TELEMETRY WITH UNRESTRAINED ANIMALS[1]

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Summary Telemetry from animals in their natural environment requires simple but efficient data coding methods. The problems common to behavioral or physiological studies with wild animals include immobilization techniques, harness design and ruggedized instrumentation development. Radio tracking experiences with the lion, elephant and buffalo and other game animals are summarized and an outline of instrumentation requirements for a study of long range goal finding ability in the green sea turtle is presented.

Introduction While there have been relatively few long range telemetry experiments involving wild or unrestrained animals, there seems to be increasing interest in this newly developing field. In the past few years the realization of satellite systems such as the Nimbus series, which primarily concentrate attention on phenomena at or near the earth's surface have made biologists wonder if such powerful techniques could be applied to the study of animal migration over long distances. These migrations in themselves have been under intensive study for several decades because there seems to be no complete hypothesis to explain the ability of various animals to systematically arrive at geographic goals with the great degree of precision that they demonstrate. Not only is the mechanism of goal finding ability sought, but it is also true that the migration of certain animals has great economic import. The processing of food resources is one aspect of this economic dependence. Another pertains to the spread of communicable diseases such as the recent outbreak of hoof and mouth disease in England, which might be correlated with the arrival of migratory birds.

Another aspect of interest in wild animal telemetry deals with observation of physiological and behavioral activity under those conditions where the normal methods of observation are difficult. Free-roaming animals seem to demonstrate sensory ability and problem-solving capability beyond those of their species which have been restrained in captivity. It will be of interest to observe by telemetric techniques the detailed and rich

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[1] This work is supported by the Office of Naval Research Contract NONR 4315(00), Air Force Office of Scientific Research Grant 1175-67 and National Aeronautics and Space Administration Grant 03-041-001.

variations of adaptation that the marine animals undoubtedly possess in their successful ability to live in the hydrospace.

Experiments in animal telemetry will take many forms but there are common problems which underly all of the techniques. These include methods of non-injurious capture, non-interfering attachment of instruments to the body of the animal, and reliability and economy in transmitting data under field conditions. Capture guns and drugs for the larger animals have become reasonably effective in the past few years.[2] Harnesses for attachment of instruments to animals are difficult to construct in such a way that they do not interfere with the normal activity of unrestrained animals. Terrestrial animals in general are preferably equipped with a collar around the neck to which instrumentation is firmly attached. Unless the antenna of the radiating transmitter is embedded in the collar, however, there is usually a high attrition rate. The most desirable radiation pattern for the transmitter is omnidirectional in the horizontal plane. This feature puts considerable constraint on electromagnetic radiators and also dictates the development of harnesses designed to keep the instrumentation fixed on the dorsal surface of the body. The requirements for low mass high reliability and reasonably long life suggest that telemetry transmitter system design consider coding methods of information transmission with high efficiency at low power drain. This infers, of course, low duty cycle and low data rates when appropriate. Beyond these common considerations telemetry systems will embody the more specific objectives of the experiments in their design. Distinction can be made between experiments involving tracking of an animal particularly during periods of nocturnal activity where the purpose of the investigator is to maintain close contact with the wild animal [3] while at the same time attempting to avoid interfering with natural behavior. These objectives are in contrast with telemetry systems designed to record and plot movement activities of animals in a limited area or habitat.[4] Here, semi-automatic or automatic methods of direction finding and plotting are most valuable. Both the tracking and locating concepts are potentially usable in the reception of specific physiological data such as body temperature, heart rate, blood pressure, etc.

The intent of this paper is to discuss experiments in the design and use of tracking telemetry devices with the big game animals of Africa and application of telemetry techniques to the study of goal finding ability in the green sea turtle.

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[2] For example see A.M. Harthoorn, "Application of Pharmacological and Physiological Principles in Restraint of Wild Animals", Wild Life Monographs, Wild Life Society, NYC,No. 14, March 1965.

[3] See for example F.C. Craighead and J.J. Craighead, BioScience 15, pp 88-92, 1965.

[4] Wm. D. Cochran, D.W. Warner, J.R. Tester and V.B. Kucchle, BioScience 15, pp 98-100, 1965.

Tracking Telemetry Design Figure 1 is a schematic of the basic-transmitter developed for animal telemetry experiments. In tracking studies it is intended to be pulsed at a low duty rate. This typically means an on-time of about 10 milliseconds at intervals of 1 second.

The circuit has a nominal RF output of 100 milliwatts at 150 Mhz. The overall efficiency is 20% with the oscillator stage running continuously. This stage draws about 1 milliamp at 9 volts. If we assume an operating lifetime of 50 days with a mercury battery source, the transmitter and batteries will weigh in the order of 200 grams. The circuit itself without batteries occupies a volume of 1.6 cubic cms using discrete components. Better power efficiency can be obtained with other circuits but in experiments using pulse rate coding for data transmission it is desirable to provide precise off/on control of the transmitter. Decreasing the lion" time to less than 10 milliseconds tends to require increased receiver bandwidth with an overall reduction in system sensitivity. Pulsing the oscillator would accomplish considerable saving in continuous power drain; however, the crystal itself has a finite rise time of 2 to 3 milliseconds and poor stability during rapid starting. These considerations lead to the decision to provide the continuous generation of the oscillator frequency at low level. Each of the amplifier stages is a doubler. This provides sufficient isolation to avoid regeneration in the small volume of the transmitter at 100 milliwatt levels of power.

One of the more successful antenna configurations is the transmission line design as originally constructed for this application by Motorola Aerospace Systems.[5] This design provides a vertically polarized radiation at 150 Mhz with a nominal input impedance of 50 ohms. The antenna itself occupies a volume of 6.5 cubic cms. This unit is easily incorporated into the harness along with the transmitter and battery supply. The harness itself should provide a conductive ground plane for the antenna with as much surface area as possible.

The pulse interval of about one second was selected as the result of field experience using a hand-held three-element yagi antenna for direction finding. With experience an operator can take a bearing on an animal moving in the dark by listening to 6 or 7 pulses from the transmitter. The one second interval seems to be a reasonable upper limit for subjective comparison of signal strength related to directional bearings. The receiver designed for this operation can either be mounted on the hand-held yagi antenna or carried by the operator. With an ideal bandwidth of 500 cycles the theoretical tangental sensivity is -140 dbm. This is equivalent to a free space path length of 1280 km assuming 0 dbm radiated power. Practical ranges in the field will be from 2 to 10 km when operating from a ground vehicle in a reasonably flat terrain. The greatest loss

[5] Based on the DDRR Antenna, J. M. Boyer, Electronics, 36 No. 2, pp 44-46, 1963.

occurs at the transmitter antenna which is seldom in an ideal orientation. Heavy foliage does not seem to have an appreciable effect at the practical ranges.

Figure 2A is a schematic for coding the basic tracking transmitter with two channels of temperature data. If tracking is the sole objective of an experiment, the thermister in one of the temperature channels is replaced with a fixed resistor, and the basic trigger circuit, Figure 2B, is used to key the transmitter. This circuit using the silicone control switch has proven to be extremely economical in power drain and reliable in pulse rate coding applications. The current drain is on the order of microamperes until the switch fires.

The two-channel temperature keying circuit provides separation of data channels with unequal transmitting periods. Typically, for example, Channel A will transmit for 20 seconds and Channel B for 10 seconds. Temperature data is normally recorded using a digital counter for measurement of pulse interval time, and the two channels are separated in the analysis of the data. When the temperature data is displayed in analog form using a Rustrak recorder, the two channels are visually separated as a result of the darker line being developed for the 20-second channel.

Experiments with Animals Plates 1A and B are photographs of the two-channel telemetry system used in the study of body surface temperature in the Zebra (Equus burchelli). Experiments [6] conducted to data have suggested that the zebra coloration is related to physiological control of body temperature in response to solar radiation. The reflectivity of tanned zebra hide is sufficiently different in the black and white areas as to create temperature differences on the order of 15°C in direct sunlight.

Plate 2 is a photograph of an African lion (Panthera leo) equipped with a typical instrumentation collar for tracking experiments. Studies [7] with these animals were conducted at the Serengeti National Park, Tanzania, East Africa. Some nine different experiments have been carried out with the use of telemetry. This effort is being directed toward a study of predation and its effect on the grazing animals of the Serengeti National Park. Another aspect deals with the study of surface body temperature and transient changes in response to novel sensory stimuli. The lions in this region are easily approached in a vehicle. Immobilization is usually effected with a syringe dart at close range. The lion seems to be particularly insensitive to instruments attached to its body and even to probes inserted surgically beneath the skin.

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[6] In collaboration with Wm. J. Hamilton, III, University of California.

[7] In collaboration with George B. Schaller, Serengeti Research Institute and Rockefeller University.

Plate 3 shows the installation of a small telemetry transmitter with a short whip antenna on the African buffalo. Telemetry of surface body temperature suggests strong correlation with behavior. Adult animals typically weigh 500 to 800 kg and are dependent on finding shade in order to prevent excessive body temperature during most of the sunlight hours. Grazing activity seems to be restricted to periods when the animal is not subjected to high body temperatures and, in fact, a knowledge of the surface body temperature is reasonably predictive with regard to the activity of the buffalo. The buffalo is difficult to instrument because of its habit of rubbing its neck and shoulder area against trees. This usually leads to difficulty with instruments attached to this part of the body.

Plate 4 shows the installation of a radio-equipped collar on a wild African elephant in the Lake Manyara Park region of Tanzania, East Africa. A narcotic drug was used in this instance to restrain this bull elephant. Almost daily radio relocation of the elephant was effected during some 40 days after installation of the collar. At no time was there an observed attempt by the elephant to remove the collar or damage the equipment. These animals seem to be sensitive to the presence of instruments, but also strangely reluctant to remove items attached to their bodies.

Plate 5 shows the installation of tracking equipment on the Spotted Hyaena, with the aid of the immobilizing drug, succinyl choline, which is effective for periods of about 10 minutes. Experiments with tracking the hyaena have been difficult because of the long distances these animals can cover with continuous running. In the Ngorongoro Crater region where the hyaena is confined to the crater floor, observation of hyaena predation was accomplished for a 10-day period using telemetry techniques. A chain collar was used in this instance for mounting the tracking transmitter on the neck of the animal. Some damage was done by other hyaenas to the equipment, although it operated for the period given.

A number of telemetry experiments have been carried out [8] in the study of the wild javalina (Collared peccary) in the desert mountains of Arizona. A shoulder harness was used in most of these studies for attachment of the transmitter. There seems to be no effective way of attaching instruments to these animals in the wild for periods longer than several months, although similar harnesses were effective on captive animals for periods up to two years.

The green sea turtle (<u>Chelonia</u> <u>mydas</u>) represents an entirely different type of telemetry technique. Here [9] we are involved in a set of experiments leading to a better

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[8] Under the direction of Gerald I. Day, Arizona Game and Fish Department.

[9] In collaboration with Archie Carr, University of Florida.

understanding of the environmental factors used in long range goal finding ability of this marine turtle.

Plate 6 is a photograph of one of the earlier transmitting floats attached to an adult turtle weighing approximately 100 kg. Our current efforts in the study of this animal have led to instruments designed to provide data on magnetic heading and swimming speed of turtles released at sea at times when they attempt to relocate their nesting beaches. Figure 4 is a block diagram of sensor coding for a transmitter installed on the float attached to the turtle. Data on course behavior is transmitted every 20 minutes from a low power high frequency transmitter, using a vertical whip antenna. Typically, the carrier signal is on for 10 seconds for direction finding purposes. Velocity information is pulse rate coded in the range from 1/2 to 2 pulses per second to represent average velocity from 0 to 4 miles per hour. A compass senses heading and data is transmitted at the same 1/2 to 2 pulse per second rate. Both velocity and magnetic heading data are smoothed with a 10-second time constant averaging network to eliminate the effect of wave action. The compass is a spinning magnetometer type which provides a resolution of ±1° bearing with an accuracy of 1% of the local magnetic field-. Transmission of data by ground wave transmission has been effective over ranges of 200 miles.

Conclusion In summary, animal telemetry techniques offer considerable potential for extending knowledge in the understanding of physiology and behavioral aspects of free-roaming animals. The successful utilization of instruments on these animals will require experience in the development of harness techniques to preclude interference with the data and/or injury or interference to the animal under study. When data rates are low, pulse rate modulation at about 1 pulse per second offers system economy and provides an adequate signal for obtaining bearings with hand held directional antennas.

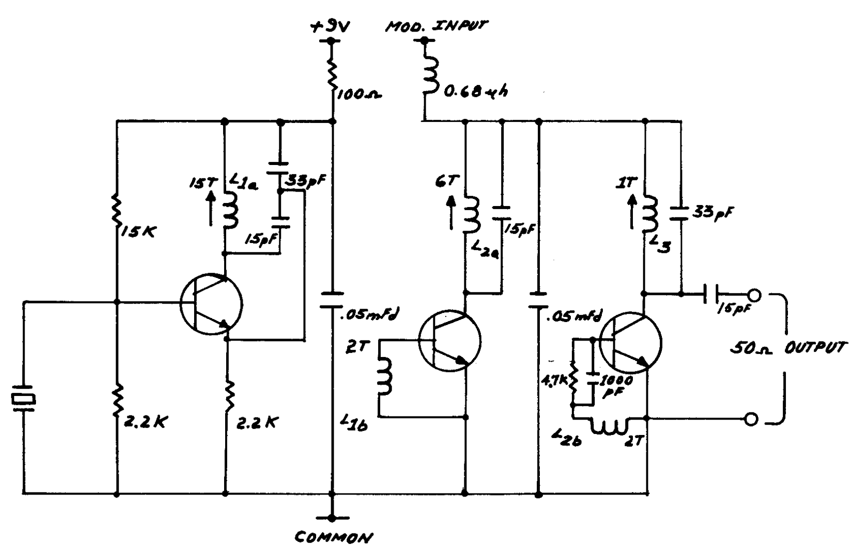

FIG. 2 V.H.F. TRANSMITTER

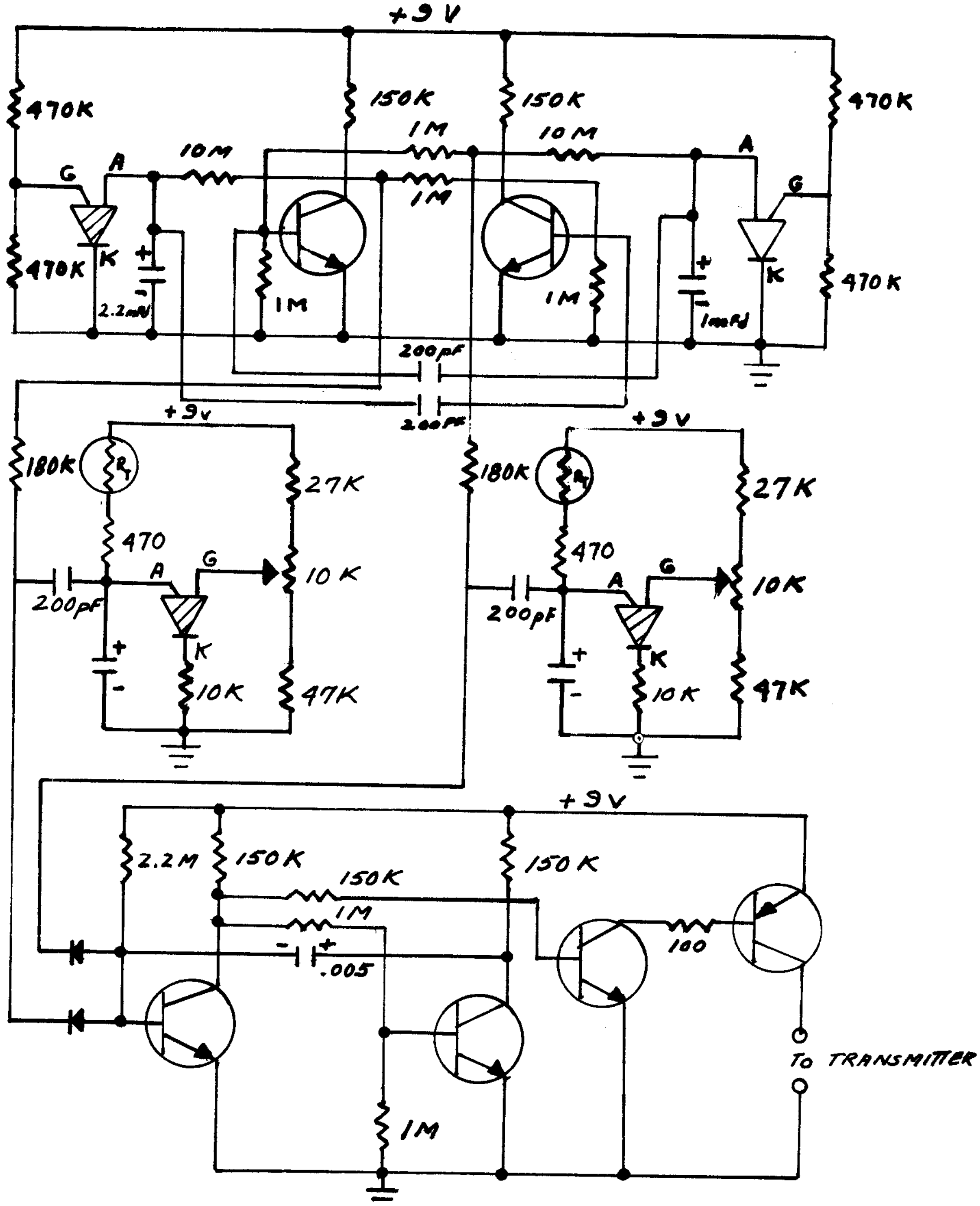

FIG. 2A TWO CHANNEL TEMP. COMMUTATOR

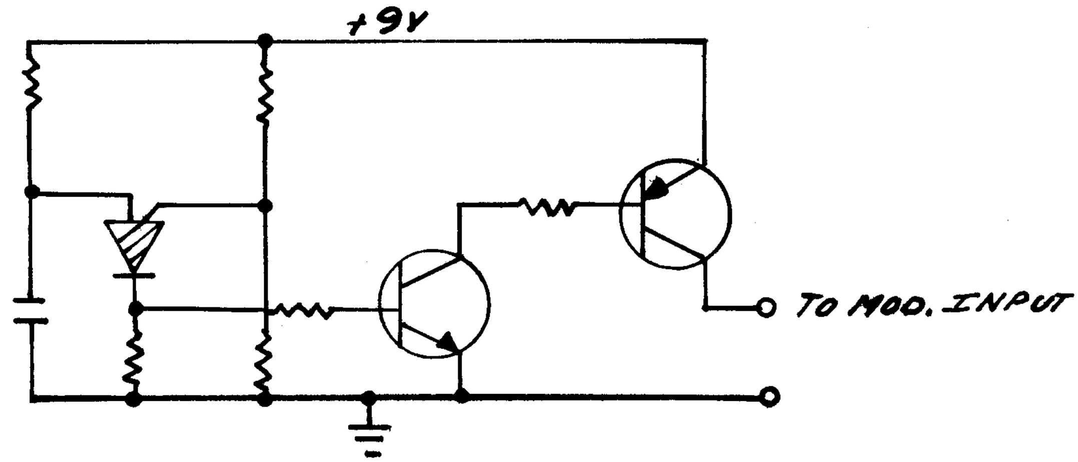

FIG. 2B BASIC TRANSMITTER KEYING CIRCUIT

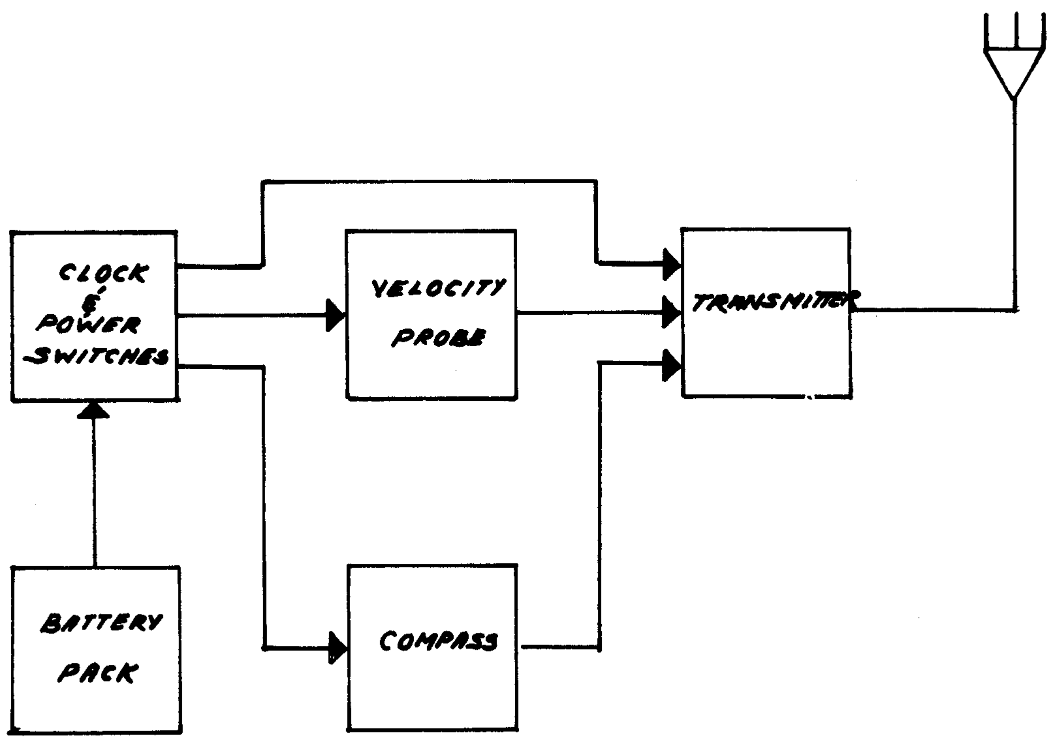

FIG. 3 TURTLE TRACKING SYSTEM

Plate 1A A dual channel telemetry transmitter for the study of skin temperatures in the zebra. This view shows the transmission live antenna mounted on a temporary ground plane surface.

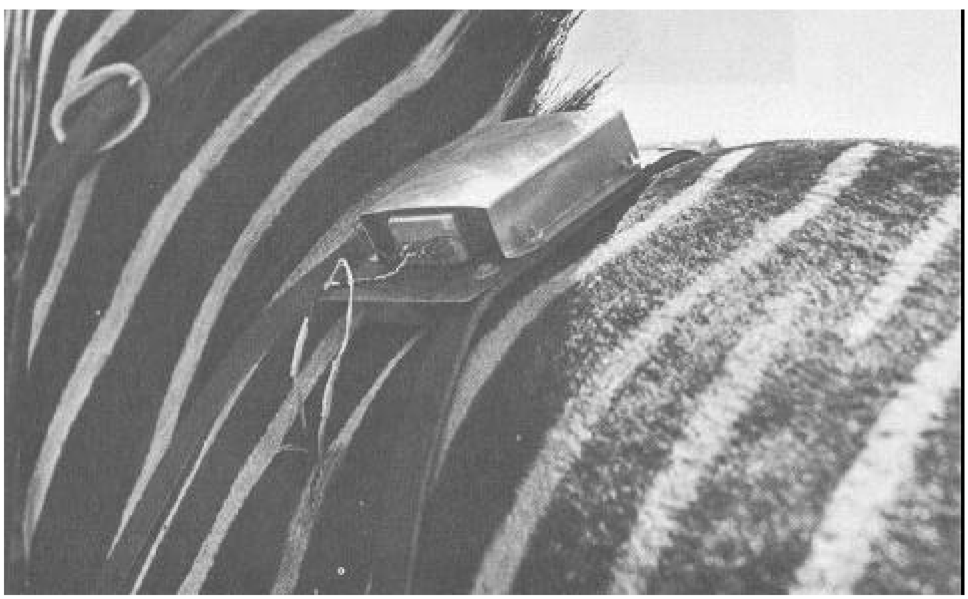

Plate 1B A temperature telemetry transmitter and sensor probes in a temporary harness.

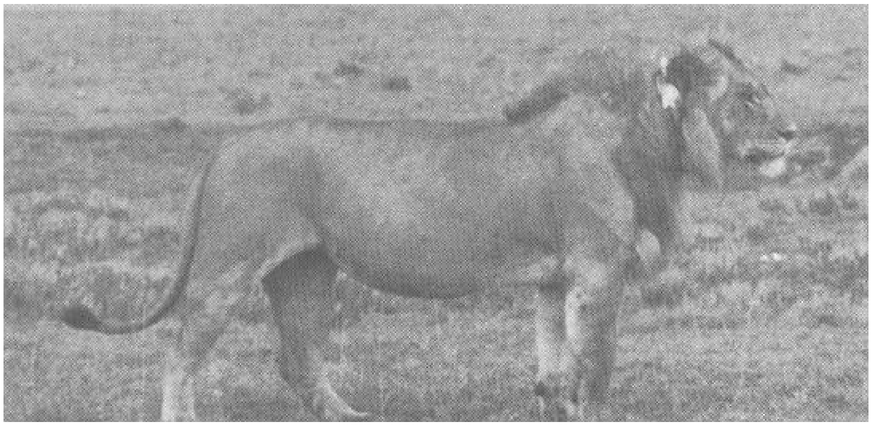

Plate 2 Tracking transmitters on the lion. The upper transmitter (white) was destroyed in a fight with another male lion. A second transmitter with a self contained antenna was mounted at the lowest point on the collar. This provided for successful completion of the tracking experiment.

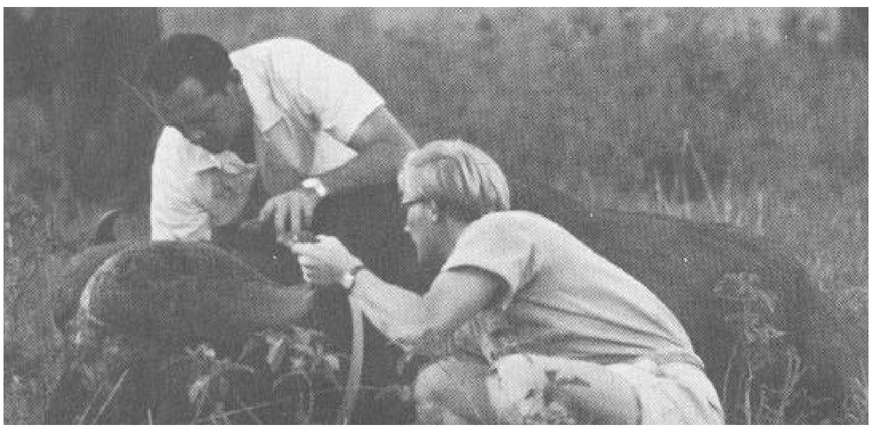

Plate 3 Installing a temperature telemetry unit on the narcotized African buffalo.

Plate 4 Placing the transmitter equipped collar on the African elephant.

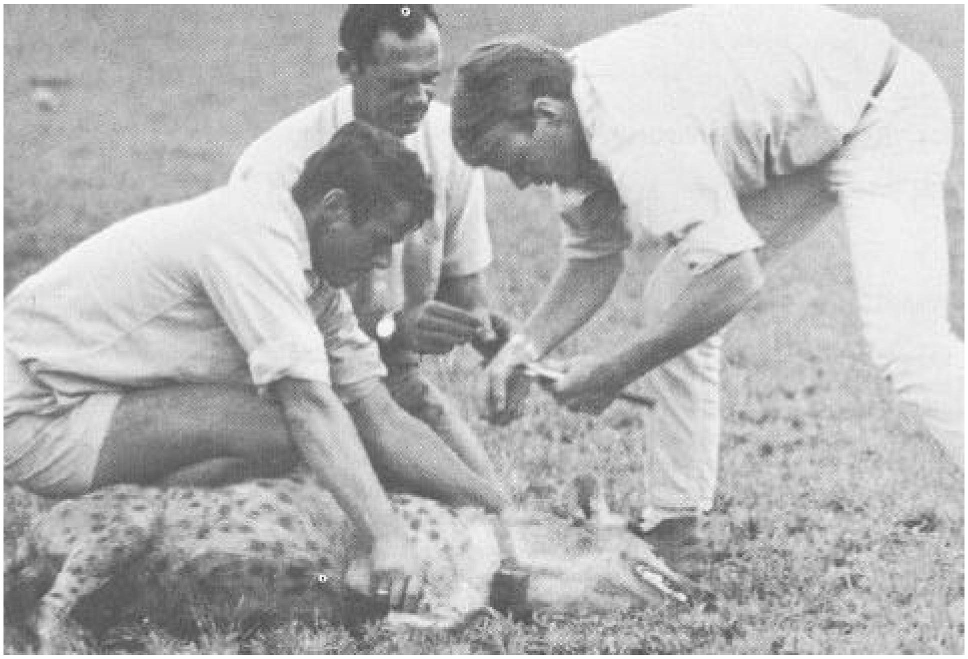

Plate 5 The Spotted Hyaena being instrumented for tracking experiments.

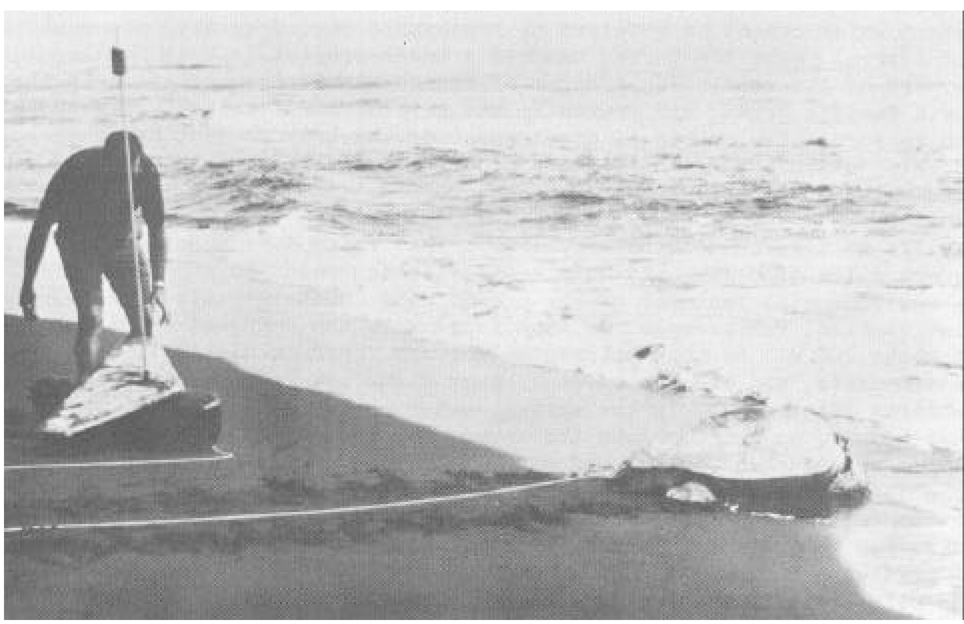

Plate 6 A long range transmitting float for study of green sea turtle goal finding ability.