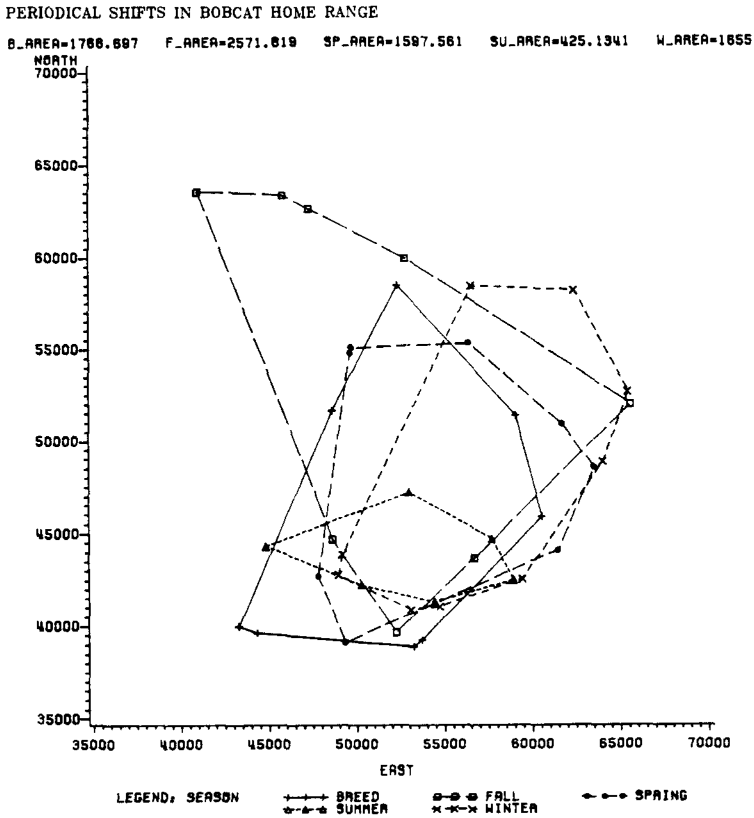

Figure 3. SAS plot of seasonal home ranges of an adult male bobcat radio tracked on the Savannah River Plant, South Carolina, August 1980 to August 1981.

quently want to determine the percent utilization of the different habitat types within a home range, or perhaps the change in habitat utilization percentages between seasons. In addition to the problem of scaling the home range plot to perfectly agree with available area maps, there remain the problems of superimposing 2 different "maps" to determine the percentage of observations falling within a given type, as well as the tedious task of counting these points. A possible solution to these problems is offered by the capabilities of the SAS/GRAPH GMAP procedure. Digitizing the key information of the study area surface map using a digitizing tablet would result in a map dataset which could be merged with the animal location and home range boundary point dataset. A graphic output could then be generated which would show habitat types (through the use of various shadings), home range boundaries, and animal locations all on the same ouput. In addition, the program could "count" the number of observations falling in a given habitat and determine percent utilization of that type. The potential to use this map capability with high-resolution graphic output device offers possibilities to further enhance this package to provide a comprehensive analysis of radio-telemetry data.

Conclusion

During the period of development, versions of some of these programs were used for bobcat (*Lynx rufus*) wood duck (*Aix sponsa*), and wild hog (*Sus scrofa*) studies involving over 10,000 observations. To begin analysis of raw field data from any radio-telemetry study, all that is needed is a good base map of the study area with which to identify and assign x-y coordinates to stations. The program package then offers capabilities for a fairly comprehensive analysis of radio-telemetry data. Several advantages of the package accrue from it being SAS based. One advantage is that SAS is commonly available and well documented. Another advantage is the ease of use including "customizing" of the programs by the analyst without formal computer training.

Copies of the programs are available from the authors on request.

Literature Cited

Council, K. A., and J. T. Helwig, eds. 1981. SAS/GRAPH User's Guide. SAS Inst., Inc., Cary, N.C. 126pp.

Eberhardt, L. E., W. C. Hanson, J. L. Bengston, R. A. Garrott, and E. C. Hanson. 1982. Arctic fox home range characteristics in an oil-development area. J. Wildl. Manage. 46:183–190.

Garshelis, D. L., and M. R. Pelton. 1981. Movements of black bears in the Great Smoky Mountains National Park. J. Wildl. Manage. 45:912–926.

Gilmer, D. S., S. E. Miller, and L. M. Cowardin. 1973. Analysis of radiotracking data using digitized habitat maps. J. Wildl. Manage. 37:404–409.

Helwig, J. T., and K. A. Council, eds. 1979. SAS User's Guide. SAS Inst., Inc., Raleigh, N.C. 494pp.

Hill, H. S., L. W. Grimes, and H. C. Krasner. 1981. Plotting home ranges for wildlife data. Proc. Annu. SAS Users Group Int. Conf. SAS Inst., Inc., Cary, N.C. 6:22–25.

Husch, B. 1963. Forest mensuration and statistics. The Ronald Press Co., New York. 474pp.

Koeln, G. T. 1980. A computer technique for analyzing radio-telemetry data. *In* Sweeney, J. M., ed. Proc. National Wild Turkey Symposium. 4:262–271.

Marchinton, R. L., and L. K. Jeter. 1966. Telemetric study of deer movement-ecology in the southeast. Proc. Annu. Conf. Southeast. Assoc. Game and Fish Comm. 20:189–206.

Mohr, C. O. 1947. Table of equivalent populations of North American small mammals. Am. Midl. Nat. 37:223–249.

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

Silvy, N. J., J. L. Roseberry, and R. A. Lancia. 1979. A computer algorithm for determining home range size using Mohr's minimum home range method. Proc. Int. Conf. Wildl. Biotelemetry. 2:170–177.

Siniff, D. B., and J. R. Tester. 1965. Computer analysis of animal-movement data obtained by telemetry. Bio Science. 15:104–108.

Steventon, J. D. 1982. Martin use of habitat in a commercially clear cut forest. J. Wildl. Manage. 46:175–182.