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USE OF TELEMETY AS A MEANS OF STUDYING SPACING AND BEHAVIOR OF ANIMALS*

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Understanding how wild, unrestrained animals utilize space in their natural environment implies knowledge of their precise location over a given period of time. In addition, to consider the social interactions of spacing one must have knowledge of the locations of many animals simultaneously. The recent development of telemetry techniques has made it possible to obtain excellent data for the study of movement patterns and the concept of home range for many species of vertebrates. A research team at the University of Minnesota has developed an automatic radio-tracking system located at the Cedar Creek Natural History Area in east-central Minnesota. This system continually monitors and records movements of animals carrying miniature radio transmitters [14,2]. Animal position and activity data, recorded minute-by-minute for up to 52 animals, have been utilized for the study of many mammal and a few bird species [12,6,7,5,3,11]. The purpose of this paper is to introduce the reader to types of informa-

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tion which can be obtained with this technique and to relevant published literature.

The most detailed analyses of movements and relation to spacing have been with data on larger mammals such as red fox, snowshoe hare and white-tailed deer. Computer programs have been developed to handle the large amount of data generated by the system. Siniff and Tester described initial attempts at computer analysis of radio-tracking data [9]. At present an extensive "software" system has been specifically designed for the analysis of position and activity data on a CDC 6600 computer.

Analysis of these data has required new methods both in terms of data handling and data processing. The home range patterns we have observed, which are not adequately described by past models [1, 12] have led us to consider other models and approaches. Within a home range there are usually several areas of intensive utilization or centers of activity; these may shift in time, depending on individual or environmental variables. For mammals which are established in a particular area, the home range is a stable entity where the animal stays year after year. Juveniles have been observed to have often a dispersing pattern where they appear to be searching for some "uncoupled" area in which to become established. Usage patterns in general are contagiously distributed; however, the exact nature of a satisfactory mathematical model is not clear at this time. Therefore we have initiated work in the area of computer simulation to measure some of the characteristics of an adequate home range model [10]. These attempts derive their basis from the probability distributions we observed utilizing telemetry as the animal traveled in its normal daily activity. The simulation we have carried out is stochastic in nature and through its use we have established certain guidelines which help interpret animal movement patterns. The movements of animals we have observed were not of a classical random-walk nature and thus the simulation model we have formulated required that certain areas were utilized with higher probability than other areas in the home range. Parameters of the negative binomial probability distribution have been used to compare the simulated movement patterns to those observed by telemetry. In general, the negative binomial distribution is a good approximation for telemetry data and the values of the various estimated parameters suggest a method for intra- and inter-species comparisons.

The simulation model is a method which appears to have numerous applications in the study of spatial and temporal aspects of animal behavior. Simultaneous simulation of several individuals in an area provides guidelines for evaluating social interaction. Interpreting whether avoidance or attraction is taking place requires some "yardstick" for comparison, and it is anticipated that this simulation procedure may provide such a criterion. Certainly it is now possible to more fully understand what is meant by random contact between in-
individuals, given that the pattern of movement is contagious.

Although the automatic radio-tracking system at the Cedar Creek Natural History Area is unique in terms of its scope and automation, many investigators associated with this project are now using portable tracking equipment to study movement and activities of animals at other locations. Because the transmitter makes it easy to locate individuals even after death, some studies have been made attempting to evaluate mortality factors. Hessler and Schladweiler have utilized telemetry techniques to study mortality of artificially propagated pheasants and mallard ducks, respectively [4,8]. Other studies are now in progress utilizing portable equipment to study social spacing and mortality in wild populations of waterfowl and upland game birds. Recently we have had inquiries concerning the possibilities of placing radio-transmitters on humans to study special aspects of their behavior, and future studies may be made in this area.

We have also utilized telemetry methods to study the effects of low level radiation on animal behavior. It is evident that one of the problems of the future is the greater risk of exposure to ionizing radiation. Possible effects of ionizing radiation on the behavior and breeding biology of lower mammals is important to the understanding of possible effects on human populations. With the telemetry system it is possible to capture wild mammals, expose them to a sub-lethal radiation dose, and then monitor their behavior after release. We have carried out work of this nature on raccoons and snowshoe hares to determine changes in movement and activity rhythms [13]. Since we have been faced with detecting changes in behavior, it was necessary to develop suitable methods of analysis prior to attempting to evaluate effect of sub-lethal radiation. With the simulation model we anticipate gaining further insight into changes in behavior and are now proceeding with the analysis of such data.

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