RADIO TELEMETRY FOR RESEARCH ON LARGE LAND MAMMALS

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Summary The use of radiotelemetry for simultaneously monitoring physiological and environmental parameters, while an animal is being tracked in its natural ecosystem, provides new opportunities for increasing our knowledge about the larger land mammals by the acquisition of new information on their migratory movements, social behavior, bioenergetics, and physiological processes such as thermoregulation and water balance. The perfection of satellite tracking and monitoring systems specifically designed for wild animals, such as caribou and elephants, in remote areas of the Earth is feasible; and such systems hold considerable promise in providing access to information that has been exceptionally difficult to obtain in the past. Challenges in the development of practical radiotelemetry systems include: light-weight, long-lasting sources of power; developing systems that require little power; increasing the variety of implantable physiological sensors; improving the resolution of locations (to 100 m or less) for tracking an animal by satellite; improvement of antennas for greater efficiency in transmissions without interfering with the animal’s activities; and interfacing implanted sensor-transmitters with long-range transmitters on the animal’s surface. The perfection of systems for attachment of instrument packages to polar bears, elephants, and other wild animals is also demanding.

Introduction Radiotelemetry systems for the larger, free-roaming mammals have recently become practical tools for research, as in the study of grizzly bears in Yellowstone National Park by Craighead and Craighead (1971); and concurrently the capturing and handling of most large mammals, including elephants, rhinoceros, and polar bears, with immobilizing drugs has been perfected, largely through the efforts of Harthoorn (1970). The main problems are now in the refinement of systems for locating and monitoring animals by satellite, development of new sensors, and extending the lifetime of systems beyond one year. In this paper some of the problems for investigation are reviewed briefly, along with some of the requirements of equipment. Further discussion of opportunities for research is given in another paper (Buechner, et al., 1971).
Ecological problems  Patterns of movement (daily, seasonal, migratory, nomadic) in relationship to vegetation or prey animals as sources of food, weather conditions, the availability of water, daily and seasonal requirements for cover, intraspecific behavior, and human activities need to be determined more precisely for most species of the larger mammals. The basic objectives are to determine the significance of movements in the biology of the animal and to provide information for management purposes. Examples of animals to be studied are: the caribou in Canada and Alaska, grizzly bears in U.S. National Parks, the Alaskan brown bear, polar bears in the circumpolar region, elk and mule deer in the western United States, the Saiga antelope in Russia, African elephants, African antelopes (wildebeest, Thomson and Grant gazelles, topi, springbuck, hartebeest, etc.), the sloth in Panama, the tiger in India and Nepal, and the vicuna in the Andes of South America.

Home range and territory (the defended portion of the home range) need to be studied more thoroughly with reference to social use of space (Calhoun, 1963; Eisenberg, 1966; Brown and Orians, 1970) and the natural regulation of numbers (Wynne-Edwards, 1962). The extent of the home range and territory among predatory animals such as wolves, lions, leopards, tigers, and cougars is especially important in terms of the regulation of prey populations and effects of man’s cultural activities. Also, territoriality seems to be manifested to some extent in human beings, and understanding this behavior in other animals may contribute toward a better understanding of human behavior.

Energy-flow relationships between ungulates and vegetation as an ecosystem process constitute an important area for investigation. For these studies measurements of the individual animal’s rate of metabolism is required. Such measurements might be determined by monitoring respiration rates in free-roaming deer and other animals (McCullough, 1970). More meaningful measurements of metabolic rate can be made by determining the differences in oxygen levels in the aorta as the blood leaves the heart and in the vena cava as the blood returns to the heart. Such measurements are feasible, but considerable ingenuity will be required in solving some difficult technological problems in developing a practical system. Other data (such as movements, activity, food selection, and differential use of habitat by the different sex and age classes in the population) that are essential for studies of energy flow can be obtained more completely with the aid of radiotelemetry than by traditional methods alone.

Predator-prey relationships in the natural regulation of numbers, population fluctuations, and the genetic viability of prey populations can be studied intensively by using radiotelemetry for surveillance of the predator’s activities (as in George B. Schaller’s research on the African lion).

Behavioral problems  Intraspecific studies of territorial, hierarchical dominance-subdominance, mother-young, group, mating, aggression, and other types of behavior in
relationship to evolution, spacing and its maintenance, numerical regulation, populations as ecosystem processes, and significance in terms of human behavior (Etkin, 1964; Marler and Hamilton, 1966; Hinde, 1970) can be enhanced through radiotelemetry.

Interspecific studies of predator-prey relationships, the suppressing effect of one population on another as an ecosystem regulatory phenomenon (Calhoun, 1963), and the use of food and space in relationship to niche structure of the ecosystem are important areas for investigation. Radiotelemetry is useful for homing in on individual animals for direct visual observations and for monitoring physiological responses to stimuli. A rise in blood pressure, for example, was detected in a seemingly calm elephant when confronted by an observer (Howard A. Baldwin, personal communication).

**Physiological problems**  Thermoregulation, as in the camel (Schmidt-Nielsen, et al., 1957) and other ungulates, including buffalo, giraffe, eland, oryx, hartebeest, and cattle (Bligh and Harthoorn, 1965; McGinnis, 1970), is one of the most important areas of physiological studies. Water balance needs to be investigated further in desert animals (like the camel) that require water, semiarid ungulates (like the kudu) that use little water, and those (like the gerenuk) that apparently use no free water at all and seem to rely entirely on metabolic water. Circadian and other endogenous biological rhythms (Enright, 1970); blood pressure responses, as in the wild giraffe (Van Citters, et al., 1966); photoperiodic regulation of physiological processes, such as reproduction and bird migration (Farner, 1955, 1961); and hypothermia in bears of various kinds (Craighead, et al., 1971) are examples of other areas in which the technology of radiotelemetry is valuable.

**Requirements of equipment and environmental constraints**  Specific requirements for different species of mammals will be available in a forthcoming review of user requirements (Pascucci, Liskov, and Garvin, 1971).

Most studies so far have been conducted over relatively short periods of time, from a few days up to 3-4 months. Longer studies of more than one year are required for polar bears, caribou, and elephants. Low temperature (-40°C) as well as high temperatures (+40°C) pose problems in battery performance and longevity. It would be advantageous to have biogalvanic batteries that use body fluids as electrolytes for long periods of time without toxicity to the animal from zinc, platinum, or other metals used in the system. Research in the development of biogalvanic batteries shows some promise. Other biological sources of power, such as the energy from muscular action in wing beats, may substitute for batteries to operate electronic equipment. Solar panels performed extremely well as a source of energy (Craighead, et al., 1971) in tracking an elk, and show considerable promise for radiotelemetry systems for the larger land mammals. Changes in systems concepts are needed to develop miniaturized systems that require little power, thereby
reducing the external and internal instrumentation to minimum weights for maximum comfort and least interference with the animal’s activities.

Improved antennas are required for consistently high resolution (±1 km or less) of locations in satellite tracking of animals. Systems are needed to maintain antenna direction in relationship to receivers in satellite or ground systems. Like batteries, antennas are a limiting factor in the development of practical radiotelemetry systems.

Excellent sensors are available for measuring body temperature, heart rate, blood pressure, and other parameters of the body (Mackay, 1968). A wide variety of additional sensors is needed to detect, for example: behavioral activities, motion of appendages, individual distance, sound, levels of hormones in the blood stream, oxygen consumption, radioactivity, and flow velocity. These sensors must function within the environment of the body where they are implanted. The behavioral and physiological parameters that can be sensed seem to be limitless, and many imaginative ideas for sensors are presented by Mackay.

Implanted sensor-transmitters need to be integrated with electronic instrument packages on the surface of the animal to provide for storage of data transmitted by the sensors, and subsequent transmission to ground stations directly or via satellites. Such systems are required for continuous or short-interval monitoring of physiological and behavioral parameters from orbiting satellites, since two passes per day are insufficient or most studies. Stationary satellites can provide data on a continuous real-time basis, thus eliminating the storage requirement but not the interfacing of implanted sensors and long-range transmitters.

**Satellite systems**  
As a means for obtaining data systematically at regular intervals, independently of weather conditions, day or night, anywhere on the surface of the Earth, satellite systems are advantageous. The feasibility of satellite systems for tracking animals has been demonstrated (Craighead, et al., 1971). A decade of research and development is required to produce economical and efficient satellite systems specifically designed for tracking and monitoring animals (Buechner, et al., 1971).

**Known habits of large mammals**  
Adequate information about the habits of most large mammals is available for the initial design of electronic instrument packages and their attachment to the animal, internally or externally, but there are difficult problems in keeping a collar on a polar bear or elephant, meeting the rough treatment expected when male antelopes fight in the defense of a territory, constructing light-weight packages, and keeping antennas properly oriented. Testing of instruments is essential, first in environmental chambers in the laboratory, then on animals in captivity, and finally on
the free-roaming animal in its natural environment where the experiment will be carried out. One or two years of testing may be required for the development of reliable equipment.

**Conclusion** Radiotelemetry offers new challenges and unusual opportunities for delving more deeply into the behavior and physiology of the larger mammals in their natural environments. Engineering developments are needed to develop practical systems for biological investigation, ranging from implantable physiological sensors to satellite tracking systems. The payoff in perfection of monitoring systems is likely to be considerable, not only in terms of increasing biological knowledge but also in terms of socially pertinent information in the management of the world ecosystem.

**References**


