1963

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

Frank C. Craighead, Jr.
John J. Craighead

Environmental Research Institute
Montana Cooperative Wildlife
Research Unit

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~~ The ecological and behavioral information obtained by radiotracking are best interpreted by recognized that ~~summer~~ food supply and the mating urge is the key to understanding much of the ~~summer~~ behavior, ~~movement and~~ movement and ranges activities of the Yellowstone grizzlies. Food is of two kinds - natural and refuse supplied by man. Where food is abundant, as in Hayden Valley 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 early (april and may) spring ~~and fall and winter, the period of hibernation.~~* ~~This dispersal is typical of spring with a tendency for the~~ Many bears then gradually concentrate in Hayden Valley, first seeking early spring natural foods and then mates (June). 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~~ seven 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.

They are then held here by both natural and man-supplied food to areas providing more & different food as well as hibernation sites.

Insert B

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.

#76

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

#7

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.

#75

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.

Travel

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.

REFERENCES:

1. Craighead, F. C. et al., 1963. Radiotracking of Grizzly Bears, Bio-Telemetry, Proceedings of the Interdisciplinary Conference; New York, March 1962, pp. 133-148.
2. Craighead, F. C. et al., 1963. Progress Report.
3. Craighead, F. C. et al., 1963. Progress in Bio-Telemetry Studies of Grizzly Bears, Proceedings 18th Annual Instrument Society of America Conference, Bio-Telemetry Session, Chicago, 1963.
4. Varney, R. J. et al., 1963. Special Tracking Project Final Report. Philco Corporation Western Development Laboratories.

RADIOTRACKING OF GRIZZLY BEARS

Progress Report 1962 Season

During the fall of 1961 two grizzly bears (#37 and #40) were instrumented with small transistorized transmitters developed by Philco's Western Development Laboratories. Number 40 was tracked for one month just prior to going into hibernation in Yellowstone National Park. This animal was tracked with portable directional receivers whose maximum effective pickup distance was ½ mile. The results of this first year of tracking were presented at a telemetry conference held at the American Museum of Natural History, New York.

Throughout the winter of 1961-62 we ordered and assembled equipment needed for the base and mobile receiving stations that were a planned part of the complete wildlife tracking system. Philco engineers redesigned the transmitter (enclosure) and improved the portable receivers. On June 18, 1962, field work on the radiotracking of grizzlies was resumed. Emphasis was first placed on setting up and testing the base, fixed field, and mobile receiving stations--all operating on 110 volt current and utilizing directional yagi antennas. This combination of tracking stations was not fully functional until September 2 when the mobile unit was completed and put into operation. Even after this period there were technical problems and difficulties that had to be ironed out in the course of locating and tracking instrumented grizzlies. When these were finally worked out at the

close of the season, the tracking system's performance and potential were not only satisfactory but exceeded our expectations.

WILDLIFE TRACKING SYSTEM AND GENERAL PERFORMANCE

A detailed description of the wildlife tracking system is treated later. Briefly it consisted of a base station located at our laboratory at Canyon and a fixed field station situated on top of a commanding hill eight miles (airline) from the base station and in the heart of the grizzly bear summer habitat.

These provided location through triangulation or, where only one station was functional, the determination of a bearing. In the latter case the mobile unit was driven to a suitable position and the instrumented grizzly located through the intersection of two ~~one~~ or more bearings. When the grizzlies traveled beyond the range of both fixed stations, the mobile unit was used to locate the bear, determine his position, and then track him from a distance. The portable tracking units performed the same functions as the other stations, their unique contribution and and greatest asset being that they enabled us to move in on the grizzlies and to observe and follow them at close range.

It was revealed through tests and actual tracking of grizzlies that the redesigned transmitters and the improved combination of receivers had the following characteristics and general performance:

1. Range -- Base and field station (fixed) an operational reception of 8-10 miles and up to 20* miles under favorable conditions; portable units an operational range

mobile unit an operational range of 6-8 miles and up to 20 miles under favorable conditions;

of 3-5 miles and 6+ miles under favorable conditions.

2. Transmitter Life -- From 2-3½ months with 6 or more possible; batteries replaceable.
3. Size and weight -- Transmitter-collar antenna assembly 2¼ lbs. with mercury battery pack; transmitter weight 1.8 oz.; size 1" x 1" x 2"; waterproof and shockproof; portable receivers approximately 4 lbs.
4. Signal pulsed at different rates with the pulse stable enough to readily identify individual transmitters (animals).

A comparison of this performance with the original tracking system requirements as postulated reveal that the system, as perfected to date, either fulfills or in most cases exceeds the requirements. The transmitter assembly exceeds the weight originally thought desirable. However, weight is largely a function of range, life, and ruggedness and could be reduced at the expense of the other factors. The present weight is readily tolerated by the grizzlies.

TRANSMITTERS

Philco's Western Development Laboratories provided us with six transmitters, newly designed by their electronic engineer, Joel R. Varney. The transmitter schematic, description and temperature and voltage tests are presented in the enclosed report. The power output of these transmitters varied from 90 mw to 170 mw, and each was pulsed differently from a low of 62 pulses per minute to a high of 109 per minute. If pulsed much

below 62, difficulty may be experienced in picking up the signal on the general coverage receivers. With their critical tuning it is possible to pass the signal during a lull. All six transmitters were field tested for signal range, but only three were used to instrument grizzlies. They operated on a frequency of 32.0036 Mc. Field tests and tracking results indicated that the higher powered transmitters were more suitable for tracking grizzlies in the rough and timbered Yellowstone country than were the lower powered ones.

Transmitter Number	Pulses per Min.	Power Output	How Used
1		90	To test receivers
2	107	90	Grizzly #96
3	62	90	Fiberglassed-tests
4	82	140	Grizzly #37
5	109	90	Tests-returned to Philco
6	73	170	Grizzly #40

REFINEMENTS IN COLLAR PREPARATION

With minor changes, the first transmitter-collar assembly (#2) was fiberglassed, and the bear instrumented as in the previous season. For fitting to the neck the collar was broken and joined at the antenna tuning capacitor. As a result, this could not be fiberglassed though it was strengthened with acrylic, wrapped with tape, and encased in ⅜" polyethlyne braided rope. Nevertheless, this appeared to be a vulnerable spot, the weakest link in the collar.

The next two transmitter assemblies to be used (#6 & #4) were prepared in a different fashion. The metal strap antenna was cut in half between the transmitter and the tuning capacitor.

Holes were bored on either side of the cut to permit size adjustment and bolting together. The transmitter antenna assembly including the tuning capacitor was then strengthened with fiberglass cloth and epoxy resin. A small hole was made through which to tune the capacitor. Only the adjustable bolted portion was left bare. When instrumenting, the antenna was bolted together at the desired fitting. Next, the collar was wrapped with $\frac{1}{4}$" polyethylene rope, and the final wrapping over the bolted connection being completed after the collar had been put on a grizzly. The rope ends were heat sealed and wrapped with tape. This provided a much stronger collar with less likelihood of its being torn off or damaged. Instrumentation could be completed in a half hour or less. In addition to this change the battery pack was altered. Seven mercury batteries connected in series were wrapped with tape and then inserted into a fiberglass tube the same diameter and length as the pack. This was fastened to the antenna with tape and and then firmly secured with fiberglass wrapping and epoxy resin. An advantage was that the batteries could be removed from the preformed tube and replaced by new ones with a minimum of cutting. Irregularities in the fiberglass case, or holes where water might enter, were smoothed or sealed with acrylic. Transmitter assembly #3 was prepared like 6 and 4, but instead of being wrapped with rope, it was encased in a section of light rubber hose. There were apparent advantages to this encasing, but it was not used on a bear.

The completed collar #4 was wrapped with a bright color plastice tape when put on grizzly #37. This enabled the collar to be seen more readily, a distinct advantage in diagnosing trouble should the bear be seen but the signal not heard.

Some hair on the neck was also clipped. Unless this is done, the long fall pelage covers the collar, hiding it from view even at close range.

GENERAL TRACKING PROCEDURE

The combination of tracking receivers was not completed until the season was well advanced and optimum performance of the entire system was obtained only at the close of the season. The first grizzly (#96) was instrumented August 17, the second (#40) on September 8, and the third (#37) on October 4. The mobile unit was completed and put into service September 2 but was not available when the first grizzly was instrumented. The theoretical life of the battery pack operating the transmitter on #96 was 3½ months, and the last check for signals from instrumented bears was made on October 30. The actual tracking period was 2½ months.

After instrumenting and upon release the grizzlies were tracked with the portable units. In subsequent days the bears were located by checking for the signal with base, field, and mobile stations. The procedure was much the same for all but the portable units. After the receiver had warmed up, a test transmitter on the same frequency was turned on and the receiver tuned to pick up the signal. When the signal was peaked, the

transmitter was turned off, and the operator listened for a signal from one of the instrumented grizzlies. While listening, the antenna was rotated through 360 degrees or until a signal was heard. If no signal was received, the receiver was retuned with the test transmitter and the process repeated. If still no signal was received, the tuning was altered to either side of peak and the antenna again rotated. When a signal was picked up, the receiver was tuned to get maximum signal strength, and then the antenna rotated to again determine the maximum signal strength and thus the direction of the signal source. Direction from the field station was read off the direction indicator dial on the antenna control box. With the other units compass sightings were used to obtain direction. The pulse rate was counted to identify the signal. The signal was then monitored continuously or intermittently depending on circumstances and the information required. If possible, a fix was obtained by getting two or more bearings with the combination of receivers. These were plotted on contour maps. When it seemed desirable, the trackers then moved in on the grizzly with the portable direction finders. This final operation was the payoff as this permitted close approach and actual observation. Due to technical difficulties, the portable receivers were not initially as effective as they might have been, but final results more than exceeded expectations.

INSTRUMENTING AND TRACKING

Two of the major aims of the radiotracking work have been

to develop and perfect a radiotracking system and to utilize this system in obtaining information about the grizzly. Developing the system has had to precede data gathering, and for this reason we have attempted to instrument bears about whom we already had considerable information regarding activities, habits, and movements.

The first bear to be instrumented with a radio in 1962, #96, was a relatively unknown. She was the littermate of #76 (Peg Leg), a grizzly we were well acquainted with. She was a 4 or 5 year old female weighing 335 pounds when captured. She was shot at night with a CO_2 gun and after being struck with the dart disappeared in the darkness. When finally located, she was recovering from the effects of the immobilizing drug and had to be roped, pulled to a culvert trap, and pushed inside. The next day she was again drugged and immobilized for instrumenting. She had previously been trapped on July 27, 1961, and at that time weighed 270 lbs. This animal had a pointed rather than a broad wedge-shaped head. The circumference of her head and neck were the same--28". This morphological characteristic was not ideal for a collar. Nevertheless, she was instrumented in the afternoon of August 17 with a transmitter assembly having a life of approximately 105 days. We followed the technique used the year before. The next day we picked up her signal from our hilltop field station at 9:45 a.m. and monitored her until 12:30 p.m. Her direction was due east. We tried to move in on her using a portable finder while keeping touch with the field

station by walkie talkie. We were unable to pick up her signal on the portable receiver though we covered an airline distance of 4 miles. The effective range of this receiver at this time was only ½ mile. While trying to approach the bear, we received her signal loud and clear at the field station. Her location remained due east and at least 4 miles away. We checked for the signal again from 6:30 to 8:30 p.m. but were unable to pick it up. We never again received this signal though we checked from August 18 to September 8 using the base and field stations and the mobile unit when it became available. We monitored for the signal from the top of Mt. Washburn on August 30 and subsequently at high spots throughout the Park--Lake, West Thumb, and Old Faithful. On September 8 #40 was instrumented and from then on all monitoring for this animal was a check for the signal from #96 as well.

The next two grizzlies instrumented (#40 and #37) had both been instrumented the year before. The same bears were selected in order to provide continuity of information. Number 40 was a mature female that had been tracked intermittently for a month in 1961. When trapped in July, 1960, she weighed 175 lbs.; by October of the same year she weighed 230 lbs; approximately a year later when instrumented she weighed 300 lbs.; and on October , 1962, when captured and again instrumented, she had increased to 340 lbs. She, like #96, was shot after dark with an immobilizing drug. When located, she was able to sit up and so was roped, dragged to a culvert trap, and pushed inside. She had sufficient use of her jaws and

paws that had we not particularly wanted her we would have refrained from handling her.

Number 37, a three-year-old weighing 440 lbs., was trapped near Old Faithful. He previously had worn a dummy transmitter collar for over a year and was then instrumented in 1961. We had been gradually accumulating an interesting history of this animal and were relatively well informed on his movements and activities.

Numbers 40 and 37 were instrumented with previously mentioned changes in collar preparation. The most powerful transmitter (170 mw) was placed on #40 and the next most powerful (140 mw) on #37. The calculated useful life of the battery packs powering these two transmitters was 60 days. The signal from #40 was monitored for a week and then lost, but checking and listening continued for over three weeks until we determined that the transmitter was no longer functioning. On September 29 and subsequently the animal was observed with the collar intact but with no signal being emitted. We suspect a transistor burned out. Several unsuccessful attempts were made to retrieve the collar. During the period that this transmitter functioned, we obtained information useful in perfecting the system. Throughout the season Philco engineers sent us portable receivers of varying design. With the portable unit we had at the time we were able to pick up the signal from #40 at a distance of 2½ miles and then move to within a few hundred yards of the bear in dense timber. The best range we had previously obtained with this same receiver with a 90mw

transmitter was about ½ mile. On two occasions this animal was tracked continuously for four hours using a portable receiver. At close range we experienced difficulty obtaining a null or change in signal strength and thus could not determine signal source. In dense timber this was hazardous as we ran the risk of suddenly jumping the grizzly. The tracking of this animal with the various receivers and the subsequent two weeks intensive search for her provided information on the capabilities of the system and revealed some of the problems we had yet to overcome. A systematic search for the signal was made over an extensive area of Yellowstone with the mobile unit. The tracking results were negative as we were listening for a signal that apparently no longer existed. However, from this monitoring accompanied by testing we learned that from a relatively elevated spot we could cover a lot of country ~~of~~ line of sight (10 to 20 miles) and do quite well behind hills and in timber, providing there was not too much shielding effect. It appeared that we could pretty well count on picking up instrumented animals within within 4-6 miles of our mobile unit. Poorest reception occurred when the signal source was at the same elevation as the tracking unit with raised topography and timber intervening.

Number 37 was successfully tracked for a period of two weeks from October 5 through October 18. After this date the signal was never again heard though an intensive and extensive search was made over large expanses of Yellowstone in an attempt to relocate this animal. Following release, #37 was tracked

with the hilltop field station and the mobile unit and was also located and tracked with the portable units. He moved an airline distance of 18 miles from Trout Creek to the Old Faithful area, and his movements were tracked and course plotted during this journey. From the field station, we determined that he was moving toward Old Faithful, and the next evening he was located with the mobile unit. We picked up this animal on all units with the exception of the base station and determined his position through triangulation with the combination of field station and mobile unit and by means of the mobile unit alone from two or more points. He was continuously tracked for a period of 36 hours. He was also lured into bait, tracked while coming in to it and observed all one night and parts of others while feeding and associating with companion bears. Observations were made on the condition of the collar and the bear's reaction to it at close range. From the security of a trapblind, flash photographs were obtained of #37 wearing his radio collar. Although he was located and briefly tracked with the portables, he was not as closely followed and observed as planned. The portables were still not performing as expected, and their range with this transmitter was too limited.

Typical of such attempts was the following as recorded in field notes: "After locating with the field station an attempt was made to close in on grizzly #37 with the portables. Two and a half hours were spent in this endeavor but no signal was picked up in the rough timbered country

encountered. We were unable to get close enough to him, and from the field station we learned that he was on the move and traveling at right angles to the course we had started off on."

The signal from #37 was last heard the evening of October 18 and the bear was also seen with the collar still intact. An increasingly intensive search was made for this animal from the 19th through the 30th, starting in the area where the signal was last heard and spreading to all parts of the Park accessible by road. Typical of this search was the following: On October 24 the mobile unit was employed in the southwestern parts of the Park. If we use 4 miles as a conservative or average distance that the signal could be picked up, we covered 616 square miles that day in an attempt to locate the grizzly. Toward the last of the month, Philco engineer Joel Varney determined that our portable receivers were off frequency. After correcting this, we obtained an effective range of six miles. Employing this portable from a moving vehicle, we drove over most of the main Park roads on October 28 and 29. Figuring an average or operational range of 4 miles, we monitored 784 and 736 square miles, respectively, or over 1500 square miles in two days. This is an area equal to approximately half the entire area of Yellowstone National Park. There were, of course, distant parts of the Park that could not be reached, and rough terrain and other conditions made it possible for the instrumented bear to have been within receiver range and still not detected. We suspect he had traveled beyond reach of our detecting equipment. However, the figures do give

some idea of the potential of such a system for locating and tracking animals over vast areas. The close of the season found us with an electronic research tool that could meet the demands set up by our ecological objectives.

PERFORMANCE OF COMMUNICATION SYSTEM

In 1962 we added a mobile transceiver and two portable units operating on the Citizens Band 27mc channels. In addition an efficient base station antenna improved transmission and reception over the homemade antenna used in 1961.

The communication system was invaluable in tracking and in testing. It has proved adequate for our needs. The effective range of our combination of base and mobile units is between 8 and 15 miles, and 1 to 3 miles employing walkie talkies and mobile units. The increased distance obtained with the portable tracking units (6 miles) will make it desirable, if not necessary, to go to one watt walkie talkies with their greater range. In testing a 140mw transmitter with the mobile receiver we were able to receive the signal at distances where the CB reception had faded out. Continued refinement of the voice communication system should increase range and performance.

PROBLEMS ENCOUNTERED

The problems encountered can be classified under two headings, ecological and electronic. The former proved more difficult to remedy than the latter.

Trapping of bears and the capturing of particular griz-

zlies presented more of a problem than had been anticipated. In previous years the trapping success percentages were 76, 72, and 60 as compared with 32 in 1962. Decreased trapping success was due to some animals becoming trap-shy and to a greatly increased food supply. A wet spring and summer encouraged a lush growth of vegetation. This along with a good berry crop and an unusually good pine nut crop provided ample food, and thus decreased the incentive for bears to enter baited traps.

The major effort at instrumenting and tracking was planned for late summer and fall when the equipment would be ready. In past years the grizzlies had not dispersed from their summer concentration until mid-September. In 1962 they started dispersing in mid-August and scattered widely, many beyond the Park borders. This early dispersion was probably also influenced by food supply. It tended to increase the difficulty of trapping and capturing grizzlies, and it increased the problem of tracking them at a time when the tracking system was incomplete or not functioning optimally.

Throughout most of the summer, a reconditioned SX-71 Hallicrafters was used as the base set. This general coverage receiver was not as sensitive as desired on the 32mc frequency, the tuning was too critical, and it tended to drift. This reduced the range and usefulness of the base set. By the end of the season the Hallicrafters was replaced by a NC109 with improved performance.

Until the end of the season the portable direction finders

did not perform up to expectations. These were crystal controlled, and the crystals were found to be slightly off frequency with the transmitting crystals, though specifications for both were the same. With a matching of crystals, range increased from ½ mile to over 6 miles.

A test transmitter was used to tune the general coverage receivers to the proper frequency before checking for the signal from the instrumented grizzlies. When all transmitting crystals are ground to the same specifications, tuning is greatly simplified and signal pickup, particularly at a distance, enhanced. Transmitter #2, which was put on grizzly #96, may have been slightly off frequency, and this may have accounted for our inability to pick up a signal after the first day. It took time for all personnel involved to become familiar with the receivers and efficient at tuning. It is quite possible that initially some signals were missed due to our inexperience.

EVALUATION AND TRACKING RESULTS

By the end of the 1962 season we had a wildlife radio-tracking system capable of locating and tracking instrumented grizzlies at a distance and in rough and heavily wooded terrain. Individual grizzlies could be recognized from the pulse rate of the transmitter. Portable directional receivers made it possible to move in close on the grizzlies and follow their movements and observe their activities. The system met our original requirements and can still be improved.

Ecological and natural history data had been gathered using the tracking system, but completion and perfection of the system has had to receive emphasis and priority. We have not yet done sufficient tracking with a fully functioning system to analyse results.

We learned that following drugging, instrumentation and release bears usually remained in timber close to the release spot for about a 24-hour period. They apparently slept off the continuing effects of the drugs before moving about.

Animals released in the area of capture tended to remain there and had a limited range for periods of a week or more.

Once an animal decided to move, he covered ground rapidly and appeared to have an objective in mind.

The bears were active day and night but most active at night. Considerable daylight time was spent in a timbered retreat. Night feeding at baits terminated before daylight, and bears moved off to daylight retreats.

In a number of cases grizzlies started moving in to baits or known food supplies before dark.

From the tracking we learned which bears the instrumented one associated with and were able to observe their reaction to the collar. Neither the instrumented animal nor companion bears appeared to notice or worry the collar. They seemed to completely ignore it, though they may have made attempts at removal within a day or two after instrumenting.

In dense timbered stands typical of Yellowstone, it was possible to approach within a hundred yards or so of a grizzly

without either seeing or hearing him, even though his approximate position was known via radio.

Some data on feeding habits was obtained and activity patterns are either taking shape or being confirmed.

COLLABORATION AND COOPERATION

Mr. Joel Varney, Philco engineer working under direction of Dick Davies, visited us August 6-10 to see first hand the problems we were encountering and test equipment he had designed. He gave us invaluable assistance and obtained information helpful in improving future transmitters and receivers. He made another short visit October 26-29 and again made numerous contributions and helpful suggestions. It was at this time that he ran down the trouble with the portable receivers and remedied the difficulty.

Mr. Hoke Franciscus, amateur radio operator (W3ELV), visited us from August 12-18, helped us improve reception on our base and field stations, and contributed to numerous aspects of the project. During the past winter he had advised on radio equipment and helped with the building of telemetering devices planned for future data gathering.

Without the considerable contributions of Philco engineers and the help of Hoke Franciscus we would have been unable to achieve the gratifying progress made over the last year.

The same organizations that cooperated in our 1961 effort supported and helped us in 1962.

CONCLUSIONS AND FUTURE WORK

We finished the season with a tracking system that more than met our original specifications and objectives, and we obtained information and discussed plans for further perfecting it. The system in its present state of development has a potential not only for tracking and following the movements of grizzlies, but of securing a wide range of hitherto unavailable information on these animals. The application of the system in the study of other big game species should pose less problems than with the grizzlies and will prove to be a valuable tool in both research and management. From now on the pendulum should swing from development to data gathering. The major problems and hurdles have been overcome. What might be termed ecological problems, some arising from conditions beyond our control, will always exist, but many of these can be anticipated and through various measures reduced to a minimum.

Future work will be directed toward instrumenting grizzlies early in the season (soon after coming out of hibernation) and following and observing them until winter arrives. If possible, grizzlies #37 and #40 will be instrumented, and attempts will be made to put a transmitter on the dominant boar in the grizzly bear hierarchy. It seems quite likely that all three instrumented bears will be recaptured in 1963. This will enable us to carefully examine the transmitters and to perhaps determine why or how we lost track of these animals.

We will seek to secure a closed vehicle suitable for use as a mobile tracker and laboratory. This will improve the

efficiency of operations and provide us with a vehicle that can be used exclusively for tracking. The mobile unit pickup truck is also needed for hauling traps, weighing bears, and general duty. We plan to equip a vehicle with an antenna mast that can be readily cranked up and down and with a semi-collapsible yagi antenna. This will make it possible to drive in heavy traffic or over back roads overhung with trees. Rotating loop antennas will also be secured to the roof of our other vehicles and wired so they can be plugged into portable units. The portable units can thus substitute as mobile units. Directional indicators will be installed, and one of the mobile CB communication units.

Philco engineers plan to rebuild the three portable directional receivers incorporating the last design changes that enabled us to obtain 6 mile reception. These will also be further altered and improved in line with Joel Varney's recommendations based on field use. An attempt will be made to combine a directional receiver and voice communication transceiver into one instrument. Transmitters number 1 and 5 will be stepped up to 170mw and all new ones will have this power output. The time interval of each pulse may be reduced in some transmitters to provide increased life with the same power supply. It may also be feasible to use lighter battery packs with comparable power for some tracking objectives. We may experiment with a 3-5 Mc transmitter and compare performance with 32Mc. For some types of tracking the lower frequency may have advantages. Philco engineers plan to miniaturize

the transducers we built for telemetering environmental and physiological information. The prototypes were tested last winter and additional testing is continuing. It is hoped that they will be ready for field application in 1963.

Electronic timekeepers, instruments capable of turning transmitters off and on, are under development by a number of companies. It may be possible to acquire a few of these and start experiments with a command system. The possibilities will be explored.

Tracking and locating from a plane has some advantages over terrestrial tracking and can be a quite useful supplement in migration studies or with wide ranging animals. The possibility of running some tests with present equipment from a helicopter and the feasibility of using a hot air balloon for an elevated field station will be investigated.

DETAILS OF RADIOTRACKING - 1962

TRACKING SYSTEM STATIONS AND UNITS

Base Station (Canyon)

Hallicrafters Sx-71-replaced by National NC109 Dow-Key pre amp 110 volt AC. 5 element Mosley antenna (YB-30-5) incorporating a gamma matching system. Forward gain of 9 D B over a half wave dipole. Pattern provides wide angle coverage while maintaining a front-to-back ratio in excess of 20 D.B. The input impedance is 50 ohms. Antenna height 25 feet and just slightly above roof ridge. Mounted in horizontal position, hand rotated. Approx. 50' of RG 58 U coax.

Field Station (Trout Creek)

Speaker and headphones National NC188 with Dow-Key in-line coaxial pre-amplifier (booster) 1.5 through 30 Mc. 3 element Hy-Gain model 113-B Citizens Band beam cut to 32.02 Mc. Forward gain of approximately 8 D B over a half wave dipole. Erected on a 30' telescoping mast secured with rope guylines. Mast hinged at bottom to facilitate raising and lowering. Location a high hill.
A trio-rotator and control box with five-wire cable used to control antenna rotation. Direction indicator on control box.

Antenna coax (RG 58 U) and control cable 45'. Power supply portable gasoline generator, 110 volts, 1700 watts.

Tried FL-8 audio filters connected to output of receiver via the headphone jack to increase selectivity but found unnecessary.

CB portable or mobile unit for communication.

Mobile Unit (Pickup Truck)

National Nc 188 with in-line coaxial pre-amp. Receiver enclosed in plywood box and cushioned with rubber mat. Used interchangeably for field station and mobile unit.

3 element Hy-Gain 28 Mc antenna (model 103G) reduced to 32.02 Mc. Gamma match, forward gain of approximately 8 D B. 30' of RG 58 U cable. Hinged base fastened to bed of truck permits raising and lowering of antenna. Antenna rotated by hand. Antenna and mast quickly removable. Antenna height above ground approx. 21', above truck bed 18'.

Power supply ATR Universal inverter for operating 110 volt 60 cycle AC equipment. Input 12 volts DC, output 110 volts 150 watts, continuous operation. RF interference suppression. Headphones. Compass for direction.

CB mobile unit for communication.

Portable Units

Three portable directional tracking units:



BIO-TELEMETRY

Radiotracking of Grizzly Bears

1963

PROGRESS IN BIO-TELEMETRY STUDIES

OF GRIZZLY BEARS

Presented by

Frank C. Craighead, Jr., National Geographic Society
and Montana State University

18th Annual Instrument Society of America's Conference
Bio-Telemetry Session
Chicago, Sept. 9, 1963

Presented for the research team: Frank C. Craighead, Jr., Environmental Research Institute; John J. Craighead, Montana Cooperative Wildlife Research Unit; Joel Varney, Philco Corporation; Maurice Hornocker, Montana Cooperative Wildlife Research Unit; Hoke Franciscus, (W3ELV) Carlisle, Pa. Cooperating and supporting agencies include the National Geographic Society, National Science Foundation (G-17502), Philco Corporation, U.S. Fish and Wildlife Service, National Park Service, Boone and Crockett Club, New York Zoological Society, Wildlife Management Institute, and the Environmental Research Institute.

Since reporting on the progress of our radiotracking work in 1961 at the bio-telemetry meeting in New York (1) we have made eleven instrumentations of grizzly bears (Ursus arctos horribilis). Two animals were instrumented in 1961, three in 1962 and six so far during this summer of 1963. Some of these bears have been under radio surveillance for a month or longer and others - due to loss of collar, or mechanical failure - have been tracked for shorter periods of time. Before the present season is over we expect to track some of the instrumented grizzlies for two or more months and follow one to its "hibernation" den. Recently, we have been simultaneously monitoring four instrumented grizzlies from our Yellowstone bio-electronic laboratory. We can pick up the distinctive signal from any one of these 4 bears, twenty-four hours a day at distances of 10 to 12 miles. Each animal is wearing an 1.8 oz. "Philco" transmitter pulsed at a different rate. In the case of these four animals the rates are 50, 62, 74 and 92 pulses per minute. The power output of the different transmitters varies from 90 to 200 mw. All four pulse rates can be separately distinguished and bearings obtained, although at times some difficulty in making fixes is encountered if all 4 bears are in the same general direction or if one or more of the signals are weak due to distance or shielding effect.

An instrumented bear is located by obtaining compass bearings from the base, field, and mobile stations. We then move in toward the point of intersection with portable direction finders designed and built by Philco Corporation. Our present tracking system has the demonstrated capability of locating instrumented animals at distances of 15 to 20 miles as well as a "closing-in" ability that on occasion has enabled us to approach to within 40 feet of a bear before being detected.

In the course of studying the grizzly bear, we have captured and ear-tagged 164 different animals. Each of these marked grizzlies is given a number, and I will refer to these numbers in naming or identifying instrumented individuals. Bear No. 40, which we have been tracking and monitoring for a month this season, has been instrumented and tracked for three consecutive years. Bear No. 7 has been instrumented twice in the same year while two other animals, No. 37 and No. 96, have been instrumented and tracked for two consecutive years. The career of No. 37 as a "radio bear" terminated when he was shot by a hunter just outside the south boundary of Yellowstone Park. Grizzly No. 96 wore a transmitter collar for almost a year's time. She hibernated with the collar on and then came out of hibernation still wearing it. She made her debut with two cubs as well. Soon after leaving her den, she travelled from the northeast portion of Yellowstone Park to Hayden Valley where we made a recapture by shooting her with a propulsive syringe dart containing an immobilizing drug. While she was anesthetized, we removed the transmitter. Although the batteries in the transmitter-collar were dead, the transmitter was still in working condition. We placed another radio collar on the bear but unfortunately, the battery pack in the new collar became shorted after a week of operation. The bear immersed in water, apparently soaking in one of the many thermal pools common in the area. This transmitter was in turn removed by recapturing the grizzly sometime later.

Although we are still developing the tracking system and yet have much to learn about its potentialities, we now have had three years of tracking experience from which to evaluate possible applications and future use.

The tracking system we have developed, tested, and put into operation has not only fulfilled our original requirements but has exceeded our expectations in many respects and we have not yet taxed its capabilities.

Some idea of the potential of the system is revealed by the figures computed in searching for instrumented grizzlies at the close of the season in 1962. In two days we monitored approximately 1500 square miles of Yellowstone country using a mobile tracking unit. A four-mile signal range was used as a basis for computing the area covered. From the top of Mt. Washburn approximately 1200 square miles were theoretically covered at a single monitoring with the possibility of good signal reception from many localities within this coverage.

Our present tracking system consists of the following:

Base Station consisting of a general coverage receiver (NC 188) or a modified crystal-controlled transistorized Citizens Band transceiver coupled to a five-element antenna on a forty-foot tower. Control accessories include rotator, control box and direction indicator. Under most operational conditions the range or reception is 10-12 miles and up to 20 miles under favorable conditions.

Field Station located eight miles from the Base Station in the heart of the grizzly bear summer range, consisting of a general coverage receiver or a modified transistorized crystal-controlled citizens band unit. A three-element yagi antenna cut to 32 mc reception is mounted on a 30' telescoping mast. A rotator and control box as well as the general coverage

receiver are powered by a portable gasoline generator. The operational range is approximately 8-10 miles and up to 15 miles under favorable conditions.

Mobile Units - trucks, pickups, or panel wagons with seatings for accommodating a telescoping mast and a three-element antenna. Antenna coax cable connects with a general coverage receiver or with the crystal-controlled transistorized C.B. units modified by Philco. General coverage receivers were used in 1962 but better results are now being obtained with the modified CB walkie-talkies. The range of the Mobile Units is similar to that of the Field Station.

Portable Direction Finders or Portable Directional Receivers complete the receiving equipment. These are the same modified CB transceivers already mentioned. Readily removable loop antennas are attached to the top of these receivers and a whip-type sense antenna enables the operator to determine the direction of the signal source. Antennas from all other tracking stations (Base, Field and Mobile) can be connected to the portable receiving units. Various modifications and improved models have been field tested over the past three years. Present models weigh 3 lbs., are ruggedly constructed and have an operational range of 2-4 miles when battery powered as portable units.

The transmitters are crystal controlled, transistorized, are 1" x 1" x 2" in size, weigh 1.8 oz., vary in output from 90 to 200 mw pulses and have undergone several changes in design. The antenna is a resonant metal loop that when reinforced and padded serves as a collar for attachment. The transmitter frequency is 32.02 mc. Seven Mallory mercury cells, type 1450, power the transmitter from 60 to 100 days.

A citizens band, voice communication system is employed with the tracking system. It consists of a base, three mobile, and five portable units - all stock items.

At the present time we cannot submit detailed ecological results from our radiotracking as the field work is still in progress and the data have not yet been fully analyzed. I would like, however, to mention briefly a few interesting things we are learning about grizzly bears.

1. We have found that grizzly No. 40, one that has been instrumented 3 times in three years, has spent most if not all of these years within a very limited area. Roughly this area or home range is about 5 miles long by 3 miles wide. Within this range sow No. 40 has for weeks at a time confined her activities to an even more restricted area of a few square miles. She has spent most of the daylight hours resting and sleeping, and these daytime retreats have been in the same location for three years. Daytime beds of this as well as other bears tracked, consist of shallow excavations. They are scooped from the earth usually in heavy timber or dense windfall.

2. In a ten-day period grizzly No. 7 travelled over a range about 14 miles by 4 and this range increased considerably in size as the season progressed. In the first ten days she crossed the Yellowstone River three times and climbed high on the slopes of Mt. Washburn. She travelled and foraged during daylight hours as well as at night. At times she approached close to concentrations of Park visitors but was seen by neither visitors, rangers nor ourselves on these occasions. The radiotracking has shown that grizzlies can

and, perhaps frequently are close to humans without being detected. Information obtained from this and other instrumented grizzlies may suggest how encounters between park visitors and grizzlies might be avoided.

3. Both grizzly No. 75 and grizzly No. 7 had yearlings that travelled with them. Although in each case, we were tracking a single animal, we were actually obtaining information about a family unit of three. By following bears No. 7 and No. 75 to their daytime retreats, we found that the yearlings normally bedded down close to the sows during the daytime. At our approach No. 75, an old and belligerent grizzly, gave a warning "woof" to her yearlings when we were 125 feet away and they took off at a run. Copious saliva around the edge of her bed revealed that she had been as nervous at our near presence as we had been at hers. Possibly a decision to attack or flee had hung precariously in the balance.

4. When bedded down during the day all bears tracked have, at one time or another, been approached closely and by-passed at less than 100 yards without being disturbed. They apparently have a reluctance to leave their daytime retreats unless pressed to do so. Even in dense woods and windfall difficult for a man to traverse, they can move so quietly they cannot be detected by ear. Some grizzlies have circled us keeping just out of sight.

5. On another occasion we tracked a boar, No. 76, into a thick stand of lodgepole. Soon after entering the dense timber we "jumped" a large unmarked grizzly we had passed by and then startled still another grizzly, No. 75, and her yearlings. In addition we heard

other bears and found ourselves literally surrounded by grizzlies. Numerous beds and feces indicated that this was an area where grizzlies concentrated to rest and sleep during the day.

6. Radiotracking grizzlies has provided considerable direct as well as indirect information about their diets and can provide much more in the future. It is also providing data on habitat preferences and the relation of these preferences to food supply, seasonal conditions and cover requirements. In following the instrumented bears, we have observed numerous excavations where all of them have unearthed the nests and tunnels of field mice (Microtus spp.) and we have frequently watched them catch mice. These small rodents have attained high population levels in the Park this year and the grizzlies have been preying on them. Northern pocket gophers (Thomomys talpoides), likewise, are more numerous than they have been over the last five years. These, too, are being consumed by the bears in considerable numbers. Our observations obtained through radiotracking indicate that both sows No. 7 and No. 75 are feeding on rodents to a greater extent than sow No. 40. Number 40 supplements her diet at a refuse area and is largely dependent on this source of food during July and August. This partially accounts for her almost complete lack of movement or foraging during the day and her regular nightly visits to this source of food. The nature and extent of human influences on the grizzly populations though significant is still not fully known. Such information is needed for informed management and may be essential for future preservation of the species. In the vicinity of No. 75's daytime retreat we found numerous lodgepole pines with the bark freshly

stripped. We concluded that she was seeking the cambium and the pitchy sap that exuded. This particular bear was also teaching her offspring to utilize the edible cambium and sap.

7. Information obtained to date indicates that a decided difference exists in the foraging ranges and in the activity patterns between males, barren females, sows with cubs and sows with yearlings. For example, continuous changes in signal strength reveal the greater activity of a mother with energetic and hungry cubs. This has been repeatedly verified by visual observation of instrumented animals. Boars may tend to travel more and cover greater distances than barren sows or sows with offspring. One young adult boar has been radio-tracked in a circular trek of fifty or more airline miles.

In addition to the tracking briefly described we have built and experimented with sensing devices or transducers for telemetering environmental data. During fall or in winter we plan to instrument a grizzly with a transmitter employing a thermistor to control the pulse rate of the transmitter. Changes in pulse rate due to changes in temperature can be converted to temperature readings of the collar under pre-hibernating and hibernating conditions. We have also experimented with audio amplifiers coupled to small transmitters that enable us to receive distant animal sounds and interpret them in relation to animal behavior.

I have given a brief sketch of the types of data we are gathering. Perhaps this is a good time to point out that the primary function of our bio-telemetry or big game tracking system is to extend the range of man's observational powers. In practical application this is accomplished in two ways. First, a variety of

data is gathered from a distance with a minimum of time, effort and manpower. Information on position, animal movement, ranges and activities acquired from afar has a unique value. The presence of the observer does not influence the actions or behavior of the subject. The instrumented animals can be monitored continuously - at night as well as during the daylight hours. Information on periods of activity and speed of travel hitherto impossible to obtain by more conventional methods can and is being recorded. Physiological parameters can also be telemetered from free roaming animals and we are embarking on this phase at present. This ability to obtain a variety of information continuously and from afar has evident advantages. However, I would like to emphasize that an even greater asset of a tracking system is its capability of putting a scientific observer in a predetermined position where he can observe a particular instrumented animal and reason about and interpret what he observes on the spot. In some 3,000 square miles of grizzly bear habitat, eighty-five percent heavily wooded, man and grizzly can arrange to meet with the man alone aware of the grizzly's presence and location. He can observe undetected. This ability to locate, move in or follow and then observe is in itself a tangible research reward.

At the present time we can instrument a grizzly bear, monitor its signal 24 hours a day for a month or two, and plot its movements during this time from a distance. From minor but detectable signal changes we can deduct certain activities. At almost any time within this two-month period we can fix the bear's position through the intersection of two or more bearings and then move in and make visual observations in rough and heavily timbered country. We can approach sufficiently close to observe feeding activities and breeding and social behavior of the instrumented bear, to hear its departure if unobserved, or to continue tracking it when it moves off before being sighted.

Though there is a widespread, growing and keen interest in the application of electronics to ecological research and to the management of wildlife, there are still some who doubt its usefulness and practicality. Our results indicate it has a tremendous research potential and that in planning comprehensive field studies of the future, bio-telemetry will be given ever more serious consideration as a method of gathering data. Within a few years I foresee that many Universities offering advanced degrees in ecology or in resource management will have courses in bio-telemetry. I feel certain that a majority of State Fish and Game Departments will eventually establish research and management programs employing bio-telemetry systems and methods. Some have already made a start and many are expressing interest. Practical applications for Federal agencies are numerous and there is little doubt that land managing agencies will become increasingly involved in the use of electronics for studying wildlife, gathering data for management, telemetering environmental information such as temperature, light intensity, moisture conditions or telemetering physiological conditions from free roving animals. Some agencies will even telemeter physiological information from humans for other than purely medical objectives.

A big game radiotracking system has many applications and at least a few of these are worth mentioning at this time as examples of the many possibilities.

Currently, we are conducting a study of the migration of elk (Cervus canadensis) for the National Park Service in Yellowstone National Park. Conventional plastic color-coded neck markers are being used. The information gathered by observing marked animals is delineating the general pattern of elk migration in spring and fall. Such data will not provide a continuous pattern of movement. This only can be obtained by daily monitoring instrumented

elk within the herd. The migration and movement data that can be obtained in this way will have direct application in the management of the elk herds. There is also both a research and a management application in the use of radiotracking to "keep tab" on exotic game species introduced into a new area or native species that have been transplanted. Bio-telemetry also has unexplored possibilities in education, specifically, the interpretive services of National Parks. Interpretation of Park attractions and values is an important aspect of National Park management and administration. It would be quite feasible to devise and set up electronic systems in visitor centers or field museums that could visually and audibly portray location and movements of instrumented wild animals. This information could then be related to the big game and range management procedures and problems of a specific national park such as Yellowstone where the need to reduce the number of elk to within the carrying capacity of the winter range poses a problem in public education and must be explained to the visiting public and to sportsmen's groups.

References:

1. Craighead, F. C. et al, 1963. Radiotracking of Grizzly Bears. Bio-Telemetry, Proceedings of the Interdisciplinary Conference; New York, March 1962, pp. 133-148.