USE OF SATELLITES IN STUDYING BEARS--STATUS REPORT

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HISTORY

In 1962 an Interdisciplinary Conference on Bio-telemetry at the American Museum of Natural History in New York City gave impetus to the then young but developing field of wildlife telemetry (Slater Lloyd 1963). This technique of utilising electronic equipment and systems to track animals and to gather various types of ecological and physiological information had by 1966 progressed to a point where it was well recognized as a useful and practical wildlife research tool. Its application in ecological research was expanding worldwide. Along with this was the growing awareness that the use of satellites could enhance and complement current wildlife telemetry for both research and management. In 1966 a conference was held at the Smithsonian Institution in Washington, D.C., to explore the feasibility and to examine the potential of satellites for tracking and monitoring wild animals. It was sponsored by the Smithsonian, American Institute of Biological Sciences (AIBS) and National Aeronautics and Space Administration (NASA). At this conference possibilities were proposed for tracking

both elk and bear by satellite. Grizzly bears had been successfully tracked to dens and home ranges plotted. Elk had been instrumented and tracked for distances of ~~several~~ over one hundred miles--from the National Elk Refuge in Jackson Hole, Wyoming, to the Lamar Valley in Yellowstone National Park.

In 1969 the National Academy of Sciences recommended a program of satellite tracking of free-ranging animals. This stimulated a joint endeavor with NASA and cooperating organizations in which an elk (Cervus canadensis) was tracked and monitored by the Nimbus 3 satellite. (Craighead, F. C. et.al. 1972). This feasibility experiment was followed by still another to monitor a black bear (Ursus americanus) in its winter den. (Craighead, J.C. ~~and F.C. 1971~~ et.al. 1971). Both experiments were carried out with the Nimbus 3 and 4 satellites using the (IRLS) ~~system~~ to locate and interrogate.

interrogation, recording and location system

BEAR AND ELK FEASIBILITY EXPERIMENTS

The IRLS unmanned data station designed for gathering oceanographic and meteorological ~~data~~ information was used to monitor the bear den and another IRLS instrument package was modified into a collar for tracking and monitoring the elk. Batteries were used as a source of power with solar cells to maintain battery charge for the elk's collar. The weight of the electronic packages was in the neighborhood of 25 pounds.

Though the equipment was heavy, both feasibility ~~and~~ experiments were successful. The elk was located to within an average distance of about five miles (8 Km.) All of the

location points for the bear den were within a circle of 4.5 miles radius (7.25 Km.). Both environmental and physiological data were obtained through telemetry in the course of the experiments. For example, the average temperature ranged from 18.1°C. (67°F.) in the bear's bed to -3.0°C. (26°F.) near the entrance and -6.7°C. (20°F.) outside the den. A light sensor inside the den pointing at the snow-filled entrance read 0°F. for nearly a month. On the 14th of March the light reading increased, revealing that the den entrance was open. This coincided with a low bed temperature and subsequent investigation revealed that the bear had left the den. The experiments showed the feasibility of monitoring wildlife by satellite but it was obvious that unless the equipment could be reduced in weight it would never be fully practical for many wildlife research possibilities.

Various meetings and workshops followed. In April 1973 a NASA, AIBS Santa Clara Conference on Wildlife Monitoring in response to national needs was held at the Ames Research Center, Moffett Field, California. It was followed by a Santa Cruz Workshop in September of the same year. The Santa Cruz report stresses that state and federal agencies have established programs for which information is needed on habitat, censusing, movement, location, physiology, and behavior of animals and their populations. Satellite tracking and monitoring was a new technology that could provide information unavailable or difficult to obtain using conventional telemetery methods. The Santa Cruz report recommended two systems--RAMS and Omega Opal--

as having the greatest capability and best specifications for locating and monitoring animals in their environment. (Santa Cruz Report. 1973).

EQUIPMENT DEVELOPMENT

The aim of equipment development was to obtain a package needing little or no modification when fastened to either the smallest or largest animal to be studied. Packaging and difficulties of attachment were recognised. Microminiaturization of gear would increase the number of species to which it could be effectively applied and would reduce harnessing difficulties. The degree of micro-miniaturization required was based on two sizes of birds: waterfowl and raptors; and small passerines. Suggested transmitter package weights for these birds was 100-200 grams for waterfowl and raptors. For passerines it was 10 grams. These weights were far lower than anything we had yet used. The RAMS system (random access measurement) using the Doppler location technique (G. Balmino et.al. 1968) made development of smaller satellite-compatible transmitters possible. Accordingly, we have, through the Environmental Research Institute with support from NASA and the National Geographic Society, been trying to expedite the Santa Cruz program and to follow the recommendations of this report. We have developed a Nimbus F RAMS DCP one-watt transmitter weighing 56 grams and compatible with Nimbus satellite frequencies (401 Mhz). This was developed for the investigator

by Joel R. Varney and Roger L. Pope (Varney, Joel R. and Roger L. Pope 1974) and is now being tested with the Nimbus F satellite.

THE IRLS SYSTEM

The Nimbus satellites are in a polar sun-synchronous orbit with an orbital period of 107 minutes. They are at an altitude of 1100 kilometers or 682 miles.

When the Nimbus 3 satellite came within radio view of the IRLS platform it began to transmit a coded address signal. When the IRLS ~~equipment~~ platform received the signal, it replied by transmitting a response signal. The satellite determined the distance to the platform (or bear den) by measuring the time between sending of the interrogation signal and the response from the platform. A minimum of two such interrogations are required to determine position. The exact location of the satellite is known at any time from its orbit parameters, thus each range measurement allowed an imaginary circle to be drawn on the earth's surface. The platform must be located on this circle. The second interrogation sequence provided data from which another circle could be drawn which intersected the first at two points. On one of these the elk or bear, in these cases, was located. The discarded point was sufficiently distant from the animal as to be considered unlikely.

The satellite passes over the same point on the earth's surface about every twelve hours, thus there were two

interrogations for the elk and the bear den occurring about noon and midnight each day.

THE RAMS SYSTEM

The random access measurement system (RAMS) uses the Doppler location technique (G. Balmino et.al., 1968). The random system transmits at predetermined intervals as compared with an ordered system such as IRLS which responds to an interrogation from the satellite. It permits large scale experiments at low cost using simple data collection equipment. The platforms transmit a one-second message to the satellite at random times at the rate of once per minute. The satellite records a Doppler frequence measurement and a time lag and formats the received data. This information is stored aboard the satellite for readout over the Fairbanks, Alaska, ground station and transmission to NASA's Goddard Space Flight Center, Greenbelt, Maryland, for processing.

The RAMS system aboard the Nimbus 5 satellite can accomodate up to 1,000 platforms per orbit. The received data is stored aboard the satellite for readout every 108 minutes (orbital period). Eight data acquisition channels allow for simultaneous reception of up to eight transmissions (Cote, Charles E., John F. duBose and James L. Coates, 1973). At Goddard the position location coordinates of each platform are computed and the data is transmitted to the investigators.

Briefly, the systems operate in the following fashion:

Each instrumented animal carries a transmitter that transmits a constant frequency. The signals received by the Doppler equipment aboard the satellite contain the Doppler frequency shift caused by the motion of the satellite. The received frequency at the satellite varies as the satellite passes near the instrumented animal. The shape of the signal received at the satellite, combined with the known orbit of the satellite, defines two lines on the surface of the earth that run parallel to the track or orbit of the satellite. The instrumented animal is located on one of these two lines. The time at which the signal received at the satellite changes most rapidly occurs when the satellite is close to the transmitter. At this time, a plane normal to the orbit of the satellite is defined. The intersection of this plane and the surface of the earth produces a line that bisects the orbit lines and on which the transmitter or electronic animal package is located. The instrumented animal must be at one of these two intersections. These intersections are normally several hundred miles apart on the surfact of the earth. Knowledge of the previous position of the animal can be used to eliminate one of the intersections. (G. Balmino et.al., 1968).

TRANSMITTER WEIGHT REDUCTION

The RAMS DCP transmitter circuitry has been constructed using hybrid thick film construction. The weight of the

present transmitter is 56 grams. The total package weighs approximately 100 grams--transmitter, 56 g., lithium battery, 33 g., antenna and harness, 10 g.

A 33 gram lithium cell would provide an operating lifetime of 3.2 months, 99 gram battery pack 8 months of operating time. A D cell weighing 289 grams would have an operating time of 23.8 months or roughly two years. This is based on transmitting one-second signals once per minute for two hours each day. (Varney, Joel R. and Roger L. Pope, 1975). ~~The frequency is 401 MHz~~

Engineers estimate that using both thick film and thin film construction, the smallest available standard parts, and other miniaturization techniques, further weight and volume reduction could be obtained. The overall transmitter weight could probably be reduced to 20 grams and the volume to o.8 in.^{3} (14 cc.), (Varney et al, 1974).

The present RAMS transmitter with a two-year battery life, waterproof encapsulation, antenna and harness would weigh between 1 and 2 pounds. This is less than the weight of equipment we have successfully used to radiotrack grizzly bear (Ursus arctos), black bear, elk, and mountain sheep (Ovis canadensis). One hundred and eighty (180) gram transmitter packages (not satellite-compatible) have been successfully carried by both golden eagles (Aquila chrysaetos) and bald eagles (Haliaeetus leucocephalus). (Craighead, F.C. and T. Dunstan, 1976).

Very high frequency stability is required for the RAMS transmitter to operate satisfactorily. Holding a 15 minute

drift to less than 4 Hz requires good temperature compensation or thermal control. If drift does not meet NASA specifications, location accuracy is affected. Meeting these specifications is a problem engineers are now tackling. The RAMS transmitter is now being tested with the Nimbus satellite and location results are encouraging.

The purpose of the current satellite tracking research is to eventually track and monitor migrating birds. This is where I think this technology has its greatest wildlife research potential. However, miniaturized equipment that can be employed to successfully track birds is more than adequate for larger animals.

APPLICATION OF SATELLITE TRACKING TECHNIQUES

The general conditions under which satellite tracking would be most productive as well as specific problems amenable to solution by satellite tracking and monitoring have been well-covered in the paper "Satellites for Research on Free-roaming Animals". (Buechner, et.al., 1971).

I wish to mention here only a few possibilities with bears. The use of satellite tracking and monitoring techniques in studying polar bears appears desirable in that the animals are isolated, often confined to inaccessible areas, are wide-ranging and widely dispersed. Data can be obtained simultaneously from widely instrumented animals and from those difficult to locate or to follow from aircraft.

Grizzly bears are a threatened species in the lower 48 states. They have recently disappeared from some areas of suitable habitat, and future management may resort to transplants to bolster a dwindling population or to locally

reintroduce the species. Satellite tracking could be used to monitor these animals and develop a transplant methodology not now in existence.

There will always be some conflict between the grizzly and man. Troublesome bears such as those entering camp= grounds or those inadvertently injuring man are currently being moved as far from their point of capture as possible. Such bears should be instrumented in order to follow their movements. In this way the public--such as outfitters, back-packers and trailriders--can be alerted when the need arises. Movements may be 50 to 100 miles over rough isolated terrain, thus satellite monitoring would be effective. Position accuracy of the RAMS system is ±5 kilometers. (Cote et. al., 1973). Satellite monitoring could be a very useful management tool for studying bears and could prevent maulings and injuries when judiciously used. This could conceivably reduce the possibility of lawsuits against management agencies based on negligence in informing the public of known dangers.

The grizzly and black bear both have strong homing instincts. This creates management problems when bears are distantly released with the hope that they will remain where relocated. The phenomenon of homing which involves both animal orientation and navigation could be studied using satellite monitoring systems. An understanding of the homing process is needed to help in the management of aggressive or troublesome bears in areas where the bear population is critically low and killing the bear is not a

solution but only a step toward ecosystem extinction.

Both environmental and physiological parameters were successfully telemetered in the elk and black bear feasibility experiments using the IRLS system. Similar data along with location can be obtained using the RAMS system. Synchronous satellites or low-orbiting satellites in near-polar orbits (Nimbus) can be used. In addition to remote sensing already mentioned, the animal's habitat can be inventoried, evaluated, and precisely described using the Landsat multispectral imagery. The process is based on the unique reflective values of different vegetative types. (Craighead, J., 1976). It will be a tremendous aid in designating critical habitat of wide-ranging threatened species such as the grizzly.

We are thus now approaching the time when bears of the same or different species can be simultaneously monitored worldwide for research or management purposes and when both the animal and its immediate environment or extensive habitat can be simultaneously studied and results integrated and coordinated. Today in our world of exponential growth we desperately need to quickly assimilate research findings and quickly apply them and research techniques to crucial wildlife management problems.

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