SPATIAL ECOLOGY: HISTORICAL VIEW, HOME RANGE, METHODOLOGIES, AND ETHICS

Brian Balmer and Marc Hanke

Spatial ecology is the relationship between the distribution and abundance of organisms, and the resources available in the surrounding environment. Early ecological theory (1800's) assumed that organisms were uniformly distributed throughout their environment (reviewed in Tilman & Kareiva 1997). However, Darwin's observations on the "habits of worms" generated some of the first hypotheses challenging this view (Darwin 1881). Darwin suggested that "changes in vegetation" and "trampling of (by) man and animal" were two factors that may influence worm distribution. Thus, organisms were not distributed uniformly or randomly, but aggregated in patches based upon resource availability and competition. This concept is the basis for modern spatial ecology theory.

Home range is one of the core concepts of modern spatial ecology. Burt (1943) provided the first definition of home range as a distinct separation from that of territoriality. Home range is the area over which an animal normally travels and searches for food (Burt 1943). Territoriality in its most simplistic terms is defined as any defended area (Nice 1941). Although both of these concepts affect an organism's distribution and thus spatial ecology, Burt (1943) identifies the difference between the two as any animal has a home range in which it searches for food, however, only animals that protect part of a home range are said to have territories.

Early studies utilized visual observations or mark-recapture studies in association with habitat and abiotic measurements to identify aspects of an organism's spatial ecology. However, these studies were typically labor intensive and not possible on organisms that could not easily be observed. Biotelemetry has revolutionized current spatial ecology research. This mechanistic approach remotely measures physiological, behavioral, energetic, and/or environmental data, at a specific time and space for an individual organism (Cooke et al. 2004). Biotelemetry techniques require the attachment of a transmitter to an individual organism to permit the subsequent remote monitoring of that individual over an extended period of time (Samuel & Fuller 1996). Radio telemetry and archival loggers were some of the first techniques to remotely monitor the spatial ecology of an organism (reviewed in Cooke et al. 2004). This methodology involved utilizing a VHF (Very High Frequency) radio receiver to locate an individual organism's position via an attached transmitter. Archival loggers, either attached directly to the organism or deployed at specific locations, were typically utilized to measure additional biological parameters in addition to location data. Although radio telemetry enhanced the ability of researchers to identify spatial aspects of organisms, this methodology was still labor intensive and in the case of archival loggers, required reacquisition of tagged organisms or the archival loggers from their deployed locations. Advances in satellite-linked telemetry have reduced the labor intensive requirements of manually tracking and visually locating tagged organisms and the need to reacquire archival loggers. Satellite-linked telemetry utilizes a satellite-based data collection system to provide biological and environmental data on tagged organisms.

Although there are many benefits to biotelemetry, there are also limitations to this technique (reviewed in Cooke et al. 2004). A large amount of data is produced with biotelemetry projects, and understanding the patterns in these data sets can be difficult. In addition, the statistics associated with these large data sets may require complex or unconventional analysis techniques. Many of the measurements obtained from telemetry data are also from a small number of individuals, thus the statistical assumption of independent data points is violated. Biotelemetry techniques are best utilized when they can be coupled with other data sets such as visual observations, blood chemistry values, or contaminant levels from tissue biopsies. For example, McClellan and Read (2009) looked at the relationship between satellite-linked movement patterns of green sea turtles (*Chelonia mydas*), habitat analyses based upon digital elevation models, and fisheries data from the Department of Marine Fisheries observer program, to provide insight into the spatial ecology of green sea turtles in North Carolina.

Another limitation for telemetry projects is the cost of tags, particularly satellite-linked tags, which results in small sample sizes for a particular study. However, this limitation has to be weighed against the benefits of utilizing biotelemetry over other techniques that may not be as useful to address the research question. For example, Bonfil et al. (2005) utilized pop-up, archival satellite-linked tags to provide insight into the spatial ecology of white sharks (*Carcharodon carcharias)*. This species is known to make transoceanic migrations and are typically sighted in geographically remote locations. Thus, although sample size was relatively small in this study, satellite-linked telemetry was the appropriate techniques to address the research question. Between 2003 and 2004, 25 white sharks received pop-up satellite linked tags. The data collected from these tags identified an individual white shark with the fastest transoceanic migration of any swimming fauna (11,000 km in 99 days), which also suggested direct links between white shark populations that prior to this study were hypothesized to never coalesce. Calibration of data recorded by transmitters is also a requirement that depending on the study may be as intensive of a process as the original proposed study. Cooke et al. (2004) illustrated numerous examples of these calibrations on a variety of species including chewing activity in blue crabs (*Callinectes sapidus*), swimming speed in sockeye salmon *(Oncorhynchus nerka)*, and heart rate measurements in the spotted ant bird (*Hylophylax naevioides)*. Attachment and deployment of transmitters also requires a set of specialized skills that may require additional time prior to initiating a research project. For example, acoustic tags are surgically implanted in many species. Thus, researchers not only need to be trained in capturing the target organism, but also in the procedures to attach or in this case surgically implant a given tag design. This limitation is also directly related to the final limitation of biotelemetry projects, ethics and animal welfare. Wilson and McMahon (2006) provide an excellent review of the main ethical considerations of tag attachment including organism discomfort, energetics, survivorship, attachment duration, sample size, and capture stress. Moore et al. (2006) surgically implanted acoustic tags as well as "dummy" tags in Atlantic salmon (*Salmo salsar)* within a laboratory setting to identify any behavioral or physiological effects associated with tag implantation. This study identified rapid healing of the surgical site as well as minimal physiological effects to the tagged individuals, suggesting that implantation of acoustic tags is a viable method of telemetry for certain species.

Proposed Readings:

Tuesday (Background):

Burt WH (1943) Territoriality and home range concepts as applied to mammals. Journal of Mammalogy 24:346-352

Cooke SJ, Hinch SG, Wikelski M, Andrews RD, Kuchel LJ, Wolcott TG, Butler PJ (2004) Biotelemetry: a mechanistic approach to ecology. Trends in Ecology and Evolution 19:334-343

Thursday (Techniques and Ethics):

Hart KM, Hyrenbach KD (2009) Satellite telemetry of marine mega vertebrates: the coming of age of an experimental science. Endangered Species Research 10:9-20

Wilson RP, McMahon CR (2006) Measuring devices on wild animals: what constitutes acceptable practice? Frontiers in Ecology and the Environment 4:147-154

Literature Cited

Bonfil R, Meyer M, Scholl MC, Johnson R, O'Brien S, Oosthuizen H, Swanson S, Kotze D, Paterson M (2005) Transoceanic Migration, Spatial Dynamics, and Population Linkages of White Sharks. Science 310:100-103

Burt WH (1943) Territoriality and home range concepts as applied to mammals. Journal of Mammalogy 24:346-352

Cooke SJ, Hinch SG, Wikelski M, Andrews RD, Kuchel LJ, Wolcott TG, Butler PJ (2004) Biotelemetry: a mechanistic approach to ecology. Trends in Ecology and Evolution 19:334-343

Darwin C (1881) The formation of vegetable mould through the action of worms, John Murray, London

McClellan CM, Read AJ (2009) Confronting the gauntlet: understanding incidental capture of green turtles through fine-scale movement studies. Endangered Species Research 10:165-179

Moore A, Russell IC, Potter ECE (2006) The effects of intraperitoneally implanted dummy acoustic transmitters on the behaviour and physiology of juvenile Atlantic salmon, *Salmo salar* L. Journal of Fish Biology 37:713-721

Nice MM (1941) The role of territoriality in bird life. American Midland Naturalist 26:441-487

Samuel MD, Fuller MR (1996) Wildlife Radiotelemetry. In: Bookhout TA (ed) Research and Management Techniques for Wildlife and Habitats. The Wildlife Society, Bethesda, p 370-418

Tilman D, Kareiva P (1997) Spatial Ecology, Princeton University Press

Wilson RP, McMahon CR (2006) Measuring devices on wild animals: what constitutes acceptable practice? Frontiers in Ecology and the Environment 4:147-154