Paper 37

Telemetry Experiments with a Hibernating Black Bear

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INTRODUCTION

During the winter of 1966-67 the body temperature of a male black bear (*Ursus americanus*) was telemetered in winter sleep under natural denning conditions (Craighead *et al.* 1971). To improve equipment and techniques for studying the physiology and behavior of bears under natural conditions, a captive black bear was used to continue the investigations during the winter of 1971-72. This paper describes the experiments and the results.

Other investigators (Essler and Folk 1961; Folk *et al.* 1965, 1968, 1972; Hedge *et al.* 1965) have studied the physiology and hibernation behavior of captive bears under simulated natural conditions. Our own long-range objectives are to develop the means of obtaining ecological, behavioral and physiological data from unrestrained hibernating animals in the wild through the use of recent electronic and technological advances, including earth-orbiting satellites (Craighead *et al.* 1971).

The specific objectives of the work described here were to develop and test telemetry equipment suitable for monitoring a typical physiological parameter (body temperature) by satellite; to refine immobilizing and handling techniques; to visually observe a bear throughout the hibernation period and correlate its behavior with body and den temperatures; and to outline surgical techniques for implanting telemetry transmitters in the body of a wild black bear.

METHODS

Simulated den conditions

A male black bear cub approximately 8 months of age was obtained from the Montana State Fish and Game Department in October 1971, and on 11 November 1971 was placed in a concrete block building containing (1.8 × 2.4 × 2.4 m) cells with no windows and steel mesh doors. An interconnecting doorway with a sliding gate permitted us to move the bear from one cell to another. Ambient light was reduced to a level simulating the interior of a den covered with snow.

Fig. 1 An infrared scope (shown here without the light-blocking drape) was used to observe the hibernating bear (Fig. 1A) without disturbing him.

Enough light entered around the door jambs for the animal to probably distinguish night from day much as he might from within a natural den. A 1 × 1 × 1.2 m wooden box was placed in one cell to provide an enclosure. Loose straw was put in the cell for bedding material. The bear constructed a bed by dragging straw into the box. Food and water were discontinued after 15 December when the bear became noticeably lethargic and was feeding irregularly.

Instrumentation

Detailed records were kept of the bear's activity and body temperature, the

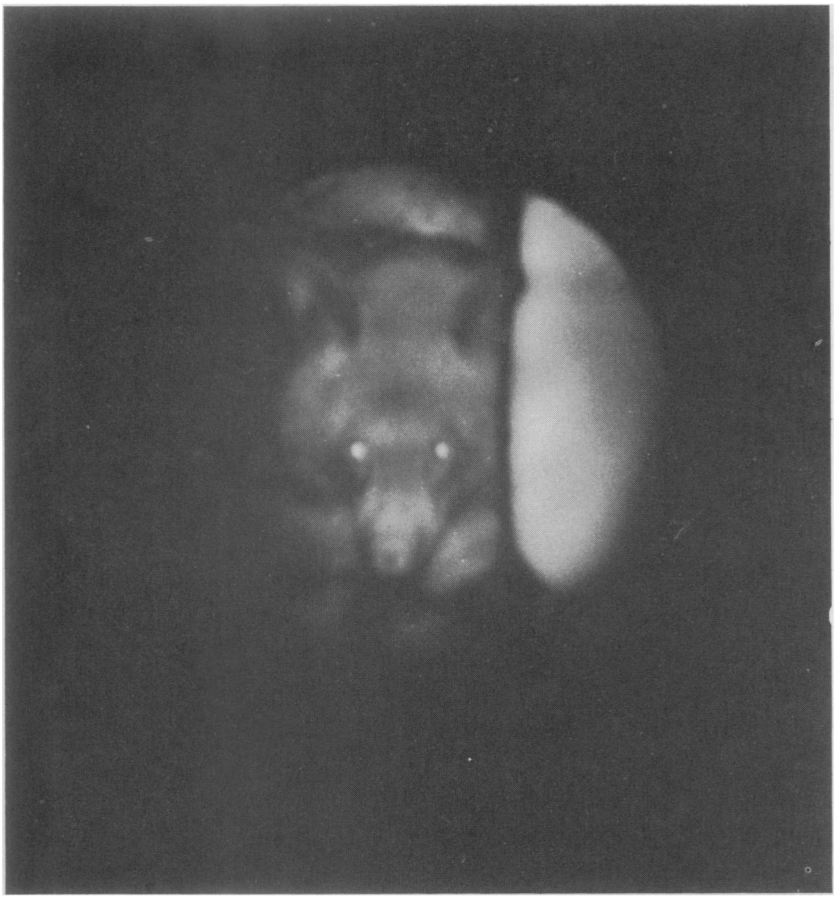

Fig. 1A

den temperature, local barometric pressure, disturbances, and other factors which might influence hibernation behavior. Temperature in the den room was recorded using a Ryan Thermograph, a clockwork-driven chart recorder which provides a continuous record for 30-day periods. Temperature and relative humidity were also recorded with a Casella hydrothermograph placed 10 m from the den room. Having found no significant differences between the temperature records at the two sites, we removed the Ryan recorder from the den after the first month of operation to eliminate disturbances during the changes of charts.

The bear's body temperature was measured with a temperature-sensitive telemetry transmitter implanted in the abdominal cavity. Data from the transmitter were recorded by equipment near the den room. The recording equipment was designed to be compatible with a satellite data-collection system (the IRLS experiment on the Nimbus-3 satellite). Although it was possible to transmit our data via the satellite this was not attempted since we had earlier demonstrated the feasibility (Craighead *et al.* 1971).

Barometric pressure was obtained from daily Weather Bureau records. Variations over the short distance separating the den and the Missoula recording station were insignificant.

The bear was observed with the aid of an infrared weaponsight loaned to us by the Department of the Army (Fig. 1). The scope was mounted on a tripod and trained on the den box. A black cloth draped over the scope prevented light from entering the den during daytime observations. Observations were made daily to determine the animal's degree of lethargy, changes of position, and whether he had urinated or defecated.

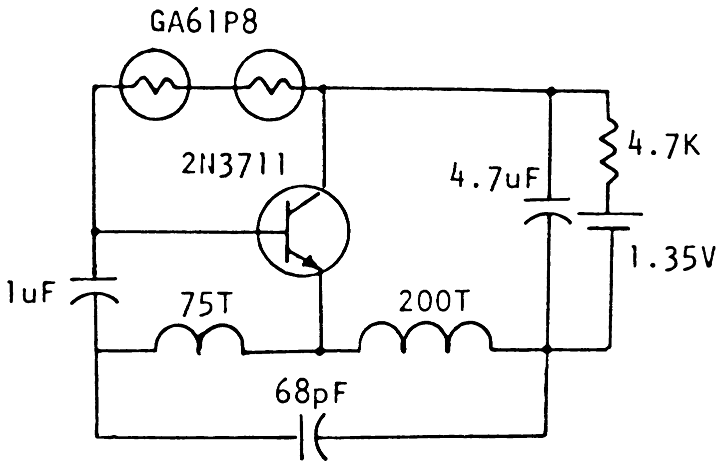

Fig. 2 Circuit for body temperature telemetry transmitter used on a hibernating black bear.

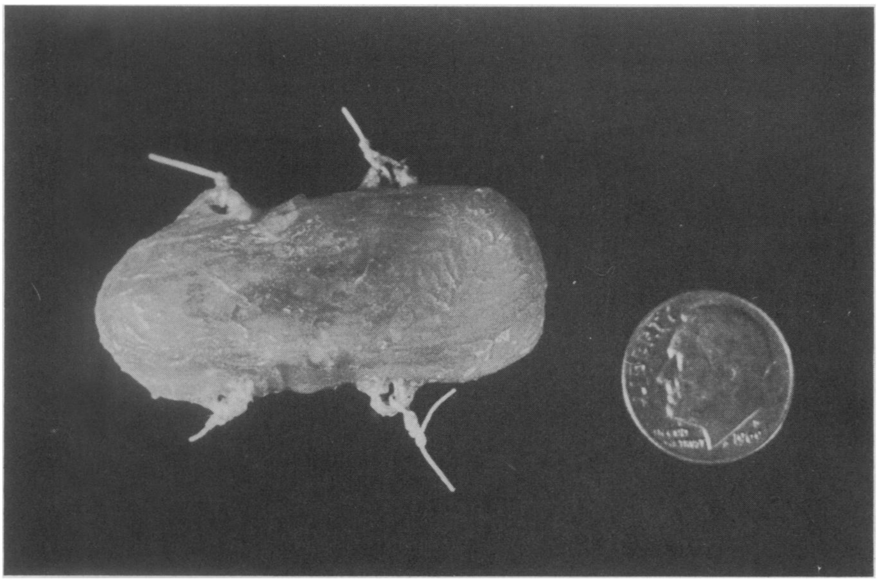

Fig. 3 Body temperature telemetry transmitter after removal from the bear in April. It was attached to the peritoneum with sutures to keep it in a known location.

Temperature transmitter

The circuit of the temperature-sensitive transmitter is a simple 1 MHz blocking oscillator with a pulse rate determined by two thermistors in the collector-base path (Fig. 2) and is similar in design to units used by Mackay (1970) and Goodman (1971). A Hg-625R cell provides an estimated lifetime of several years (at 37°C). Previous work with this transmitter had proven it to be reliable and accurate (Craighead *et al.* 1971).

Transmitter components were imbedded in epoxy for mechanical support and protection. The transmitter assembly was then waterproofed with a mixture of beeswax and paraffin. An outer covering of Dow-Corning Type-A Medical Silastic was used to prevent tissue reaction when implanted in the bear's body. The completed unit was 4.5 × 2 × 1 cm in size and weighed 12.8 g (Fig. 3).

The transmitter was calibrated in a constant temperature water bath and its thermal time constant measured by subjecting it to an abrupt temperature change of 10°C. The thermal time constant was found to be 1.3 minutes in well-stirred water. The temperature indicated by the transmitter in 4 time constants (5.2 minutes) was 98.2 percent of the final value. This is equivalent to an error of less than 0.2°C.

The transmitter was recalibrated in the water bath after removal from the bear. We found no measurable shift in the temperature calibration.

Body temperature recording equipment

Signals from the temperature transmitter in the bear's abdominal cavity were picked up by a circular loop antenna (14 turns of No. 24 wire, 50 cm in diameter) placed on the floor of the den directly under the bear's bed. The antenna was connected to a standard broadcast band receiver in an adjoining room by a 9 m cable. Pulses from the transmitter detected by the receiver were converted to direct current by a pulse rate converter (Varney 1974) and recorded on a Rustrak model 288 chart recorder at a chart speed of 2.5 cm per hour. A block diagram of the recording setup is shown in Fig. 4.

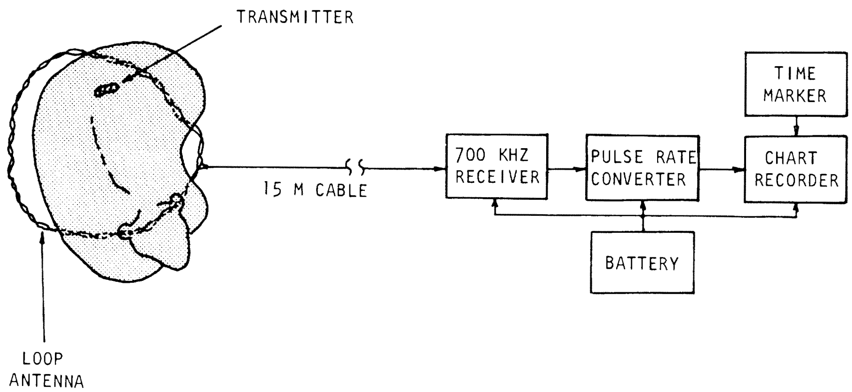

Fig. 4 Body temperature recording equipment used on a hibernating black bear.

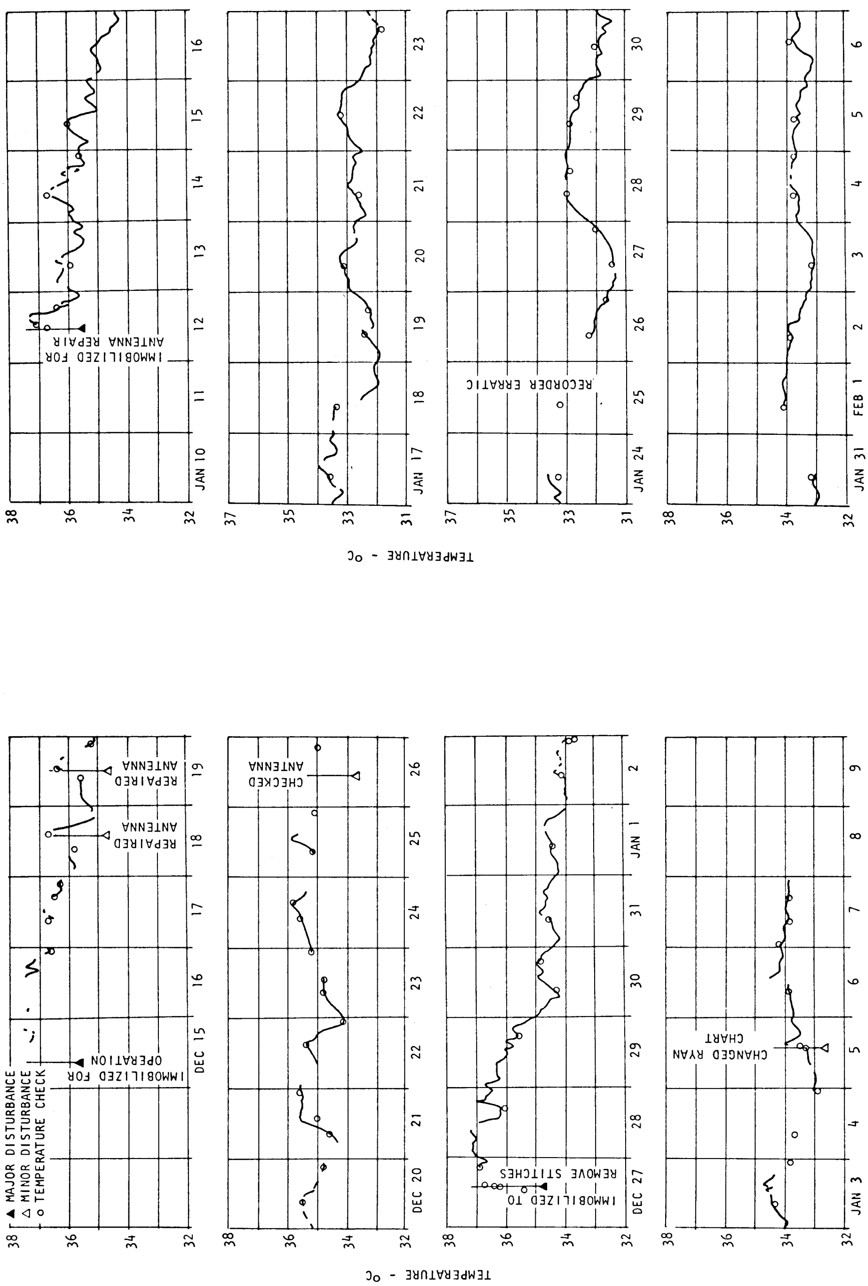

Fig. 5 Daily body temperature data of a hibernating black bear.

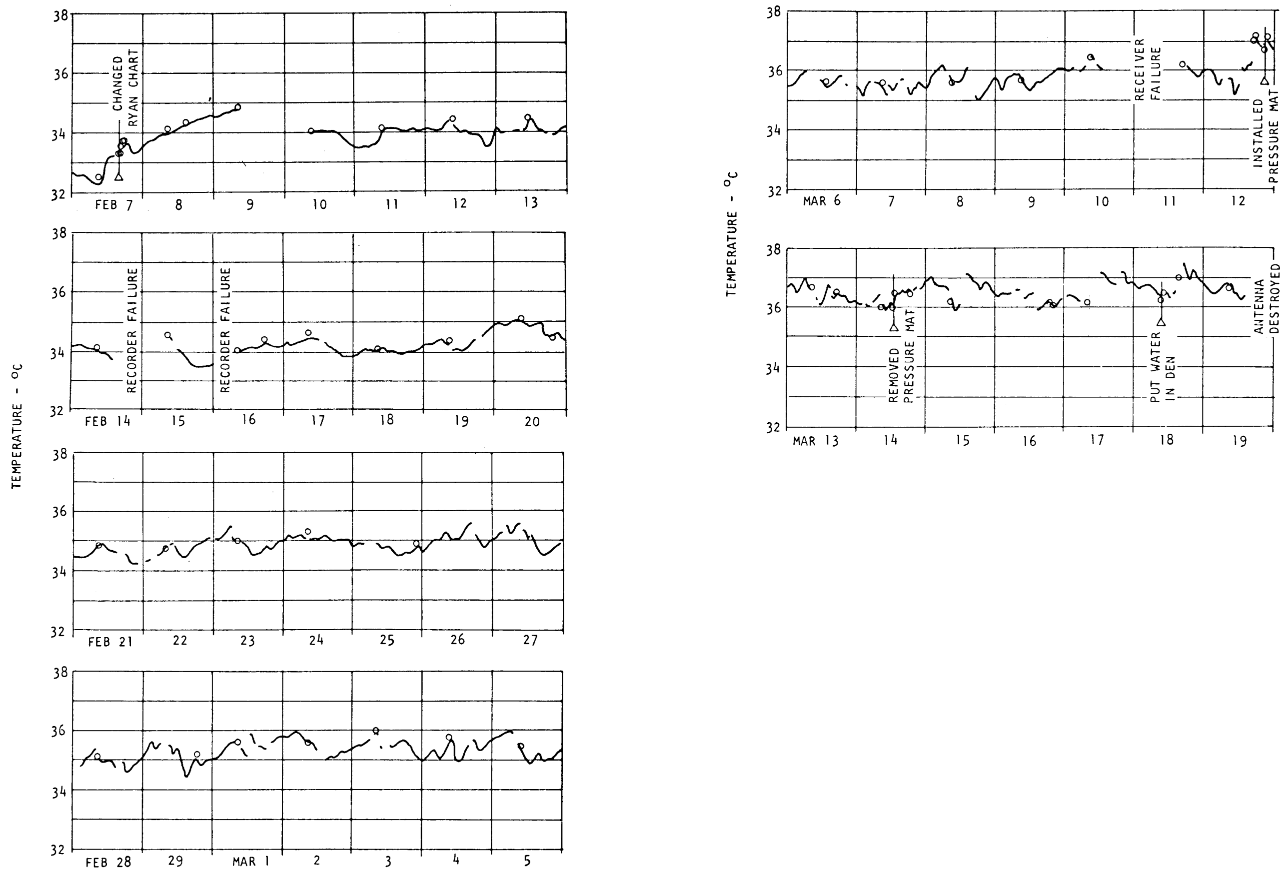

Fig. 5 Daily body temperature data (cont'd.).

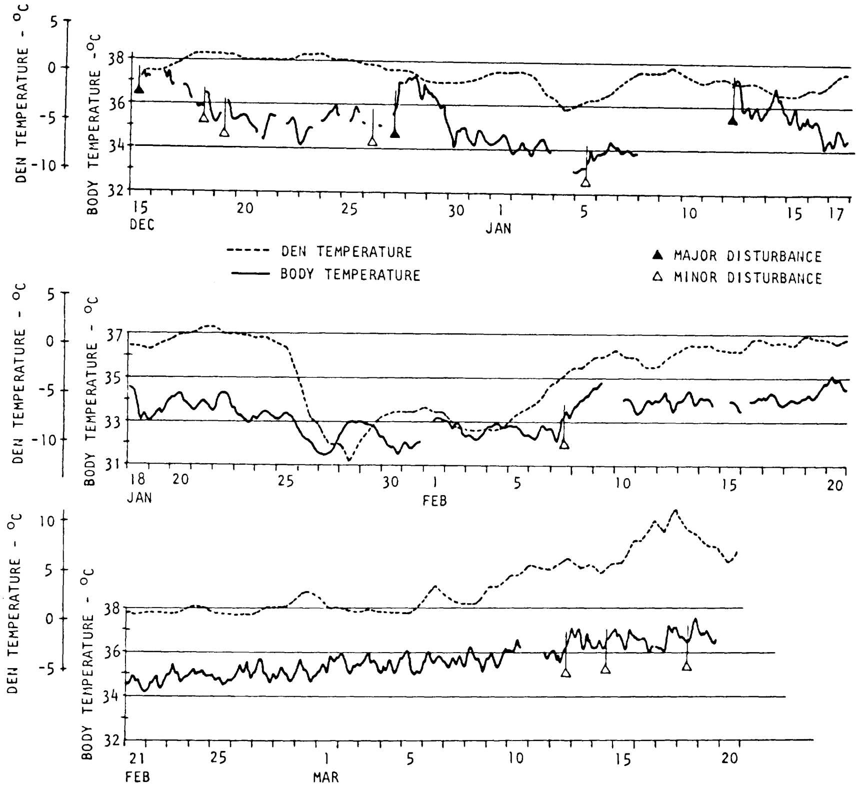

Fig. 6 Body temperature and ambient den temperature for a hibernating black bear.

Surgical procedures

We immobilized the bear to implant the temperature transmitter by firing a syringe dart containing 45 mg of phencyclidine hydrochloride (Sernylan) in a 100 mg/cc solution into the shoulder muscles. An additional 15 mg was administered after the dose took effect and the bear taken immediately to a local veterinary clinic for the operation.

The bear was placed in a slightly head-down position on the operating table to prevent saliva from blocking air passages. A 0.125 grain dose of atropine was given to reduce salivation. The belly was shaved with an electric clipper, washed, and disinfected. A 10 cm incision was made through the skin and fat along the midline from just below the umbilicus to 3 cm anterior to the penis. This location (the *linea alba*) was selected because it is relatively free of large blood vessels and would present fewer problems if field surgery were attempted.

An incision through the peritoneum into the abdominal cavity permitted placing of the transmitter (which had been sterilized overnight in Zephiran chloride [1 : 1000]) into the abdominal cavity. It was anchored to the peritoneum in four places with nylon sutures. The peritoneum was then sutured with chromic cat gut, Furacin powder sprinkled into the incision, and the skin sutured with heavy nylon. A 2 cc injection of penicillin-streptomycin was

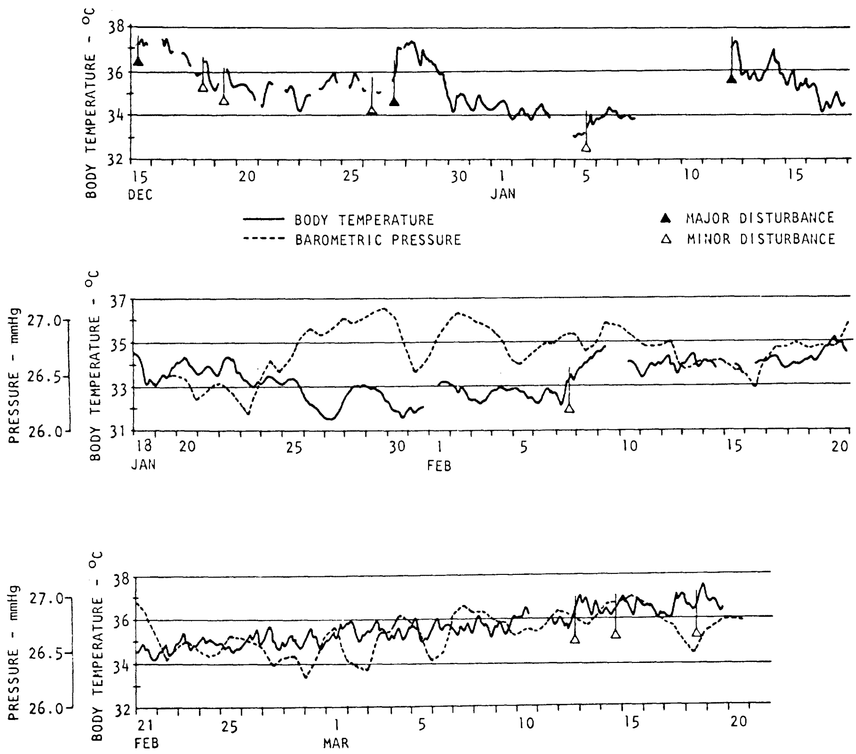

Fig. 7 Body temperature and barometric pressure recorded for a hibernating black bear.

given at the conclusion of the operation. The entire procedure took about 45 minutes.

We immobilized the bear 12 days later (27 December) to examine the incision and to remove the external stitches. Healing was normal, but a slight inflammation was present in the caudal portion of the incision. Topical application of Combiotic, combined with a 2 cc intramuscular injection, were used to combat the infection. The incision was checked again on 18 January and had completely healed. Regrowth of hair on the belly was slower than expected.

We followed the same operating procedure in removing the transmitter from the animal on 5 April. Examination of the peritoneum revealed that the transmitter had been encapsulated in a thin layer of scar tissue. We detected no adverse tissue reaction or inflammation.

Body temperature data

Temperature data from the implanted transmitter were recorded continuously for more than 3 months (Fig. 5). To check on the automatic recording system, we made manual counts of the transmitter pulse rate with a stop-watch during daily equipment checks. Some gaps occur in the data when the bear was out of his bed or oriented unfavorably to the receiving antenna; these occurred more frequently at the beginning and end of the hibernation period and provide an index of the animal's activity while entering into and emerging from deep sleep. Data gaps due to equipment problems, rather than animal movements, are noted on the graph.

Disturbance to the bear such as anal temperature determinations and other procedures necessitating trespass into the den are also apparent on the graph. The same data in a more compressed form are plotted against den temperature in Fig. 6, and barometric pressure from 19 January to 20 March in Fig. 7.

Day-night rhythms

Diurnal changes in body temperature were not pronounced though they occasionally did occur for short periods (e.g. 30 Dec.-2 Jan. and 20-22 Jan., Fig. 5). Such changes were on the order of 0.5 to 1°C. During other periods, they either did not occur at all or, if present, were obscured by larger trends due to other factors. Folk and Essler (1961) reported day-night body temperature rhythms of the black bear in captivity and Craighead and Craighead (1967) recorded similar results from a wild black bear in a natural den.

Responses to disturbances

The largest and most significant changes in body temperature occurred in response to disturbances, and varied relative to duration and intensity of the disturbance. On three occasions when the bear was immobilized, his temperature rose 2°C in a period of 2 hours.

When disturbances were less severe (for example, when we entered the den for a minute or two to change charts in the temperature recorder or to repair a disconnected leaf) temperature readings increased typically 0.5°C. Body temperatures behaved erratically, rising and/or falling for several days afterward.

Response to cold

Data from the period between 24 January and 10 February are particularly interesting (Fig. 6). A severe storm moved into the Missoula area with subzero temperatures and high winds. Accordingly, the temperature in the den began to drop on 25 January. The bear's temperature dropped as the den temperature declined. On 27 January the body temperature of the bear reached a low of 31.8°C, approaching the lowest temperatures reported in the literature (Hock 1957). Then, although den temperature continued to drop, body temperature rose abruptly to 33°C. This cycle was repeated between 30 January and 1 February. We suspect that a spontaneous arousal mechanism was operating, with 32°C being the lower limit the bear could safely tolerate; a metabolic increase ensued when this limit was approached. If this behavior is typical of all black bears and grizzlies, it may serve as an alternative to the regular periodic awakening that occurs in other mammalian hibernators, but which has not been demonstrated in bears.

In general, long-term body temperature trends followed variations in ambient temperatures. This is particularly evident in Fig. 6 for the period between 5 February and 20 March. A gradual increase in den temperature took place during that time and was accompanied by a 3°C increase in body temperature.

Influence of barometric pressure and relative humidity

We believe that variations in barometric pressure had little effect on temperature or activity of the bear but data were not conclusive. No correlation between body temperature and pressure is evident in Fig. 7 from 20 January to 20 February. There was a gradual increase in pressure from 21 February to March which was paralleled by a rise in body temperature, but this was probably due to increases in den temperature occurring during the same period rather than to pressure changes. Relative humidity data taken during the hibernation period did not appear significant.

Comparison of rectal and abdominal temperatures

On three occasions we took a series of rectal temperatures for comparison with the telemetered abdominal-temperature data. This was done during periods of immobilization when the sutures were removed on 27 December, when repairs were made to the den antenna on 12 January, and when the transmitter was removed on 5 April.

Rectal temperatures were taken with a glass-mercury thermometer inserted approximately 9 cm into the rectum. The thermometer was allowed to stabilize for 2 minutes after insertion before readings were taken. Abdominal readings were recorded by placing a portable radio beside the bear and timing the transmitter pulse rate with a stopwatch.

Rectal temperature readings ranged from 1.3°C below to 0.3°C above the abdominal readings (Fig. 8). Data are insufficient for generalizations, but

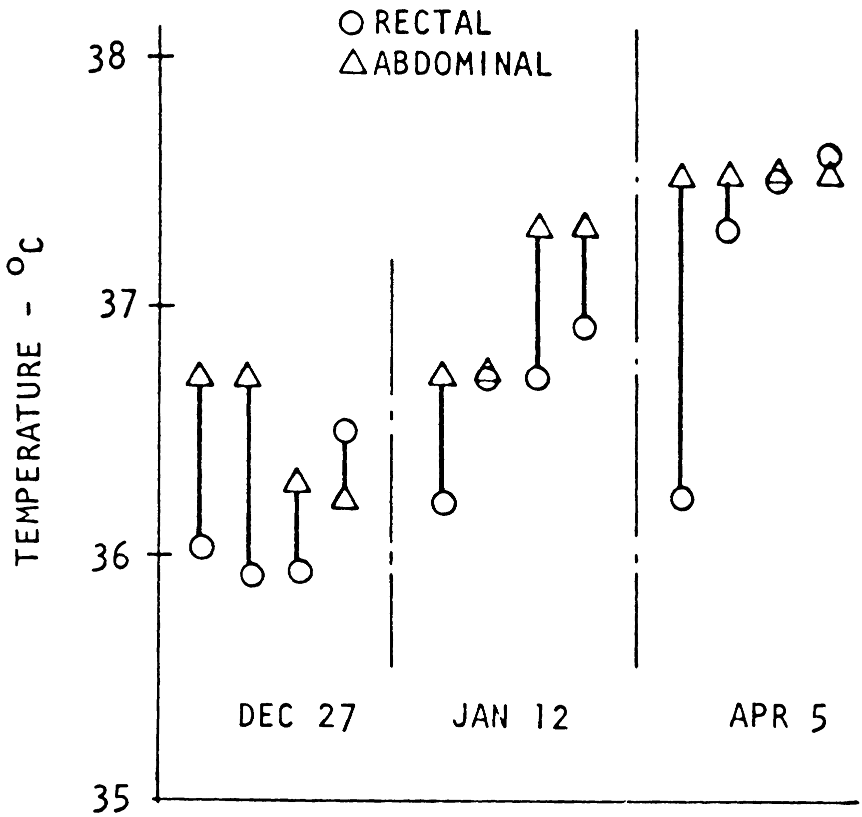

Fig. 8 Comparison of rectal and abdominal temperatures of a hibernating black bear.

give a rough idea of the variation to be expected between the two methods and permit evaluation and correlation of rectal temperature data obtained during previous field studies.

Weight loss during hibernation

The bear was weighed whenever possible during the experiment to determine rate of weight loss during hibernation (Fig. 9). The bear weighed 34 kg in November when placed in the den to acclimatize. Feeding was continued, and weight increased to 42.5 kg at the time of the implant operation on 15 December. Food and water were not offered after that time. The bear became dormant, and his weight declined gradually during the winter to a low of 30.8 kg when the temperature transmitter was removed on 5 April. This represents a weight loss of 11.7 kg or 27.5 percent. During the 112-day period from 15 December to 6 April, the average weight loss was 0.1 kg per day. Feeding was resumed on 7 April, and the bear's weight increased to 41 kg by 19 April. In 12 days the bear regained weight at an average rate of 0.85 kg per day.

A load-cell weighing system was evaluated for future use in more detailed studies of weight loss and metabolism. It consists of a reinforced plywood platform supported by three load cells which produce an output voltage proportional to the weight on them. They are connected to readout equipment that can be located at any desired distance. The system provides both a meter readout and a continuous chart record of the total weight on the platform. The platform is mechanically solid compared to a conventional spring or balance system, with downward deflection for a 45 kg load being only 0.76 mm. The system is accurate to within 0.5 percent of the full scale load

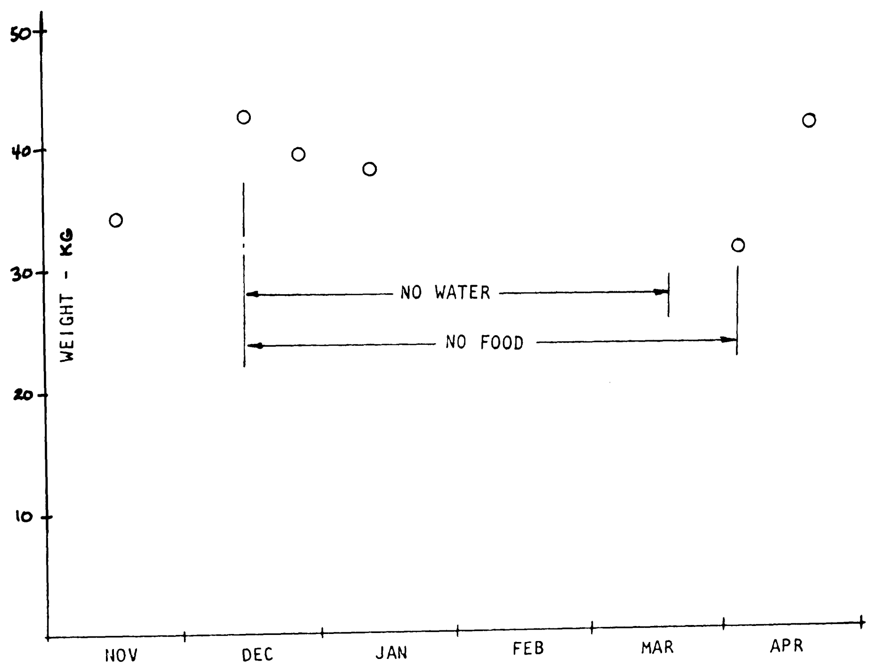

Fig. 9 Changes in weight of a hibernating black bear between November 1971 and April 1972.

of 45 kg, or 0.23 kg. Larger loads can be accommodated by using less sensitive load cells.

Tests of the weighing system were satisfactory and indicated that this technique holds promise for future studies. In further experiments with hibernating captive bears, a weighing platform could be placed beneath the bed to give an accurate, continuous record of weight loss during winter that would permit correlation of weight loss with temperature changes and metabolic increases during spontaneous arousal. Measurements could be made on a year-around basis by placing the platform where the bear would walk across it periodically. It could also be used to quantify activity at the beginning and end of the hibernation period by recording amount of time spent in the bed. It may be possible to use the system in the den of a wild hibernating bear, although construction of an unobtrusive platform and its installation in a natural den would pose problems.

Activity monitoring

In future experiments with wild bears in natural dens, it will be valuable to measure shifts of position and movements of the animal within the den. Information about such movements can be obtained with the temperature monitoring system used in this experiment. The range of the transmitter is limited to about 1 m, so data were not obtained when the bear was not lying in his bed directly over the loop antenna. An examination of the temperature record for signal dropouts gave a general indication of activity or inactivity of the bear. This was not foolproof, however, since signal loss can also occur when the transmitter is aligned orthogonally to the receiving antenna.

From observation with the infrared scope we concluded that the bear probably did not urinate or defecate during a period of 96 days, thus supporting Folk's conclusions (1972).

Release of bear

The bear gradually became less lethargic during March and began leaving its bed for short periods during the latter part of the month. On 19 March he located the antenna cable and disrupted transmission. Since the animal was nearly out of hibernation, we terminated the experiment and removed the temperature transmitter from the bear on 5 April.

The bear was immobilized again on 19 April to remove stitches from the abdominal incision. The temperature telemetry transmitter that had been removed earlier was inserted rectally and a continuous temperature recording was made for 2 hours to observe the effect of the immobilizing drug on temperature regulation. The indicated temperature remained nearly constant at 38.5°C. The bear was held until 15 June, then fitted with a radio-location collar and released.

DISCUSSION

While we attempted to simulate the natural conditions of hibernation in order to develop and improve our telemetry equipment and monitoring techniques, many factors differed from a completely natural situation and probably influenced the information obtained. Experience gained in temperature monitoring changed some of our initial ideas about den-monitoring methods and suggested new lines of development and investigation.

Implanting the temperature transmitter in the abdominal cavity would be a very ambitious undertaking under adverse field conditions in midwinter. We concluded that it would be preferable to conduct any necessary implant surgery early in the fall when it would be possible to capture a wild bear and hold it a few days for observation and recovery. This would reduce the risk to the animal and increase our confidence in the resulting data by providing a longer period between surgery and the beginning of hibernation. Before release, the bear would be fitted with a radio collar and radiotracked until it entered a den for winter. With the temperature transmitter already implanted there would be no need for surgery in the field.

If necessary, it is feasible to implant telemetering devices subcutaneously without attempting to enter the body cavity. Such surgery is relatively minor and has little effect on the animal even when done in midwinter. Temperatures obtained from a subcutaneous implant differ somewhat from deep body temperature recordings (Craighead *et al.* 1967), but differences can be minimized by selection of the proper location (near good blood supply and under a thick coat of fur or layer of fat). It should also be possible to obtain good EKG potentials from a subcutaneous implant by running leads under the skin for short distances from the transmitter.

The rapid rise in body temperature and changes in behavior of the bear in response to disturbances while in a lethargic condition, indicate that frequent visits to a natural den would disturb the animal and would influence results of behavioral or physiological monitoring. This was confirmed by earlier field experience. On all occasions when bear dens were visited and examined, the bears were alerted or partially aroused from lethargy by our presence. On five occasions bears emerged from the dens; one animal did not return. Therefore, instrumentation must be designed for unattended operation over long periods of time. Satellite monitoring has a distinct advantage in this respect.

Some bears emerge from their dens for short times during early spring. A time-lapse camera installed outside a den and triggered when the bear moved away from a proximity detector inside the den, would photograph the bear at intervals revealing early post-hibernation behavior.

Heart rate may provide a better measure of lethargy and response to disturbance than body temperature. However, measurements of body temperature and their relationship to ambient den temperatures and heat conservation mechanisms under natural conditions are basic to a thorough understanding of how bears hibernate. The fact that the bear exhibits minor drops in body temperature compared to other hibernators, arouses quickly when disturbed, and spontaneously in response to low ambient temperatures, becomes active enough to leave a den or defend itself, and can quickly regain body weight following winter sleep, all suggest the bear has evolved a highly efficient hibernating mechanism. It will require sophisticated electronic monitoring equipment to precisely record the hibernating process under natural conditions of denning. We believe this can be best accomplished using satellite technology.

ACKNOWLEDGEMENTS

This research was supported by the National Geographic Society and by National Aeronautics and Space Administration Research Grant NGR-27-002-006. We are grateful for the help of many people during the course of the study. Barometric pressure data was provided by Eric Nelson. John Hechtel assisted throughout the project in handling and maintaining the bears, and in radio-tracking them after release. Dr. B. W. O'Gara provided us with assistance in caring for the bears, the implant surgery was done by Conrad Orr, DVM, and John Mitchell made many helpful suggestions.

We wish to express our appreciation to the W. C. Dillon Company for the loan of the load cell weighing system, and to the Montana State Fish and Game Department for providing us with the bear used in the project.

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