

Edapt. on Net.

Black Bear # 6 ?
was the 1st bear to
be monitored by satellite
would we doubt have
been given a name
but - - -

7.C.C.
file copy

Draft - February, 1972
F. C. Craighead, Jr.

SATELLITE SPIES ON SLEEPING BEAR

Three Men in a Den

A lone figure was sitting on snowshoes. The deep snow unmarred except for a few human tracks stretched beyond him to a dark green barrier of scattered spruce and fir. The man's attention was neither directed to the immobilizing gun beside him nor to the projectile syringes carefully arranged on a knapsack. Even the camera lay idle. Oblivious to his winter surroundings he was listening intently, picking up the sounds and muffled noises that seemed to emanate from the earth directly beneath him. The voices, though weak, were distinct. "Let's roll her over." "Do you think there's room?" "We can try." "Good, now feel along the inside of her leg. Can you detect a pulse?" "No, I can't feel a thing." "John, how's her breathing?" "A little rapid but steady. Now I feel a faint pulse. Hand me the vacuum bottle and the needle. Shine the light over here: I think I've got a vein. There comes the blood. I didn't get the femoral artery but we'll get enough." "Hold her head down, she's beginning to move." "Dammit, that stopped the blood flow." "The vial is almost full. Let's get out of here." "If the drug effects wear off it's going to be a wild scramble with all of us packed in this den

with a black bear." "Boy, am I sweating." "No wonder she hasn't built a bough bed--the heat from this thermal area keeps the den warm all winter."

The bear growled and raised her head as the flashlight disappeared. John and Maurice were wriggling their way through the narrow entranceway toward the den opening, and just in time. The effects of the drug were diminishing. Control of her jaws was returning. Propelling my way with elbows and legs I followed John and caught a glimpse of light as he emerged into the blinding glare of light reflected from the wintery Yellowstone landscape. As we appeared, Charlie Ridenour commented, "I'd give a fortune to have had a tape recorder. You should have heard that conversation."

We had successfully immobilized a black bear in its den and had obtained a blood sample, thus making our first intimate acquaintance with a hibernating bear. [From blood samples of grizzly bears we were obtaining information on blood chemistry that might help us understand why the bears show no sign of arteriosclerosis.] A blood sample from ^{this} ~~a~~ hibernating black bear at a time when thyroid levels should be low might be revealing. Using a small centrifuge we would separate the blood serum from the red blood cells and ship in ice to Dr. Morgan Berthrong for chemical analysis. |

might add
some results
here

Bear and Man

Our research team had briefly interrupted the six months' winter sleep of one of Yellowstone's black bears. Later, as our studies advanced, we visited other sleeping bears for longer periods of time obtaining twenty-four hour (nycthermal) body temperature patterns that little by little helped us put together some of the information concerning the winter sleep of this large carnivore... one that has been intimately associated with man since time immemorial, a relationship based on esteem and equality. The bear has been hunted since the Pleistocene era of the cave bear and our primitive ancestors. Not only has he been killed for food but also greatly admired and frequently worshipped by adversaries from Neanderthal man to the American Indian. Bear cults and rites, even in the present, symbolize the transfer of the bear's strength, ferociousness and courage to his human contemporaries. Throughout our modern world, bears of different species are sought as trophies, killed for food, trapped or poisoned as predators and simultaneously admired by enthralled sightseers seeking a glimpse and photographs of this large and fascinating humanoid animal. We have much to learn from this large mammal that in his own way has evolved to meet the same changing environmental conditions that challenged man. However, the continued

close bear-man relationship is now entirely up to the discretion of technologically dominant man.

While resting in deep snow during a steep climb to another den, I had momentarily reviewed some of our past research with bears and mused over the uncertain fate of an evolutionary partner.

Now it was nearly time to interrupt my reminiscences and continue to the den above, the winter abode of black bear #6. Our expedition members had terminated a three-mile trek on snowshoes at the base of a steep slope that defied further travel except on all fours. Struggling upward slightly more than we slipped back we had gained the halfway mark. Here we stopped to catch our breath and zip open our parkas.

Checking the Sleeping Bear

During October and November we had tracked this black bear for 27 days using the radiotracking system we had developed for studying grizzly bears. Jay Sumner and Jim Claar followed and observed him while he selected and prepared his winter den. Now in February I was peering through the snow-choked entrance to verify that our bear was still sleeping--not in the torpor of true hibernators but lethargic with a reduced heart rate and somewhat depressed body temperature. This black bear could quickly awaken from his winter sleep and if disturbed would even rush out of his den. If undisturbed, he would

doze in his den for six months without eating. He would live off the thick layers of fat accumulated during the late summer and early fall months. Efficiently adapted for a long winter sleep, he would neither urinate nor excrete. The bear seen in the dim cave light was in a dormant condition and at my cautious peek did not move. We rarely looked in a bear den without having the animal open his eyes or growl, an indication that he detected our presence. During winter sleep, the bear is highly vulnerable to his main enemy, man. Nevertheless, the ability to sleep through adverse winter weather when food is not available is an advantage in the survival of this large species. It is an adaptation to adverse environmental conditions that might, at times, well serve man. A capability of sleeping long periods of time could be an asset on extended space flights. Physiologically bear and man have much in common. But the bear has attributes we lack such as the ability to handle metabolic products whose accumulation in man would be toxic. It is not inconceivable that if we can learn how the bear hibernates we might, with modern technology, duplicate the process ourselves. The purpose of this initial winter excursion was to reconnoiter and cache gear for a feasibility experiment in monitoring a black bear den by satellite - part of our long range objectives of learning more about the bear.

Surveying Den Site for Satellite Monitoring

On leaving the den site John and I looked for a rocky outcrop where we might position an antenna that would transmit to and receive signals from the orbiting Nimbus satellite. On up the hill was a site with a relatively unobstructed view of the sky. With the aid of ropes Harry hauled up the cable spool, Joel and I each backpacked a battery, John and Derek the antenna tripod and transmitting equipment. By the time we assembled the gear it was noon and the satellite was passing by unseen high above us. It would pass again at midnight. On some orbits it would be nearly overhead, on others close to the horizon. When low and to the west the hill might interfere with data transfer. Our plans to monitor the bear and his den by satellite were progressing. On our next trip we would haul in a loop antenna for the den on-site recording equipment, more batteries, temperature and light probes, cameras, camping gear, and equipment for instrumenting and immobilizing the bear. We were embarking on a rather fantastic project -- the culmination to numerous winters of studying sleeping bears using bio-telemetry methods. In collaboration with NASA engineers, we were committed to a project to test the feasibility of satellite monitoring of temperatures and light conditions in the den of a hibernating black bear. At the same time we planned to obtain twenty-four hour or nyctothermal body temperature

✓ patterns from the sleeping animal, in an effort to learn more about his thermoregulatory processes. It was both a project of great interest and a challenge.

Former Research Prepares Way for Satellite Monitoring

Our former research had paved the way for the work ahead. We and our colleagues had developed a 32 megacycle radio tracking system and employed it to track 48 instrumented grizzlies--twelve of them to active dens. We further expanded the capability of this data gathering, electronic system when we inserted temperature probes under the skin and in the muscle tissue of free-roaming elk and monitored their body temperature fluctuations in summer and during the winter months. Rapid rises or drops in temperature were correlated with changes in behavior. The same technique was employed with black bears. In a cliff den above the Gibbon River we located a "hibernating" black bear and immobilized him with a drug-filled syringe at the end of a long jab stick. This was our first attempt to employ our wildlife-telemetry system for gathering physiological information on sleeping bears and winter conditions of their dens.

✓ After this Gibbon River bear was injected with 125 milligrams of sernylan we flashed a light into the interior of the den to observe his reaction to the drug. Our activities caused him to back into the far recesses of

the cave where he moved restlessly about before suddenly making a break for the entrance. We attempted to block the den opening with anowshoes but he moved too quickly. Suddenly he had joined us on the narrow snowy ledge above the river. The warning "watchout" that John had shouted rang in our ears, but what to do? Our situation was precarious. Freedom of movement was drastically limited by deep snow, and a strong aversion to jumping off into ^{space.} ~~shore.~~ Within the instant our crew individually but in unison moved in one direction - the bear fortunately and perhaps deliberately in the other. He turned and began climbing a nearby perpendicular snow wall pawing his way through snow 5 to 6 feet in depth. Carefully and with difficulty we followed him on snowshoes. When we finally overtook him he was lying immobilized in the snow. Pulling him like a toboggan, we dragged him back to the den entrance where we brushed off the snow and proceeded to instrument him with a collar-transmitter. While he was anesthetized we slipped the radio over his head, shaved a small area on the back of the neck, made an incision and inserted a thermistor probe between the muscles to a depth of about four centimeters. The small incision was then treated with an antiseptic and sutured. With this completed I crawled into the den pulling the bear headfirst after me while outside John and Hank pushed against his fat-layered buttocks. The result of our combined exertions replaced the bear in his ² [insulated cup-shaped] bed but there was

Nevertheless I took time to glance around and marvel at the bear's beautifully constructed bed. I also recorded a few measurements. The insulated bed was eighteen inches deep, by thirty inches in diameter, cup-like in shape with nearly perpendicular walls against which the bear's body fit quite snugly. Within the confines of the thick accumulation of bed material, the bear had been liberally ~~in a microclimate~~ as though enveloped in a down sleeping bag.

barely room for the two of us in the rocky den.

To exit I slid over the bear's body ^{careful not to disturb the bed} and wriggled head-

first out the narrow den opening. With the black bear

again reposing in his pine ^{scented} ~~needle~~ bed, we descended

the steep hillside to our tarp tent along the river. From

this vantage point with its fire for warmth and comfort

we monitored, by radio, the gradual rise in the bear's

body temperature as well as the temperature of the den and

the outside air. This was accomplished by counting

at definite intervals the pulses or "beeps" per minute

from our radio receiver. A stopwatch was used and the

greater the number of pulses the higher the temperature.

These totals were immediately converted to degrees F° by

means of a previously prepared pulse rate vs. temperature

chart. A gradual drop in the bear's body temperature

indicated that he was reverting to his previous lethargic

condition of winter sleep.

THE NEED FOR AUTOMATIC RECORDING

After the bear had returned to a normal condition of winter sleep we obtained a 24-hour body temperature pattern.

Over this 24-hour period the den temperature varied from

26 to 30 degrees F. but remained relatively constant at

26 to 28° F. The lower ambient air temperature varied from

15 to 30 degrees F. During a 24-hour recording the bear's

body temperature dropped at night to a minimum of 93.75°F.

and reached a high of 96.25° F. in the afternoon, suggesting

consisting of a porous mixture of dry pine needles and finely shredded twigs

This bear, I thought, must be a master in the art of making beds.

a typical diurnal-nocturnal rhythm even though the cave was dark. While monitoring the bear we remained awake to periodically count the radio pulses per minute, convert them to temperature and record in a notebook. By the time we had completed our task, broken camp and driven our snowmobiles to West Yellowstone we had been without sleep, other than an occasional nap, for 40 hours. This grueling grind was quite an incentive to develop equipment that would automatically record the changing temperatures. On the other hand we did not want to eliminate our contact with the elements, the sound of boots crunching in cold snow, the brush of snowflakes on our face, the flickering fire, the warmth of a down sleeping bag, the friendly visit of ^{Canada} ~~Carrader~~ jays or the infiltration of our camp by an audacious marten that stealthily cut the leather straps on my ^{back} pack and stole the steaks we were saving for our last meal.

SATELLITE MONITORING FEASIBILITY STUDY

Through NASA we obtained the loan of an IRLS (interrogation, recording and location system) platform used for collecting and transmitting information from ocean bouys and weather balloons to satellites. Platform is the engineers' jargon for the remote sensing, transmitting and receiving equipment. It was the electronic gear that could be set up and left unattended at a remote station such as our bear den. The basic components of the entire IRLS system included a platform, equipment aboard the Nimbus space craft, and a ground acquisition and command station. Sensors from the ground platform which we planned to place

in a bear den would gather information for transmittal to the overhead satellite. The Nimbus 3 satellite being in a polar sun-synchronous circular orbit at an altitude of 700 miles would pass twice every 24 hours within communications range of the same point on the earth's surface, in this case an IRLS platform at a bear den. We could thus obtain data from the bear and den at 12 hour intervals. Our plans were to instrument the den with light and temperature sensors to be interrogated by the satellite and to continuously chart the bear's body temperature on a nearby recorder. Prior to each orbit, a ground station at Fairbanks, Alaska, would transmit a series of commands to the Nimbus 3 satellite indicating precisely when the den platform, as well as others, located worldwide, were to be interrogated. As the satellite appeared within radio view of the IRLS equipment at the den, it would transmit a 16 bit coded address signal. Upon receiving the signal the platform would reply to the satellite thus preparing it to store data. The satellite next transmits an interrogation signal and the IRLS platform, with its various transducers, transmits information on temperature and light conditions to the satellite where it is stored until later readout over Fairbanks. During this interrogation sequence the satellite also measures the time required for the radio signal to travel to the platform and return information later used to determine location of the station on the earth's surface. After completing the interrogation the satellite continues on its orbit

interrogating other IRLS stations. When it completes the orbit by passing over Fairbanks tracking station the accumulated data are transmitted from satellite to ground station and new sets of commands are radioed to the satellite for the following orbit. The collected data is next sent by telephone line and micro-wave length to the Nimbus data processing center at NASA's Goddard Space Flight Center near Washington, D.C. In the course of processing, the data is printed out by computer and then mailed to the experimenter. In our efforts to test the feasibility of using satellites for wildlife research by remote recording of data from a "hibernating" bear and his den we were taking a space-age leap from our earlier campfire monitoring.

GROUND LOGISTICS OF SATELLITE TRACKING

If we had visions of satellites removing the back-breaking work of monitoring bear dens while we sat back and waited complacently for the data to pour in, we were quickly disillusioned. Soon after assembling our field equipment and electronic gear in the little town of West Yellowstone, [As on previous occasions when we had monitored hibernating bears,] we took off on snowmobiles pulling sleds laden with skiis, snowshoes, camping equipment, food and the electronic equipment needed for our scientific experiments. Five miles out of West Yellowstone we left our snowmobiles and trekked cross country carrying our gear in backpacks. Harnessed like dogs, we pulled the heavily laden sleds. Some of our crew pushed while others pulled as we threaded our way through very

dense stands of young lodgepole pine. Vince Yanonne, with the bulky plate-shaped antenna strapped to his back, often had to step sideways in order to pass between closely spaced trees. Joel Varney took off his heavy parka and tied it on his sled. As he stepped into the harness again I heard him mutter, "and I thought this was going to be the easy way to monitor a bear den". Two miles later we dropped some of our gear beside a huge rock where we would camp and then continued on until our progress was interrupted by the steep, snow-covered ascent leading to the bear den. Again stashing the now useless snowshoes and skis, we struggled and crawled up the steep slope with our heavy burdens. We grasped every protruding bush or tree to keep from slipping backwards. On the uphill side of a large spruce trunk I stashed my pack and then traversed across to the den entrance. Accumulating snows had closed it since our former visit until only a slit remained. After my eyes adjusted I could detect the dark form of a bear, motionless and curled in repose. My silent approach through powder snow had not awakened him. But would not the struggles and deep breathing of the others still bringing gear up the steep slope do so? I had no doubt that the bear would soon arouse. When we were finally assembled we went quickly to work. It was a procedure we had performed at other dens and we knew just what steps to take and when. While John and Vince measured out a dose of the drug sernylan and attached a hypodermic syringe to a long jab stick, Joel and I unpacked the electronic equipment. ^{John's son,} Derek set up the movie camera at

and his daughter
a vantage point, Karen got ready to take still pictures.

Bat moved to a tree that she could climb and Harry started unwinding cable that would lead from sensors placed in the den to the tripod on the ledge above where we *had placed* would eventually secure the satellite antenna.

Out of the den and down the hill

Though our preparations had been made as quietly as possible, our presence had alerted the bear. A black nose and one ear soon protruded from the narrow snow opening. The bear raised his nose and sniffed, turned his head from side to side and then backed into the den. Seconds later he poked his head out again, nervously sniffing the still air. Derek was taking movies, Karen was taking stills and I was taking pictures of Karen taking pictures. We were all concerned lest the bear should suddenly lunge out of the den and run off through the deep snow before we could immobilize him with the drug. When he again retreated into the den John quickly advanced, peered inside, *aimed* ~~inserted~~ the jab stick

With the momentum of withdrawing the syringe spear he
and struck the bear in the shoulder with the hypodermic needle, ~~and~~ backed off fast. Momentarily surprised, the

bear retreated but seconds later burst out of the entrance and plunged down the snowy slope, stopping in a patch of *brush*.

D [straggly young timber.] We waited for the drug to take

effect. Fifteen minutes and we cautiously closed in on the *motionless*

Bear, finding him immobilized *me* Bear and then] wrapped him in a tarp. With

the entire crew either pulling on ropes or pushing we hauled him back up to the den entrance. Here we swaddled the anesthetized bear in a blanket so that his body temperature,

affected both by the drug and the cold, would not drop too low. The first bear that we had immobilized in his den had a body temperature of 96° F. soon after we anesthetized him. By the time we had instrumented him for body temperature recordings and put him back into his den his temperature had dropped to 83.5° F. We hoped to prevent this hypothermia produced by the combination of drug and cold.

Instrumenting the Den

While other members of the team were inserting the body temperature transmitter rectally into the bear and positioning the chart recording equipment, I crawled headfirst into the cramped quarters of the rocky den. Vince managed to squeeze part way in to help me place the light and temperature probes. Joel Varney had previously prepared a cable of numerous wires, each terminating in either a photodiode or a thermistor sensor. He fed these into us through a small opening in the side of the den. I strategically placed the sensors throughout the den, fastening them in place with spikes pushed into cracks in the rocks. Temperature sensor TA2 was located under the ^{shallow} bough bed, ^② material and others, T-1, T-3, T-4, and T-6 were distributed so as to measure temperature at the front, rear, and sides of the den. ^② Underneath the shallow saucer-like bough bed I placed a large loop

along with

This particular transmitter was patterned after a model designed by Dr. Stuart McKay. It was supposed to be swallowed but in this case we reversed the procedure.

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antenna which would pick up the emissions from the transmitter in the bear thus enabling us to continuously and automatically record the bear's body temperature on a nearby chart recorder.

The body temperature system that Joel had devised consisted of a temperature sensitive transmitter inserted in the bear and a wire loop antenna located under the animal. The function of the antenna was to pick up the signals from the ^{transmitter inside the} bear and transmit them to a receiver outside the den. The receiving equipment was a

broadcast band radio receiver with a pulse rate converter ^{which to} and chart recorder. The body temperature of the bear would affect the transmitter with resulting changes in the rate of pulses broadcast. The demodulated pulses would be counted automatically and converted to a DC voltage by ^{the} a pulse rate converter thus making it possible to continuously record the temperature on a chart.

As I backed out of the den quarters I placed a light sensor ^D[L-1] on the den wall and pointed it at the entrance so it would monitor the amount of light entering the den. It could thus be used to tell us when the den entrance was closed by snow or opened by the bear moving out. I diagrammed the position of each numbered sensor and then Joel and I placed similar sensors on stakes and on trees outside of the den - some high, some ~~at~~ snow level, some pointing skyward, others toward the snow cover. Because the satellite would ~~only~~ be able to monitor the sensors twice every twenty-four hours, ^{we placed} [Ryan recorders], small

clockwork driven chart recorders, ^D [were placed both] inside and outside the den where they would continuously record ^D [both] the [den and] air temperatures. With the exterior and interior den sensors finally in place, the rectal transmitter lodged within the anesthetized bear and a chart recorder operating to obtain continuous body temperature, we pushed the bear back into his den, closed the opening with snow and climbed on up the slope to secure the transmitting antenna and connect the cable from the den sensors.

Winter Bear Den is a Modified Environment

For the next seventeen days our visions of working in heated rooms at other tasks while the data poured in actually transpired. We even did some downhill skiing instead of cross country touring and winter camping. Our chart recorder powered by nickel cadmium batteries was accumulating on-site body temperature information and the capsule-like Ryan temperature recorders were providing a continuous record of the den and outside temperatures for comparison with satellite monitoring results. However, much of the work burden had only been shifted to Chuck Cote and his engineers at NASA's Goddard Space ^{flight} Center near Baltimore, Md. Here the Nimbus satellite data was processed, printed out by computer and mailed to us for analysis and interpretation.

Sensor ^{no} A2 under the bear's bed informed us ^{via} ~~that~~ satellite that from the initial ^D [placement] temperature of

0.5° C. the bed temperature rose to a high of 29° C. over a ten day period. [This warming effect ^{warmth from} of the bear's body maintained an average bed temperature of 21° C. for the same ten day period. The temperature [from ^{the thermistor} T1] in the rear of the den averaged -1.7° C. compared to -3.0° C. [for T3] near the entrance and -6.7° C. [for ² T5 situated] outside the den. [Between March 7-9 the heavy batteries powering receiving and transmitting equipment were hauled to West Yellowstone, recharged and again laboriously packed up the steep slope to the IRLS equipment and antenna. This visit apparently disturbed the bear sufficiently that he changed position in his den for the bed thermistor (T2) dropped to -1° C. while nearby T4 on the ~~flicky~~ floor of the den rose. The warming ^{his} effect of the bear's] body on den temperature was revealed when he later left the den. Temperatures from all inside sensors then closely coincided with outside ^{air} [ambient] temperatures. ² [This followed the pattern of the den we had monitored from our winter camp. However over a twenty-four hour period the den temperature varied from -3.3° C. to -1.1° C. while outside temperatures varied from -1.1° C. to -9.4° C.] In the earlier ^{Siberian River den} experiment the bed temperature ^{rose} was much higher than that recorded by satellite. In the microclimate between a very well constructed and insulated dry pine needle bed and the bear we recorded a maximum temperature of 36.0° C., just slightly lower than the body temperatures of the active and aroused bear. It was clearly evident from our accumulated bed temperatures that the black bears

the bear was acting as a heater to modify his winter environment

were "hibernating" in a localized environment ~~and~~ microclimate considerably altered by their presence. The average temperature in the bed of ^{on satellite} bear [no. 6] was 24.8° C. above ~~outside~~ ^{an} [ambient] temperatures. However, ^{nearly} den temperatures [nearby] were not greatly altered suggesting that little heat is radiated from the bear's body and that the heat lost by conduction is minimized when a good insulated bed has been prepared.

Satellite Detects Opening of Den

Voltage readings from the light sensors placed outside the den ^{varied from day to night} [revealed day-night variations], the former reading about 5 volts as compared to zero at night. ^{the light} Sensor [L1] inside the den and pointed toward the entrance gave zero readings from February 15 to March 13 when the entrance was blocked with snow. ^{The reading} [On March 14] indicated that the entrance was probably open. We ~~and~~ suspected and then verified that the bear had left the den. Our suspicion was further strengthened by ^{drop in} a bed temperature ^{to} almost [the same as] that of the outside air temperature. ^{the day before} [On March 12] we had [found it necessary to] ^{ed} revisit the bear den, [immobilize the bear and insert a new body temperature transmitter as the first one had failed to operate after transmitting data for 4-1/2 days.] This disturbance had caused the bear to leave his den and seek a new location for the remainder of his winter sleep. The relay of data from den to satellite to us had immediately informed us of this movement of a bear isolated in a wilderness area of Yellowstone. It was just one example of how ^{a satellite} [the IRLS] system [with 28 channels of information] could provide an

unusual capability for studying animals and their environment in remote locations.

During the 3-second interrogation sequences when the sensor data was being transmitted, the satellite also obtained distance information. This was accomplished by measuring the time between sending the interrogation signal from the satellite and the response from the platform at the den. This range measurement was used to calculate the position of the den by projecting an imaginary circle on the earth's surface. A second measurement provided data for still another circle which intersected the first at two points. The platform was located at one of these points. They were sufficiently distant from one another that the improbable one could be discarded.

From 26 such locations obtained on each orbit the average location error was computed to be 2.34 miles and all the points were within a circle of 4.50 miles radius. Some locations pinpointed the position of the den. Although the location of the den was already known, the experiment gave us an indication of the accuracy that could be expected in another feasibility experiment where we were using similar satellite equipment to track a wild free-roaming elk. It also provided clues and data for increasing location accuracy.

Body Temperature Recordings

While den and bed temperatures were being monitored twice every twenty-four hours by Nimbus III the bear's

body temperature was continuously recorded by the chart recorder in an insulated box near the den site. [Over a 4-1/2 day period] the bear's body temperature levelled off around 35.3° C., comparable to that of the Gibbon River bear whose temperatures ranged ~~between~~ 34.4° C. and 35.6° C.

[Over a twenty-four hour period.] This temperature ^{we recorded} during winter sleep is only four to five degrees lower than the [38 to 39° C.] temperature of an active bear in summer. This was expected as the bear is not a true "hibernator"; that is, one whose body temperature drops so low it approaches ambient temperatures and where respiration and metabolic ~~functions~~ are greatly reduced. The bear, though in a lethargic condition, can, as we repeatedly experienced, be quickly awakened to action. A true hibernator such as a ground squirrel is in a torpid condition and cannot be quickly aroused. This is not to say that the bear is not an efficient winter sleeper. Because of his large size he enters his den with an immense supply of stored food. This potential energy reserve in animals is proportional to weight but the metabolic rate is weight dependent. The large bear thus has a low metabolic rate and can fast for long periods without a reduction in metabolic level necessary in other smaller animals. [Also we have found through] ^{also verifies that} our den temperature measurements the bear has a low thermal conductance and probably cannot reach and maintain a body temperature near the ambient air temperature. It appears as though he cannot

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15 & 16
chart
Marion Johnson
act. & comp.

greatly reduce his body temperature but does not need to. In contrast other investigations have found that the bear's summer sleeping heart rate of 40-50 beats per minute drops as low as 8-12 during winter sleep.

Significance of Feasibility Experiment

The use of an earth-orbiting satellite to monitor a bear den revealed the feasibility of applying this data-gathering system to studying animals ~~and their~~ immediate environment and even their physiological functions simultaneously and in remote and inaccessible areas of the globe. Also, information can be almost simultaneously gathered from numerous instrumented animals distributed over an extensive area. [Examples of such an application might be the global study of polar bears, study of the migration of caribou or the movement of African elephants.

At the bear den each sensor was sampled five times at 1.5 minute intervals twice every twenty-four hours. In many instances sampling more frequently than every twelve hours would be desirable and could be accomplished with auxiliary equipment designed to periodically record and store data for later transmission and readout.

The use of satellites to gather a wide range of ecological data on a local, regional or worldwide basis, either with a focus on basic research or on management, has tremendous potential. Development of small transmitters suitable for use on animals and even birds is underway.

With these, State fish and game departments could utilize the system in better harvesting of big game animals. For example, changing elk migrations could be immediately determined and appropriate hunting pressure applied where needed. Water quality conditions of remote sections of rivers could be monitored daily. The moisture condition of expansive areas of plant environments and vegetative types along with other parameters could be monitored to determine annual forage production or immediate fire hazard.

The full application of satellite ~~gathering~~ ^{gathering} systems or a combination of these and ground monitoring techniques implies far more cooperation and coordination of effort by ecologists and engineers, by private and governmental agencies, by foreign scientists and our respective governments than has existed in the past. The development of an economical and efficient ^{satellite-mediated} technology will demand an integration of effort that could tend to unite diverse cultures and widely separated peoples resulting in increased understanding of basic human problems and aspirations. Such understanding is usually accompanied by tolerance, a virtue the world urgently needs if the human race ^{and our partners in evolution are} is to survive with a quality life for all. It would be nice to see this start and spread out from Yellowstone. It is well within the Park Service mission if not its competence.

Had there been even a semblance of cooperation from Yellowstone Park officials after 1968 our space age grizzly woman might have been the first grizzly to be tracked and monitored by satellite. She had been groomed for a role she would never play. Black bear number 6, whose den was monitored by satellite, moved out to a Yellowstone highway in spring. According to a concerned ranger he was giving ^{an overdose of} nausea pills as an experiment to discourage ^{him from} begging food from tourists. His radio collar was removed while unconscious from the drug and he was hauled away. This black bear that had made history, vanished like so many others in Yellowstone and was never seen again. What happened to the Yellowstone black bear?

With these, State and game departments could utilize

written

is perhaps best summed up in a statement ^{written} by a ranger ^{written} in the Lake Ben Loop. — 19 — after seeing a black bear — "Saw an honest to gosh black bear today." A few years prior to the Park Service ^{change in} attitude ^{and policy} toward black bears and independent research it was not uncommon to see 40 to ~~fifty~~ 50 black bears in a single day

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The full application of satellite meteorological systems or a combination of these and ground monitoring techniques implies far more cooperation and coordination of effort by ecologists and engineers, by private and governmental agencies, by foreign scientists and our respective governments than has existed in the past. The development of an economical and efficient technology will demand an integration of effort that could tend to unite diverse cultures and widely separated peoples resulting in increased understanding of basic human problems and aspirations. Such understanding is usually accompanied by tolerance, a virtue the world urgently needs if the human race is to survive with a quality life for all.

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Chapter VII
Physiology and Hibernation

In January of 1963 we waded through deep powdery snow that had sifted down through the lodgepoles until it covered the forest floor to a depth of 8 to 10 feet. We entered the timber where a small blaze high on a tree told us we should start our course ~~on a bearing~~ following a bearing of 240° . This would lead us back to the three-forked lodgepole that towered up over the den where grizzly #164 was sleeping. We sank deep in the fluffy snow as did the martin whose tracks we occasionally ~~saw~~ crossed a small opening, then vanished as this arboreal predator took to the trees in search of red squirrels. The north facing entrance to the den of this female grizzly was covered with snow except for a tiny opening through which some warm air escaped. It would have gone undetected had we not known just where to look. After compacting the snow we took off our snowshoes and used them as shovels. Before long a ~~warning~~ ^{sleeping} growl almost like a groan followed later by another with ominous overtones of a warning made us ~~desist~~ think the situation over and decide to leave No. 164 alone. We had returned with the hope of determining whether she had ^{yearlings with her} ~~one~~ and to evaluate the situation for later study of the sleeping bear and her winter den environment. We were not what might be called mobile should the aroused grizzly charge out of her den; ^{in fact we were quite helpless.} ~~as we couldn't~~ the only alternative was to shoot in self defense. An immobilizing dart would not take effect in time. Not wishing to put either an arm or the sow's life in jeopardy we reluctantly strapped on our snowshoes, shouldered our packs and retraced our steps. Perhaps another

year, I thought we will find a den more amenable for studying or a bear in a more dormant condition. We needed a situation where we could immobilize the grizzly at least once and instrument the den and bear for temporary recordings. This quite obviously would not suffice and as we threaded our way through the trees I was not at all sure that we would eventually find a den that ^{would} meet our requirements. In the meantime we could perhaps study the winter sleep or hibernation of the black bear. This member, known as American ^{NLS} of the bear family was in no way so aggressive as the grizzly nor was he so powerful. Above all, his instinct when cornered was to flee rather than attack. He did not have the grizzly's trait of complete lack of fear for that awesome species Homo sapiens. There were many things that we could learn about black bear dens that would apply to the grizzly. Why ^{I thought} not start our den studies with the black bear until we could safely work with a grizzly? Several years later when we returned to one of Marian's ^{spar covered} dens we were still unable to immobilize ^{a grizzly} without risking her life and Marian was not a real aggressive bear as grizzlies go. The black bear has evolved curved claws that enable him to nimbly climb almost any tree whereas the grizzly is not adapted for climbing. Instead ~~this~~ long front claws are ideally suited for digging. It may be that the ability of the black bear to climb and thus escape many dangers has made him less aggressive than the grizzly who must face a challenge or ~~it~~ turn and run. At any rate there is a tremendous difference in the temperaments of the two animals and as might be expected the black bear is more at home in the timber and prefers this habitat while the grizzly is fond of and quite at home in open country - meadows, brush, sagebrush habitat and open spaces above timberline. Because of his facility at

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digging the grizzly ^{excavate} ~~clay~~, shape and completely construct his
winter den. The black bear usually seeks out a natural cave or
shelter which he may modify or ~~use unmodified~~ as is.

The black bear has two distinctive color phases - black & cinnamon, but
the term black applies to both colors. Many black bears I spot a
white V shaped collar. ^{many} Young grizzlies also have collars but they
are not V shaped in front and they tend to disappear as the
bear ages. In general grizzlies are much larger than blacks. The
average yellowstone male will weigh — lbs, the female — lbs
and a large female will go as high as 500 lbs, a male
1000 to 1200 lbs. The average male black bear weighs about
lbs and the female — lbs. ^{One of} The largest black bears on record
have weighed ^{over} 600 lbs but this is exceptional.

From our ~~autopsies and blood chemistry studies~~ ^{on problem grizzlies that were killed} in collaboration with
Dr. Morgan Berthrong we had found ^{on mummified black bears}.

When incorrigible grizzlies dangerous to visitors were killed we performed
autopsies on them. This work was done in collaboration with Dr. Morgan
Berthrong who first noticed the complete lack of arteriosclerosis in the
coronary arteries and then through microscopic studies found the large,
medium and small arteries to be totally free of arteriosclerosis. These
findings led to blood chemistry studies to see if we could determine
why the bear, unlike man, was not afflicted with arteriosclerosis. Perhaps
it would provide us with a better understanding of this disease in
man. In pursuit of this work we routinely collected blood samples
from most of the grizzly and black bears that we captured. We had
numerous samples taken in spring, summer and fall but so far none
in winter from hibernating bears.

7.
On the high yellowstone plateau country most black bears are in winter dens well before the grizzlies retire. Just one goes in and does not appear then another until ^{even} the tardiest sleeper is slumbering. The grizzlies as we have seen tend to enter winter dens pretty much at the same time and this unanimous urge to retire seems to be triggered at least in part by a snow storm or blizzard. Often black bear tracks led us to their winter dens. Never did we locate a grizzly den in this way. Thus in the fall of ~~1967~~ 1967 with snow on the ground and steam in the air ~~the~~ we followed black bear tracks to a cave opening near thermal pools in the vicinity of Old Faithful. The bear slumbered while the snow depth increased, elk and buffalo moved less freely and centered their activities around thermal areas relatively snow free. While these animals west of the continental divide congregated in small resident herds where limited winter food was available the elk herds of Hayden valley migrated to the lower Lamar valley and ~~the buffalo~~ left the lush forage to a few sturdy bison ready & capable of digging down through layers of snow to feed on it. Winter had well advanced and a coldness and uniform whiteness ~~broken only by~~ sometimes in deadly calm at other times swept by chilling horizontal winds characterized the environment. Solitude was both at hand and afar. Over this frozen whiteness a raven flapped undisturbed by the ~~stinging~~ countless particles hitting his eyes or were they ~~also~~ protected in flight by the receding membrane? I wasn't sure. I only knew that while almost all other life quietly waited out the storms the raven often revelled in their appearance, rolling, diving, banking in the winds as though it was just another balmy spring day.

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The lone raven dipped low apparently curious about the single human form beneath him. Distinctly the raven knew that life one day might be food for him the next. He continued on but with a piece of data stored in his memory bank. Beneath and behind his disappearing form a lone figure was sitting on snowshoes, ~~with a thermometer~~ ^{Page 1} ~~for chemical analysis~~ ^{Page 2} ~~but~~.

* An hour earlier our movements and tramping around at the den entrance had aroused the bear. When she appeared at the den opening ~~we~~ we hit her with a drag laden dart. She growled and returned to the blackness of her cave. A half hour from the time the ~~dart~~ dart struck we thought the bear would be immobilized and helpless. We thought she should be. The problem was we didn't know. Nevertheless John, Maurice and I crawled into the narrow entrance & squirmed through the ~~dark~~ ^{dark} & confining tunnel guided only by a flashlight. The tunnel seemed to extend on and on. It ~~was~~ turned out to be nearly fifteen feet long terminating in a chamber only slightly longer than the tunnel itself. When well along in my worm-like movements I heard John say that he'd reached the bear and she was out. Suddenly I too was in the chamber - low-roofed, the walls reddish in color, the air heavy and moist from the nearby thermal spring. The inside of that den with the dark formless shape of the drugged female bear occupying most of the space is still vividly etched in my mind. Under similar circumstances we could never have dared to push our way into a grizzly's sleeping chamber. We tried it with the grizzly we called ~~Swede~~, several times with Marian, with 101, and the pregnant female no. 187. The response was always growls and activity within the den, an aroused alertness. This combined with deep snow that hampered fast movement and the aggressive nature of the grizzly put a damper on our enthusiasm to immobilize and anesthetize the bear.

At least for awhile we would have to content ourselves with working with the black bear. In the meantime we were developing transmitters and technique that would enable us to ~~insert~~^{implant} a temperature sensitive transmitter in a grizzly captured in fall, thus eliminating the hazards to both bear and man of ~~transmitting~~ an attempted immobilization in a winter den.

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With the ~~use of~~ the telemetry system we were using on grizzlies we planned to monitor temperature conditions in the den of a hibernating bear. At the same time we planned to obtain twenty-four hour or circadian body temperature patterns from the sleeping animal in an effort to learn more about his thermoregulatory processes. Just as in humans these 24-hour temperature rhythms would give us insight into the winter physiology of the bear and inform us of the times when he was most active and alert. Would it be during daylight hours or late at night? Would the darkness of the cave tend to change the pattern? How low would the bear's temperature drop from the 101°F normal during summer activity? The winter work ahead was of great interest to us, offered new experience and was a challenge. But our previous research had paved the way for the work ~~ahead~~ ^{to come}. We had improved our telemetry system so it had a capability of transmitting temperature data when we inserted tiny temperature probes (thermistors) under the skin and in the muscle tissue of free-roaming elk. In this way we had monitored their body temperature fluctuations in summer and during the winter months. — Now we were ready to employ the same technique on a black bear that we had tracked to a winter den in November. In January we returned to the cliff den above the Kibik River and immobilized the black bear with a drug-filled syringe at the end of a long jab stick. This was close quarters work and we were not sure how the bear would react. Would he ignore the jab of the needle, retreat further back in his den or charge? And how would we react if the bear rushed out of the den? The problem was definitely on our minds but ^{we had no} set course of action. Four of us John, myself, Hank McCutcheon and Klaus ~~Nielsen~~ ^{Nielsen} were crowded on a tiny ledge leading to the den entrance. Each of us would have to make his own decision.

After we injected the bear with 125 milligrams of sermylem there was a rustling movement then all was quiet. I ~~flushed~~ got down on my stomach and flashed a light into the interior of the den to observe the bear's reaction to the drug. This and our movements outside caused him to retreat into the far recesses of

go from ^{top} ~~that~~ Page 8 the cave; on through to last meal middle page 10.

While we were monitoring the body temperatures of the Gibson River black bear Marian was giving birth to a litter of three cubs. In the fall of 1967 we felt certain that Marian was pregnant and we looked forward to visiting her winter den ~~soon~~ after parturition when hopefully we might see her tiny helpless young. In late September her radio transmitter failed and we lost the chance to track her to a natal den. Our studies of the hibernating black bears were giving us some idea of winter conditions in the grizzly dens. Marian's den sheltering the sow and her three large cubs was located in the fall of 1968 but ~~subsequent~~ immobilizing four grizzlies simultaneously seemed only remotely possible and we had no intention of placing ourselves in a position where we might have to gun Marian down in self defence. Marian as we shall see did not dig a den and ~~hibernate~~ in 1969 nor did she hibernate in 1970 when electronically speaking we took a big step forward and ^{radio} monitored a black bear and his den using the Nimbus satellite, a rapidly moving man-made star in the sky.

During October and November we had Traces ^{p. 4} --- to bottom of p. 5. the bear.

Our expedition members terminated a three-mile trek on snowshoes at the base of a steep slope that defied further travel except on all fours. Struggling upward slightly more than we slipped back we had gained the halfway mark. We were on a level with the bear den. Here we stopped to catch our breath and zip open our parkas. Before climbing higher John and I looked for a rocky outcrop --- top p. 6 --- sleeping animal (top p. 7).

Through NASA we obtained --- p. 10 bottom to bottom of p. 23.

Questions

1. # or No.
2. Degrees or °
3. F. or C.
4. Goddard Space Center
near Washington D.C.
or Baltimore, md.
5. 24-hours or
twenty-four hours