RADIOTRACKING OF GRIZZLY BEARS
1963 REPORT
GRIZZLY BEAR ECOLOGICAL FINDINGS OBTAINED BY BIO-TELEMETRY

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In the summer and fall of 1960 we tested a prototype radio transmitter and experimented with attachment methods. The following year we instrumented and tracked two grizzly bears using miniaturized Philco-developed transmitters and portable receivers 1/. By the fall of 1962 we had developed and were operating the entire tracking system 2/. Improvements continued, but by 1963 we had shifted emphasis from development and testing to concentration on operational use and the accumulation of ecological data on the grizzly bear 3/.

The primary function of the bio-telemetry of big game tracking system developed under N.S.F. Grant 17502 is to extend the range and scope of the field biologist's observational powers.

This is accomplished in two ways: first, by gathering data from a distance with a minimum of time, effort and manpower; and, second, by enabling a scientific observer to place himself in a predetermined position where he can observe a particular instrumented animal and can reason about and interpret what he observes on the spot. This latter capability is, perhaps, the greatest asset as far as our ecological study of the grizzly bear is concerned.

We now have the proven capability of instrumenting grizzly bears, or other big game, and simultaneously monitoring three or four pulsed signals 24 hours a day for a month or two. This involves plotting the movements of the instrumented animals and deducing certain activities from a distance of ten to twenty miles. At almost any time within this two-month period we can fix the animal's position through the intersection of two or more bearings and can then "close in" and observe while undetected. We are recording this data manually but can go to automation. However, already we are able to obtain far more information than we can readily process and analyze.

Prior to the development of this research tool, the grizzly bear, roaming over 3,000 square miles of rough Yellowstone country, 85 to 90 percent

of it wooded, had all the advantages when it came to evading man. Now the tables have been turned and the research results are encouraging. This report is by no means exhaustive, but will emphasize and illustrate some of the types of ecological findings obtained by using bio-telemetry methods.

Over the last three years we have developed and gradually perfected our tracking system. Each year engineers of Philco Corporation's Western Development Laboratories have redesigned the transmitters and have improved the portable tracking units. These improvements have resulted from extensive field testing of equipment. The tracking system is now fully transistorized and battery operated. The receivers are interchangeable with either loop or yagi antenna. Reception equipment consists of a Base Station, a Field Station, several mobile tracking units, and three handheld portable tracking receivers. These are all operated on 32.02 MC and, in addition, we have a complex of base, mobile and walkie talkie transceivers for communication purposes. These operate on the Citizen Band frequency of 27 MC.

INSTRUMENTING AND TRACKING

From 1961 through 1963 the tracking period, or time during which animals were being instrumented, tracked and monitored, increased from 1 to $2\frac{1}{2}$ to 4 months.

The actual tracking of instrumented grizzly bears (monitoring of signals from different bears) amounted to 32, 76 and 119 tracking days in 1961, 1962, and 1963, respectively.

The total number of animal-tracking-days during the three-year period was 251, almost $8\frac{1}{2}$ months. Animal-tracking-days embrace the period that a signal was received from an instrumented animal but does not include monitoring beyond last signal reception. The longest period that we continuously tracked a grizzly in a single season with one transmitter and battery pack was 44 days (Table I).

In the course of a five-year ecological study of the grizzly bear, we have individually color-marked and ear-tagged 164 different bears. Each of these has been given a number and I will refer to these when discussing individual animals.

In three seasons we have made 13 instrumentations involving 8 different grizzly bears--two in 1961, three in 1962 and eight in 1963. The ages and sex of the eight instrumented bears are:

Two boars--#37 immature, #76 a young adult.

Two sows with cubs--young adults, #96 with 2 cubs; #150, 3 cubs.

Two sows with yearlings--#7 an adult, #75 a very old adult, 2 yearlings each.

Two single sows--young adults, #96 pregnant, #40 barren.

Although only seven different grizzlies were instrumented in 1963, we actually tracked and obtained information via radio on 17 different animals. This was feasible because four instrumented sows represented four different family groups whose offspring included five cubs and four yearlings. Since family groups are cohesive units, the ability to track and locate one member, provided opportunity to observe all members.

Among the eight animals mentioned, #40 has been instrumented for three consecutive years and numbers 37 and 96 for two consecutive years. Number 37 was shot outside the Park boundaries in the spring of 1963. Number 96 hibernated wearing a collar and appeared the next spring with the collar as well as with 2 cubs. One grizzly, #7, was instrumented twice in the same summer.

ECOLOGICAL RESULTS

Although we are still developing and perfecting our bio-telemetry system and yet have much to learn about its potentialities, we have used it

to procure some interesting ecological data. Much of this information we had been unable to obtain using conventional study methods. We have acquired information on grizzly bear summer ranges, on bear movements, diurnal and nocturnal activities, activity patterns, food habits, habitat preferences, behavior and interrelationships, bear-man relationships, man-made influences, pre-hibernation activities and hibernation treks.

Before citing a few examples of each, it should be recognized that summer food supply is the key to understanding much of the summer behavior, movement and activities of the Yellowstone grizzlies. Food is of two kinds - natural and refuse supplied by man. Where food is abundant, regardless of kind or source, grizzlies concentrate. This concentration results in an increased population density per unit of area which in turn affects the social structure of the grizzly population and influences individual behavior, daily activities, movement, ranges, etc. Grizzlies are dispersed throughout the Park and beyond during spring and fall and winter, the period of hibernation.* This dispersal is typical of spring with a tendency for the bears to gradually concentrate throughout the summer only to disperse widely again in fall. This picture of the grizzly population has been obtained in various ways in the course of the five-year study. Radiotracking has helped to confirm it, has provided information not previously obtained and has greatly added to our understanding of some phases of grizzly bear ecology.

Summer Ranges

In 1963 five grizzly bears were monitored day and night for periods

* The grizzly is not a true hibernator but the terms hibernation and hibernating den are in such general use that they will be employed in this report. This terminology will be treated in detail in future reports and publications.

ranging from a month to a month and a half (Table I). Their exact or approximate locations were known at almost all times. Their ranges were delineated from fixes, bearings and sightings while tracking. Lines connecting the peripheral locations were used to construct the ranges on topographic maps. The area of these ranges was determined by planimetering. The results appear in Table II and Figure 1.

Within these seasonal ranges the grizzlies spent much of their time in quite localized areas of approximately a square mile. Such areas usually comprised the sites of their daytime beds or retreats and some foraging territory. The two grizzlies with the largest seasonal ranges also confined their day-to-day activities to rather localized areas but these areas were correspondingly larger. That of sow #7 and her yearlings for example measured between 4 and 5 square miles, but her entire summer range was 106 square miles (Table II).

All of the grizzlies had daytime beds or retreats to which they retired for varying periods of time. These were shallow excavations in the earth and located in timber, usually quite dense timber containing heavy windfall.

The smallest range, that of sow #40, was 8 square miles. A similar-sized range had been plotted for this sow in the two preceding seasons. As far as we know, she has not ventured beyond this area during the summer months. Furthermore, she has neither been observed or tracked beyond its confines at other seasons of the year, although she may possibly have left it to hibernate or have moved beyond it to make short foraging trips that were undetected. The range size has definitely been influenced by an abundant food supply and by the fact that this sow, though mature, has not yet borne offspring. The relation of range size to food supply will be treated under a separate heading.

TABLE I

INSTRUMENTED GRIZZLIES
1961-1963

Grizzly Bear Designation	Tracking Period (Dates)	Animal Tracking Days	Remarks
#7	1963: 7/26--8/12	18	Grizzly removed loose fitting collar; recovered collar August 10.
	9/2---9/27	26	Last signal weak and in Pelican Creek Area
		44	
#37	1961: 9/30--9/31	1	Bear moved beyond range of receivers, removed collar which had been slipped over head.
	1962: 10/4--10/18	15	Transmitter functioning; bear lost journeying to hibernation area. Shot by hunter, in spring of '63.
		16	
#40	1961: 9/22-10/22	32	Transmitter still functioning; bear hibernated.
	1962: 9/8---9/17	10	Transmitter no longer functioning, but still on bear. Removed by bear during hibernation.
	1963: 8/7---9/4	29	Transmitter no longer functioning but still on bear at time of hibernation.
		71	
#75	1963: 8/16--9/28	44	Bear immobilized and transmitter removed; still functioning well.
#76	1963: 8/26--9/22	28	Lost signal, bear travelling, transmitter functioning.
#96	1962: 8/17--8/19	2	Lost signal, bear travelled to distant portion of park, no mobile units available.
	1963: 7/12--7/17	6	Transmitter battery pack shorted by water.
		8	
#150	1963: 10/6--11/3	29	Transmitter still functioning; bear hibernated - lost.
#164	1963: 10/26-11/5	11	Transmitter still functioning; bear hibernated - located.

Three Season Total 251

TABLE II

GRIZZLY BEAR SUMMER RANGES - 1963
Determined by Radiotracking

Grizzly Bear Designation	Number of Bearings used in determining range*	Number of Plotted Fixes*	Area of Ranges Square Miles	Activity Pattern
#76	129	21	168	Nocturnal - diurnal Nocturnal - daytime rester
# 7	256	32	106	Nocturnal - diurnal
#75	145	21	36	Nocturnal - daytime rester
#150	227	35	27	Nocturnal - diurnal
#40	140	32	8	Nocturnal - daytime rester

*Innumerable bearing or fixes made with portable receivers while tracking on foot are not included

Though the range of grizzly #150 was only 27 square miles, this bear was the most active of all the animals tracked. She was also tracked and monitored more intensively and thoroughly than any of the others. Her daily and nocturnal movements in airline distances were confined to only a few miles. However, she was almost constantly roaming day and night resting only for short intervals. Her three hungry, energetic cubs greatly influenced her activities. Continuous changes in signal strength as well as direct observations in the field while tracking confirmed her comparatively greater activity. She ranged in upper Hayden Valley along Alum Creek, a good foraging area for plant foods and rodents. Here she was able to satisfy the food requirements of herself and her growing cubs within a very limited area. Much of her foraging activity centered within a 1 square mile area. It was quite revealing that a grizzly bear and her three cubs could obtain most of the food they consumed during a full month within such a limited locale. It showed the efficiency of a grizzly bear as a forager and omniverous feeder and provided the most tangible information yet obtained for estimating carrying capacities.

The largest summer range, that of boar #76, measured 168 square miles. It represented his summer area of activity and travel during a one one month period. After a month of monitoring we lost his signal when he travelled northward beyond reach of our receivers. To do this he must have moved at least 20 miles beyond the peripheries of his summer range. This extensive movement occurred at the time of the dispersal of grizzlies from their summer ranges. The distinctive signal of 96 pulses per second was never again picked up, although the transmitter was still functioning well when the signal was last received. Every reasonable effort was made to pick up the signal with our mobile units and we made attempts from fixed wing planes, but without success.

The fall movement of young adult boars to distant parts of the Park and beyond had been established by observation of ear-tagged animals. Tracking #76 as well as #37 by radio confirmed this type of movement and shed additional light on the speed and extent of dispersion. From previous movement data gathered relative to #76, we believe that his home range is many times the size of his summer range. It also appears that this young but mature male, as well as others, have two distinctive ranges, a summer one and an early spring-late fall range, often separated by considerable distances. In the course of his travels within his summer range, #76 circled Mt. Washburn, made 5 known crossings of the Yellowstone River and completed two long treks, a circular one of 50 airline miles in 7 days and a still longer one that took him beyond reach of our receiving equipment.

We have reason to believe that at least some grizzlies may return to the area of their birth to hibernate. The littermate of #76 is sow #96, another instrumented grizzly. Soon after coming out from "hibernation," she was observed far up Cache Creek in the N.E. section of the Park with two small cubs. Number 76 was headed in this direction when last detected. Radio transmitters may, in the future, reveal whether they both hibernate in the same general area.

The next largest range of 106 square miles was that of grizzly #7 and her two yearlings. This particular animal travelled and was active both during the daytime and at night. Her activity pattern was similar to that of sow #150. She divided her time between two large open-land areas or meadows, Sour Creek and Hayden Valley. As in the case of the other sow grizzlies studied by radiotracking methods, she spent the majority of her time in a rather limited area. This nucleus of her range was an area of

4 to 5 square miles embracing the Wrangler Lake-Clear Lake terrain. It provided timbered cover for daytime beds as well as excellent foraging country. Sow #7 was instrumented twice and tracked over a two-month period for a total of 44 days. During this time she made six crossings of the Yellowstone River, two in the Yellowstone Canyon just upstream from the mouth of Broad Creek. She also climbed high (approx. 9000 ft.) on the slopes of Mt. Washburn. By September she had weaned her yearlings and was travelling alone. During the last week that this animal was tracked, she travelled southeastward to the open-meadow country in the Pelican Creek drainage, an airline distance of over 12 miles. She was attracted to this area by food - a high Microtus population and an abundance of tubers. She remained here for some time but, unfortunately, her signal failed a month prematurely terminating the tracking. This movement occurred at the time of the general grizzly dispersal from summer ranges. It appeared that we had tracked this animal from her summer range to her late fall range and, perhaps, to the general area of her "hibernation" site.

Grizzly #75 and her two yearlings established a summer range that encompassed 36 square miles. This sow was quite old and also belligerent. Though the range of this animal is larger than that of #150, she was actually much less active and her movements more routine. She usually bedded down in the daytime, whereas #150 was normally moving and foraging. Even though she had yearlings, her daily habits were more similar to those of the spinster sow #40. She spent most of her daylight hours in a timbered area of about one and one-half square miles. Here she dozed and rested day after day in the same or nearby beds. Number 75 spent one day in a large timbered island four miles north of her regular daytime retreat. She also made one trip to

the south up and over the crest of Elephant Back Mountain, on down to the Lake tourist area, returning to her haunts from the east. These excursions extended a range that otherwise would have been eight to ten square miles or comparable to that of grizzly #30. The ranges of #75 and #40, as well as their activity patterns were affected by man-made food supplies. The influence of this on the animal's behavior and movements will be treated in a later section.

Movements

The tracking revealed several types of movement patterns. One was typified by grizzlies #40 and #75. These animals spent the greater part of each day in one spot or locality. They travelled in early evening to a definite food supply returning to their daytime beds in the early morning hours. Evening after evening #40 made a three mile trip to food, starting about 6:00 P.M. and taking approximately one and a half hours. She was usually resting in her daytime bed by 6:00 or 7:00 A.M. She followed this routine on 16 occasions and probably at other times when she was not closely tracked.

Another type of movement was perhaps best typified by grizzlies #150 and #7. These animals were active day and night and rested only for short intervals. They were constantly moving, but from a given starting point the acutal airline distance they travelled in the course of a day or a night was not great. Over a dozen measured distances averaged 3.7 miles and 3.2 miles for #150 and #7 respectively. The irregular course they roamed while foraging was, of course, much greater. The maximum airline distance travelled in one direction by these two animals was five miles for #150 and six miles for #7.

In contrast to this was the movement patterns of the males, #76 and #37. The longest airline distance travelled in twelve hours by #76 was nine to ten miles and this distance was recorded on at least four different occasions. Once he travelled nine miles in the course of a single afternoon. An average of eight daily distances measured 7.2 airline miles. In a two-day period #37 travelled an airline distance of 19 miles. Sow #7 returned from high on the slopes of Mt. Washburn to her Sour Creek foraging area in a single night, an airline distance of about 5 miles. In doing this, however, she travelled a ground distance of at least 9 to 12 miles dropping down to cross the deep Yellowstone Canyon enroute. Both sexes readily travel considerable distances over rough country but males appear more prone to roaming.

Although grizzlies were found to remain and forage in very localized areas for extended periods of time, in most cases they eventually took off on treks of varying lengths. Other data, some gathered through tracking and some by other methods, indicate that these sporadic trips are part of the normal pattern of grizzly bear movements. In the fall of the year such movements take on a pattern of grizzly dispersal from summer ranges and, in some cases, might be considered a fall migration.

We can summarize some of the range and movement data accumulated by stating that ranges are distinct, overlapping and, as far as we can determine, not defended. Radiotracked grizzlies mingled and foraged with other bears even in the most frequented parts of their ranges.

Five ranges involving twelve individual grizzly bears were plotted (Fig. 1), but many other grizzlies travelled and foraged partly or entirely within the same area. Each grizzly has a much frequented daytime retreat

or range nucleus but even this is shared by other grizzlies, though, the actual bed themselves are probably not.

A timbered island retreat often frequented by #76 and occasionally #75 was located through radiotracking. On visits here we found ourselves literally surrounded by grizzlies most of which were jumped at close range. Numerous bed excavations as well as feces revealed this to be an area where grizzlies concentrated during daylight hours to sleep or rest. Yellowstone grizzlies appear to be more gregarious than solitary during the summer months.

All the ranges plotted from radio fixes or bearings embrace both open country and timber. This habitat combination appears desirable but the factor largely influencing location is the open country habitat composed of grass, sagebrush, and forbs. This is a sagebrush-grass subclimax type. Very little of this Yellowstone vegetation type is uninhabited by grizzlies, but there are large stretches of mature timber, dominated by the Lodgepole type, where grizzlies are seldom found except for short periods or while travelling.

Plants associated with the open country provide a more continuous, more available and more varied source of food than do those plants typical of the timber types. The preference, perhaps need, of the grizzly for this open-land habitat is evident from the ranges (Fig.1).

These open park-lands have resulted from a combination of ecological factors - fire, grazing, soil and moisture conditions. The maintenance of these ecological types is to some extent subject to habitat management. To manage the grizzly population in the future such habitat management may be necessary.

Food Habits and Habitat Preferences

In the course of tracking grizzly bears we have gathered considerable information on their food habits and related habitat preferences. This

information has been obtained in two ways--through direct observation of the grizzly bear activities while tracking them and indirectly through reading the signs they leave. During the fall of 1962 and 1963, the grizzlies exhibited quite different habitat preferences. In the fall of the former year, grizzly bears were found high on the ridges responding to an abundant crop of pine nuts (Pinus Albicaulis, Pinus flexilis). In the fall of 1963 their foraging habitat, by preference, was the open land and particularly the grass-sedge meadows of the stream bottoms. These areas were populated by field mice (Microtus spp.) and pocket gophers (Thomomys talpoides) that had attained the highest population densities we had yet observed in the Park. The meadows also provided an abundant supply of plant bulbs and tubers. Tubers of the grass (Melica spectabilis) and yampa (Perideridia gairdneri) were heavily utilized. Grizzlies feeding in these meadows were difficult to locate by radio. The valleys were low in relation to surrounding country and this tended to alternate or block the signal. This screening effect was largely absent when the bears were feeding on the high ridges where the timber and white bark pines grow.

Tracking the grizzlies by radio provided us with much interesting information concerning grizzly predation on high rodent populations. We frequently observed them digging up the runways of mice or watched them pounce on the scurrying rodents snapping them up in their jaws. Even more often in the course of tracking a grizzly we came across diggings that revealed the extent to which the bears were feeding on mice and pocket gophers. It was evident that all of the grizzlies were preying heavily on the unusually high populations of field mice and pocket gophers. The predation pressure imposed by the population of grizzlies, combined with that of coyotes and

numerous hawks and owls that concentrated in the same habitats, may have had a depressing effect on an excessively high population of these rodents. The influence of the rodents on range vegetation was quite noticeable and in some locations devastating. In some spots it was evident the grizzlies had been digging for tubers and, in most cases, we were able to collect samples of the plant foods they were utilizing as well as those that were discarded. Though this did not reveal new plant foods utilized by grizzlies, it did furnish information on the extent of use and occasionally individual food preferences.

Behavior and Interrelationships

We have mentioned previously that in tracking individual bears information was usually obtained on more than the instrumented animal. For example, on October 10, while tracking #150, we observed a total of thirteen grizzlies in a single afternoon. These included #48 and her three cubs plus an orphan cub she had adopted. Another family of three included at least one color-marked yearling. On October 28, we observed a family consisting of an unmarked sow and yearlings #132, #133 and #139. The sow was catching mice for her offspring. On another occasion, while tracking #150, we saw #40 and one other unidentified grizzly. In all, we contacted and observed at least 19 different grizzlies while tracking #150. Of these, 6 and possibly 7 were color-marked or ear-tagged animals. All to some extent shared the same range and favorite foraging areas used by #150.

Prior to instrumenting #150 she had adopted one of two cubs belonging to a sow that had been killed. Another of these orphan cubs had been adopted by sow #48, who had to cubs of her own as well. It is very probable that without the use of the radio-tracking system, we could not have learned that one of these orphan cubs was evidently abandoned by sow #150 after a period of

attachment. This may have occurred during the time that we shot, immobilized, and instrumented her. Number 48, we learned, had continued to take care of the other orphan cub treating it in all respects as though it were her own. This was particularly interesting information because #48 in previous years had abandoned two different litters of her own cubs.

Mention of one of many interesting incidents that occurred while tracking the instrumented bears seems appropriate in this report. On three different occasions we were forced to climb trees due to the close approach of grizzlies. None of the animals actually attacked but they became alarmed and ran directly toward us. Once while tracking #150, we spotted and followed another family for a short distance. This was a mother with three color-marked yearlings. Instead of continuing on her course, away from us, she turned up a small draw and slowly approached feeding as she came. I had separated from the rest of the party and was now cornered on a hillside in open country at least a quarter of a mile from the nearest tree. For some time I remained motionless in the sagebrush hoping the bear would alter her course. When she came within 100 yards, I was afraid to move for fear she would detect the movement but be unable to recognize me as a human. In these circumstances she might rush up to investigate. Because of their poor eyesight such behavior is characteristic of the grizzly when the direction of the wind is such that they cannot pick up scent. When the grizzly family continued to approach, I decided I could wait no longer and so rose slowly backing up the hill. As I moved, all four of the grizzlies stood up and in another instant would probably have rushed toward me out of curiosity. Once committed, an investigative move on the part of a grizzly can quickly develop into a charge. Fortunately, at this moment, my companions on the hilltop, who had been apprehensively following

the course of action, shouted and waved their arms. This had the desired effect of causing the grizzlies to hesitate, then to take off at a run away from my position.

Although the grizzlies we tracked by radio had summer ranges of varying sizes there was no indication that these were ever defended. Number 40 did not even attempt to defend a bison carcass located well within her small range. An unmarked sow and three yearlings feeding on this carcass kept #40 at a distance even though it was evident she was quite anxious to eat. Time and again #40 circled timidly and slowly approached the other grizzlies only to retreat when they exhibited slight aggressive behavior. Number 40 was not able to feed until the other bears were satisfied. Though this was her range, she had no monopoly on it. On another occasion this same bear was observed as she rushed at a larger bear feeding on a different carcass. The larger grizzly retreated but soon returned, and both bears fed together. Often numerous animals will feed simultaneously on a carcass without fighting or dominating the food. Though behavior varies with conditions and with individuals it appears that a carcass, a kill, and even a foraging spot may sometimes be defended but a range or hunting territory is not.

Grizzlies act as scavengers quickly disposing of the carcasses of large ungulates inhabiting Yellowstone Park. They are fond of carrion detecting it with their keen noses at considerable distances. It took sow #150 approximately 60 hours to locate a carcass 1 3/4 miles away from her bedding site. The sow and her cubs were the first grizzlies to find this carcass and would probably have arrived sooner had the wind direction been more favorable. Number 40 arrived later and exhibited interesting behavior when she used her shoulder to move the carcass so she could get to choice portions of flesh.

In tracking #40 and #75 we learned that #40 was definitely a timid animal as grizzlies go and #75 very aggressive. Even when we jumped #40 at a distance of 40 feet in dense timber, she took off at a run. Her actions with other bears revealed a timid nature and this behavior trait may to some extent explain the limited nature of this animal's range over a three-year period.

Bear-Man Relationships

Radiotracking has confirmed that grizzlies, in contrast to black bears, tend to avoid areas where Park visitors concentrate. It has also shown that at times visitors approach close to grizzlies and grizzlies close to people without the bear's presence being known. When resting in daytime beds grizzlies appear reluctant to leave their retreats. At such times they can be approached closely before being jumped or even by-passed by the tracker. Instrumented grizzlies have been seen and jumped at distances ranging from 40 feet in timber to 600 feet in open country. Fifteen measured jumping distances (paced) where the grizzlies were seen and where the grizzlies also detected the trackers, averaged 176 feet.

In dense lodgepole stands there have been instances where grizzlies have circled and tracked us while we followed their movements with portable tracking receivers. In timber and windfall, difficult for a man to traverse, grizzlies have moved ahead of the trackers so quietly that they could not be detected by ear.

Wherever a grizzly has identified a tracker as a man, usually by scent, they have taken off at a run. Grizzlies depend largely on their keen sense of smell to locate food and detect danger. When wind direction does not favor the grizzly, so that the human scent is not obtained, the animal may walk directly toward a man or even appear to rush at him, as mentioned earlier.

Exceptions occur, as for example when we were tracking sow #150 and her cubs in the early morning. A ground fog reduced visibility and there was little or no air movement. At a distance of about 200 feet the sow suddenly got our scent and bolted with her cubs. She was apparently unable to determine the direction of danger and ran directly for us. When we hastily started up trees she discovered us and changed her course. At similar distances grizzlies have often detected movement but apparently could not make an identification by sight. Their reaction is to investigate and this appears to be motivated by curiosity or prospects of a meal. On such occasions we have had to hurriedly climb trees or shout to distract or turn the animal. This can lead to a dangerous situation, as under such conditions, the approach may at the last moment turn into a defensive charge. At least some cases of so-called grizzly attacks found in the literature were probably nothing more than the rapid, yet awesome, approach of a curious grizzly bent on investigating a situation where its sense of smell has been inadequate. In order to smell, see and hear better the grizzly often rises up on its hind legs and this is sufficient to "confirm" an attack.

Tracking has confirmed numerous other observations indicating that the grizzly bears' eyesight is so poor they usually cannot identify a man at a distance beyond two to three hundred feet. They can detect movement, however, but if this is slight or slow it does not cause alarm. Under these same circumstances when a shift of wind brings them the man scent they invariably take off at a run, noticeably disturbed. Alerted instrumented animals have retreated rapidly for the first quarter mile and then normally slow down or even terminate their flight.

Knowledge of the conditions and situations that might lead to man-bear encounters is necessary for the management of grizzly populations in National

Parks and wilderness areas. Such information may also be quite important to the preservation of the species in Continental United States. Increasing visitor use of areas inhabited by grizzlies makes it likely that man-grizzly encounters will increase. An attack by a grizzly can be disabling or fatal to the people involved as is well documented in the literature. Often such incidents have been disastrous to the grizzly population as well, for usually more than the offending animal is eliminated in an effort to kill the culprit. It is conceivable that a series of incidents could result in a serious reduction of grizzlies, perhaps, to a point where a population could not recover.

Radiotracking of grizzlies is providing data that can help to prevent or minimize encounters of Park visitors with grizzlies. It is revealing the daytime retreats as well as areas where grizzlies are numerous. Some wooded areas in Yellowstone, particularly, "wooded islands" have so high a daytime concentration of grizzlies that they should be made off bounds to visitors. Radiotracking has confirmed our observations that the best way to avoid grizzlies is to let them know that humans are around. This can be done by taking advantage of the wind, thus, arranging for them to get man scent.

Prehibernation Behavior and Hibernation Treks

We have discussed some representative types of ecological information obtained through bio-telemetry methods. Much interesting detail has had to be omitted. However, we would like to expand on one event that dramatically reveals the possibilities and the practicality of this research tool.

One objective of our radiotracking, though not necessarily the most important, has been to track a grizzly bear into its "hibernation" den. We accomplished this during the fall of 1963. Up to this time and in the course of five years of study we had failed to locate a hibernation den. During

four seasons we had observed grizzlies up to within 12 to 24 hours of the time they hibernated. In every case they went into hibernation during a snow storm leaving no sign of their travel or whereabouts when the storm had cleared. Though we tracked some visually by following their tracks we invariably lost them due to falling and drifting snow. Of those observed regularly prior to hibernation, none revealed any pre-hibernation activity that would serve as a clue to a den site. Likewise, none were apparently in the close vicinity of a den prior to "hibernation" and most bears appeared to travel some distance in a "triggering" snow storm to reach what appeared to be a pre-determined hibernation site. In the fall of 1961 and 1962, we instrumented grizzlies with the hope we might track them to their dens. However, during these first two years of effort our radiotracking system was not perfected to the point where we were able to do so.

By late fall of 1963 it became evident that the only bear we might successfully track into hibernation was #150, instrumented October 6. We monitored this sow day and night and found she had a rather limited range in the upper end of Hayden Valley. We attempted to instrument other grizzlies in the same area but failed due to the scarcity of animals following the fall dispersal. In a final effort to increase our chances for success we instrumented one other grizzly, #164. She was trapped and released October 26 in the Old Faithful area 16 miles from the range of #150 in Hayden Valley. This sow was located by radio on the 30th of October a few miles from where she had been trapped. After this, initial monitoring attempts to pick up her pulsed signal (62/min.) in this area were unsuccessful. In the meantime, #150 was being closely followed, and her actions and movements interpreted relative to possible "pre-hibernation" activity. We had entered November, snow was on the

ground and temperatures dropping. Conditions were such that the next storm might put the grizzlies into hibernation as had been the case in the past. We still had not received the signal from #164 and thus did not know the bear's whereabouts but, in the last month of tracking #150, we had learned enough about this animal that we could, to a certain extent, predict her moves. However, it was #164 that we tracked to her hibernation den, not #150 and her cubs that we had monitored so closely. We lost the signal from #150 just hours before she and her cubs hibernated, perhaps, just as #150 entered a den. We were not aware of this until our last day of tracking but to explain and clarify what took place we will have to go back a few days to November 2. On this morning the signals received at our base station and from other locations indicated that the grizzly family (#150) was about 9 miles away and was slowly moving south and into an area of upper Alum Creek where we had not previously recorded them. In the afternoon we took off on foot and "closed in" using our portable directional receivers to guide us. While pursuing the source of the signal, we crossed fresh tracks in the snow made by the grizzly family. We followed their wandering course for a short distance but when the tracks veered from the course indicated by our directional receiver we left them. We continued to "home in" on the signal. At 3:15 P.M. we sighted the sow and her cubs about an eighth of a mile distant and moving toward us down a game trail which wound through open country interspersed with low trees. The wind was from the bear to us so we scrambled up some nearby lodgepole pines. When a few hundred years away the sow obtained our scent and took off at a run. We retraced our steps not wishing to disturb her further. At this point she was two and one-half miles from her usual haunts and might finally, we reasoned, have been moving toward her den. Her position was two miles from the "hibernation" den we later found, but this was not hers.

From base next morning at 6:30 A.M., November 3, we obtained a good signal (92 pulses per minute) that indicated the grizzly family was still in the same area where we had left them the evening before. A continual monitoring of the signal up until 12 P.M. showed no major movement on the part of the grizzlies. Up to this time we were apparently monitoring #150, although, the pulse rate was not counted and recorded after 6:30 A.M. A fix made in the field placed the grizzly in almost the exact spot where we later located a hibernation den. This was 12 miles southwest of our base station. At the time we thought this animal was #150, but it was undoubtedly #164 that had moved in from the Old Faithful area crossing the Continental Divide. At no time did we detect two signals, therefore we assumed only one instrumented grizzly was in the area. Because of this erroneous assumption we failed to recognize that we were monitoring a different animal (#164) even though the pulse rates were quite distinctive and could readily have been detected had we thought to double-check them. Had we realized that both bears were in the same area, identification would have been instantaneous. Convinced otherwise, from all previous evidence we failed to effectively use our electronic tracking tools.

Throughout the night of November 3 and into the early hours of November 4, we continued to monitor a signal at the base station that was coming from this location. In the afternoon of the 4th we hiked toward the headwaters of Trout Creek guided by our portable receivers after we were close enough to pick up a signal (3 miles). Two to four inches of snow covered the ground and a light snow storm was in progress. A fix from far up this creek placed the instrumented grizzly approximately one-quarter of a mile from where we later located the den. Evening signals showed no change of location. From the time

of the last recorded signal from #150 (12 P.M., Nov. 3) up until the evening of November 4, we lost the signal from #150 but picked up the pulsed signal of #164 without realizing that a switch had occurred.

On November 5 at 1:20, 4:25 and 7:00 A.M., signals received at the base indicated that the grizzly had not changed position but was still in the upper headwaters of Trout and Alum Creeks, about 12 airline miles from our base. The signal seemed unusually loud and clear but, as the morning wore on, it grew fainter as though the bear might be moving farther away or getting into shelter, perhaps windfall or den. At 9:50 A.M. the signal became even fainter and by 10:15 A.M. it had disappeared. When this occurred we decided to take off and track the grizzly on foot so that we would be in a position to continue following her if she was travelling to a distant "hibernation" site or we would be able to locate the den prior to the bear moving in. We realized that this might be the last day we would have to track the grizzly as weather conditions at the 8000 to 9000 elevations were such that she might "hibernate" at almost any time.

We left our vehicle and started hiking south toward the Alum-Trout Creek Divide where we had first located the bear by radio fix. Throughout the rest of the day we followed the signal bearing, hiking through lodgepole timber, and windfall. The average snow depth was about four inches. By 2:25 P.M. the signal was coming in so loud that we had to turn down the volume on the receiver. It was at this time, and not before, that we realized the pulse rate was too slow for grizzly #150, and that we were actually closing in on #164. The pulse rate of 62 per minute could only be hers. We continued to move slowly and carefully toward the signal source expecting any moment to jump a grizzly in the tangle of downed timber. We still had seen no grizzly tracks or other

sign, but as we continued, the signal came in so forcibly that the volume had to be turned completely down. We knew when this occurred that the instrumented animal could not be more than several hundred feet away. There were still no tracks or sign so we carefully looked under all likely windfall. At times, it seemed as though we must be standing on logs directly above the bear. We took fifteen minutes circling, probing and searching the last one hundred feet of our 12 mile tracking trek. Finally, down a slope and fifty feet away, we saw a packed area of snow discolored by traces of earth. This was the den entrance. We circled and approached cautiously to within twenty feet for photographs. The den opening was just large enough to accommodate the grizzly and bore back into a steep hillside. A huge unique three-forked lodgepole pine grew directly over the opening and would serve as a convenient landmark for a return trip. The slope had a north aspect and would, no doubt eventually be covered with deep snow. Signs showed that the grizzly had been resting here in front of the den opening. Had this not been the case, we would not have received the morning signals at base 12 miles away. The grizzly had apparently entered the den the night before but had been moving in and out. This accounted for the appearance and disappearance of the signal that we had received in the morning. This bear had entered the den during the night when it was snowing and so had left no tell-tale tracks leading to her winter den. Her movements since then were confined to the immediate vicinity of the entrance. This collaborated our theory gleaned from past experience that the grizzlies had moved directly to their "hibernation" dens during snow storms.

In reconstructing the activity it appears that grizzly #164 travelled rapidly from the Old Faithful area to the site of her den, an airline distance of between 12 and 15 miles, perhaps double that on the ground. She was

definitely in the den area on November 3 and remained at or near the cave entrance during the afternoon of the 4th. She rested outside the entrance on the night of the 4th and during most of the following day (5th). Not until our approach on the afternoon of the 5th did she go deep inside the den. At no time did she observe us. The last signal we received from this bear was picked up on our return trek when about one-half mile from the den. She apparently remained deep within the cave and the shielding effect of many feet of earth prevented continued reception of the signal at a distance. No signal was received at Base on the 6th and increasing snow depth prevented further reconnaissance by foot. Closing roads necessitated evacuation of the base station.

Tracking #164 into her hibernation den ended a season of radiotracking that, even without this achievement, would have been a highly successful year. It also served to definitely establish the value and practicality of bio-telemetry as an ecological research tool.

The location of this hibernation den opens new areas for research--"hibernation" phenomena, causes of infant mortality and telemetry of physiological data. It appears quite likely that the type of site selected by this bear may be typical of others and, thus, lead to discovery of additional dens without the necessity of tracking. Two former dens that had collapsed were found within thirty feet of this den. It appears that the grizzlies, as we suspected, use the same dens or hibernation sites year after year.

Perhaps, even members of the same family (same mother), return to the area of their birth to hibernate. If this is so, hibernation sites once located can be visited and studied year after year. The location of this den was in timber and at a relatively high altitude in relation to surrounding

country. It was also far removed from roads and people. It was on a north-facing slope where snow will lie deep. The den had definitely been excavated by the bear. It was not a natural or even partly natural cavity. Because we had not come across a cave of this kind in our work, we had suspected that some Yellowstone grizzlies might well spend the winter in a windfall or in tangled mats of timberline vegetation. The fact that in the past they had been active until within 12 hours of going into hibernation made us suspect that they could not do much in the way of preparation, in fact, might sleep wherever the final big storm caught them. It appears that this possibility can now be pretty well ruled out. On the other hand, we observed grizzlies regularly right up until the final storm and had followed their tracks in the storm only to eventually lose them. This indicated that the grizzlies took off and headed for predetermined destinations. The behavior of #164 and the prepared den indicate that this is probably what usually happens. This particular grizzly knew where she was going to hibernate and travelled to this area from a distance entering the cave itself during the snow storm. The location of the den was such that, had we known it was within a square mile area, we most likely could not have found it even if we had searched the region with a team of men. To have located a den of this kind belonging to a particular bear would be almost impossible using standard field observation methods. It is probably safe to say that this achievement could not have been accomplished without the use of radio or some similar type of tracking method.

Tracking #164 into hibernation has to some extent verified some of our observations over the years.

It appears that a snow storm definitely triggers hibernation though there may be other factors involved.

Most of all of the grizzlies in a given area where weather and temperature conditions are the same go into hibernation at about the same time even though other factors affecting them may vary. Though widely separated, it would appear that they all sense in some way that this is the time to go into the deep sleep of winter.

The bears go into hibernation during a snowstorm and this serves to cover their trails. Following the "hibernation storm" there are no tracks evident even in areas where numerous bears were present a day or so previously.

The grizzlies, at least the mature ones, travel to definite sites to hibernate. These may be a considerable distance from their late fall foraging areas. It may even be that very few bears remain close to their dens prior to the final trek.

There seems to be little preparation of a hibernation site in the days and weeks just preceding hibernation. It will be interesting to determine just when the dens are excavated.

There is some evidence that a family, that is, the various litters from a single sow tend to return to the area of their birth to hibernate. If so, we may find that there are areas where grizzlies concentrate to hibernate.

It appears that some grizzlies hibernate at least two or more winters in the same den or in a new den in the same area (we have definite evidence of this from tagged black bears). If a typical hibernation site can be determined by isolating criteria it should be possible to predict suitable locations and then locate dens with search parties.

IMPROVED TECHNICS AND EQUIPMENT ADVANCES

In 1963 Philco engineers stepped up the transmitter output to 200 milliwatts and switched over to a welded module construction technique. The

entire module was then potted in polyeurethane foam for mechanical support and to provide waterproofing. This construction replaced a point-to-point wiring of components on an L-shaped aluminum chassis. One temperature sensitive transmitter was produced and tested. A 1 megohm thermistor was used to obtain a temperature dependent pulse frequency. This transmitter can be used to telemeter temperature conditions in the neck region of the instrumented animal and is being developed for eventual transmission of physiological data.

Various receiver modifications were made as a result of our 1962 tracking experience. All portable receivers were modified by the addition of a BFO and a directional loop antenna and sense antenna. The loop was attached to the receiver with a UHF type connector so that it could be readily detached and the receiver coupled to the more sensitive Yagi type antennas used at our Base Station, Field Station and on our Mobile Units. This made our tracking system fully transistorized, battery operated and eliminated the general coverage receivers that required critical tuning. The transmitter portions of the modified transceivers were also tuned to the tracking frequency, 32.005 mc to permit voice communication between tracking units. Citizen Band transceivers had previously been used for this purpose. With the loop antennas alone it was often difficult to determine signal source as the equally sensitive lobes result in a 180 degree ambiguity. To overcome this difficulty a whip sense antenna was added to suppress one lobe of the loop antenna pattern. When the sense antenna is activated by a push button, it provides 13db suppression of the reverse lobe and 3db enhancement of the forward lobe, giving a 16db front-to-back ratio. In practice this proved very effective in locating instrumented grizzlies.

It had become evident that, under certain conditions, the ability to locate and track from the air would be a tremendous advantage. We experimented using a loop antenna attached to the wing strut of a plane and connected to the receiver by cable. Earphones were plugged into the receiver to cut out plane noise. A signal from a test transmitter of the type used on the grizzlies was picked up a distance of five miles from a fixed-wing plane. The signal from grizzly #150 was picked up several miles away by plane, the sow and her cubs located and then actually spotted from the air. The positions of grizzlies #7, #75 and #76 were all pinpointed from a helicopter. An outside loop was not used and signal reception faded out at distances greater than 1 to $1\frac{1}{2}$ miles. All grizzlies were located very close to fixes obtained on the ground. Number 40 was located by helicopter in the morning and later her position checked by hiking in with portable receivers and jumping her at a distance of 300 feet in the exact area pinpointed from the helicopter. Late in the fall attempts were made to locate #7 and #76 from the air using a fixed-wing plane. This was unsuccessful but by this time the signal from one animal was quite weak and the signal from the other either weak or dead.

We have built and experimented with sensing devices or transducers for pulsing transmitters that will telemeter various types of environmental data. We have successfully gathered information on temperature and light intensity, and have reached a point where this method of data gathering is being incorporated into our ecological study. In addition we have experimented with audio-amplifiers attached to our tracking transmitters and this looks promising for work on behavioral phases of the study.

Work was continued toward improving instrumentation methods, waterproofing and preparation and replacement of battery packs. Considerable progress was made but this is still an area of endeavor where additional work is needed to obtain optimum results, better performance and greater efficiency.

A cow elk was instrumented in the Lamar Valley of Yellowstone National Park and tracked on its winter range for 54 days with mobile and portable equipment. Temperature was frequently below 0°F.

COOPERATION AND COLLABORATION

Cooperating and supporting agencies include the National Geographic Society, National Science Foundation (G-17502), Philco Corporation, National Park Service, U.S. Fish and Wildlife Service, Boone and Crockett Club, New York Zoological Society, Wildlife Management Institute, Environmental Research Institute and the Yellowstone Park Company.

The project has been administered jointly by Frank C. Craighead, Jr., and John J. Craighead of the Environmental Research Institute and the Montana Cooperative Wildlife Research Unit respectively. Buildings and utilities in Yellowstone National Park have been furnished by the Yellowstone Park Company.

Research team collaborators include Frank C. Craighead, Jr., John J. Craighead, Joel Varney, Philco Corporation, Maurice Hornocker, Montana Cooperative Wildlife Research Unit and Hoke Franciscus, (W3 ELV) Carlisle, Pa.

The tracking equipment has been designed and provided by Philco Corporation under the direction of Dick Davies, Joel Varney has been in charge of design and construction. Hoke Franciscus has given advice and has constructed transmitters for telemetering environmental data, audio amplifiers and other equipment. Maurice Hornocker has participated as field biologist.

CONCLUSIONS AND FUTURE WORK

The radiotracking system has proven itself to be a practical and valuable research tool for gathering ecological data. We have obtained information concerning the grizzly bear that we had been unable to get in the past using conventional methods. We have now reached a stage where it is possible to determine

what specific information is needed even relative to a certain bear or family, and then instrument animals so as to obtain the desired information.

Future radiotracking work with the grizzly will be directed toward seeking information relative to certain key animals. For example, the dominant bear in the grizzly heirachy will be instrumented. We will slowly phase into the telemetering of physiological data from free roaming animals. We will start conservatively and work with temperature transmission and EKG's. Emphasis will be placed on external attachment of both sensors and transmitters. A review of the literature indicates that this has not been done with free roaming animals at a distance and under wild conditions.

There are many areas in ecological research where the application of bio-telemetry can provide unusual results. We plan to gradually apply our system to other types of studies and to the solution of problems that lend themselves to this technique. One endeavor will be to gather needed information on the migration pattern and summer distribution of the northern Yellowstone elk herd. Such data is basic to a full understanding of elk ecology and greatly needed for management purposes.

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20 platform interrogation sequences per orbit

Single data frame consists of 28 data words of 7 bits each.

Dummy collars

Potential of satellite monitoring

Ground Tracking System — 32 MHz

Satellite Animal Tracking

Feasibility Study — Nimbus satellite IRLS system
animal tracking & monitoring
NASA - Smith
collaborators, cooperators
Polar orbit — 700 mi — 24 hr
Reconfigured — BIP
28 channels 7.5 Hz
8
orbit 1 hr 47 min.
Ground Command
pre-programmed
10 minute transmission

[address code — 16 bit
Time reference
Command memory — magnetic core

RADIOTELEMETRY OF LARGE WESTERN MAMMALS

ANNUAL
PROGRESS REPORT

1967

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The research described in this report has been conducted in Yellowstone National Park under a cooperative agreement with the National Park Service. The principal investigators have administered the project and executed the research through the Montana Cooperative Wildlife Research Unit[1] and the Environmental Research Institute. The development and refinement of electronic equipment has been done by Joel Varney of Philco Corporation. Research Assistants were Henry McCutchen and Merlin Shoesmith.

[1] The U. S. Fish and Wildlife Service, University of Montana, Montana State Fish and Game Department and the Wildlife Management Institute cooperating.

INTRODUCTION

The principal investigators, working with electronic engineers, developed a radiotracking system that proved effective for locating instrumented grizzly bears (Ursus arctos horribilis) and studying their movements and social behavior. The system capability was then expanded for telemetering physiological information such as body temperature and heart beat. This was accomplished under NSF grant GB-2672 and grants from the National Geographic Society.

Under NSF grant GB-2672 for 1965 and 1966 and AEC grant AT(45-1)-1929, we have applied radiotracking equipment and techniques to the study of elk (Cervus canadensis) and other large western mammals in the Yellowstone National Park-Jackson Hole area. The objectives of this investigation are threefold:

1. To further perfect, develop, and test a portable radiotracking and telemetering system for big game animals.
2. To instrument free-roaming elk and other large mammals in order to improve and perfect field data gathering techniques and procedures utilizing electronic equipment.
3. To obtain certain ecological information from instrumented free-roaming elk and bear.

DEVELOPMENT AND TESTING OF ELECTRONIC EQUIPMENT

During the 1967-68 contract year emphasis was on development and testing of equipment for automatically recording telemetered information from wild, free-roaming animals. Three automatic recording systems were developed and tested.

These were:

1. Equipment designed for forty-eight hour continuous recording on tape. Automatic recording was 1 minute in every 15. Radio

signals were received through our standard tracking receiver on a frequency of 32.02 mc. The taped information was summed and printed out by a totalizer.

2. A totalizer with direct printout and continuous recording of the information signal (for example-body temperature). This equipment totalized and printed out every 5 minutes.
3. Recording equipment with demodulator and battery operated Rustrak recorder, (Plates 1 and 2).

All of the above equipment is portable, battery-operated and designed for cold weather operation. Tests were conducted on elk, black bear and humans.

New transmitters that were developed and tested for use with the automatic recording equipment consisted of:

1. A two channel body temperature transmitter for measuring body temperature simultaneously at different depths (4 cm and 7 cm) in the animals body. Resulting temperatures can be correlated with animal behavior and activity (Plate 5).
2. An ambient temperature transmitter for use in correlating animal behavior and changes in body temperature with fluctuations in ambient temperature conditions.
3. An accelerometer transmitter for detecting and measuring changes in animal activity such as sleeping, walking, running and feeding.
4. An improved extended-life transmitter that has an operational life of approximately one year. These newly designed transmitters were field tested on elk and grizzly bears.

A multiplex box was used to switch alternately between inputs allowing sequential sampling from the various transmitters.

TEST RESULTS

Ambient Temperature Recording:

Range tests and calibration checks were made with a temperature-dependent pulse rate transmitter designed for telemetering ambient temperatures between -40° and +40° C (Plates 1 and 2). The received signal is converted to a DC voltage by a pulse rate converter and displayed on a chart recorder. Temperature information is obtained from the pulse rate with a calibration chart.

Results of the range tests are shown in Figure 1. The transmitter was placed at the numbered locations shown on the sketch map with the receiver and quad antenna located at the bunkhouse. Signals of sufficient strength for good automatic recording were obtained at locations 1, 2, and 3. The range at location 3 is 0.9 miles. Weaker signals were obtained from Locations 4 and 5, primarily because of terrain shielding effects.

An overnight recording was made with automatic transmitter recording equipment. The receiver and pulse rate converter were switched on with a timer for 6 minute periods at 24 minute intervals to enable battery operation for long periods. A time marker was also used to check the speed regulation of the battery-operated chart recorder. The resulting recording is shown in Figure 2. The sky was overcast and the temperature was nearly constant at -11° C all night.

Body Temperature Recording:

An attempt was made to telemeter body temperature during winter from a free-roaming elk but the experiment failed and there was insufficient time to repeat. As a substitute, range tests and skin temperature measurements on human subjects were made with a body temperature telemetry system. The system consists of a pulse modulated transmitter whose duty cycle is controlled by the temperature of two thermistors mounted in a

probe, and battery-operated portable receiving and recording equipment. The probe is intended to measure body temperature at depths of 4 cm. and 7 cm. The thermistors at these depths are sampled alternately for 25 seconds and 15 seconds, respectively. If the thermistors are at different temperatures, two traces result on the chart recorder.

For use with human subjects, the probe was taped to the skin rather than implanted or inserted. Typical recordings obtained are shown in Figure 3.

For subject No. 1, the probe was held in the armpit and recordings were made while the subject went about various activities which are noted on the recording. The probe was taped on the abdomen of subject No. 2, and the skin temperatures were measured from 7:30 P.M. until early the following morning.

We concluded from tests conducted with the Rustrak recorder (Plates 1 and 2) that we were not obtaining the maximum distance possible with this system. We also encountered some problems in the multiplexer box which switches between four inputs. This equipment is being modified as a result of the field performance tests. More testing is being done to perfect the automatic recording equipment. The Rustrak recording with the multiplex switching between inputs (Plates 1 and 2) appears to best fit our requirements for gathering information on 24 hour body temperature patterns under winter conditions. The tape recording system provided the best range but the totalizer in this system is not sufficiently receptive to change in signal strength to permit accurate totalizing of signals of changing intensity.

The battery-operated totalizing printer with direct input has less range than the other systems but greater sensitivity so that it can be used to record numerous types of desired information at short range. It proved to be well suited for recording signals from our ambient temperature

transmitters and from the accelerometer transmitter. The pulse rate converter with visual display of pulses per minute proved to be an accurate and valuable tool for monitoring the transmission of ambient and body temperature data. This provides an on-the-spot evaluation of received data and equipment performance. Information obtained from the field testing has aided in evaluating three different approaches to automatically recording data in the field and the information obtained will be used to modify and redesign future equipment. Emphasis is being placed on the development of lightweight portable equipment. Schematics and details of equipment construction are presented in the report "Summary of Biotelemetry Equipment Work, 1967 Season" (see enclosure).

SOME RESULTS OBTAINED FROM INSTRUMENTED ANIMALS

Radiotracking of grizzly bears and elk continued through the 1967 field season. Four grizzlies and two black bears were instrumented and data gathered on daily movements, home ranges, centers of activity, prehibernation behavior and denning.

GRIZZLY BEAR

One female grizzly was instrumented in an attempt to determine the period of developmental arrest from conception to implantation. Delayed implantation has been conclusively demonstrated in the grizzly bear (Craighead, Hornocker and Craighead, in press) but the length of the delay period is unknown. (See report, "Reproductive Biology of Young-Age Female Grizzly Bears, 1968").

Some animals were instrumented in order to test newly developed equipment and others were instrumented in order to gather biological data.

Table 1 summarizes the radio-location data for four grizzlies and Table 2 presents data on the size of their ranges. Female No. 40 (Plate 3) has been instrumented for seven consecutive years and the size of her home range and her centers of activity within her home range have

been accurately determined and thoroughly described. Four of her winter dens have been located by the use of radio and this information is presented in report, "Grizzly Bear Prehibernation and Denning Activities as Determined by Radiotracking", Craighead, F. C. and John J. Craighead, 1968. Information on home and seasonal ranges and daily, seasonal and migratory movements of 40 grizzlies radiotracked during a seven year period will be presented in a report, "Home Ranges and Movements of Instrumented Grizzly Bears".

During 1967 home ranges were determined for females No. 187 and 101, Table 2, Figure 4. Number 187 was a 4½-year-old female known to have mated and thought to be pregnant. Her prehibernation movements were closely monitored. She made two treks to her den before finally returning to hibernate. Female 101 had 1 yearling and two adopted ones. Throughout the summer they travelled, slept and foraged together, and were apparently inseparable. Both of the adopted yearlings nursed the female. The female, however, hibernated with only her single offspring; the two adopted yearlings denned within the home range of their mother (Sow No. 40) but their den or dens were not located.

We disturbed No. 101 at her den while tracking her; she abandoned the den and then selected a new site and dug another den within a period of about a week. Her activities during this time were closely monitored by radio. Details of the behavior and movements of females No. 187 and 101 will be reported in greater detail in future reports.

The foraging habits of No. 40 and No. 188 were studied by radiotracking these bears and making visual observations in the field. Plate 4 shows female No. 40 at an elk kill. Kills are initially defended but eventually communally shared. The feeding habits of grizzly bears have been compiled over a nine year period and will be the subject of another report.

BLACK BEAR

Two black bears were instrumented during 1967 to determine movements and ranges. Bear No. 1 had also been instrumented the previous year. Locating data are presented in Table 3.

On September 19, 1966, a young adult male black bear (No. 1) was instrumented with an extended-life transmitter and tagged with a color marker, at Canyon Village. This instrumentation was a preliminary attempt to test the radiotracking system on this species and to obtain data on movement and homing behavior. On September 23, 1966 the bear was retrapped at Canyon Village by National Park Service Rangers and released at Hayden Valley 7 airline miles to the south of Canyon. On September 30 the bear was located in a denning area near Lake, approximately 15 miles south of Canyon. The bear remained in this area moving in and out of its den. The signal from the bear was monitored throughout October. The last signal was obtained on October 29 when the bear finally denned for the winter.

The following summer black bear No. 1 was seen at Tower and on August 3, 1967 the bear was immobilized and the radio-collar removed. The distance from Lake to Tower is 25 airline miles. On September 12, 1967 the bear was trapped at Canyon Village 10 airline miles south of Tower and again was instrumented with an extended-life transmitter. The bear remained in the Canyon area until September 17 after which the signal was lost. On September 25 the signal was located near Lake in the same area where this bear had denned the previous year. A final signal was picked up on October 2 and the bear denned after this date.

Several features of this bear's movements are of interest. The distance the bear moved from one extreme of its range to the other was 25 airline miles. In making this movement, the bear crossed Dunraven Pass and negotiated other rugged mountain terrain. Timing of movements for both years shows a high degree of correlation. The bear denned in the

same area both years. No defense of a home range was observed. The bear entered the home ranges of other black bears and at times foraged jointly with these bears. We obtained no evidence that the black bear in Yellowstone is territorial.

Black Bear No. 3 was trapped November 20, 1967 at Mammoth as it was preparing to den. It was instrumented with a radio and released in the Old Faithful area approximately 25 airline miles away on November 21.

From November 21 to November 29 this bear wandered in the vicinity of the release site making no attempt to home to the site of capture. The animal was monitored by radio and visually tracked in about 10 inches of snow. Between November 21 and November 29, the bear located a rocky cliff with numerous natural caves. Tracks showed that the bear traversed the area back and forth entering and leaving caves. It seemed certain that the bear was seeking a winter den site. We lost the radio signal in this area on November 29 and presumed the bear had denned since no tracks leaving the area were located, nor was the signal picked up after that date.

It is of interest that black bears released in a similar manner during the summer months normally home to the area of capture. Onset of lethargy presumably drove Bear No. 3 to "hibernate" near the release site.

POLAR BEAR

Inquiry from biological researchers concerning application of our radiotracking system for big game animals has increased steadily. Some of the inquiries from scientists working in foreign countries have been submitted to the Division of Biology and Medicine, Atomic Energy Commission for comment and review. Specific requests for help have come from Dr. Charles Jonkel, Canadian Wildlife Service; Jack Lentfer, Alaska State Fish and Game Department; and Thor Larson, Norwegian Polar Institute, Norway. These biologists are conducting research programs on the

polar bear (Ursus maritimus) but do not have access to biotelemetry equipment or to researchers experienced in the development and use of such equipment. At the invitation of Dr. Charles Jonkel of the Canadian Wildlife Service, we made a trip to Hudson Bay in September, 1967, to confer on the feasibility of utilizing our electronic equipment on the polar bear.

At Churchill we met and conferred with Dr. Albert W. Erickson, University of Minnesota, Dr. Vagn Flyger, University of Maryland, and Thor Larson, Norwegian Polar Institute, University of Oslo, Norway.

Funding was provided by the U. S. Bureau of Sport Fisheries and Wildlife, the Canadian Wildlife Service and the Environmental Research Institute. Our objectives were to familiarize ourselves with the polar bear environment and field research conditions in order to assist and advise our colleagues and to demonstrate in the field the use of our equipment. We were prepared to instrument and track two polar bears and to leave the equipment with Dr. Jonkel. The equipment consisted of two transmitters, two receivers, a quad antenna and other items of gear.

The Canadian researchers were unsuccessful in capturing polar bears during our stay and so we were unable to instrument any animals. However, we demonstrated the use of our equipment to the biologists present and tested it thoroughly under arctic-tundra conditions. Tests showed the equipment would be effective. From the informal conferences and field testing, we concluded that we could contribute substantially to the International Program of Polar Bear Research by providing the researchers with minimal equipment needs and "on-the-spot" aid in assembling and utilizing our biotelemetry system. There was unanimous agreement that this approach would be far superior to independent development and experimentation by individual researchers in the field of biotelemetry. Programs in Alaska, Canada and Norway could be initiated much faster, at far less expense and with much less work and frustration if the polar bear researchers could

use a perfected radiotracking system and have competent field instruction and consultation during the initial stages of their programs.

Similar requests for aid in biotelemetry have come from Dr. Hugh Lamprey, Serengeti Research Institute; Dr. G. Schaller, Arusha, Tanzania; Dr. V. Sokolov, Academy of Science, Moscow, USSR; and K. S. Dharmakumarsinhji, Vice Chairman for Wildlife, Bombay, India. Numerous requests have been received from U. S. biologists, including Dr. Maurice Hornocker, University of Idaho, who is working on the cougar (Felis concolor) and Dr. Richard Taber, University of Montana, working on mule deer (Odocoileus hemionus) and the bighorn sheep (Ovis canadensis).

ELK

Several elk were instrumented to test equipment and to experiment with types of data that could be obtained. Merlin Shoesmith, graduate student, University of Montana, instrumented two elk with extended-life transmitters in order to:

1) determine the movements and distribution of Mirror Plateau elk on the winter range with respect to altitudinal and feeding exposure situtations and
2) to measure the degree of individual exchange and association among elk bands.

A marked Mirror Plateau cow (60-183) was instrumented on January 20, 1968 and was tracked on the winter and spring range through May 21. Analysis of the radio-tracking is not complete. However, data included here illustrates some specific types of information that can be acquired by radio-tracking.

Table 4 summarizes the monthly movement and habitat exposure of an instrumented cow on winter and spring range. During February, cow 60-183 moved 11.65 airline miles through deep snow. Near the end of

February, this cow moved from north Specimen Ridge to the Hellroaring Patrol Cabin (8 airline miles). The 10-mile total for April (Table 4) represents longer daily foraging movements as spring "green-up" began.

There was a general shift from predominant use of northern exposures to southern exposures about March 1 (Table 4, Figure 5). The instrumented cow was tracked as she crossed from Specimen Ridge to Hellroaring Slopes. (See intersection, Figure 5). Increased use of southern exposures during April and May is correlated with commencement of "green-up".

Table 5 and Figure 6 illustrate the movement of 60-183 with respect to elevation. There was a general decline in monthly altitudinal movement and mean elevation from winter to spring range. The increase in mean elevation from April to May represents a movement to higher slopes as new grass appeared.

Individual exchange occurred daily among elk bands on the spring range as indicated by marked elk (Figure 7). All elk bands shown here were located within a one-square-mile area where most of the color-marked cows calved 1-2 weeks later. Cow 60-183 remained in a relatively large elk group from May 18 to May 20. The group consisted of about 50% of the same marked individuals during this period of time. Prior to instrumenting elk 60-183, she had been observed in association with a large number of color-marked Mirror Plateau and non-Mirror Plateau elk during a three-year period (Table 6, Figure 8). Frequency of occurrence of these associations over a period of three years shows that a high percentage of them (80% and 74%) were one-time associations. Ninety-six percent of the marked Mirror and non-Mirror Plateau elk that associated with 60-183 were observed with her only twice. These data show a low degree of association between individual elk (excluding family units) and suggest highly developed individual behavior traits. Frequency of occurrence of associations between cow elk 60-183 when instrumented from January 20 to May 21, 1968, supported the

association patterns obtained by observing marked elk, that is frequent one- and two-time associations with other elk, but infrequent multi-associations with other elk. Elk apparently do not form close and lasting associations with members of their own or other bands except in the case of cows with calves or cows with bulls during the breeding season.

During June, 1968, a cow elk was instrumented with a motion-sensing transmitter. She was tracked and visually observed during numerous 24-hour periods. The accelerometer readings were correlated with activity visually observed in order to determine types of movement and activity that could be detected with the motion-sensing transmitter. Feeding, bedding, walking and running could be clearly differentiated as well as more subtle movements. Considerable progress was made in automatically recording types of movements at distances of a mile or more.

Nythemeral body temperature readings were automatically recorded from a free-roaming elk at 4 and 7 cm depths. Work on this project will continue through the summer of 1968.

Table 1

GRIZZLY BEAR RADIO-LOCATING DATA - 1967

Bear No.	Number of Days Radio Operating	No. of Days Attempted To Locate By Radio	No. of Days No Attempts To Locate By Radio	No. of Days Successful In Locating	Percent Days Successful from Attempts made To Locate	No. of Days Visual Sightings Attempted with Aid of Signal	No. of Days That Visual Sightings Were Made	Percent of Sightings Successful from Attempts Made
40	16	14	2	13	93	1	0	0
101	49	38	11	36	95	16	12	75
187	65	59	6	54	92	9	7	78
188	15	13	2	13	100	0	0	0
Totals	145	124	21	116	94%	26	19	72%

Table 2

GRIZZLY BEAR RANGES DETERMINED BY RADIO TRACKING
1967

Bear No.	Tracking Dates	Animal Tracking Days	Number of Days Located Or Sighted	Area of Range in Square Miles	Remarks
188	8/22 - 8/26				Lone three-year old male
	9/5 - 9/14	15	13	6.7	
40	9/11 - 9/26	16	13	11.1	Lone Sow (Pregnant)
187	9/4 - 11/7	65	54	39.8	Lone Sow (Pregnant)
101	9/6 - 9/28				Sow with yearlings
	10/19 - 11/13	49	36	43.1	

Table 3

BLACK BEAR RADIO-LOCATING DATA - 1966-1967

Bear No.	No. of Days Radio Operating	No. of Days Attempted To Locate By Radio	No. of Days No Attempts To Locate By Radio	No. of Days Successful In Locating	Percent Days Successful from Attempts Made to Locate	No. of Days Visual Sightings Attempted with Aid of Signal	No. of Days That Visual Sightings Were Made	Percent of Sightings Successful From Attempts Made
1 (1966)	41	18	23	12	67%	0	0	0
1 (1967)	21	8	13	6	75%	0	0	0
3 (1967)	9	6	3	6	100%	4	1	25%

Table 4. General movement and location of instrumented cow 60-183 on winter and spring range.

Month*	Total Movement**	Slope Aspect at Location Site							
		NE	N	NW	W	SW	S	SE	E
January	8.35	4	3	32	0	0	0	0	0
February	11.65	3	9	2	1	5	1	0	0
March	6.15	0	0	0	1	1	8	5	0
April	10.00	0	1	0	4	8	1	0	0
May	8.20	0	0	0	0	4	4	0	0

*Duration of radio location was January 20 through May 21.
** Airline Miles.

Table 5. Movement of instrumented cow 60-183 with respect to elevation.

Month	Vertical Change in Elevation	Mean Elevation
January	1500	7478
February	1600	7012
March	800	6221
April	500	6214
May	400	6650

Table 6. Frequency of association of instrumented cow 60-183 with marked Mirror and non-Mirror Plateau elk.

Number of Times Observed with 60-183	Total Marked Elk Observed	Percent of Total	Total Mirror Elk Observed	Percent of Total
1	147	80	45	74
2	30	16	13	22
3	4	3	1	1
4	2	1	1	1
5	0	0	0	0
6	1	-	1	1
7	0	0	0	0
8	1	-	1	1
Total	185	100	62	100

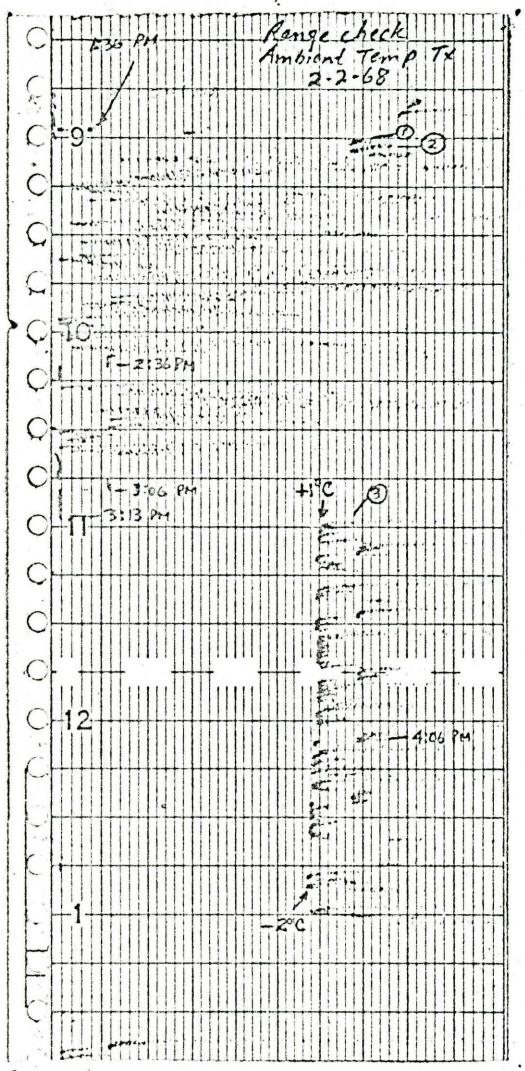


Figure / : Ambient Temperature Transmitter Range Check

□ = TRANSMITTER LOCATIONS

OLD FAITHFUL AREA YFRE-ASRC-SUNYA

la Sketch map of OLD FAITHFUL AREA OF UPPER GEYSER BASIN, Y. N. PK. (Schaefer)

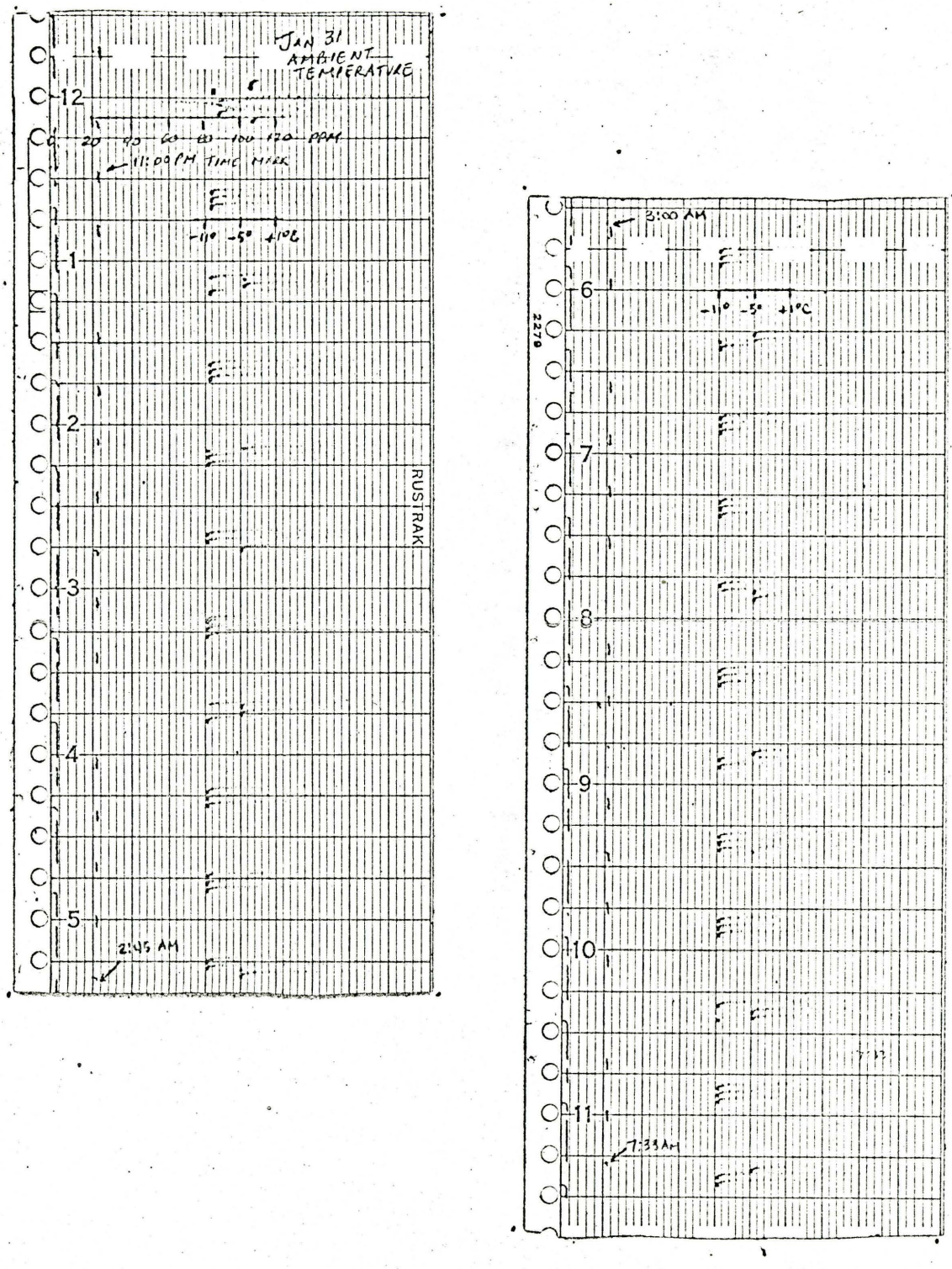
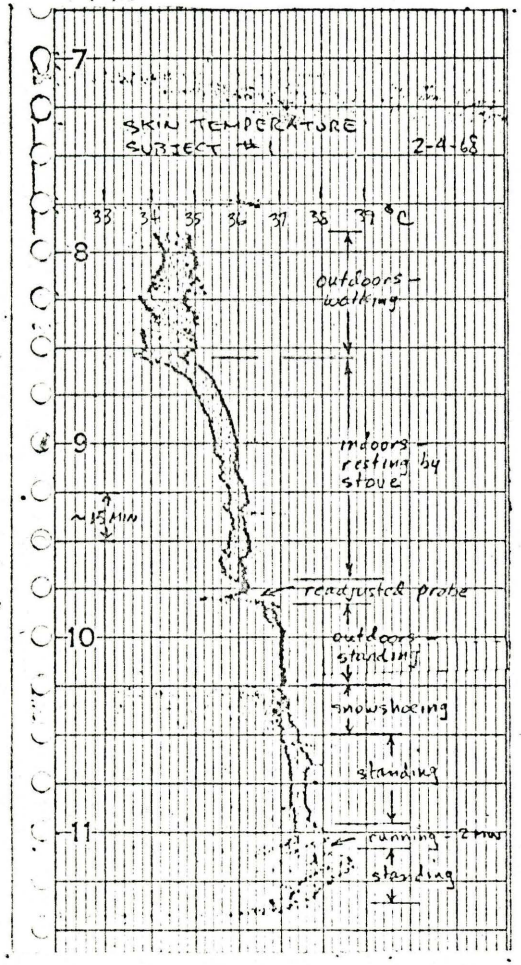
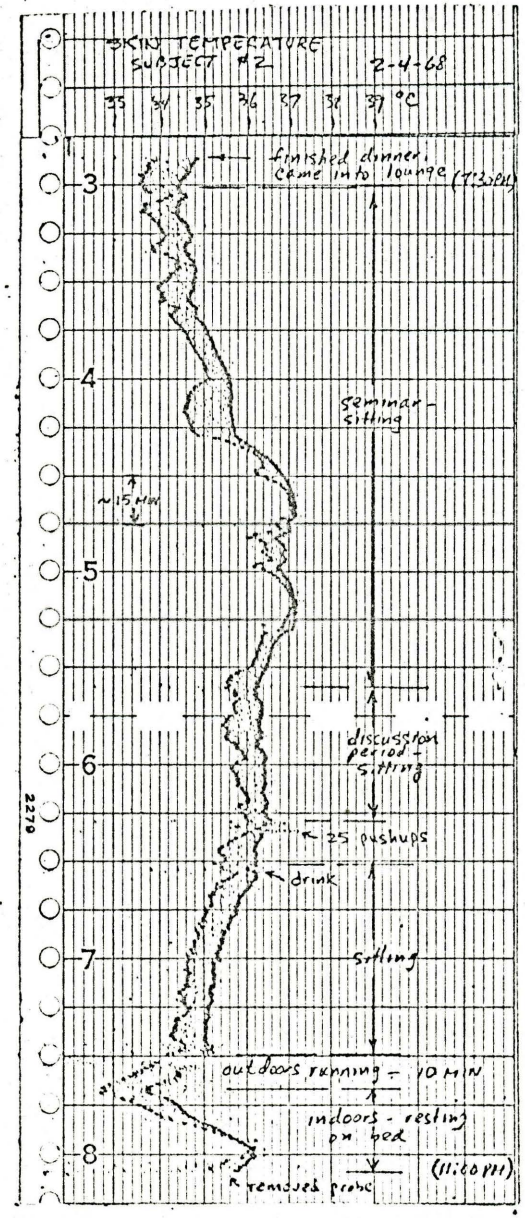


Figure 2 : Overnight Ambient Temperature Recording





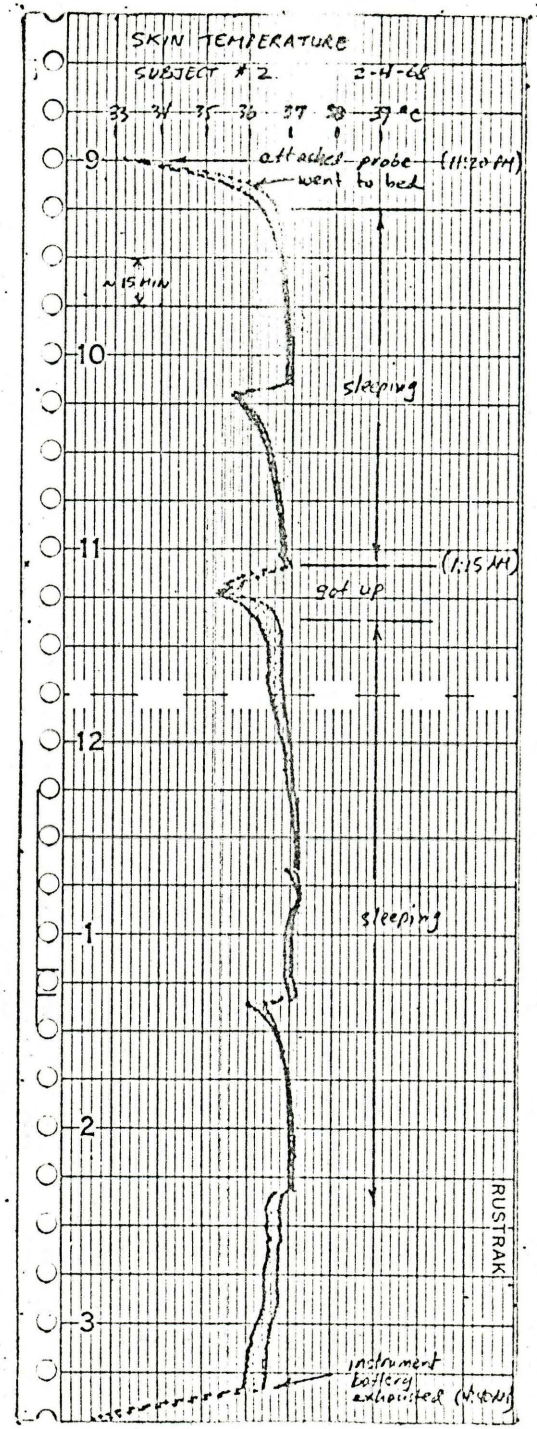
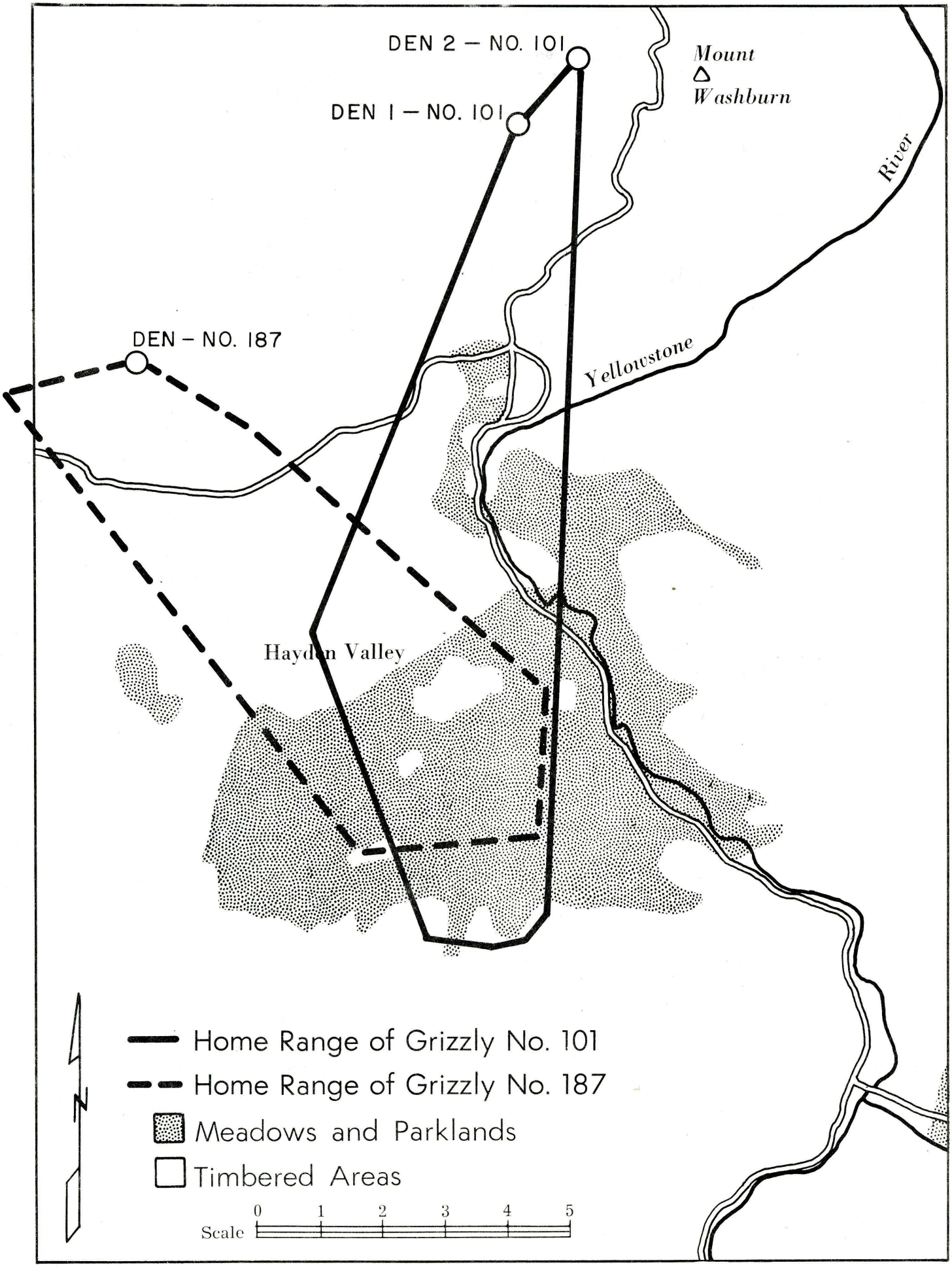


Figure 3: Skin Temperature Recordings



GRIZZLY HOME RANGES—1967

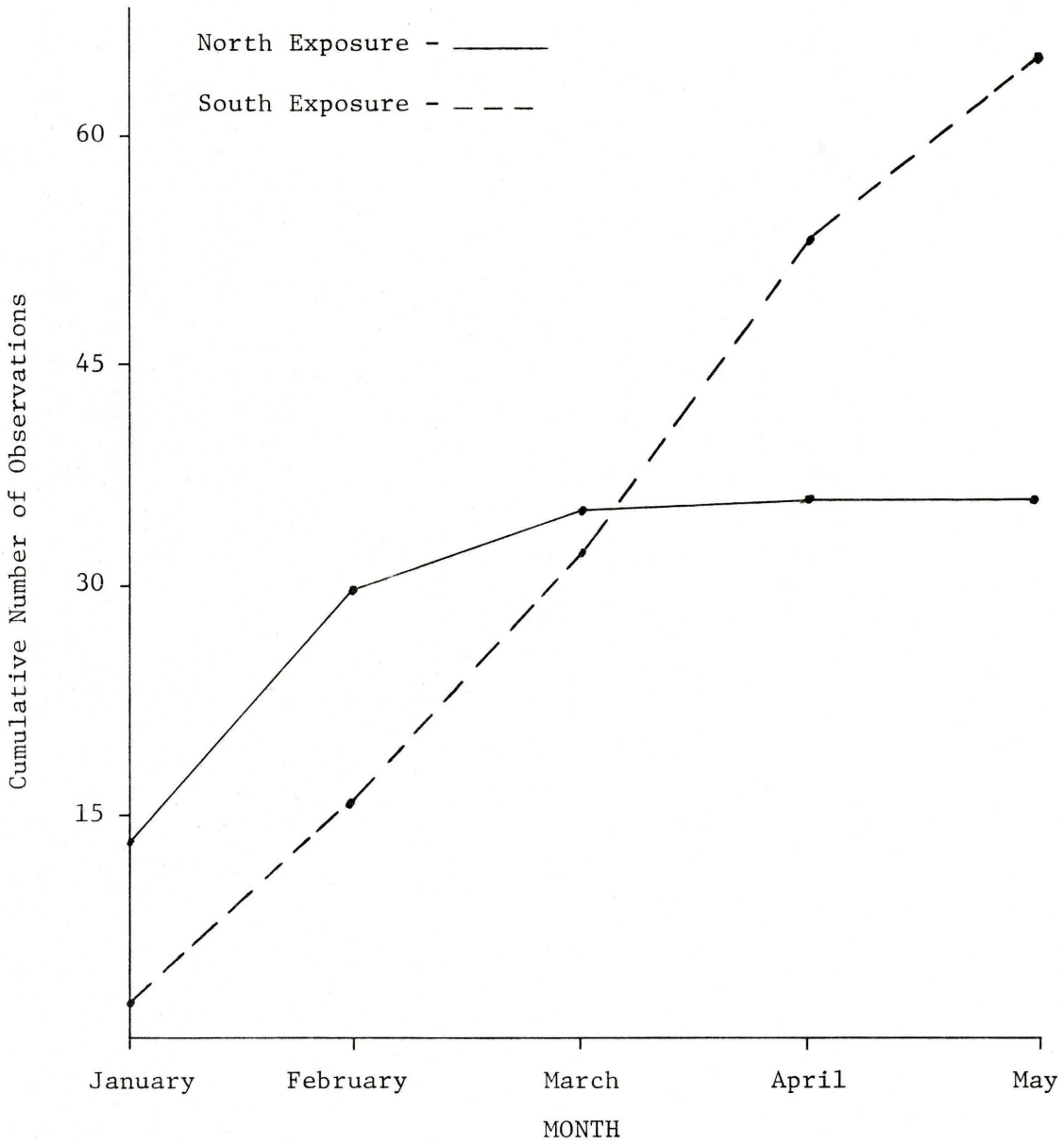


Figure 5. The occurrence of instrumented cow 60-183 on winter and spring range with respect to northern and southern exposures.

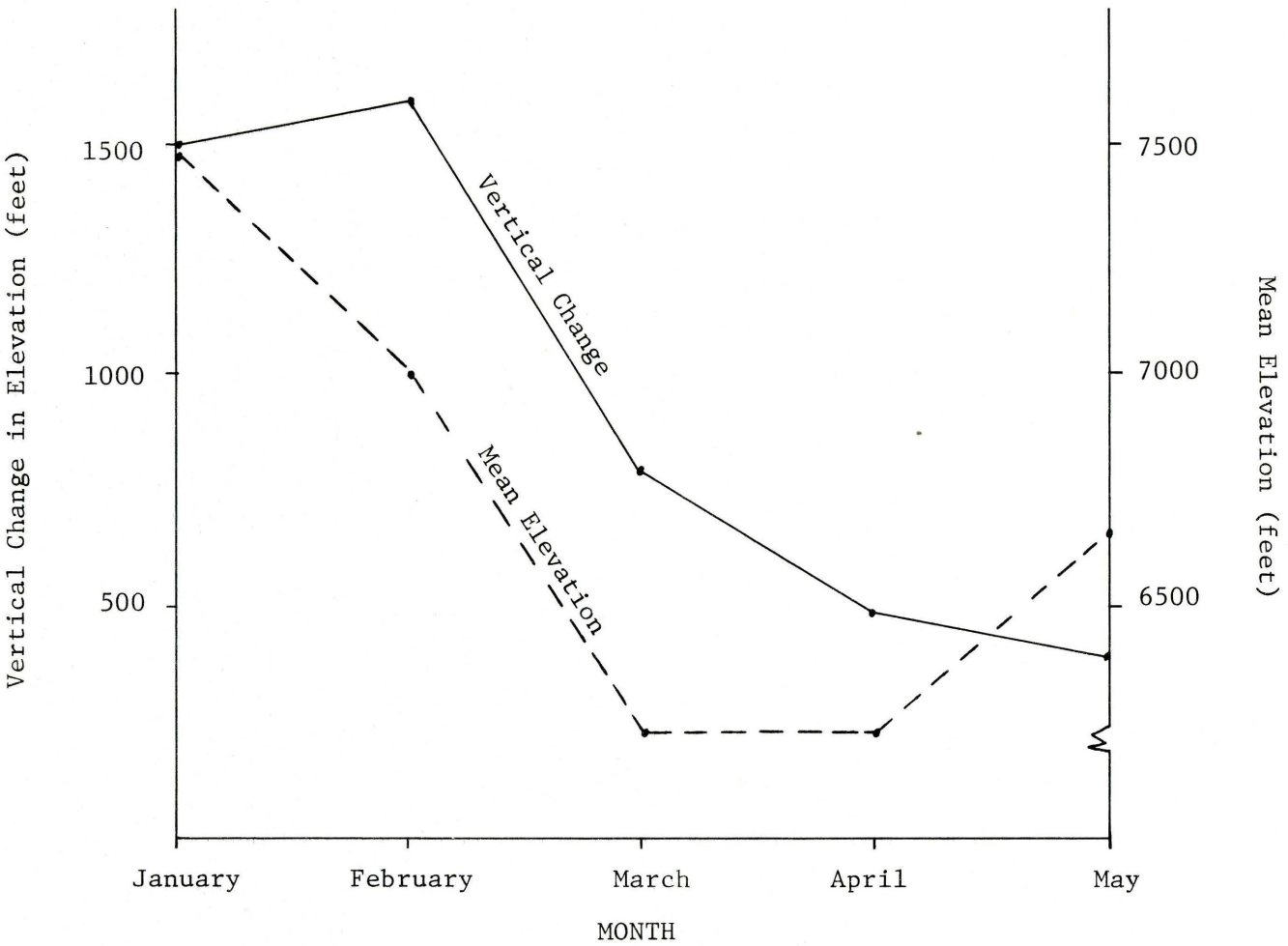


Figure 6. Movement of instrumented cow 60-183 with respect to elevation.

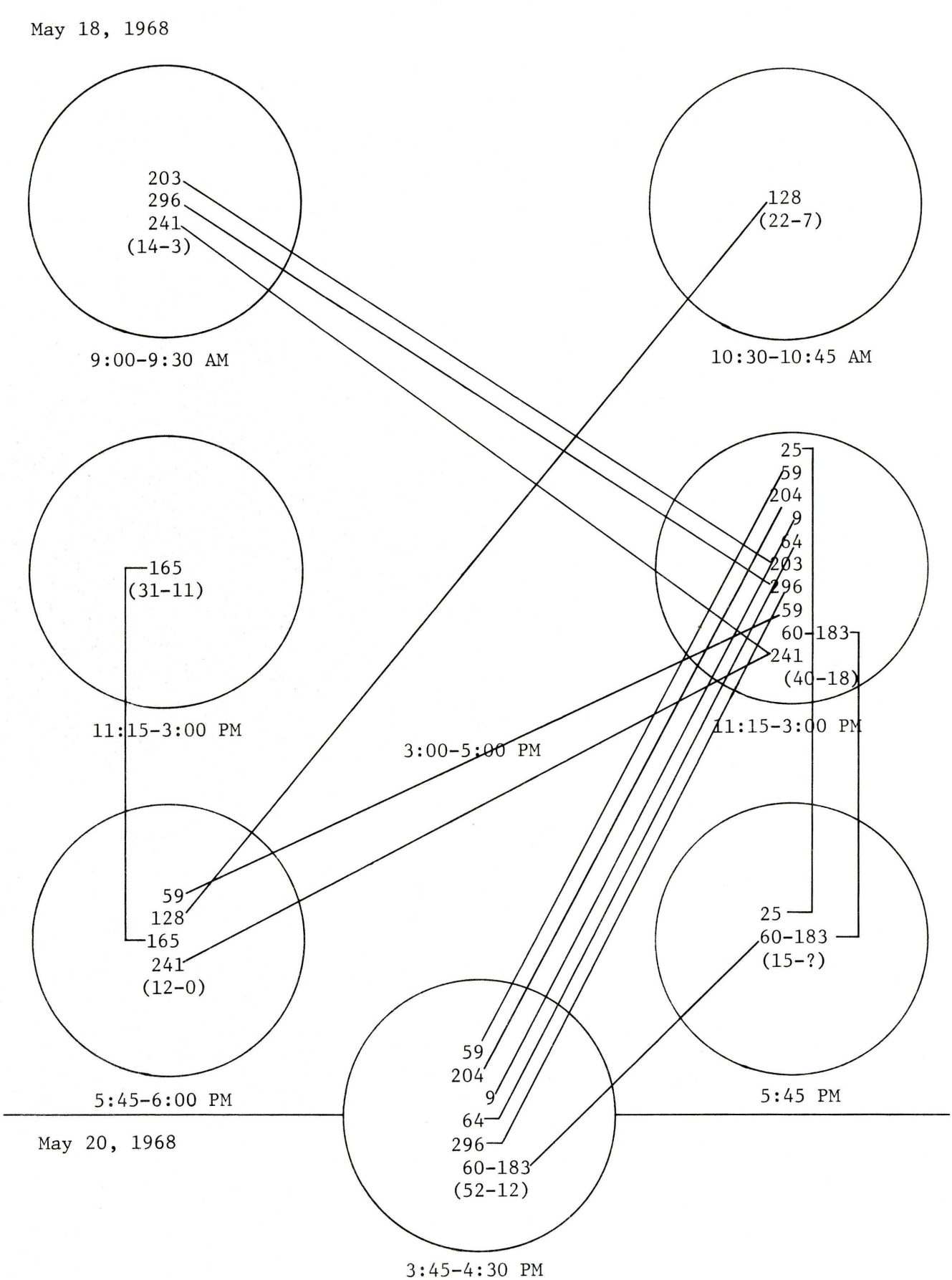


Figure 7. Individual exchange among elk bands from May 18 to May 20, 1968. Each circle represents one elk band with the pendant numbers of the marked elk involved in exchange. Group size and the number of marked elk in each band, respectively, are indicated in parentheses.

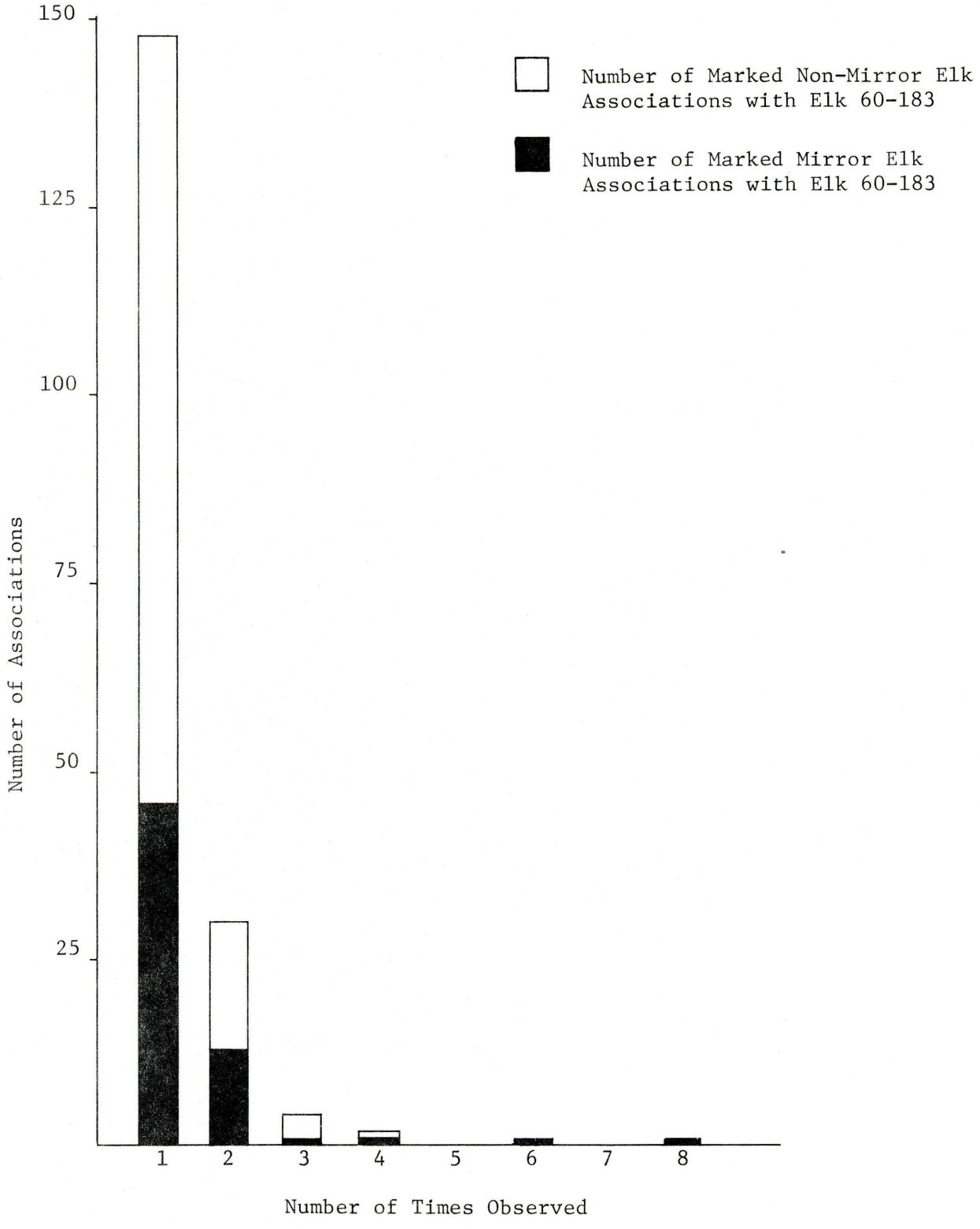


Figure 8. Frequency of association of cow elk 60-183 with marked Mirror and Non-Mirror Plateau elk over a 3 year period

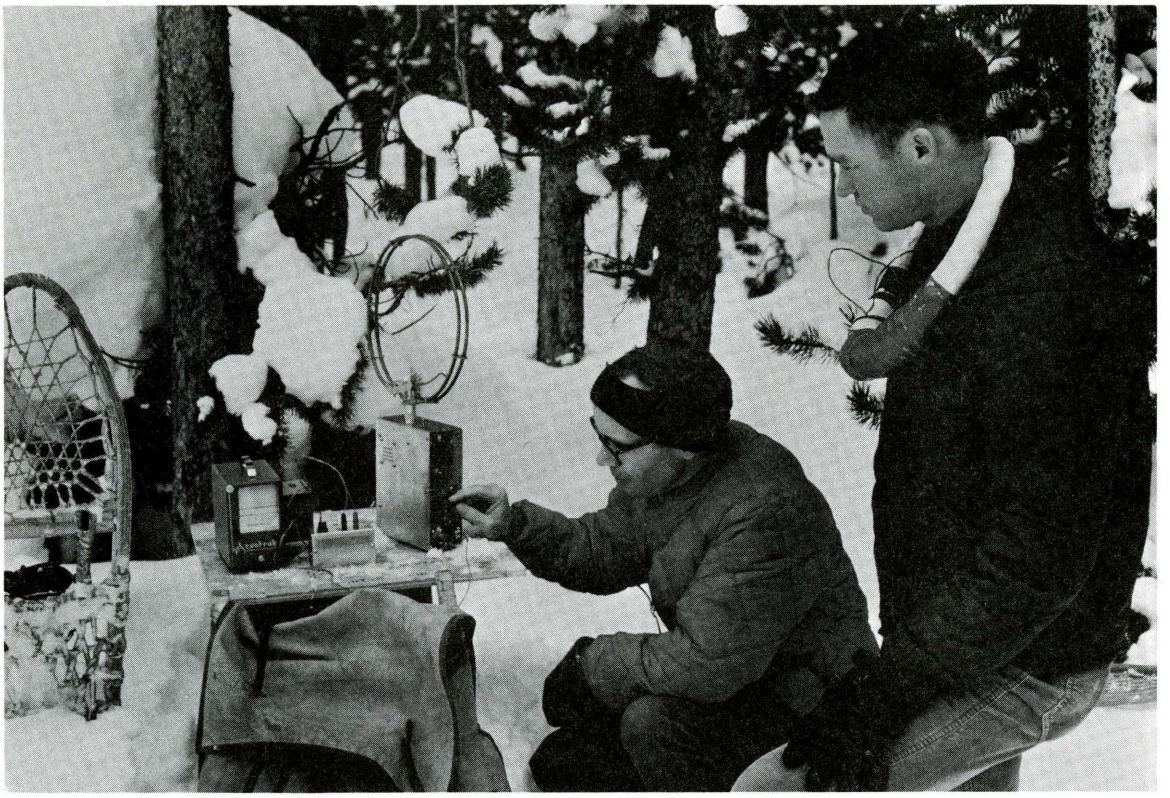


Plate 1
Battery-operated portable receiving and recording equipment.

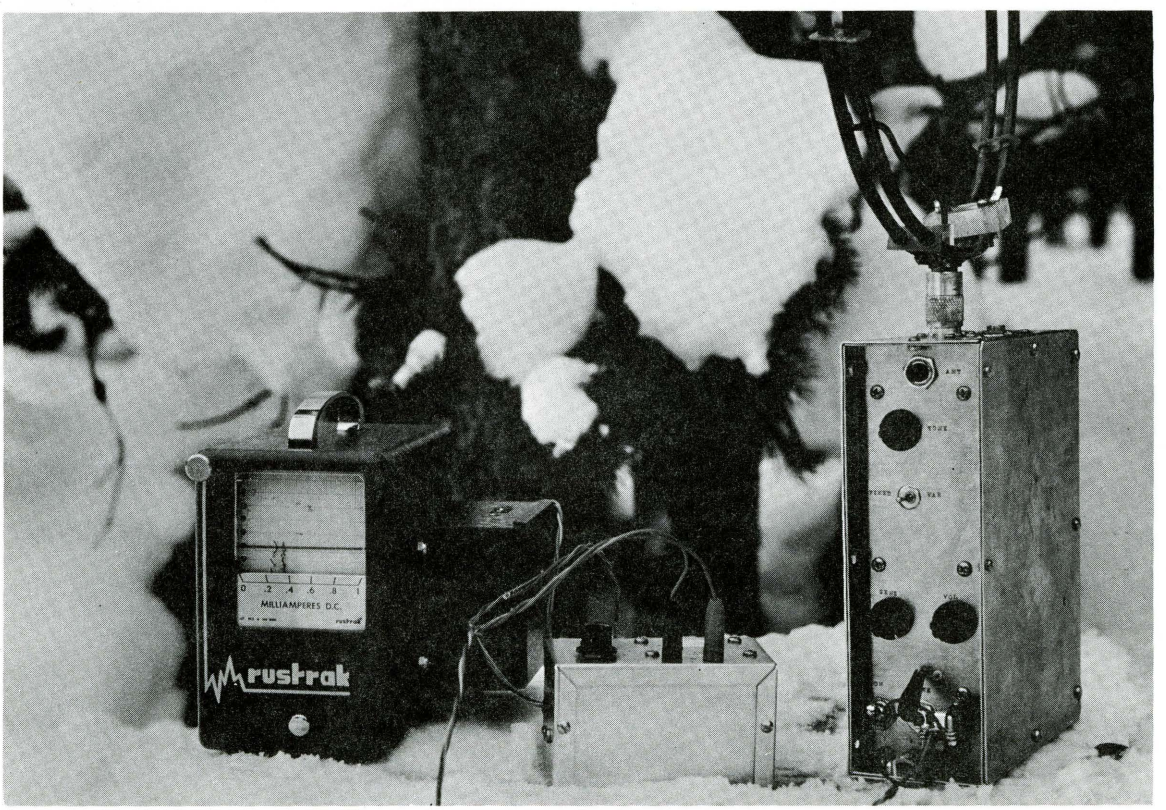


Plate 2
Automatic transmitter recording equipment showing Rustrak recorder, multiplexer box and directional receiver.



Plate 3

Female No. 40 has been instrumented for seven consecutive years.



Plate 4
Instrumented Female and Cubs on an Elk carcass.



Plate 5
Inserting temperature probes. Elk is immobilized with phencyclidine hydrochloride.