periodically monitored over a total period of more than 11,000 potential tracking days. In other words, radio signals have been emitted from one or more transmitters for this period of time. The full potential for tracking and for making observations has, of course, not been realized. In this case limited manpower is a bottleneck. New extended-life transmitters have permitted continuous tracking of elk for 8 consecutive months with a potential for one year from a single battery pack. A standard pulsed transmitter on an elk transmitted continuously for 112 days with a single battery pack. Some very interesting data on elk ecology and elk behavior has been obtained through biotelemetry methods. Seasonal and home ranges have been delimited, seasonal activities recorded, daily activity patterns graphed and herd and harem formation behavior observed. Interesting and significant food habits information has been gathered. As with the grizzlies, new information has been obtained that has not been recorded in the literature. Experiments leasing toward the telemetering of physiological information from free roaming animals have centered around the elk because of the greater ease in working with them. The most exciting advance in this area has been the telemetering of body temperature from a cow elk and the potential it revealed for studying circadian rhythms in wild free roaming animals.

Transmitters were developed and tested for use on golden eagles. These were on the same frequency and thus integrated in and compatible with the rest of our biotelemetry system.

New developments in equipment include extended-life transmitters, body temperature transmitters, EKG transmitters, lobe switching-dual yagi antenna, environmental telemetry probes and 27 mc voice transmitter for recording animal sounds.

GRIZZLY BEARS

INSTRUMENTED GRIZZLIES

In 1965 six different grizzlies were instrumented and tracked by radio for a total of 245 tracking days. Two of the six were instrumented twice during the season. Instrumented animals included: #'s 40, 188, 194, 202, 206 and 210. Five animals were radio-tagged with the expectation that monitoring and studying of these individuals would reveal information on denning and prehibernation behavior. Two weaned male yearling grizzlies were instrumented in order to learn more about their behavior following early separation from the mother. Two bears were successfully tracked into their dens. The instrumented bears included a known-age sow, 2 weaned yearlings, a two-year-old male and two large boars. The transmitters used on the grizzlies were standard continuously pulsed tracking transmitters, new extended-life transmitters employing an ON-OFF pulse pattern and a temperature-sensitive transmitter with the pulse rate controlled by a thermistor.

Grizzly #40

This female bear was instrumented and tracked for the fifth consecutive year. She was instrumented twice during the summer and fall of 1965---first with a temperature-sensitive transmitter and later with a standard continuously pulsed transmitter. Number 40 weaned her yearling, came into oestrus and was observed breeding. With the use of radio, we learned that she did not reuse her former hibernation den but dug a new den in the same general area. This female (probably pregnant) dug and prepared her new den well in advance of hibernation time. The den appeared to differ from the one she had prepared for herself and cub the previous fall and was apparently lined with grass rather than boughs. It was impossible

TABLE I

RADIO-TAGGED GRIZZLIES
1961-1965

Bear No.	Sex and age	Tracking Dates		Animal Tracking Days	Remarks
6	5-year old female	1964	7/10-8/5	18	First cub captured and marked. Daughter of #7. Radio removed after 18 days.
7	Adult female	1963	7/26-8/12	18	Grizzly removed loose fitting collar. Recovered collar August 10.
			9/2-9/27	26 44	Tracked to fall range, last signal weak.
14	Adult male	1964	9/5-10/15	41	Large boar weighing 890 lbs. Would go 1000 lbs. by hibernation time. Transmitter functioning on last date but tracking discontinued.
34	Adult female	1964	7/23-8/25	34	Sow with 2 yearlings. Left summer range for fall range with transmitter still functioning.
37	Immature male	1961	9/30-9/31	1	Bear moved beyond range of receivers, collar missing when retrapped.
		1962	10/4-10/18	15 16	Transmitter functioning, bear lost journeying to hibernation area. Shot by hunter in spring of '63.
40	3-year old female	1961	9/22-10/22	32	Transmitter still functioning, receiver range inadequate. Bear hibernated.
	4-year old	1962	9/8-9/17	10	Transmitter no longer functioning, but still on bear. Removed by bear during hibernation.
	5-year old	1963	8/7-9/4	29	Transmitter no longer functioning but still on bear at time of hibernation.
	6-year old	1964	9/4-11/9	67	Tracked to hibernation den with cub, transmitter still functioning. Bear's first litter.
	7-year old female	1965	6/28-9/6	71	Removed 1964 collar and reinstrumented with a temperature sensitive transmitter.
			10/13-11/16	35 244	Reinstrumented and tracked to den, transmitter functioning after 11/16.

75	Old Adult female	1963	8/16-9/28	44	Bear immobilized and transmitter removed, still functioning well.
76	Young adult male	1963	8/26-9/22	28	Sow with two yearlings. Lost signal, bear traveling, transmitter functioning.
96	Young adult female	1962	8/17-8/19	2	Lost signal, bear traveled to distant portion of park. No mobile tracking units
		1963	7/12-7/17	6	Sow with cubs. Transmitter battery pack shorted by water.
				8	
150	Adult female	1963	10/6-11/3	29	Sow with cubs. Transmitter still functioning, bear hibernated, lost during hibernation trek.
		1964	8/11-11/4	4	Sow with yearlings. Trouble instrumenting at night, bear lost collar.
				33	
158	Male yearling	1964	10/11-11/9	30	Yearling with sow and 2 yearling littermates. Tracked to hibernation den, transmitter still functioning.
164		1963	10/26-11/5	11	Transmitter still functioning, bear hibernated, den located.
170	Adult female	1964	7/3-7/13	11	Sow with two cubs tracked in release and homing experiment. Transmitter removed after 11 days.
188	Weaned male yearling	1965	10/2-10/20	19	Boar lost while moving to hibernation area. Transmitter still functioning. Checked for signal over 40 day period.
194	Orphan yearling male	1964	10/16-10/18	3	Lost track of animal while following others. Transmitter recovered in spring. Dropped collar was located & retrieved.
		1965	9/16-10/15	31	
				34	
202	Weaned male yearling	1965	9/17-9/24	8	Tracked to hibernation den. Transmitter functioning when monitoring was stopped.
			10/5-11/21	47	
				55	
206	Large adult male	1965	8/2-8/5	4	Bear lost collar. Transmitter retrieved 8/17

210	Large adult male	1965	8/26-9/24	30	Bear moved far and fast to fall range. Unable to continue tracking.

Total - 733 Tracking days

18 different grizzlies
29 instrumentings

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Bear No.	Sex and age	Tracking Dates		Animal Tracking Days	Remarks
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			9/2-9/27	26	Tracked to fall range, last signal weak.
				44	
14	Adult male	1964	9/5-10/15	41	Large boar weighing 890 lbs. Would go 1000 lbs. by hibernation time. Transmitter functioning on last date but tracking discontinued.
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	7-year old female	1965	6/28-9/6	71	Removed 1964 collar and reinstrumented with a temperature sensitive transmitter.
			10/13-11/16	35	Reinstrumented and tracked to den, transmitter functioning after 11/16.
				244	
75	Old Adult female	1963	8/16-9/28	44	Bear immobilized and transmitter removed, still functioning well.
76	Young adult male	1963	8/26-9/22	28	Sow with two yearlings. Lost signal, bear traveling, transmitter functioning.
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		1964	8/11-11/4	4	Sow with yearlings. Trouble instrumenting at night, bear lost collar.
				33	
158	Male yearling	1964	10/11-11/9	30	Yearling with sow and 2 yearling littermates. Tracked to hibernation den, transmitter still functioning.
164		1963	10/26-11/5	11	Transmitter still functioning, bear hibernated, den located.
170	Adult female	1964	7/3-7/13	11	Sow with two cubs tracked in release and homing experiment. Transmitter removed after 11 days.
188	Weaned male yearling	1965	10/2-10/20	19	Bear lost while moving to hibernation area. Transmitter still functioning. Checked for signal over 40 day period.
194	Orphan yearling male	1964	10/16-10/18	3	Lost track of animal while following others. Transmitter recovered in spring.
		1965	9/16-10/15	31	Dropped collar was located & retrieved.
				34	
202	Weaned male yearling	1965	9/17-9/24	8	Tracked to hibernation den. Transmitter functioning when monitoring was stopped.
			10/5-11/21	47	
				55	
206	Large adult male	1965	8/2-8/5	4	Bear lost collar. Transmitter retrieved 8/17
210	Large adult male	1965	8/26-9/24	30	Bear moved far and fast to fall range. Unable to continue tracking.

Total - 733 Tracking days

18 different grizzlies
29 instrumentings

to closely inspect the den without disturbing the bear but closer scrutiny in spring may reveal some interesting differences in den construction attributable to the variable needs of a mother with advanced cubs and one possibly giving birth to young.

Number 40 wandered a little beyond her previously established range boundaries thus slightly enlarging the area of her home range. The annual ranges plotted for this animal reveal the gradual expansion of a home range over the years. The general relation of the ranges of this grizzly and her weaned yearling, #188, were revealed.

Grizzly #188

This yearling male grizzly was the weaned offspring of #40. By radiotracking, we hoped to discover whether a yearling on his own and hibernating alone for the first time would return to the general area of his parental den. Number 188 established a summer and fall range within the area inhabited by his mother. He remained here until October 15 on which date he was tracked and closely observed. Falling temperatures and snow started this bear moving and he left the familiar area in which, up to this time, he had spent all his life. He traveled fast and far at a time when we were busy tracking other grizzlies. The last faint signals were obtained from this bear far to the south of his summer range. Attempts over the next 30 days to pick up his signal from vehicles and afoot proved futile. There is little doubt but what he moved off into new and strange territory to hibernate.

Grizzly #202

Grizzly #202 was instrumented September 17 and again on October 5. He was monitored by radio for a period of 55 days. This male

yearling was from the third known litter of sow #65. We had never instrumented #65 nor located her den, but we knew the general area in which she hibernated. Each fall #65, with her litters, moved into the Canyon area and each spring she reappeared here when the snow was still relatively deep. By instrumenting her weaned yearling #202, we thought we might learn whether or not he would hibernate in the area of his birth site. We, also, hoped to learn what kind of den a male yearling used or prepared, whether it was dug in advance of winter and if and how the den differed from the dens of sows we had located in the past. Number 202 was monitored closely, followed on his hibernation trek, monitored while digging his den and the den itself located. The den was within the known range of his mother.

It is interesting that the two instrumented male yearlings behaved differently. Number 202 hibernated within his mother's home range and in the general area where we suspect he was born. Number 188 left the area of his mother's home range and wandered far into new and strange territory. Unfortunately, his den site was not located. It is apparent that this first fall dispersion with selection of a hibernation site influences the size and character of the bear's future home range.

Grizzly #194

Number 194 was tracked by radio in 1964 and was reinstrumented September 16, 1965. He was then a two-year-old and one of four male orphans that had previously banded together for mutual benefit and security. He was instrumented with an extended-life transmitter which emitted 22 pulses in ten seconds and was ON for ten seconds and OFF for twenty seconds. He was monitored by radio for one

month (Sept. 16 to Oct. 15). The transmitter was then found in the upper end of Hayden Valley lying close to the remains of a buffalo carcass that had been consumed by the grizzlies. The bear removed the collar while feeding, although it had been fitted quite snugly around his neck. The extended-life transmitter was recovered approximately 5½ airline miles from the point where he was immobilized and instrumented. In the fall of 1964, the signal from #194 was last monitored in this same area. Two seasons of limited tracking data on this grizzly indicate that he possibly moves out of Hayden Valley to hibernate, traveling far to the west or southwest. He may cross the divide into the Old Faithful drainage.

Grizzlies #'s 206 and 210

Both of these grizzlies were large mature boars weighing in the neighborhood of 800 lbs. when instrumented. Number 206, Scarface II, was a contender for the dominant position in the grizzly bear heirarchy. Both grizzlies were immobilized at night and were instrumented under difficult conditions. The purpose of radio-tagging these large sub-dominant boars was to learn more about their habits, ranges and activities. Both were instrumented with extended-life transmitters.

Number 206 had a neck enlarged and hardened by scar tissue. It was 40 inches in circumference, slightly larger than the circumference at the base of his skull. It was evident that it would be difficult to keep a transmitter collar on this bear. After a few days, he managed to remove the collar. It was tracked down with directional portable receivers and sighted from a distance of 60 feet. We located a daytime retreat of this bear but learned little else about him.

The general area of #210's summer and fall range was determined, and frequently used daytime beds located. These were large, deep, den-like beds. They appeared to have been used and enlarged over a period of years. Like other big boars, #210 moved out of Hayden Valley in the fall and headed for his fall range. His departure on September 17-18 was correlated with snow and unusually cold temperatures for this time of year. The ground was covered by six or more inches of snow and night temperatures dropped to 12°F. and 13°F. Number 210 moved fast and far. Limited manpower prevented continuous tracking so we lost radio contact with this boar and never again located him, though we monitored extensive areas. We failed to locate a hibernation area or fall range but we know that these were distant and isolated, as has been the case with all large boars tracked or monitored to date. Their initial movements are at night and often take them beyond range of radio surveilliance from mobile units. The bears are thus lost unless a special attempt is made to pick up the signal from the air or to search the back country on foot or on horseback as was done with #14 in the fall of 1964.

ECOLOGICAL AND BEHAVORIAL RESULTS

Much of the information gathered in 1965 is treated under the same headings used in the previous report and the range and den tables have been revised to date. Instrumenting of bears was more selective and the information sought was of a more specific nature. Greater emphasis was placed on behavior, as biotelemetry lends itself well to such studies and there is much to learn.

RANGES

Past experience with radiotracking indicated that continuous and close monitoring of instrumented grizzlies, though feasible, was not essential for determining seasonal or home ranges. We found that the range of a grizzly could be sufficiently well established by getting daily fixes and by recording bearings that would indicate the general but not exact location of the bear. The position of a bear along a bearing taken with the portable receiver can often be judged to within a half mile or closer by means of relative signal strength. Bearings alone thus served to inform us of the general location of a grizzly at any given time. For this reason the radiotracking of grizzlies to determine ranges in the summer and fall of 1965 was not as detailed as the work carried on previously. However, the area and extent of ranges is nearly as accurately and clearly defined as those of grizzlies that were monitored more continuously and closely. Whenever bearings or fixes indicated that a grizzly had moved to the peripheries of his range or beyond the then established range, his exact position was obtained through radio fixes and or through subsequent tracking, jumping and sighting.

Radio-monitoring has to be used with judgment based on field experience and a knowledge and understanding of the species involved, and even the individual instrumented. It can, otherwise, be prohibitively time consuming and provide detailed location data far in excess of practical needs. In the summer and fall of 1965, we tried to tailor the radio-monitoring to fit the requirements necessary for determining a particular bear's range.

GRIZZLY BEAR RANGES

DETERMINED BY RADIO TRACKING

1963-64-65

ear	Bear No.	Bearings Used in Determining Range	Number of Plotted Fixes	Area of Ranges in Square Miles	Remarks
963	40	140	32	8	Lone five-year old female
	150	227	35	27	Sow with cubs
	75	145	21	36	Sow with yearlings
	7	256	32	106	Sow with yearlings.
	76	129	21	168	Lone five-year-old male
964	6	49	11	12	Lone five-year-old female
	14	58	5	12	Large adult male
	34	151	26	13	Sow with yearlings
	40	106	27	15	Sow with cubs
	158	98	14	22	Yearling (family of sow and three yearlings)
		Bearings and Fixes			
965	40	65		20*	Sow with yearling. Lone sow (pregnant)
	188	24			Weaned yearling male
	202	141		27*	Weaned yearling male
	194	31			Two-year-old male

* approximate area, subject to alteration

No attempt is made here to fully analyze the data on grizzly ranges. However, the ecological and behavioral information obtained by radiotracking are best interpreted by recognizing that food supply and the mating urge are the keys to understanding much of the behavior, activities, movement and ranges 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 spring (April and May). Many bears then gradually concentrate in Hayden Valley, first seeking early spring natural foods and then mates (June). They are then held here throughout the summer by both natural and man-supplied food only to disperse widely again in fall to areas providing more and different food, as well as hibernation sites. This picture of the grizzly population has been obtained in various ways in the course of the 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.

Four additional ranges were delineated and the areas computed. Three of the ranges have been plotted on the master range map. Two home ranges, including den sites, were delimited, raising the total to four home ranges studied. In two cases, the relation of ranges of a parent sow to her independent offspring were determined.

Number 40 was observed from April to November and was monitored over a 106-day period but not as closely as in past years. Her range and movements were determined from 65 bearings and fixes, plus radiotracking on foot on which occasions she was located, jumped and observed. The numerous bearings and fixes taken while moving in on this (or other bears) are not recorded - only the position where the bear was jumped or observed.

Range of 40

The home range of sow #40 was again determined. Her range has now been plotted over a five-year period, from 1961-1965. This has revealed the evolving of a lifetime home range. The earlier ranges plotted for this animal do not include the denning area and are thus smaller than the actual home range. Nevertheless, there has been a gradual increase in range as this animal matured. The size increased slightly in 1964 when she had a cub and was expanded still more in 1965. It was enlarged considerably in 1965 by early spring movement to the northeast and across the Yellowstone River and by a fall extension on the other end to the southwest. The latter resulted from selection of a new den site; the former a wandering to get food in spring for herself and yearling.

Number 40's home range is relatively small and it is doubtful if it will ever approximate the size of some of the far wandering grizzlies. It is, however, typical of one of two types or patterns of ranges. In the one case, the home range consists of seasonal ranges (spring, summer, fall) that are nearly identical with year-round food supply and den sites not widely separated. The range is, thus, a single compact unit. The other range pattern is characterized by spring and summer ranges embracing food supplies

and these widely separated from a fall range including hibernation den sites. This can be visualized as two distinct ranges with the bear often traveling rather rapidly from one to the other. When the food supply in either the summer or fall range is poor, the grizzlies move in search of food, thus, at times greatly, though perhaps only temporarily, expanding their home ranges. Grizzlies number 14, 7, 76, 34, 96 and 210 are examples of bears with widely separated seasonal ranges that in combination comprise their home ranges; while number 150, 39 (mother of #158), and, perhaps, 65 (mother of #202) are grizzlies with ranges much like that of #40.

Weaned grizzly #188 had a summer range within that of his mother's (#40). It was, however, quite distinct from hers and the nucleus of his range and day-bed area was Sulphur Mt., an island of timber and hot springs not frequented by his mother. In fact, we have never tracked or observed #40 in this area. In view of the fact that this yearling had spent all of his life in a rather restricted area, it seemed logical that he might hibernate nearby and continue to do so, thus establishing a range pattern similar to his mother's. However, in late October when this grizzly took off into new and strange territory to seek a distant hibernation site, he established a range pattern different from his mother's and one that he will probably continue to follow throughout his life.

The home range of weaned grizzly #202 was determined by radio-tracking over a period of 55 days and from 141 radio bearings and fixes. This grizzly's movements were within the known range of his mother, #65. She was not radiotracked but her approximate range was determined from sightings over the years. Though up to this time #202 and his mother had traveled over more country than had

#40 and her yearling, #202 did not take off for distant parts like #188 but hibernated within his mother's range, and we suspect not far from his place of birth. Within his range this bear, like others, frequented certain places for food and used others as daytime retreats.

Grizzlies #194 and #210, the former a two-year-old orphan, and the latter a large mature boar, both established summer ranges in Hayden Valley and both took off for distant areas to seek fall food supplies and to hibernate.

It is of interest that the young members of a bear family often take off in spring and in fall (as was the case with #188) and travel or wander considerable distances. This appears to be typical behavior of weaned yearlings and two year olds. It takes on added significance when the prior movement and ranges of the bears are known through radiotracking. For example, the range of grizzly sow #39 and her yearlings was well defined in 1964. Yearling #158 and the family were tracked by radio and all were tracked to their hibernation den. In the spring of 1965, #39 weaned her two year olds and they dispersed. One of them was shot just outside the southern border of Yellowstone Park or 29 miles south of the southernmost extension of his mother's home range.

The size of grizzly ranges varies greatly and is influenced by many factors including food, availability of mates, den sites, age, sex, habitat type and distribution, individual character differences and social factors. An interpretation of the range data gathered by radiotracking and through observation of marked animals is planned and should provide for a better understanding of the grizzly and prove helpful in management of the species.

TERRITORIALITY

Observations made in April and May of 1965 shed new light on our conceps of grizzly bear territoriality. Where grizzly bears congregate in summer, as in Hayden Valley, a definite hierarchial system has evolved with a single dominant boar in command and others fitting in down the line to the lowest strata of orphaned cubs and yearlings. During this period of concentration, the ranges of bears overlap and there is little or no apparent territorial defense, even where they congregate to feed or where they rest. However, bears of dominant status feed where they desire and subdominant bears may give way. There is at times a show of dominance that in some ways is akin to defense of a feeding territory. Nevertheless, communal feeding sites and even isolated food in the form of carrion are usually not defended. There appears to be little or no defense where members of the same family or litters from the same mother are involved. There is more when strange bears or bears from other families meet. The defense of a source of food (carrion) has been described in a previous report, an example being when a boar more aggressive than sow #40 (a young sow) prevented her from feeding on a dead buffalo well within her established home range. Sow #40 fed only after the other bear was satisfied.

In the spring of 1965, we observed an unmarked boar feeding on a buffalo carcass on an island in the Yellowstone River. The radio-tagged sow #40 and her yearling #188 also discovered this source of food. The unmarked boar came in to feed on the carcass in late afternoon or after dark. The sow and her yearling waited patiently on a nearby river terrace and came in and fed only toward morning after the boar had satisfied his hunger and had left. On one occasion we saw both the boar and the sow and

yearling approaching the carcass at the same time. The boar, upon detecting the sow, turned and slowly circled back in a maneuver to get between the sow and the wooded retreat to the east. This had the effect of causing the sow and her yearling to move off keeping a respectful distance (300 to 500 yes.) from the boar as he circled toward them. In other words, as the boar circled back, #40 also moved back. This was an exhibition of territorial defense, that is, defense of an area surrounding a temporary food source. It was more apparent, more pronounced, and more effective than other similar behavior patterns observed in summer or fall. Such territorial defense is probably more apparent in spring when food is scarce than in fall when the bears are fat and well-fed. Defense of a hunting territory or range among birds-of-prey is more evident when prey is scarce.

Where grizzlies congregate, the status of the individual in the hierarchy is more evident than when the bears are dispersed, but social position influences behavior at other times, the degree depending on a variety of conditions and circumstances. Under dispersed conditions an exhibition of dominance at a food source may be tantamount to territorial defense. This may also be true at den sites but most likely a more defensive attitude is exhibited by the animal with a den or young to protect. The defense of a carcass, when it occurs, appears to be related to the position of the bear in the bear hierarchy and the aim is apparently to intimidate the other bears that are present.

Territorial defense of a home range, summer range or fall range has not been observed. It seems certain, at least, that the peripheries of such a range are not defended. A show of sominance when and where needed seems to substitute for any clear cut defense of a definite territory - large or small.

PRE-HIBERNATION BEHAVIOR AND HIBERNATION TREKS

A pattern of grizzly bear behavior and movement to dens has emerged from observations made on instrumented bears tracked to their dens over the last three years.

Adult grizzlies select their den sites and excavate their dens prior to the onset of winter and considerably ahead of hibernation time. New dens are dug as early as the first week in September. Grizzlies returning to reuse old dens may not dig them out and enlarge them until time to use them. This is apparently what #164 did in 1963.

#40 1964

#40 1965

During pre-winter snow storms many grizzlies travel to their den sites, but when the weather changes and becomes clement, they often return to their foraging areas and routine. Number 40 did this in the fall of 1964 (Oct. 15-18). On Novemb er 1 she again traveled to her den in a snowstorm but this time remained after the weather became milder, warm and clear. Snow, however, remained on the ground. In 1965 she traveled to her den site on Oct. 15 during a snow storm, and though the weather again changed to sunny and warm and the snow melted, she remained close to her den. The main difference in behavior seemed to be that after Oct. 15 of 1965 she was more lethargic than at a similar date the previous year. It may be that because snow and cold temperatures arrived much earlier (Sept. 15) hibernation physiology and the onset of lethargy, perhaps a hypothermic lethargy, came earlier. When this condition did not coincide with snow and cold temperatures in late fall, the grizzly did not enter her den to hibernate but did remain close to it.

lethargy

A weaned male yearling grizzly preparing a den for the first time moved to his den site during good weather and not during a storm. All others have traveled in snow storms, but these others all had dens previously prepared.

The combination of snow and low temperatures is apparently influential in initiating hibernation physiology. Snow storms cause the grizzlies to move to their dens and snow storms and low temperatures combined finally put them into their dens - usually at a time when they are to some degree lethargic. In the Hayden Valley region of Yellowstone Park, the maximum ambient temperature at the time of hibernation is about 32°F. or lower in the shaded areas of the den sites. The hibernation dates or date at which the bears entered their dens varied from October 21-22 in 1961 to November 11 in 1965. The 1960 date was October 29 and 1962 was early November but the exact day was not determined. The earliest hibernating date coincided with a fall where snow and cold weather arrived by September 11 with snow and cold weather continuing more or less uninterrupted until hibernation time. The latest recorded hibernation date coincided with a fall season where warm fall weather continued right up to hibernation time with the exception of a September snow storm and cold spell. Each year all of the grizzlies in the area under study went into hibernation simultaneously. The time at which grizzlies hibernate is definitely influenced by environmental conditions.

#202

A drop in temperature accompanied by snow on Oct. 15 was correlated with a move by #202 away from his regular summer haunts. On Oct. 25 he crossed the Yellowstone River and moved northeastward throughout the 26th. By evening of the 26th, he had reached the south rim of the Yellowstone Canyon, the area in which he hibernated. During the 27th, 28th and 29th, the signal at our Base Station indicated #202 was digging a den. On October 28 we "moved in" on

this bear following his radio signal. At 12:30 p.m. we jumped him at close range and from the exact spot that we had encircled on the map within a triangle of bearings. We didn't see the grizzly, nor did we locate his den site. As it turned out, the bear had moved from his den just below the Canyon rim to a day bed where we jumped him. On November 4 we again "moved in" following the signal and located #202 and his den which was situated over the steep rim of the Yellowstone Canyon on a north-facing slope. The den was in a narrow strip of trees with a gravel talus slope on one side that looked like a possible snow avalanche run. There was a definite avalanche run on the other side. The den surroundings gave the impression of complete isolation. Under the best of conditions, it would be difficult to approach closely undetected and it would probably be impossible to get to it in winter without considerable risk. The question arises as to just what would make a young bear select such a spot. A good guess might be that this was the general area where he was born and that the family den or dens were in a similar type of site. Perhaps, early imprinting influenced his choice. Evidence indicated that his mother probably hibernated somewhere in this Canyon area. But, as far as we know, except in his spring trek from a den and his return travels last fall with his mother to a den, this bear has spent all of his life in the immediate vicinity of Hayden Valley. His first purposeful and independent movement away was when he crossed the Yellowstone River and headed straight for what turned out to be his den site. Radio monitoring and observations revealed that he had not prepared his den in advance as mature bears had done in the past but

had dug it within a few days of selecting the site. A factor affecting this bear's choice of a site was the apparent urge or instinct for single bears not part of a family unit to be alone and isolated during the potentially vulnerable period of hibernation (deep sleep). A criterion for all dens so far located has been isolation.

When we closed in on #202 with our directional receivers, three different bearings from closely spaced positions along the bend in the canyon rim indicated that the grizzly was down in the canyon just below us. We climbed down the canyon at this point but were soon stopped by a perpendicular drop. We could go no farther following this route. We glassed the canyon below, the steep walls and talus slopes but saw neither bear nor probable den site. At 4:30 p.m., just as we started to leave, we loosened a large rock that crashed into the trees below. Simultaneously with the crash we heard a roar and later what we thought was the alarm "huff, huff" call of a grizzly. We again scanned the rugged terrain below and finally spotted the straw-colored grizzly in a small opening almost directly below us. The sudden noise had brought him to his feet and from out of concealment (probably den entrance). The blue of the radio-collar was clearly visible and along with the pulse rate (80/min.) identified him. Through the glasses we saw a pile of fresh earth about 10 to 15 feet from the grizzly. At the edge of this was a bed of boughs and what appeared to be the den entrance. We watched the grizzly from 4:30 until 5:00 p.m. and in this period of time he stood motionless except for an occasional slow movement of his head when he raised his nose in order to get our scent. He should have detected us as the wind movement was from us down toward him, but gave no indication of doing so. Several times the bear seemed to almost fall

asleep. He let the muzzle of his nose rest on the ground and turn back under him much like the first reaction of the bears to being drugged. This was identical to the lethargic behavior of #188 that we observed on Oct. 14 but the bear was much more drowsy, less active, and loathe to move.

This typical lethargy as exhibited by #202, #188 and #40 was more pronounced than in past years. It may have been associated with a slight drop in body temperature as early as mid-October. However, in 1964 #158 showed a rectal temperature of 102°F. when trapped on October 11. We believe the lethargy exhibited was due to the fact that the early September snow storm and low temperatures triggered hibernation physiology, but the environmental conditions required for finally putting the grizzlies in their dens were delayed until mid-November and instead were replaced by relatively mild warm weather. We, thus, had a chance to observe lethargic bears that normally would have been inside their dens.

#40

On August 12, 13, 16 and 20, signals placed number 40 in the vicinity of her former den (1964). During August she spent considerable time here. A visit to the den on August 14 revealed that her den had partially caved in and the bottom was filled with mud. Weak signals on Sept. 3 placed #40 in the area where her 1965 den was later located. It is quite likely that she was selecting a new den site or starting excavation at this time (In 1964 #40 started digging a den on Sept. 8 but abandoned this for another site). No signals were received from September 7 until she was trapped and reinstrumented. The transmitter had been operating for 71 days. Number 40 was reinstrumented on October 13. On October 15 we tracked her as she moved westward from about the center of her range.

This turned out to be the final trek to her den. The day was clear and warm changing to snow by 4:00 p.m. Snow continued to fall throughout the night. During much of the day we attempted to "close in" on this bear but she was moving faster than we could travel through the tangles of downed timber. We did not catch up to her but in late afternoon from upper Alum Creek we obtained a fix that placed her close to her new den site (located later). She apparently reached her den site by dark and a fix the next day placed her at her den.

On October 25 we moved in and located the den with the bear within. We approached to within 30 feet but did not disturb her. The grizzly was apparently somewhat lethargic at this time. She remained close to her den or within it from October 15 to November 16 when the den was again revisited. At this time she was within the den and snow around the entrance revealed no tracks. She apparently entered her den for the winter during the storm of November 11. This grizzly moved to her den a full month before entering it. In 1964 she moved to her den and remained close to it for 10 days prior to entering for the winter.

WEATHER CONDITIONS

From the standpoint of weather conditions, the fall of 1965 differed from any of the preceding study years and this affected grizzly behavior, particularly, in relation to hibernation and movement to den sites. A cold spell with snow and low temperatures occurred early in the fall from Sept. 15 through Sept. 28. This was the coldest period of snow and low temperatures that we had yet experienced so early in September. Four to six inches of snow were on the ground at Canyon and more at higher elevations. Minimum temperatures dropped to 12° and 13°F. at the Lab. (Thermometer on outside of building). Temperatures were recorded down

to 7°F. This combination of an early snow storm and low temperatures did not put any known grizzlies into hibernation but it did disperse some to fall ranges, and it appears to have triggered hibernation processes so that the bears became lethargic, moved to their den sites and were ready to hibernate by late October. For example, on Sept. 18 with snow on the ground #210 left Hayden Valley. He traveled fast to a distant location and we were unable to pick up his signal again.

Another weather change occurred on October 15. The morning was warm and sunny but the barometer was dropping. It started clouding up about noon and by 4:00 p.m. it was snowing lightly increasing through the night until 3 to 4 inches had fallen at Canyon. On the 15th we tracked #40 as she moved into upper Alum Creek. By late afternoon in falling snow she was at or close to her den which we found later (Oct. 25). This approaching storm initiated movement of other grizzlies as well - #194 and #81 and her two cubs. Number 40, as indicated, went to her den and #202 left his Sulphur Mt. summer bedding area and traveled into upper Elk Antler Creek. Number 188 took off at this same time and traveled to a distant hibernation area. From this time on, periodic monitoring revealed that #40 stayed close to her den. Clear, warm sunny days followed and practically all the snow melted. Nevertheless, #40 remained at her den. Number 202 went to his den site and remained there without snow on the ground. This has not been observed in the past. A combination of lowering temperatures with a big snow storm had put the grizzlies into hibernation and in most cases they traveled during the snow storm to readh previously prepared dens.

Age and sex, as well as weather conditions, may also be a factor influencing their behavior. It is quite likely that #40 is pregnant and this may have instinctively caused her to prepare a den and move to it early. There is also an indication that she has prepared and lined her den differently this yaar as compared to last when she hibernated with her cub. The yearling #202 did not prepare a den much in advance as did #40 and #39 last year. Number 164 was a barren female and she traveled in a storm to quickly enter her den and she either used her old last year one or prepared it sometime during the summer or early fall.

The behavior of #40, the lethargic condition of all the bears and the movement of #188 to a den site without a storm would seem to reveal that hibernation physiology had been triggered prior to actual entering of dens or movement to them. The Sept. period of snow and unusual cold may have done this. Temperatures during this cold spell were lower than at the November time of hibernation in 1964.

All bears that we have tracked to dens moved to them during storms with the exception of weaned yearling #202. All the others were mature grizzlies and had prepared their dens prior to final movement to them. Number 202 had made no prior preparations so his hibernation trek and movement to select a site and dig a den were one and the same.

GRIZZLY BEAR
PRE-HIBERNATION PHENOLOGY
(Yellowstone National Park)

Bear No.	Bear Age & Sex	Den Digging Date	Date Final Movement to Den	Weather Conditions	Temp. °F. Max.-Min.	Date Entering Den	Weather Cond.	Temp °F. Max-Min
164	Young adult female	Prior to hibernation	Nov. 4 1963	Snowing 4" - 6" on ground	32	Nov. 5	Snow Storm	32
40	Six year old female with cub	September 8 (den abandoned) September 17-18	Nov. 1 1964	Snowing 12" - 18" on ground	45 32	Nov. 10	Snow Storm	40 24
158	Male yearling with adult sow	Prior to hibernation	Oct. 29-30 1964	Snowing 12" - 18" on ground	58 38	Nov. 10	Snow Storm	40 24
40	Adult female probably pregnant.	September 3	Oct. 15-16 1965	Snowing 3"-4" new snow	54 30 41 30	Nov. 11	Snow Storm	43 28
202	Weaned yearling male.	Oct. 27-29 No previous preparation	Oct. 25-26 1965	No snow	55 26 63 25	Nov. 11 came out Nov. 21 Reentered	Snow Storm	43 28
150	Adult female with 3 cubs	Prior to hibernation	Nov. 3-4 1963	Snowing 4"-6" on ground	32	Nov. 3-4	Snow Storm	32

Dens #

40, 164, 158 & 150 ?

grouped

&

along north sloping

ridge

DENS

Five instrumented grizzlies have been tracked to their respective dens. Actually, a total of nine grizzlies were tracked due to the fact that some were members of family units that hibernated together. The bears tracked to dens in 1965 included a weaned yearling male and a mature female (probably pregnant). Grizzly sow (#40) has been tracked to her den in two successive years. Separate dens were dug each time and den digging was initiated in September about two months prior to hibernating.

All the dens used by grizzlies have been dug by the bears. No natural shelters have been utilized. Grizzlies may not always use dens that they dig but it appears that den digging for the grizzly is an instinctive behavior just as nest building is for birds. The data so far obtained also indicates that grizzlies seek an isolated spot in which to hibernate (see illustration). This too is probably instinctive behavior that favors survival during a period when the animal is particularly vulnerable.

All information on active dens is not yet available but all dens inspected to date have been lined with a bough bed. Most dens have been dug at the base of large trees. All have been dug into slopes and all have been on north-facing slopes with the entrance opening to the north.

Accompanying figures show the profile of two different dens. One reveals a construction that serves as a heat trap to prevent escape of warm air.

None of the grizzlies that we have tracked to dens have reused the same den the following year. However, evidence of bed boughs in the litter piles outside of the dens of #164 and of #40 (1964 den) indicated that these had been used in prior years. Similar evidence

GRIZZLY BEAR DEN DATA
Yellowstone National Park

Grizzly No.	Den Location	Vegetation Type	Soil Structure	Den Elevation	Aspect of Entrance	Species Den Tree	Den Measurements Chamber L W Ht inches			Entrance L W Ht inches			Yrs. Used	Den Lining	Hibernation
164	Upper Alum Creek	Lodgepole Pine	Soft earth (loess)	8,200	North Slope	Lodgepole Pine	59	53	48	60	17	40	1963	boughs	Nov. 5
158	Upper Trout Creek	Lodgepole Pine	Packed soil Gravel layer	8,400	North Slope	None	64	60	60	32	30	42	1964	boughs	Nov.10
40	Upper Alum Creek	Lodgepole Pine Spruce-Fir	Packed loess	8,200	North Slope	Spruce	48	42	48	36	30	30	1963 1964	boughs	Nov.10
Unknown 1.	Upper Trout Creek	Lodgepole Pine	Hard Compacted	8,200	N.W. slope	Spruce	43	63	43	64	26	26	Prior 1963	boughs	
Unknown 1.	Absaroka Range Mist Creek	White-bark Pine	Rocky	9,000	S.W. Slope	White-bark Pine	54	60	36					boughs	
40*	Upper Alum Creek	Lodgepole Pine	Packed loess	8,200											Nov.11
202*	Yellowstone Canyon	Spruce-fir	Rocky	7,800	North slope										Nov.11

1. Inactive den

* Data still incomplete

was found outside of some of the inactive dens that we have located.

In the spring of 1965, from April 27 through April 29, we made a trip into the den of grizzly #40. Snow varied from a depth of four or five to ten feet or more. We traveled by ski-doo, one person driving and the other two touring behind on skis. The last stages of the trip were made traveling by ski with back packs.

Grizzly #40 and her yearling had left the heavily forested den area about a week before we arrived. Signs in the snow at different levels told us an interesting story of the grizzly hibernation and late winter activity. The mother and her cub apparently spent the early part of the winter deep in their den but emerged toward spring. The floor of the earth den under the spruce tree was lined with a well worn bed of boughs. Outside of the den we also found numerous bough beds that had been constructed on the snow. These were at different levels indicating different times for construction. Apparently, the mother and yearling had come out of the den in late winter, had built beds and slept on these rather than return to the den. Evidence indicated that on several occasions, they slept on reverted to a more lethargic condition and were covered by subsequent snow storms. This was revealed by partial snow caves with vent-like air holes rising from them and formed by the melting effect of the bears' breath rising through the snow. The grizzlies had also entered and used a cave-like den formed by a rock outcrop.

It was of particular interest to us that these bears had not remained in a dormant condition throughout the hibernating period but had experienced periods of lethargy and periods of relatively greater activity, the periods of activity apparently increasing toward spring. We judged that these animals had emerged from their den and had been relatively active for at least two to three weeks,

perhaps more, prior to our arrival. The activity pattern, as indirectly revealed by the bough beds outside the den, made us suspect the grizzlies came out on sunny days, built a bough bed for insulation from the snow and then slept with the advent of inclement weather and were covered over by the falling snow. When awakening, they arose and destroyed all of the snow-cave covering except the section where their heads had been.

On April 28 at 10:45 a.m., the air temperature inside the den just above the bed was 32°F. The air temperature in the shade outside, three feet above the snow, was 40°F. and the air temperature in the sun, 3 feet above the ground, was 50°F. It seems quite likely that the air temperature within the den, particularly with the bears inside never approached the low ambient temperatures outside and may not have dropped much below 32°F. during much of the winter. A heavy blanket of insulating snow would also serve to keep den temperatures relatively mild.

No feces were found in this den nor in others examined and none in the near vicinity. All evidence indicates that the Yellowstone grizzlies fast from the time they enter their dens until they leave them in spring. This means that they live on their body food reserves for annual periods varying from 5 to 6 months. They are not noticeably thin when they leave their den areas in spring and travel in search of food. In fact, they appear almost as heavy as they did just prior to hibernating. It is possible that under the winter environmental conditions existing in Yellowstone the grizzlies are not merely dormant

but may approach a state of true hibernation with hypothermia and greatly reduced metabolism. It is evident that the den, the bough bed, the deep insulating snow cover, are all factors creating a hibernating environment that tends toward a constant temperature. The grizzlies body temperature during hibernation may more closely approach the environmental temperature of its den than has been previously suspected.

Grizzly #40 did not leave her den in search of food until the spring days had become warm enough that daytime melting and night freezing produced a snow crust capable of supporting her weight. This has also been the behavior of most other grizzlies observed in early spring.

PROGRESS IN PHYSIOLOGICAL TELEMETRY

We have been moving steadily toward a capability to telemeter physiological information from free roaming wild animals. One aim has been to minimize equipment and to keep the bio-telemetry system as uncomplicated and unsophisticated as possible. Physiological information is, therefore, being telemetered on the same radio frequency used for radio locating and tracking. Our approach has been to develop transmitters and antennas that are externally attached rather than implant these devices. Implanting requires major surgery, affects the animal under study (at least temporarily) and has other drawbacks. We have concentrated on telemetering two physiological variables - body temperature and electrocardiogram waveforms and/or pulse rate.

BODY TEMPERATURE TRANSMITTER

The development of a temperature sensitive transmitter followed by tests on elk in January and February 1965 and on a grizzly in the summer of 1966 paved the way for the development and use of a body-temperature transmitter. The purpose of this was to develop

biotelemetry technics to a point where circadian rhythms could be obtained and these correlated with behavior and activity patterns. It would be of considerable value just to determine a normal 24 hour temperature rhythm for a wild free roaming animal. Elk were chosen as the subject for the experiments as they offered several distinct advantages over grizzlies.

On the afternoon of January 29, 1966, we immobilized a cow elk from the Old Faithful elk band and instrumented her with a body-temperature transmitter. This consisted of the standard tracking transmitter but with the pulse (signal) regulated by a thermistor probe attached to the ends of long wire leads. It was designed to measure temperature variations between 94° and 102°F. The transmitter thermistor-probe was implanted under the skin in the upper neck region of the elk. A deep implant was not attempted as the purpose of the experiment was to test the equipment and to check the feasibility of telemetering body temperature. We realized that we would be measuring body temperature somewhat affected by low ambient temperatures. However, temperatures obtained by the implanted probe are referred to as body temperatures. Our procedure was simultaneously to record body and ambient temperatures at definitely spaced intervals. This was not always possible due to the demands of other work. However, monitoring was near continuous over three 24-hour periods. Readings were obtained about every half hour and at times more frequently. Preliminary interpretation of results is as follows.

The body temperature readings ranged from a high of 98.5°F.

to a low of 93.7°F. These occurred with simultaneous ambient temperatures of 35°F. and 5°F. respectively. In general, the high body temperatures corresponded with the high ambient temperatures and the lower body temperatures with the low ambient temperatures. It appeared that ambient temperatures influenced the body temperature measurements. However, specific body temperature recordings did not always correspond with changes or with the trend in ambient temperature levels. This indicated possible alterations in body temperature due to other causes. Maximum air temperatures were recorded between 1:00 p.m. and 3:00 p.m. and the minimum between 4:30 p.m. and 7:30 a.m. These were also periods of highest and lowest body temperature measurements.

There were no detectable changes of body temperature with changes in behavior or activity, except in one case. The instrumented cow elk was cornered in deep snow and was forced to alter her course of travel. Although there was little increase in physical exertion, the animal appeared nervous and agitated. Over a half-hour period, body temperature rose from 95.3°F. to 97°F. with only an accompanying 3°F. rise in ambient temperature. This was from 24°F. to 27°F. and was measured in close proximity to the elk. The body-temperature rise started at the time the elk's path was blocked and she was frustrated in her attempts to continue on her course of travel. Although a single such example is insufficient for drawing conclusions, it does suggest that additional research might reveal that certain types of animal behavior can be correlated with slight changes in body temperature. It is quite possible that daily temperature rhythms can be measured at a distance through telemetry and correlated with daily activity patterns. Possibly, seasonal changes in daily activity patterns may also be

detected and measured in this way. Daily temperature rhythms could have been exhibited during this experiment but they were obscured by the influence of varying ambient temperatures. Through observation made possible by radiotracking, we have determined twenty-four hour activity peaks and lows for individual elk. These generally correspond with the high and low body temperature fluctuations obtained during this experiment.

In this experiment body temperatures were telemetered over a maximum distance of one mile. The instrumented animal did not roam farther. Receiving equipment consisted of a portable, hand-held receiver with loop antenna. Tests with the body-temperature transmitter have resulted in good reception over a distance of ten miles with a 3-element yagi or portable quad antenna. We experienced no difficulties with the implanted probe being pulled loose. With further perfection of techniques, it appears feasible to telemeter body-temperature over distances of many miles and for extended periods of time from free roaming elk.

Body-temperatures were recorded in the field by counting pulses per minute and converting by means of a pulse rate - versus temperature curve. Automatic chart recording is feasible and would be desirable for longer periods of monitoring.

The results of this experiment were quite encouraging and indicate that this could prove to be a fruitful line of endeavor in studying animal behavior and in obtaining a better understanding of the animal's physiology and of "biological clocks".

ELECTROCARDIOGRAM

The electrocardiogram telemetering system developed and tested is a pulse frequency modulation system capable of telemetering EKG waveforms from free-roaming animals over a distance of several miles

(Table). The system consists of (1) a transmitter attached to the subject that is modulated with the EKG waveform to be monitored, (2) a receiver, (3) a discriminator which recovers the EKG waveform and (4) a display unit, which can be either a chart recorder or an oscilliscope. When pulse rate only is telemetered, the transmitter and receiver are all that is required.

The transmitter consists of a low frequency differential amplifier followed by two single-ended amplifier stages which drive an astable multivibrator. The electrocardiogram waveform is picked up by two electrodes attached to the subject and amplified by the high gain differential amplifier of the transmitter. The low frequency amplifier and transmitter units are attached to a 11" diameter metal loop, which acts both as a collar and a loop antenna.

The signal from the transmitter is picked up, amplified, and detected by the receiver. The pulse train from the receiver audio output is fed into the discriminator where it is shaped by a schmitt trigger and a monostable multivibrator so that the pulses have constant width and amplitude. The pulse train is then filtered to recover the EKG waveform from the subcarrier and displayed on an oscilloscope.

We have been using a Tektronix type 321A oscilloscope because it is highly portable and can be operated from batteries. It is, thus, quite suitable for field work.

An EKG transmitter suitable for use on wild animals was tested on humans on numerous occasions under a variety of conditions. These included subject's activities, such as running, climbing, exercising and resting. Pulse rate was monitored for nearly a 24 hour period. Good EKG waveforms were displayed on an oscilloscope under these

conditions over distances of ¼ mile. No attempt was made to obtain greater distance though this could readily have been done. The 1" X ½" electrodes were taped to the subject. For use on wild animals, the electrodes will have to be altered and probably implanted just under the skin. Experiments are being continued with the EKG system and changes and improvements will be made in the next model. Nevertheless, we have reached a point where the existing equipment can be used to instrument an elk and obtain an EKG waveform. Pulse rate can be readily monitored over 24 hour periods and correlated with activity. This will be our next step.

We appear to be well within reach of telemetering pulse rate and EKG waveforms from free roaming elk over distances of 3 to 5 miles. The same can be done with grizzlies but preferably under hibernating conditions. The following table summarizes the EKG system performance.

EKG SYSTEM PERFORMANCE SUMMARY

Transmitter

Frequency	32 Mc
Peak Output Power	80 mw
Pulse Width	1 msec
Duty Cycle	20%
Average Current Drain (9 volts)	6 ma
Estimated Battery Life	800 hrs. (7 Mallory RM1450R Cells)
Input Sensitivity	0.4 mv pk-pk for full subcarrier deviation
Common Mode Rejection	74 db

Overall System

Signal-to-noise ratio required for full quieting	16 db
Output voltage (into 10 K ohm load)	4 volts pk-pk
Frequency Response	5 - 40 cps

Estimated Ranges: System range under field conditions will depend strongly on the terrain and receiving antenna; the following estimates are based on average ranges obtained with the present tracking system:

	Loop Antenna	3 Element Yagi
1. Location only	1.5 miles	7 miles
2. Monitoring heart rate by changes in subcarrier tone (no discriminator)	1	5
3. Good quality recording of EKG waveform	0.5	3

IMPROVED TECHNIQUES AND EQUIPMENT ADVANCES

Some of the objectives pursued toward perfecting the bio-telemetry system were:

1. To develop and improve the directional properties of the tracking system.
2. To extend the transmitter battery life.
3. To develop new or revised antenna designs in order to obtain greater directional precision and better signal reception.
4. To improve the cold weather performance of the directional receivers.
5. To test field performance of the transmitter under very low temperature conditions.
6. To improve and test equipment for telemetering certain physiological information from free-roaming wild animals.

Receivers were made more durable and foolproof so they would stand up under rigorous field use and so they could be used by untrained personnel. Receiver sensitivity was increased and performance at low temperatures was improved. A new type of receiver was constructed with rechargeable nickel cadmium batteries. These batteries are operational for about 30 hours between charges.

Improvements were made in receiver performance. This was accomplished by:

1. Reducing the receiver noise figure.
2. Increasing overall sensitivity, which allows the receiver detector to operate further above threshold than was possible with earlier models.

It was found that the audio level of the modified Osborne

receivers was severely reduced by temperatures below freezing. This was caused by two effects:

1. Reduced output voltage of the carbon-zinc receiver batteries at low temperatures.
2. Changes in the bias current in the audio output stages.

The following steps were taken to improve the low temperature performance:

1. The batteries were placed on a long extension cord and connected to the receiver at the auxiliary power plug. This enabled the investigators to carry them in a pocket where they could be kept warm by body heat.
2. Two temperature compensating germanium diodes were placed in the base circuits of the output stage of the audio amplifier to stabilize the bias current in the transistors with changes in temperature.
3. An insulated box was constructed of polyurethane foam and heated with a naphtha-burning hand warmer. The receiver was carried in the box during extremely cold weather. The box proved useful but not essential as the circuit change resulted in satisfactory operation at 0° F.

Rechargeable nickel cadmium batteries will operate at lower temperatures than carbon zinc or mercury cells (down to 0°F.) and give better receiver operation in cold weather. Such batteries were incorporated in a new receiver and gave excellent performance and will be used in future receivers.

In order to increase transmitter life, extended life transmitters were developed and field tested on elk. The basic contin-

uously pulsing transmitter (originally used on grizzly bears with a life expectancy of 90 to 120 days) was altered by the addition of a keyer circuit that turns the transmitter on for ten seconds and off for twenty seconds.

The number of pulses that the transmitter gives during the on-period can be adjusted as desired to provide identification of individual animals. A 10 second on-period with a 100 ppm keyer results in 16 pulses. Field tests have shown this to be satisfactory for tracking purposes. The number of pulses can be increased if desired, although battery life will be reduced somewhat.

A revealing field test of this transmitter was provided when three grizzlies were simultaneously monitored and one tracked and jumped. Two were instrumented with the extended life transmitters and one with a regular transmitter pulsed at 80/min. Grizzlies #194 and #210 each had an extended life transmitter and at the time were bedded down about ½ mile apart. All three signals came in on the portable receiver. By careful adjusting of the BFO, it was possible to change the signal pitch thus emphasizing one signal and for practical purposes largely eliminating the others. We moved in on #210 and jumped him in his bed from a distance of 150 feet. Similar performances were repeated on quite a few occasions. The signals are easier to identify if there is a difference of at least five pulses during the ON period.

Since there is no battery drain during the off-period, the life expectancy of these transmitters was increased to nearly one year. The longevity over the continuously pulsing transmitter was thus increased by about 9 months. Use of these transmitters provides continuous monitoring for a period of one year and thus greatly extends the capabilities of the system and offers opportunities for a wide scope of studies.

The short interval, or off-period, of 20 seconds between on-periods of 10 seconds has proved to be more satisfactory in most field work than the longer off-period of 15 minutes and on-period of 3 minutes obtained with Accutron timer transmitters. In addition, the cost of the transistor timer circuit is substantially less than that of the Accutron timers.

A second method used to increase transmitter life was the development of long-life transmitters controlled by Accutron timers. By controlling the on-off period of the pulsed transmitters, it was possible to extend the life of a single transmitter and battery pack to a year or more. One transmitter with Accutron timer was set to transmit for three minutes every half hour and two others were set to transmit for three minutes every fifteen minutes. All three were used effectively on elk. None were tried on grizzlies because of the expensive timer used ($196). The chance of recovery and reuse was far greater with elk. The transmitters with the shorter off-period of 15 minutes were more practical for field use.

The field life of the regular, continuously pulsed transmitters with the mercury cell battery packs was increased from 74 days (obtained with grizzlies) to 110 days on an elk. The longer life was obtained by better battery packaging and by coating the battery packs with Silastic and with paraffin.

It was found that proper operation of the sense antenna on the portable receivers depends on the direction of the loop winding; that is, whether the winding is clockwise or counterclockwise. When differently wound loops were used on the same receiver, the direction of strongest or weakest signal was reversed. This had presented a disturbing if not serious field problem. The loop antennas of the various receivers had, in the past, been freely interchanged. Thus, unknowingly, the sense antennas could be

reversed and a 180° ambiguity result.

A cubex quad antenna was used to track grizzlies in 1964 because its reception compared favorably with the three-element yagi antenna, yet it could be readily dismantled and carried on a back pack. A second cubex quad antenna (27 mc) was altered for 32mc reception and was used to track both elk and grizzlies during the 1965 field season. It was also altered so that it could be readily taken apart and put together for portable use in back country. The wire elements were reduced and were made from No. 20 stranded copper insulated wire. One and one-half inch high-gear clamps were used to fasten the fiberglas rods to the metal spiders.

Tests were conducted on the automatic recording of data using tape recorders and oscilloscope. Both methods show promise and will be incorporated into the overall biotelemetry system.

Improvements were made in the packaging or potting of the transmitter collars. Fiberglasing the collars to make them shockproof and waterproof and then later encasing in plastic hose were time consuming steps. Consequently, a rubber mold was prepared for pouring a fiberglas resin or other plastic coating around the transmitter; thus greatly reducing the time needed to prepare a finished collar. Results are promising but an optimum plastic is still being sought.

For some aspects of behavioral studies it is desirable to be able to record animal sounds and calls from a distance. To facilitate this a 27 mc citizens' band voice transmitter was further perfected and tested. This can be placed miles from a receiving station and set so as to pick up and transmit the calls or noises of various species of birds or mammals. Field tests with this are still in progress. Animal calls have been received and tape recorded from a distance. At the same time ambient temperatures have been recorded and correlated with animal activity.

The development of a load switching antenna system and body temperature and EKG transmitters are treated in other sections.

BIRD TRANSMITTERS

A logical step to increase the capability of our bio-telemetry system was to develop transmitters suitable for use in studying large birds. Transmitters operating at a higher frequency than the 32.02 MC of our grizzly bear and elk transmitters have advantages. However, this would have entailed the development of a separate system complete with transmitters, receivers and antennas. The transmitters, therefore, have been designed to integrate with our present system and are on the same frequency with a power output of approximately 90 MW. The initial purpose of developing these transmitters is to use them on golden eagles. Ultimately, we hope that radio-monitoring of golden eagles, beside providing ecological information will aid in studying the effects of pesticides on golden eagle reproduction and survival.

A number of transmitters were constructed and tested and were modifications of circuits described by others. The basic unit is a one stage crystal controlled, pulsing oscillator (squeegee-type). It weighs 36 grams including three button-type batteries and leather mounting pad for attachment. The range of this transmitter can be increased by addition of an amplifier stage and the life extended by use of more powerful batteries.

The life with 3 mercury batteries (1.4 volts) in parallel is estimated to be from 30 to 60 days. Two types of antennas were tried. One was a wire loop that has been successfully used by others but has the disadvantage of encircling the body of the bird. The other was a 10½" whip of steel banjo wire. It was coupled to the circuit through a small disc condenser and reinforced at the stress point of attachment.

One innovation was that we attached the transmitter with whip antenna to the tarsus of the bird. The antenna protruded horizontally from the rear of the bird when in a perched position. It was attached with leather straps that were constructed as an integral part of the

transmitter.

Distance checks were run on the transmitters and a good signal was picked up from the transmitters with both whip and loop antennas at a distance of 1¼ miles over level ground and through heavy timber. Our base station antenna was used for receiving. A great horned owl and a golden eagle were instrumented to check the birds' reactions and behavior with leg attachment.

It is desirable to take more accurate bearings when locating birds at a distance than can be obtained with a single 3-element yagi antenna. Accordingly a lobe switching system was designed that uses two yagi antennas to obtain both high resolution and high gain. Two antennas were mounted on a common crossmember and skewed slightly so that their patterns overlap. The receiver was electronically switched from one antenna to the other so when the antenna was rotated slightly, the signal from one of the antennas became weaker while the other became stronger. These signals were compared by a diplexer unit which (in conjunction with a receiver) generates a 1 KC audio tone that nulls when the two signals are equal and increases when they are unequal.

Field tests were conducted with this array. Nulls were quite pronounced and bearings more accurat e than those taken with the three-element antennas.

Suitable transmitters and receiving antenna for tracking golden eagles were thus designed and tested. Further testing on trained birds is needed. This will be followed by instrumenting of fledgling eagles at nests. Improvements in design will be made as indicated by field performance.

COOPERATION AND COLLABORATION

Cooperating and supporting agencies include the National Geographic Society, National Science Foundation, Philco Corporation, U. S. Fish And Wildlife Service, National Park Service, Environmental Research Insittute 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.

The biotelemetry equipment has been designed and constructed by Philco engineer, Joel Varney. Hoke Franciscus has worked on the construction of bird transmitters and other devices. Bob Ruff and Sid Dunkel have assisted in field work as well as the following students: Jack Seidensticker, Jay Sumner, Lance Craighead, Ralph Jingu and Harry Reynolds.

CONCLUSIONS AND FUTURE WORK

We are gradually improving and extending the capability of a bio-telemetry system for simultaneously studying wild animals, their environment and certain aspects of animal physiology. There is, of course, need for continuing equipment and technique development and perfection. We hope to continue with this over the forthcoming years.

An exciting advance was made in the telemetering of body temperature from a free-roaming, wild elk. This has tremendous potential for studying animal behavior and for relating physiological data to animal activities and to environmental conditions.

Major hurdles have been passed in the telemetering of EKG waveforms and pulse rate from wild animals over long distances. This objective should be attained within the next year.

When we can successfully telemeter both body-temperature and EKG from wild animals we will be in a position to instrument and study hibernating grizzlies or black bear. The development of repeater stations and solar panels for recharging batteries will be necessary. These are already in the early development stages. The information that can be obtained in this way from hibernating bear may have practical application for man. The ability to slow down body activities comparable to a hibernating bear has application in space travel, medicine, world food consumption, research on aging and im many other ways.

There is a wide open field for the use of currently developed bio-telemetry methods and equipment in the study of a variety of animals and environments. Only slight modifications are needed to adapt the system to different species or conditions. We plan to continue our biotelemetry research and may try the system on black bear, mountain sheep and Kodiak bear. We also hope to make arrangements so other scientists can use the bio-telemetry system to gather specific data they seek in their own ecological studies. A first attempt at this may be our effort to instrument and track Kodiak bear in cooperation with the Alaska Wildlife Refuge Division of the U. S. Fish and Wildlife Service.

List of Illustrations

1. Isolated location of den site of grizzly #202. The X in blue circle shows position of den beneath perpendicular cliffs of Yellowstone Canyon.

2. Light spot in circle is grizzly #202 at entrance to his den. Picture was taken from observation point above shown in illustration #3. Steep avalanche slope can be seen beyond bear and sloping steeply toward river below.

3. Observing #202 from point where bear and den were sighted. A bearing from this station with portable receiver intersected bearing from across indentation in canyon rim. The second position is shown in illustration #4. The bearings intersected below canyon rim where bear was finally located. Unusual difficulty was experienced in tracking this grizzly to his den. The signal tended to draw us to the canyon rim but once on the rim we obtained a strong signal bounced from the opposite canyon wall. This gave us a false bearing in that direction and at nearly right angles to our former course.

4. Looking down on den site of #202 from south rim of Yellowstone Canyon.

5. Den of #40, November 3, 1964, showing scattering of dirt pulled out of the den just prior to hibernating. Den entrance at base of tree is typical of most grizzly dens located.

6. Bough bed within the den of grizzly #40.