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A RADIO TELEMETRY SYSTEM FOR ELK:
ITS USE AND EFFICIENCY

By

Jeffrey W. Denton

B.S., University of Montana, 1971

Presented in partial fulfillment
of the requirements for the degree of
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CHAPTER I

INTRODUCTION

Biotelemetry is rapidly becoming useful in gathering large quantities of data otherwise nearly impossible to obtain. Radio components are being engineered more efficiently for multipurpose field use. Large and often mobile animals can be pinpointed, monitored, and followed at a distance. Telemetry allows biologists to work directly with animals instead of the apparent presence of animals. Knowing when an animal is in a given location gives insight into migrations, home ranges, habitat use, and a multiplicity of factors related to animal ecology.

A technique cannot be used to its fullest extent until its limitations and capabilities are understood. This thesis deals with limitations and capabilities of a telemetry system used in investigations of Rocky Mountain elk (*Cervus canadensis nelsoni*) ecology in the northern Sapphire Mountains of Western Montana. The system is described for aerial and ground telemetry. Mountainous terrain presents special problems, and this study establishes guidelines for future studies in such terrain.

Animal welfare and observability, observer welfare, factors affecting accuracy of radio locations, equipment use and problems, accuracy and expected results, and human influences as they relate to the telemetry system are considered.

This study was conducted as a part of the Sapphire Elk Ecology Study which is part of the Cooperative Elk-Logging Study involving the School of Forestry, University of Montana; Montana Fish and Game Department; Intermountain Forest and Range Experiment Station, Region I, United States Forest Service; and the Bureau of Land Management.

CHAPTER II

STUDY AREA

Location

The study area lies in the Sapphire Mountains between the Bitterroot and Rock Creek Valleys in parts of Missoula, Ravalli, and Granite Counties, Montana. Ground telemetry work was restricted to that area between Ambrose Creek and Spring Gulch on the Threemile Game Range west of the Bitterroot Divide (Fig. 1). Aerial telemetry work was carried out in the region north of Ambrose Creek to the Clark's Fork River, and from the foothills on the west side of the Sapphire Mountains east to Rock Creek, including the drainages between Butte Cabin Creek and Ranch Creek across Rock Creek (Fig. 1).

Physiography

Topography varies from gently rolling foothills on the east side of the Bitterroot Valley to moderate and steep slopes in the mountains near the Bitterroot Divide. East of the Bitterroot Divide and east of Rock Creek, the mountains are characterized by deep, moderate-to-steep-walled drainages and gently sloping ridgetops. Elevation varies from 4,000 to 8,000 feet.

Climate

The climate of the area is typical of Western Montana, which is under the influence of the Pacific weather regime. Long cool winters

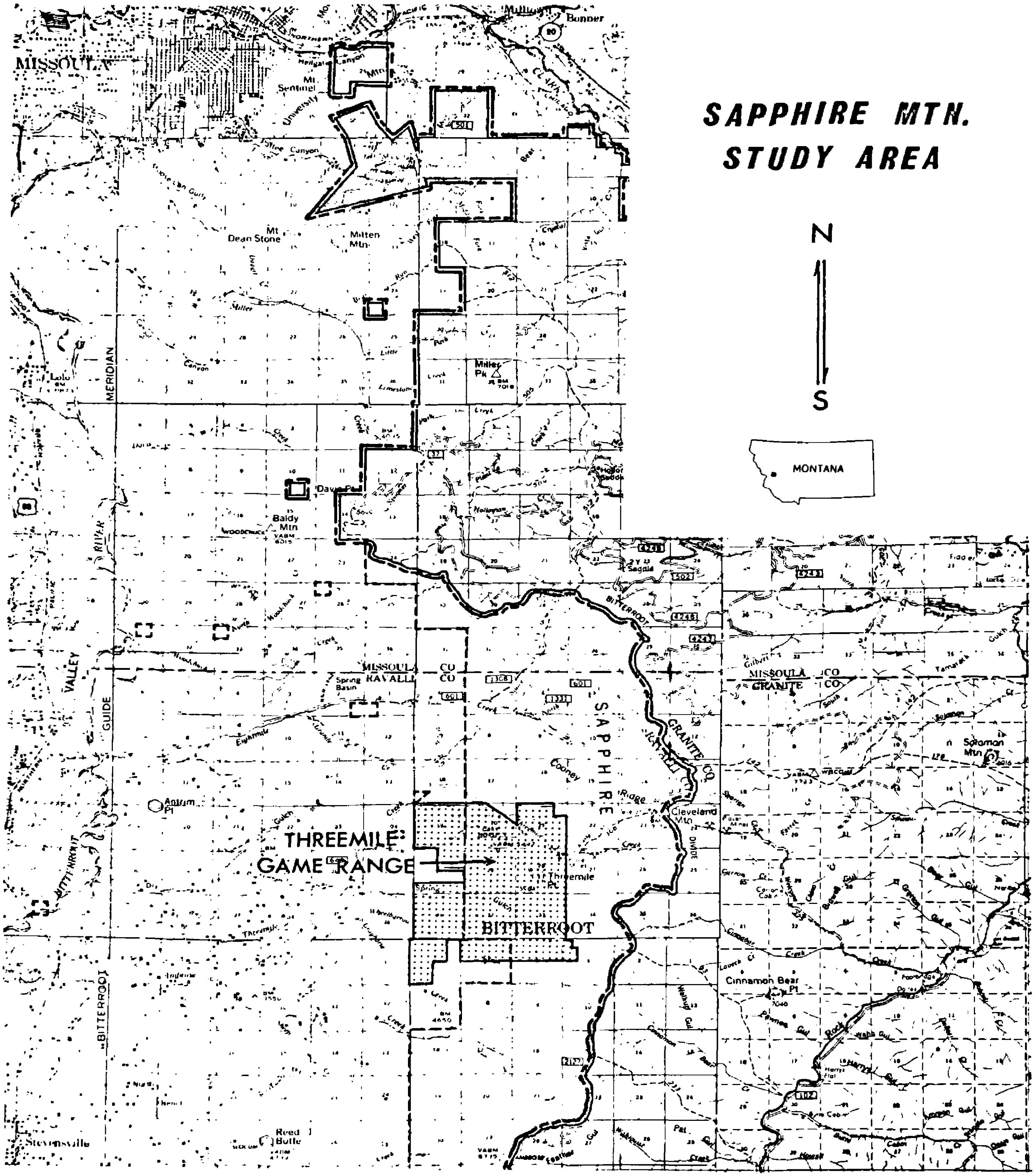

Fig. 1.--Location of study areas in Sapphire Mountains of western Montana.

and short hot summers occur with a major precipitation period in May and June and a minor period in September. Convection thunderstorms occur during July and August (National Weather Service, pers. comm.).

Weather data were recorded by the National Weather Service in Stevensville and Missoula, Montana. Both stations are adjacent to, but 2,500-2,600 feet lower than, the study area. Temperatures may be cooler at higher elevations since shaded areas on the Bitterroot Divide averaged 16° F. below the July through September Stevensville temperatures (Stehn 1973). Frequent temperature inversions further confuse the validity of the Weather Service data for the study area. Fifty-eight year normals are presented in Table 1.

Vegetation

Four major habitat types are present on the study area. Interspersed among these are several minor types. Three of the four major habitat types are forests; the fourth is grassland. Nomenclature of species follows Hitchcock et al. (1965-1969). Major habitat types were described by Pfister et al. (1972).

Areas characterized by coniferous trees are classified as forest types. The three major types are: ponderosa pine (Pinus ponderosa), Douglas-fir (Pseudotsuga menziesii), and subalpine fir (Abies lasiocarpa). All types contain a variety of forbs, grasses, grasslike plants, and shrubs that vary from site-specific to nearly ubiquitous.

Ponderosa pine types occur between 4,000 and 5,000 feet elevation. Common major understory vegetation on north slopes and moist sites consists of snowberry (Symphoricarpos albus) and white spiraea (Spiraea betulifolia). Idaho fescue (Festuca idahoensis)

Table 1.--Weather data from Stevensville and Missoula stations of the National Weather Service, based on the past fifty-eight years[a]

	Stevensville	Missoula
Elevation	3,370 ft.	3,210 ft.
Mean normal annual precipitation	12.64 in.	12.83 in.
Normal annual temp.	44.5°F.	55.9°F.
Annual temp. range		
Maximum	94°F.[b]	105°F. in early Aug.
Minimum	-24°F.[b]	-33°F. in Dec. & Jan.
Wettest months mean precipitation		
May	1.52 in.	1.87 in.
June	1.73 in.	1.91 in.
Driest month mean precipitation		
August	0.69 in.	0.72 in.
Hottest month (July)		
Mean temp.	64.5°F.	67.0°F.
Mean high	. . .	85.0°F.
Mean low	. . .	49.0°F.
Coldest month (Jan.)		
Mean monthly temp.	23.0°F.	19.2°F.

[a] From Climatological Data for Montana, Annual Summary, 1972. Dept. of Comm., National Oceanic and Atmospheric Administration, Environmental Data Service. Vol. 75, No. 13. 17pp.

[b] 1972 data only.

dominates dry northwest, west, south and east slope understory vegetation. Arrowleaf balsamroot (*Balsamorrhiza sagittata*) occurs with bluebunch wheatgrass (*Agropyron spicatum*) as understory dominants on xeric lower elevations (around 4,500 feet).

The Douglas-fir type occurs between 4,000 and 7,000 feet elevation. Ponderosa pine and lodgepole pine (*Pinus contorta*) are seral dominants in lower and upper elevations of this type, respectively. Lower reaches contain bunchgrass-dominated openings on cool, dry south to northwest slopes while pinegrass (*Calamagrostis rubescens*) and elk sedge (*Carex geyeri*) dominate the timber understory. Upper reaches are characterized by kinnikinnick (*Arctostaphylos uva-ursi*) or snowberry. On mesic northeastern slopes, below 6,000 feet, ninebark (*Physocarpus malvaceus*) and ocean spray (*Holodiscus discolor*)are found. Beargrass (*Xerophyllum tenax*), and thinleaf huckleberry (*Vaccinium membranaceum*) are found on the most mesic sites on all slopes with the exception of the northeast aspects between 5,000 and 6,500 feet.

Subalpine fir types are present from 5,500 to 8,000 feet. Few mature stands are present, but seedlings occur under seral lodgepole pine on all aspects. Beargrass, thinleaf huckleberry, and grouse whortleberry (*Vaccinium scoparium*) characterize the understory. Smooth menziesia (*Menziesia ferruginea*) is abundant in north slope understory vegetation.

The grassland type occuring below 4,000 feet is generally a disclimax of cheatgrass (*Bromus tectorum*). It is similar to Daubenmire's (1970) description of Palouse grassland. This grass-forb type varies from single species dominance to bunch grass dominance.

Other communities exist throughout the area. Riparian shrub vegetation consists of various mixtures of mountain maple (Acer glabrum), chokecherry (Prunus virginiana), western serviceberry (Amelanchier alnifolia), red dogwood (Cornus stolonifera), and quaking aspen (Populus tremuloides). The latter also occurs infrequently between Douglas-fir and ponderosa pine types. These shrubs also occur on shrub-dominated clearcuts with wild currant (Ribes lacustre), black elderberry (Sambucus racemosa), and Scouler willow (Salix scouleriana). Riparian meadow vegetation is composed of sedges (Carex spp.), redtop (Agrostis alba), and Kentucky bluegrass (Poa pratensis). In addition to shrubs, clearcuts may contain conifer seedlings and thimbleberry (Rubus parviflorus) on north slopes. Depending on their age, south facing clearcuts contain sedges (Carex spp.), pinegrass, beargrass, arnica (Arnica latifolia) and fireweed (Epilobium spp.). Some clearcuts and logging road edges have been seeded with orchard grass (Dactylis glomerata), and timothy (Phleum pratense). Western larch (Larix occidentalis) occurs sporadically on north slopes at high and low elevations as a seral species.

CHAPTER III

MATERIALS

Transmitter Collars and Collar Construction

Sixteen transmitters, operating in the 150 MHZ range, were used; seven in 1971 and ten in 1972. One of those used in 1971 was recovered, rebuilt, and used in 1972. Three 1971 and three 1972 collars, purchased from Davidson Electronics, were preassembled, potted in acrylic, and ready to place on elk. The remaining four used in 1971, and seven transmitters used in 1972, designed by Cochran (no date), and purchased from AVM Instrument, were preassembled. Attaching batteries and potting these transmitters was done at the School of Forestry, University of Montana.

Transmitters were wired to antennas, diodes, and four, 1.35 volt Mallory ZM12 mercury batteries (Fig. 2). The single batteries of two pairs were connected in series, while the two pairs were connected in parallel giving 2.7 volts of power (Fig. 2). Such assemblies were attached with wire or tape to 0.13 x 0.50 x 36 inch nylon bands. Ends of the nylon bands overlapped, allowing riveting when the collars were put on animals. The ends were taped together forming a circle and checked for fit in a rubber collar mold (Fig. 3). Transmitters and accompanying batteries were then dipped in molten beeswax four or five times, allowing complete cooling between dippings. Air pockets in the wax were collapsed and filled with wax to insure waterproofing of batteries and electrical connections. Rubber molds were sprayed with

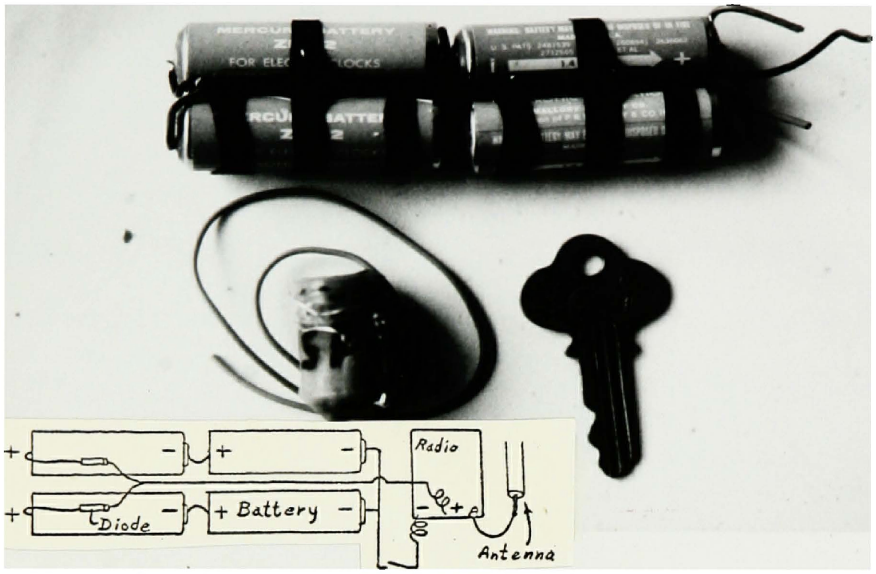

Fig. 2.--Transmitter and battery pack for radio collars. Insert: Schematic of transmitter package wiring. Photo by Robert C. Beall.

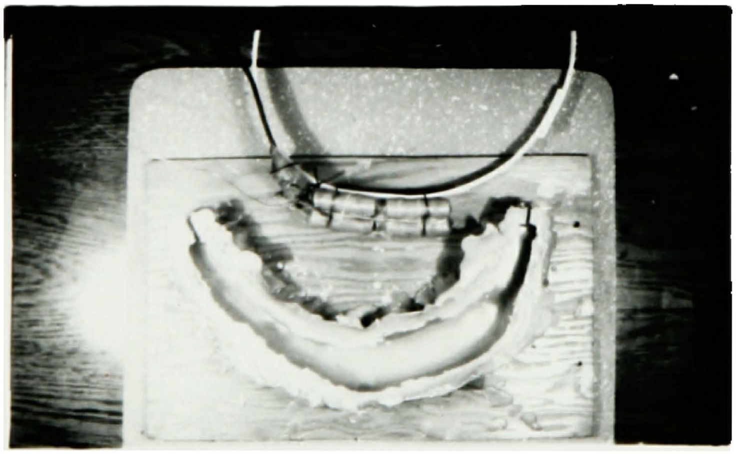

Fig. 3.--Nylon band and attached transmitter package ready for fitting in rubber collar mold.

silicone to prevent sticking, and a 0.25 inch layer of acrylic was poured in and allowed to harden. The wax covered assemblies were then placed in the mold.

Since acrylic becomes hot while curing, the acrylic was mixed to the consistency of thick cream and poured over the transmitter assemblies three times to protect the wax coating on the transmitter package. Each layer was allowed to harden and cool completely before the next layer was applied. This required preparation of three 0.25-0.50 cup batches of acrylic, but allowed heat dissipation from the thin layers and prevented heat buildup and melting of the wax.

Acrylic plugs were spaced to leave a gap in each collar which served as a hinge. This spacing of plugs also allowed the ends of the nylon to protrude when the rest of the mold was filled with acrylic (Fig. 4a). A two part mold gave the same results (Fig. 4b). Acrylic was allowed to reach a soft putty stage for plugs. At that point, acrylic was mixed to the consistency of thick whipping cream and poured into the remaining empty mold space either in layers or all at once. The application was done as described above. Heat would cause a bubbling in the new layer thus weakening the collar. The antenna was embedded in the acrylic alongside the nylon band. Two wire leads completing the transmitter circuit were left protruding outside the acrylic. After the collar was removed from the mold, it was sometimes necessary to add putty-consistency acrylic to thin spots in the collar and around the transmitter. Rough spots were filed off to insure the comfort of the animal. Completed collars (Fig. 5) weighed 2-3 pounds.

The tapes holding the protruding ends of nylon bands were removed when collars were placed on the animals. The two free ends

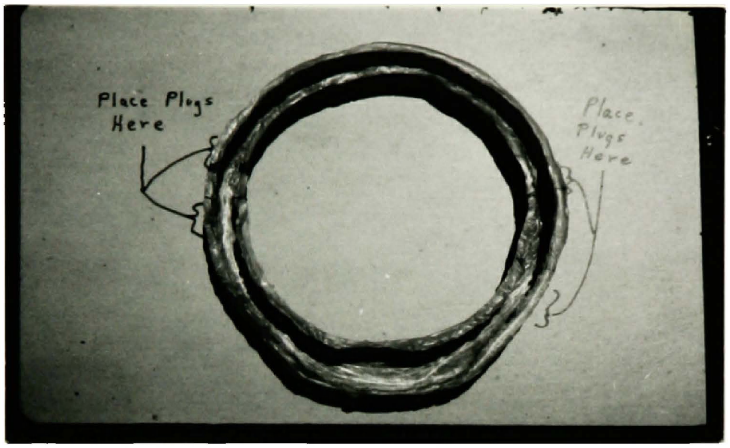

Fig. 4a.--Rubber mold illustrating placement of acrylic plugs to provide area for hinge and rivet area.

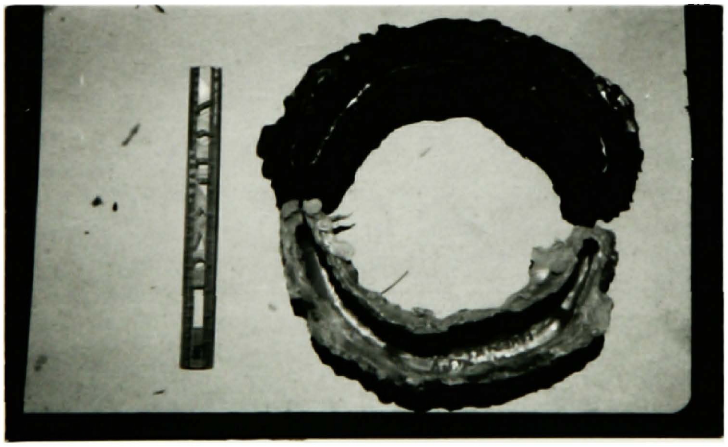

Fig. 4b.--Two-part rubber mold requiring no acrylic plugs.

and the hinge allowed placement of a collar on an animal's neck without having to slip it over the head (Fig. 6). The nylon ends were then riveted and wires initiating radio function connected and soldered. The hinge gap, rivet gap, and wire were filled and covered with putty consistency acrylic. If acrylic was too thin, a weak joint resulted, as in the case of elk A (Ream et al. 1972). In cold weather, curing was accelerated by contact with one's hands (Ibid.).

Trapping and Tagging Elk

In the winters of 1971 and 1972, seven and nine elk respectively, were trapped, tagged, and radio collared by Robert Beall using a corral trap and bait as described by Ream et al. (1971). Four-inch wide collars, made of conveyor belt material with nylon color strips sewed to them, were also put on most radioed animals for identification.

Receiver Systems

A double-whip dipole antenna system with a right-left, signal directional switch designed for fixed-wing aircraft was used (Craighead et al. 1971b). A model LA 11-S portable receiver (Cochran, no date) was used in conjunction with the antenna system and earphones (Fig. 7a). The particular receiver used for most of the flights had a variable resistor that didn't zero out completely. When the gain (volume) setting was at zero, the signal would nearly overload when within a radius of 200 yards from a transmitter. Other receivers of the same model were used with equal success, but greater manipulation of the gain control was required. Cessna 182 fixed-wing aircraft and pilots were supplied by Johnson Flying Service, Missoula, Mon-

Fig. 5.--A completed collar.

Fig. 6.--A completed collar showing how it opens to fit on an animal's neck.

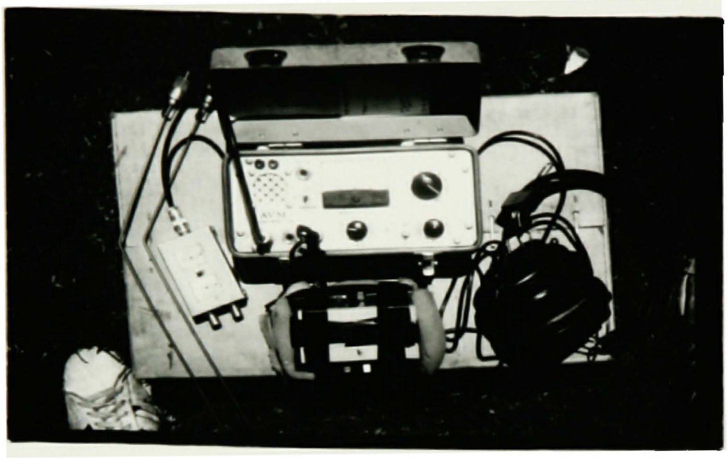

Fig. 7a.--From left to right: antennas, directional switchbox, receiver, battery pack and earphones used in aerial tracking.

Fig. 7b.--Antennas installed on permanent attachments on Cessna 182 aircraft.

tana. In 1971, a Forest Service plane and pilot were used part of the time. In 1972, one plane was equipped with permanent antenna connections and leads (Fig. 7b). When this plane was not available, antennas were mounted on brackets designed for external attachment to the Cessna 182 landing gear (Craighead et al. 1971b). Copper scouring pads were used to insure adequate connection between brackets and fuselage (Fig. 8). Paint was scraped off rivets on the fuselage to provide bare metal contacts with the scouring pads.

Acetone, a toothbrush, pipe cleaners, and paper towels were used periodically to clean all electrical connections.

Ground telemetry work utilized the same type of portable receiver with an eight-element Yagi antenna on a 10 foot mast (Fig. 9). A base plate, marked in compass degrees, was read using an indicator attached to the mast, parallel to the longitudinal direction of the Yagi antenna. This system was oriented to the location of two known, stationary transmitters. A Silva hand compass was used to further check orientation and azimuth bearings.

Other Equipment

Aerial photographs were used to plot locations from aircraft and for ground work. One data sheet per flight was used to record data and a field notebook was used for any notes thought important.

Transmitters were similar to those described above. Two radio collars were used. Tom Stehn manned the receiver stations because of previous experience in their use. One person was required to move the transmitters from point to point. One data sheet was needed by the receiver man and one by the man hiking or travelling by truck with the transmitters.

Fig. 8.--Antenna bracket mount on Cessna 182 showing positioning of copper scouring pad.

Fig. 9.--Eight element Yagi for ground telemetry.

CHAPTER IV

METHODS

Aerial Telemetry

Aerial telemetry work was undertaken from 27 May to 1 December 1972. Similar work was completed by C.L. Marcum from 8 June to 1 December of the previous year.

In 1971, flights were attempted every three days. In 1972, flights were made every day possible in June, every third day in July through October, and tri-weekly in November. Weather and availability of planes and pilots caused some deviation from this format. Each flight was designed to locate all radioed elk, or as many as possible. Elk locations were noted as follows: date, time of day, visual (actual sighting of the radioed animal), approximation (location without visual sighting of the animal), observed behavior of the animal(s), composition of the animal groups seen (bulls, cows, calves), name of drainage, amount of overstory cover, and aerial photograph number. Some of these data are being used in other portions of the Sapphire Study.

First flights were trial and error education flights to allow familiarization with equipment, topography of the study area, and development of searching technique. Tutoring by C.L. Marcum and further in-flight experience led to a direct-line-circling search method in preference to a decreasing size rectangular search. Searching consisted of four phases: (1) initial signal reception, (2) approaching the signal source, (3) locating the signal source in a central area by circling, and (4) narrowing the location by decreasing circle size with intent to observe the animal. These will be fully discussed in Chapter V.

The location of visually observed animals were plotted as accurately as possible on aerial photographs. Approximate locations were, to the best of our ability, plotted as circles within which the transmitters were located. Experience showed that the less material an observer had to handle in-flight, the better; therefore, data were recorded on the photos in-flight and transferred to data sheets afterward. Photo locations were transferred to acetate photo overlays to avoid the cluttering of photos.

Distance from the signal source to where it was first received was recorded as searches were made. Hand signals and special flight patterns resulting from dangerous topographic features were qualitatively noted after the flight was completed.

Equipment problems affecting observations were described as they occurred, or were solved. These included receiver problems, aircraft trouble, and transmitter malfunction. Performance of equipment was noted as to transmitter and battery pack longevity.

Transmitter pulse rates differed from animal to animal. Ease of search was described for relative pulse rates: slow (less than 60 pulses per minute), moderate 60-100 pulses per minute, and fast (100+ pulses per minute). This was noted during the flights.

In-flight interviews with pilots were conducted to gather data on altitudes, circle diameters, and difficulty of search phases. Attitudes toward early morning flying, mountain flying, and elk studies in general were "felt out."

Adverse weather conditions sometimes caused aborted or partially completed flights. Weather was noted when it affected observability of animals or upset flight format.

Flights were made at different times of day as spring progressed to summer and fall. Flights were generally made from 0.50 hours before to 2 hours after sunrise and from 2 hours before to 0.50 hours after sunset. These times coincide with the two major feeding periods of elk (Altman 1952; Murie 1951; Stehn 1973). Spring and fall flights were made during either morning or evenings. Summer flights were morning flights only.

Records of passengers, their ability to withstand the rigor of this type of flying, and their contribution to the observations were made.

Behavior of visually-located elk was recorded as running, travelling (walking), standing, feeding, or bedded. Changes in behavior from the first time the animal(s) were seen to the time the plane left the area were also recorded.

Visibility of animals depended upon the density of overstory vegetation and background color. Relative cover estimates were made from the plane, based on optical judgement and difficulty in seeing the ground beneath the canopy. These were noted as heavy (Fig. 10), moderate (Fig. 11), and open timber (Fig. 12) (includes grassland and clearcuts). Photo overlay grids were used to check flight cover judgements. Snow cover was noted when present. Observability of animals was described for light conditions and times of day that facilitated or hindered observation.

Fig. 10.--Typical heavy timber-relative habitat cover rating.

Fig. 11.--Typical moderate timber-relative habitat cover rating.

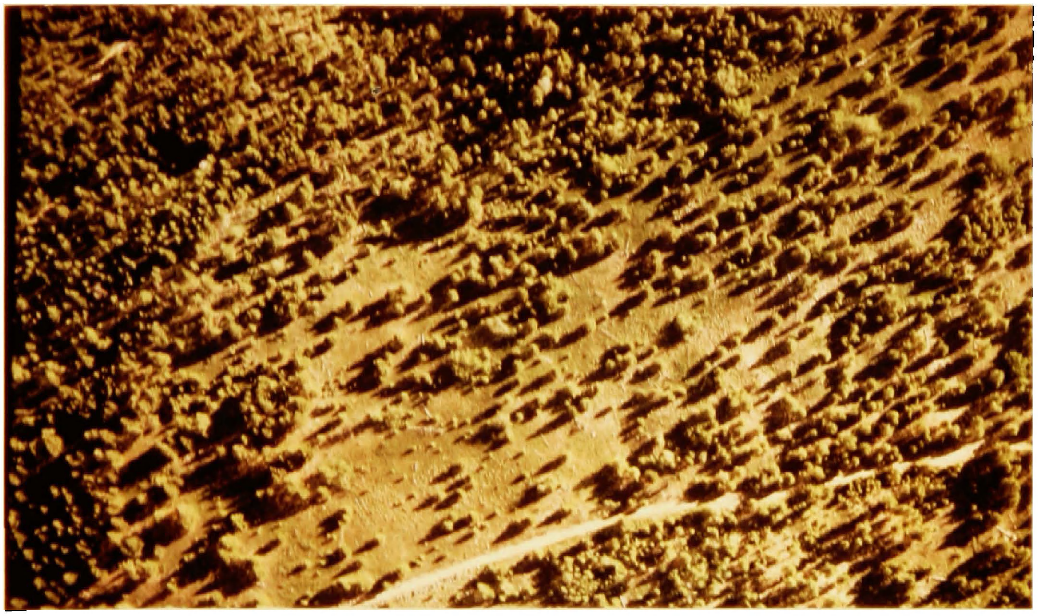

Fig. 12.--Typical open timber-relative habitat cover rating.

Experience showed that a certain number of locations are needed for the observer to learn the use of equipment and for the pilots, who had not flown the elk study previously, to learn the required flying patterns. These were noted when "new" pilots were used, and while I was learning to use the equipment.

While flying to locate radioed animals, other elk or groups of elk were sometimes seen isolated from, or within the vicinity of radioed animals, but not with them. Such observations were also recorded.

In many cases animals were located by approximation and seen upon further search. Both approximate and visual locations were recorded to test accuracy of approximations. If a transmitter was within the approximation circle, it was termed a successful trial. Transmitters were also placed in unknown locations by co-workers and approximated by aerial telemetry. All these approximate locations were transferred using a Vertical Sketchmaster, checked with a Map-o-Graph (Artograph Co.), and areas calculated with the aid of a Dietz polar planimeter.

Ground Telemetry

Ground telemetry field work began 1 July 1972. This part of the study tested the accuracy of azimuth bearings in mountainous and flat-to-rolling terrain. A number of random points were located on aerial photographs as they were visited on the ground by a person with transmitters. At each point, two transmitters, one with a steady signal and one with a pulse rate of 80/minute were hung four feet above the ground facing north-northeast. Azimuth bearings were taken by a man at a receiver station on a high point in the area. Received signals are strongest when the open end of the Yagi antenna is pointed directly at a transmitter location. Distinct nulls occur 30-40 degrees off center of the strongest signal. The mean between the two nulls is considered the bearing to the nearest degree. This is the same method described by Stehn (1973) and is similar to methods used by Slade et al. (1965). Anderson (1971) used higher hills for receiver stations in a riverine forest monkey study. Tester et al. (1964) used 80-100 foot antenna towers.

Signals, too indistinct to provide bearings, were termed unsuccessful, as were random points whose exact location on aerial photos were questionable. Walkie-talkies were used to synchronize bearing readings with stops at random points. Bearings, time and any other pertinent notes were recorded by the receiver man. The transmitter man recorded time, topography, cover, and activity of transmitters. A pickup truck was used to travel from point to point in roaded areas. Hiking 0-4 minutes in a random direction from the vehicle maintained randomness. In inaccessible areas hiking for fifteen minute intervals in a random direction between points maintained randomness. To eliminate bearing bias on the part of the receiver man, at least one transmitter was periodically shut off, separated from the other by a long distance, or put into motion by walking with it. Walking with transmitters was also used to test receiver personnel's ability to recognize change of activity. Verts (1963) was able to discern gaits of skunks by audible signal.

CHAPTER V

RESULTS AND DISCUSSION

Aerial Telemetry

Aerial Search Methods

Direct-line-circling searching consists of four phases. The first is searching for and receiving a signal from a transmitter. Knowing the general area, drainage, or ridge an animal was on the previous flight, an observer can usually pick up the signal. Ranges of transmitter reception were usually not greater than five miles when searching over mountains. Ranges of ten miles were common when approaching along the foothills and when animals were west of the Bitterroot Divide. A maximum distance of twenty miles was recorded for one transmitter. This signal was received north of Lolo Peak in Lolo Canyon from a transmitter in the Threemile Creek drainage.

If a signal was not received, a systematic search was necessary. Flying along major divides, such as the Bitterroot Divide, allowed the observer to pick up signals from major drainages. Animals may move over twenty miles between flights, and thinking an animal may move a short distance between flights can bias an observer into searching too small an area.

If flying main divides did not yield a signal, increasing altitude from 1,000 feet above the ground to 1,500-2,000 feet above the ground avoids some of the signal blockage by topography in rough areas. Signals from deep canyons or steep slopes can be blocked by other ridges. North-south flight lines spaced about two miles apart allowed observers to search all such situations in the study area. If an animal was not found after ten minutes, all other animals were located and then search was continued for up to thirty minutes of the flight. If the animal was still not found, a search was made during the next flight. After three extensive search flights, a transmitter malfunction was assumed or that the animal traveled beyond the boundaries of our searches. Elk M and E serve as examples. These animals were periodically checked for every five flights after apparent signal loss. Usually phase one of the search took less than five minutes.

Phase two of the searching process consisted of homing in on the general area of the signal source. This took the observers to within 0.25 miles of the transmitter. Upon receiving the signal, the plane was oriented in the direction determined by equal signal strength on both sides of the plane. This oriented the plane directly away from or toward the signal source (Craighead et al. 1971b). If the signal weakened with distance, the direction was away from the transmitter. Turning 180 degrees corrected the situation. Flipping the signal directional switch every 1-2 seconds was a way of constantly checking the correct approach. Topography may, in the case of long distance approaches, momentarily block the signal. This was the case when approaching high ridges behind which the signal was emanating. The closer the transmitter location the louder was the signal. Continually decreasing the gain control allowed an observer to maintain signal strength discrimination. At the point where the strongest signal occurred at the lowest gain, the aircraft was within 0.25 to 0.13 mile of the animal. At this point the signal was sometimes slightly to one side of the plane, and plane speed was too fast to correct rapidly enough. If the signal nearly overloaded with equal strength on both sides of the aircraft, the animal was directly below the plane. A null signal should occur as one passes over the transmitter, but it was very difficult to distinguish. Altitude of this phase was usually the same as phase one.

Search phase three allowed an observer to encircle the target area. If search phase two went directly over the animal, search phase three was omitted. If the signal was to one side, a large 1,000-1,200 foot diameter circle was flown to try to completely contain the signal within it. Altitude above the ground was approximately 500 feet. If a portion of the circle had a strong signal on the outside, the circle was shifted in that direction. If a portion of the circle had a weak signal on the inside or both sides, the circle was shifted toward the outside at that portion. The latter situation often occurred when animals were in deep draws and the search circles were too near the head of the draw. The tendency of new observers was to circle prematurely, before signal strength was on low enough gain. Up to six circles were made in this search phase. If the signal was confusing after several circles, it was found helpful to fly a mile or two away from the area and make another approach.

Search phase four involved closing the circle down to a small (300-400 ft.) diameter circle, maintaining the signal inside. Usually, if topography permitted, this maneuver was performed between 200 and 300 feet above the ground for closer inspection of the surface below. During search phases three and four the plane circled to allow the observer's side of the plane to face the interior of the circle for observation purposes. Anywhere from zero to ten circles were required to see the animals. Some were not seen. When animals were spotted, the optimum situation was to observe them during the entire circle. An aircraft bank angle of 60 degrees and circles of the above description were usually adequate. Cover may be too thick, topography may not allow circling or may obscure animals from view for a portion of the circle, or pilots may not be able to fly in small enough circles.

Plotting locations may not be a simple matter for all persons. Aerial photographs should be in order before the flight. With experience, a person can learn which photos cover a certain area. It was found that eight of the more than thirty photos were used for the majority of locations. A map with photo centers plotted on it helps in unfamiliar areas. Plotting elk locations on photos is easily done for open areas where a few scattered trees serve as landmark references on the ground and on the photo. In patchy and heavy timber, ground characteristics like rockslides, roads, bends in draws, blowdowns, clearcuts, old fire lines, and rock outcrops are good photo reference landmarks. Often, one must gain altitude after a location to see landmarks and insure accurate plotting of locations. Up to three drops and gains in altitude may be necessary to accomplish this in unfamiliar or homogeneous appearing country and areas where many small drainages occur. With practice, animals can be located beside specific trees on the photos. In areas where man is constantly changing the appearance of the landscape on a large scale (i.e. logging), photos should be periodically updated. This is a factor that can confuse observers even on familiar areas. Three to five circles, in addition to phase four search are usually required to plot the location.

Hand signals to the pilots simply consisted of pointing and tilting one hand in the direction and bank the observer desired to go. The hand should be held at arms length in front of the observer to allow the pilot to see the hand and where he is flying with minimum effort. Verbal communication supplements hand signals.

Special Flight Patterns

Special flight patterns are necessary under a variety of conditions. Locations in and about canyons require special flight patterns. Deep draws with narrow walls were approached by dropping over a ridge into and down the canyon. Pilots preferred to approach these from the upper end, so that in case of trouble, one can coast out and down the canyon and possibly find a place to land. Approaching from the lower end requires maintained air speed and a steep climb at the head of the draw, which is dangerous. The former approach accomplishes two purposes: location of the transmitter in relation to the length of the canyon and lateral (which side or bottom) transmitter location. Open canyons can be circled at high altitudes for visual observation. Steep canyon location can only be observed for a few seconds during a single pass. Animals on such slopes are sometimes easier to spot, as the observer can see more ground surface through the trees from down in the canyon than from above. On steep mid-slope locations, circling was done to get visuals or close approximations, then passes were used for closer observation.

Flights along ridgetops establish the longitudinal and lateral locations much the same as canyon passes. Ridgetops can also be circled effectively.

Dense timber required locating an animal precisely "by instrument," then making passes over the spot "standing on a wing." This allowed looking directly between tree canopies perpendicularly at the ground below. This is done at low altitudes of 100-300 feet above the ground. Single passes in canyons, steep slopes, and wide grassland areas allowed approaches within 50-60 feet of the animals.

With practice, seven to nine animals were located in 1.5 to 2 hours. A mean location time of 11-12 minutes was required. Most flights were two hours long, including thirty minutes to and from the airport. Ream et al. (1972), with the same system, located seven animals in 1.5 hours, including time to and from the airport. Some time is involved travelling from one geographic area where an elk is to the next. An example would be from Miller Creek to Welcome Creek.

Pilot and Observer Training

An education period should be allowed when new pilots and observers undertake aerial telemetry with this telemetry system. Pilots varied in the number of locations required to learn the desired flight patterns adequately. In 1972, seven pilots did not have previous experience tracking elk. Two of these adapted to our wants in one flight and eight or fewer locations. Four did not fly with me, and one flew on a day when all animals were in open situations. The last five pilots mentioned flew only one flight. Only two pilots with experience were unsatisfactory. New pilots seem to grasp what is required if the first locations are visuals. This situation gave the observer a definite area about which to explain the desired flight patterns. When first locations were approximations, the endless circling was disappointing to the pilot, attentiveness was lost, and willingness to do a good job was lost.

New observers need an educational period to become proficient in equipment use and care, learn the topography of the study area, develop observer-pilot communications, and learn what to look for when searching for animals. I required four flights or twenty-two locations to become confident in finding animals. Locating and seeing an animal on the first flights builds confidence quickly. At first, approximations were disappointing. The degree of confidence that a transmitter is in an approximated area is low. When a period of search results in a visual, confidence in approximations is reinforced. First flights may last up to three hours and end with little satisfaction.

Training pilots and observers should be done during those times of year when animals are easily seen. April, May, and June are ideal. Flights can be made any time of the day, so locations of animals in all types of habitats and topographic situations are possible. Experienced observers should train "new" pilots and observers. Experienced pilots should fly novice observers during training. New observers need two flights with tutoring by an experienced observer. This gives the novice the general methods; the rest is a matter of practice.

Pilot Evaluation

Fifteen pilots took part in the study in 1972. Such a variety of pilots is not desirable. Each "new" pilot must learn to interpret hand signals and fly the desired patterns. These flights were "sacrifice flights" and not many good locations were obtained. Five, two, and one pilots flew one, two, and three flights respectively. Seven pilots flew five or more flights. Attitudes of pilots were partially responsible for observational success. All but one pilot had an interest in the study as a hunter, as general interest, or enjoyed the change of pace. The single individual was a non-hunter and particularly adverse to flying at 5:30 a.m. During flights he was argumentative to the point of distraction. This affected his attentiveness in relation to flying small and low enough circles, circling the target area consistently, and responding to hand and verbal requests. These flights were cut short and the pilot was not accepted again.

Some pilots complained when called upon to fly early morning hours several days in a row, while others did not, explaining the fact through their interest in the project and responsibility to a client.

All pilots were safety conscious. If a flight pattern was beyond their ability or the capability of the aircraft, I was either told so or the pattern just was not flown. The former information system is preferred, the latter wasted time. Observers welcomed advice concerning dangerous situations and alternative avenues of approaching these.

Five pilots were excellent. Three of these had flown the previous year. Two other pilots flew the previous year but either could not, or refused, to fly satisfactorily. Better pilots were constructive in proposing new approaches to allow better observation of animals, and often aided in sighting animals as well. One must be careful of overinterested pilots around hunting seasons. One pilot was found on part of the study area closed to hunting following a flight which located elk in this vicinity. Other hunters in the study area were interviewed, and they had obtained information about elk from that pilot. No animals, to my knowledge, were killed as a result of this situation.

Flying ability varied from pilot to pilot. Ability was related to attentiveness. Quick responses to hand signals and knowing when and where certain flight patterns could be flown were necessary in circling areas of a few acres. Keeping circles above the area of interest without wandering requires attention to the terrain and the observer.

Pilots should not be judged entirely on flight results (Table 2). Weather, season, and individuality of elk are factors that can affect flight success. When choosing pilots, it is suggested that you fly with several, choose those which you consider best, and employ them as often as possible. This gives an observer constant dependability and increased observation efficiency.

Passenger Influences

During the 1972 flights, a total of fifteen passengers were present on twenty flights. Often they spotted animals not seen by the observer. Their aid resulted in several would-be approximate locations becoming visuals.

Motion sickness was the overwhelming problem for passengers (Table 3). Persons accustomed to commercial flying and, in two instances, part-time pilots, were susceptible to motion sickness due to the rigorous type of flying involved. Quick elevational changes, seemingly endless circling, and sometimes rough air currents were contributing factors. The center of gravity of the plane is the front seat; those passengers in the back seat are under the stress of more lateral motion than those in the front. Flights were sometimes cut

Table 2.--Pilot performance ranking

Pilot rank[a]	Flights made	Locations made	Percent visuals	Percent approx.
1[b]	8	61	55.0	45.0
2[b]	18	90	65.5	44.5
3[b]	5	29	55.0	45.0
4	4	31	59.8	40.2
5[b]	5	30	53.0	47.0
6[d]	2	16	75.0	25.0
7[b]	13	68	59.0	41.0
8[b]	5	35	57.0	43.0
9[b]	2	10	50.0	50.0
A[c]	1	5	100.0	0.0
B[a, c]	2	6	66.7	33.3
C[c]	1	3	33.3	66.7
D[c]	1	5	20.0	80.0
E[c]	1	8	87.5	12.5
F[c]	1	2	100.0	0.0

[a] Ranking is done by ability, interest, as well as results. Hunting season flights are excluded as are flights involving equipment problems.

[b] Pilots with previous experience on the elk study.

[c] These pilots made only one flight and were not ranked. In the case of pilot B, one flight in a storm. In the case of pilots C, D, and E, another person flew with them.

[d] Opportunist pilot and all elk in open areas.

Table 3.--Passenger response to aircraft flight conditions

Total passengers	No medication		Medication		Short smooth flights
	No sickness	Sickness	No sickness	Sickness	No sickness
15	5	6	2*	3*	2**

*One of these passengers flew previously and is included in no medication and sick column.

**One of these passengers flew later and is included in no medication and no sickness column.

short when passengers were sick. On one occasion, we landed, let the passenger out, completed flight radio tracking, and returned before heading to Missoula. Purchasing motion sickness medication (Dramamine) and convincing passengers to take it previous to flying alleviates some of the problem. Most persons becoming ill were somewhat reluctant to fly again. It should be understood that all tracking will be completely done during a flight whether a passenger gets sick or not. A check for motion sickness bags in the plane should be made if passengers are to accompany an observer.

Observer Bias

Passengers, untrained at spotting radioed elk, helped dampen observer bias. The bias develops after many elk have been observed. The observer looked for elk where he instinctively though elk "ought to be." Self-discipline and adequate intensive search usually corrected for the effects of such bias. At times observer bias would yield a visual sighting sooner than intensive searching would.

Equipment Problems and Performance

When using the bracket antenna mounts, cleaning all electrical surface contacts was necessary. Aircraft engine exhaust oil and carbon build up on the bottom of the fuselage and the antenna system in flight. Dirty surfaces result in poor contacts which appear to cause a loss of discrimination of directional signals. Permanently attached antenna terminals were covered with threaded caps to protect them from dirt. Cleaning was required if these caps were left off between flights. I would suggest as a matter of convenience, if one plane is not always available, to equip two planes with permanent connections. Placing brackets takes time and on cold mornings, persons hurry and may not have clean enough connections.

The loss of directional signal discrimination seemed to be a major problem. Several factors contributed to this. Poor or dirty connections were one. Once a loose transistor in the receiver itself was responsible. Directional signal differentiation was also lost when the receiver power source was below peak power. Periodic checking of the eight 1.5 volt batteries is necessary. Battery pack longevity, based on three battery changes, varied from 26-36 hours. The receiver has an attachment for an external power source and a switch between internal and external sources. Two 6-volt lead acid storage batteries were connected in series to serve as a backup power system. The batteries are rechargeable and have a life of 72 hours.

This became the primary power source because of its dependability. There were isolated instances when discrimination in flight varied from good to poor. It was discovered that dipping the wings of the aircraft alternately in quick succession alleviated this problem fifty percent of the time. This may be due to loose connections. The other fifty percent of the time, dirt, weak batteries, or unknown factors caused loss of discrimination. If the problem persisted, the receiver was thoroughly checked by an electronics specialist.

Aircraft problems occurred twice. An oil pressure failure caused a flight to be aborted (Marcum, pers. comm.), and a carburetor freezeup was corrected in flight. When other flights took priority over ours, planes and pilots were not available.

Transmitter performance is summarized in Table 4. Expected longevity is based on the current drain of the circuit. Faster pulse rates generally use up available power faster. It is unknown whether malfunctioning of transmitters which were not recovered is due to power shortage or some other factors. Cochran (1964) states that both the physical and electrical stability of a radio collar are important to longevity. All but one of "lost" transmitters were still operating when recovered, either by retrapping collared animals, finding collars on the ground, or returned by hunters. In 1971, the transmitter on elk G malfunctioned due to a loose transistor (Beall, pers. comm.). Elk B's 1971 collar was operating when recovered, but batteries were corroded. This was a Davidson pre-made collar. The transmitter package was not dipped in beeswax. All the 1971 radios recovered can be reused when repotted as can the one 1972 transmitter recovered. Elk F's transmitter was repotted and used on elk P in 1972.

Structure seems to be a problem with acrylic collars. Severe blows, possibly from fighting, caused collars to fall off two bulls in the fall of 1971 (Ream et al. 1972). One collar fell off a bull in the fall of 1972 due to breakage. All these collars were made from the same

Table 4.--Transmitter performance, 1971-1972

Year	Elk	Sex	Radio type	Pulse rate	Date animal collared	Date radio stopped or removed	Life expect. (days)	Actual life on animal (days)	Reason
1971	A	F	DAV[a] STR[b]	. . . . .	1/13/71	11/8/71	. .	240	Poor joint in acrylic. Collar fell off and recovered.[c]
	B	F	DAV[a] STR[b]	. . . . .	3/1/71	1/30/72	. .	334	Transmitter operating when retrapped. Removed and replaced (See B below).[c]
	C	F	DAV[a] DR[d]	. . . . .	3/1/71	10/26/71	. .	238	Animal shot, collar returned. Still operating when killed.[c]
	D	M	AVM	. . . . .	3/2/71	12/1/71	. .	272	Acrylic broke, apparently by severe blow, unknown origin. Collar recovered, operating under three feet of snow.[c]
	E	M	AVM	. . . . .	3/5/71	11/3/72	860	610	Transmitter quit, possibly battery power depleted. Not recovered.
	F	M	AVM	. . . . .	4/8/71	10/7/71	. .	182	Acrylic broken, possible fight with another bull. Recovered, functioning.[c]
	G	M	AVM	. . . . .	5/4/71	11/11/71	790	191	Transmitter malfunctioned. Recovered in retrapping. Replaced transmitter.[c]

TABLE 4--Continued

Year	Elk	Sex	Radio type	Pulse rate	Date animal collared	Date radio stopped or removed	Life expect. (days)	Actual life on animal (days)	Reason
1972	B	F	AVM	. . . . .	1/30/72	3/72	. .[e]	42	Transmitter malfunctioned, reason unknown. Unrecovered.
	G	M	AVM	62/min.	1/28/72	10/21/72	1070	265	Transmitter acrylic broken off. Recovered, operating in snow.
	H	F	DAV[a]	very fast	12/22/71	5/73	. .[e]	509	Transmitter quit, reason unknown. Unrecovered.
	J	F	AVM	100/min.	1/3/72	7/31/72	860	210	Transmitter malfunctioned, reason unknown. Unrecovered.
	K	F	DAV[a]	very fast	1/28/72	1/73	. .[e]	238	Transmitter quit, reason unknown. Unrecovered.
	L	F	AVM	52/min.	1/30/72	. . . .	. .[e]	500+ still	Working June 22, 1973.
	M	F	AVM	56/min.	2/11/72	10/6/72	. .[e]	238	Transmitter quit, reason unknown. Unrecovered.
	O	F	AVM	46/min.	2/26/72	. . . .	. .[e]	483+ still	Working June 22, 1973.

TABLE 4--Continued

Year	Elk	Sex	Radio type	Pulse rate	Date animal collared	Date radio stopped or removed	Life expect. (days)	Actual life on animal (days)	Reason
1972	P	F	AVM	75/min.	2/20/72	10/22/72	. .[e]	239	Animal shot, radio recovered, still operating
	R	F	DAV[a]	very fast	2/72	5/72	. .[e]	100-120	Transmitter malfunction, reason unknown. Unrecovered.

[a] Davidson.

[b] Standard range.

[c] From Ream et al. (1971).

[d] Double range.

[e] Most 1972 transmitter life expectancies were approximately twenty-four months.

mold and thin spots were not reinforced with acrylic after removal from the mold. The rest of the 1972 collars were built thicker, and to date, none of them have fallen off; however, none of these were on bulls. When the acrylic breaks, it tends to cut the nylon band and the collar falls off. A poor field-formed joint on the collar of elk A was responsible for it breaking.

The transmitter on elk J malfunctioned. It was noted by Robert Beall (pers. comm.) that this transmitter had a variable pulse rate. After seven months of operation, the signal could be picked up only on a gain setting of eight on the receiver. Above this setting a loud scrambled signal occurred and below this setting no signal was received. In the fall of 1972, a signal on the frequency of J's transmitter was received as normal. Pulses occurred at thirty second intervals and a location was not possible. Elk G's 1972 collar, when it was suspected that it had fallen off, could only be received within one mile of its location and was a very weak signal. It was found lying flat on the ground with the antenna almost completely broken.

In 1972 and 1973 transmitters on elk B, E, H, J, K, M, and R were assumed to have malfunctioned or quit working. All of these but B and R lasted over six months. Exact reasons for malfunctioning or quitting are not known for those collars which have not been recovered. Pulse rates become slower or signal strength weaker before transmitters quit; however, with M and E transmitters went out with no such warning. It is suspected that other factors as well as current drain cause signal extinction.

Pulse rates differed from transmitter to transmitter (Table 4). Those termed as very fast are often approached and located late in phase two or early phase three search. It is easy to maintain flight directly at these signal sources and often the approach plane goes directly over the top of them. There is enough time between pulses to allow the ear to adjust and maintain ability to differentiate signal strength. A steady signal transmitter, artificially placed on the study area, confused me. My ears could not maintain their ability to differentiate the directional signal for more than a few minutes. When near the transmitter, the receiver nearly overloads on zero gain. The loud, steady signal was flown observing the signal strength meter instead of by sound. It was difficult to observe and plot the location while watching the meter at the same time. Different pulse rates allow a further identification of animals. Moderate pulse rates are adequate for locating animals. Slow pulse rates are sometimes difficult to locate in search phase three. The reason for this is that the aircraft travels long distances (200 ft./sec.) between pulses. It takes longer to hear and judge signal strength from both sides of the plane. Time between pulses makes it difficult to remember which side had the stronger signal. Optimum pulse rates for aerial tracking should be considered in the 100 to 300 pulse/minute range. Anderson (1971) suggested 300/minute as optimum for ground telemetry. Ream et al. (1972) recommends the 100 to 300/minute rates for aerial telemetry.

There are occasions when other radio users in the area cause interference. The interference is in the form of static and voices. This usually occurs after 8:00 a.m. Early morning and late evening flights did not encounter this problem. The aircraft radio was turned off during tracking flights. Receiving and transmitting from the aircraft radio could harm components in our receiver (Varney, pers. comm.).

Radio collars (2-3 lbs.) and color collars of conveyor belt material apparently caused no harm to the animals. No hairless areas, loss of mobility, or discomfort was noticed. Craighead et al. (1971) noted no harmful effects of a 11.3 kg. instrument collar used in satellite tracking of elk.

Hunting Season Influences

During hunting seasons it is possible that aircraft lead hunters to elk. Ream et al. (1972) consider it unlikely, as hunters may not be able to see aircraft maneuvers through the timber canopy. If aircraft were followed, Ream et al. (*Ibid*.) thought it difficult for a hunter to find and kill an animal as a result.

Modification of flight techniques were designed to alleviate the possible problem. First an area was checked, from the air, for hunters or hunters' vehicles. If their presence was noted, a search consisting of two phase two searches was implemented. A high phase two approach was made, noting the point of greatest signal strength. At the point of greatest signal strength, a second high altitude approach was made at a right angle to the first approach line. This gave a very rough approximation with no closer observation. Some of these passes did, however, result in visual locations. In 1971, nearly all hunting season locations were approximated. In 1972, if no evidence of hunters existed in an area, intensive search followed normal procedures. Many of these flights were evenings of week days, lowering the possibility of hunters being in the area, and making it improbable that a hunter could stalk and kill an animal before darkness. In roaded areas, even if hunters were not seen, diversionary circling over areas where no radioed elk were located was implemented.

Weather Influences

Weather conditions were the greatest source of trouble in maintaining a strict flight format. Flights were not made when clouds hid the mountain top adjacent to Missoula. Cloud cover such as this would allow low elevation searches, but not searches in all areas occupied by radioed elk. Cloud cover often differed in Missoula and on the study area. Valley fog is common in Missoula in autumn, sometimes preventing air traffic from landing or taking off. Valley fog was not prevalent on the study area. There were occasions when valley fog occupied drainages on the study area, preventing locations in them on two flights.

In spring, high overcast and small rain squalls pose no problem. Spring winds and driving rainstorms cause rough flights and decreased visibility respectively. Scheduled flights should be cancelled under such conditions. Summer convection thunderstorms can "build around the plane" and be dangerous if lightning is prevalent (Marcum, pers. comm.). Late fall weather can be dangerous when snowstorms move quickly over an area, obscuring landmarks. It is a good idea to watch the weather in the direction of the airport to allow time to return before a storm arrives. If caught in the mountains, the only way out is to follow familiar drainages and low passes between drainages into a major valley like the Bitterroot. The pilots were usually alert to these situations.

Excessive winds in Missoula were reason to cancel flights. If trees in town were being tossed by greater than 15 m.p.h. winds, flying was regarded with skepticism. Flights were aborted on several occasions when wind caused air to be too rough for intensive search. Often, however, rough air in the Bitterroot Valley did not necessarily mean rough air on the study area. Air masses coming off the Bitterroot Mountains and out of Lolo Canyon cause tumbling air currents in the Valley. These often stabilize as they start rising over the Sapphire Mountains (Potter, pers. comm.).

Flights were usually cancelled if pilots thought a complete flight could not be made due to storms, cloud cover, and winds. Information concerning storm fronts, winds, and cloud conditions are available from the National Weather Service, but their information concerning flights is often conservative. Consequently, pilots should be consulted for final decisions. If weather was too bad once we were in the air, we turned back.

June flights were made both morning and evening. On the cooler days flights probably could be made any time of day. In July, August, and early September only morning flights were made. Evening flights may be dangerous or ineffective due to build up of convection thunderstorm systems. Flights during the day were considered impractical during these months. Convection currents resulting from high temperatures in the mountains prevent intensive search (Turner, pers. comm.). Convection currents begin forming at about 9:00 a.m. Cool or rainy days may be good for safe flying and visual observations; however only morning flights were made in July and August. Mid September through November flights were made mornings or evenings, depending on how hot the day was. Cooler days in October and November lend themselves to flights at any time of day, depending on wind and convection currents.

Time of Day and Light Conditions

Different light conditions prevail depending on the time of day a flight is made and topographic conditions. Evening flights on sunny spring days are characterized by low angle light rays that cause blond elk coloration to contrast with the green vegetation on open west slopes (Fig. 13). This would be the best situation for photography. Animals on other aspects or in timber are in shadows. When observers' eyes are adjusted to the bright sunlight, shadows appear very dark (Fig. 14). Light before sunrise is not bright, but it is even, without contrasting shadows similar to an overcast day (Fig. 15). After sunup, the area east of the Bitterroot Divide is brightly lighted, while areas west of the Divide are in uniform shadow. Experience showed that seeing animals under different light conditions for the first time serves as an education. With experience, animals are as easily seen under one light condition as another with the exception of easy observations in open areas during spring evenings and difficult observations with combinations of bright sunlight and dark shadows.

Aerial Location Summary

Fifty-four flights were made from 8 June to 1 December 1971 using the double whip antenna system. Of 312 possible radio locations, 295 were successful. A mean of 5.51 observations of radioed animals occurred per flight; seventy-three (24.8%) of the radio locations were visuals of radio collared elk and 222 (75.2%) were approximations. However, an additional fifteen for a total of 310 visual observations

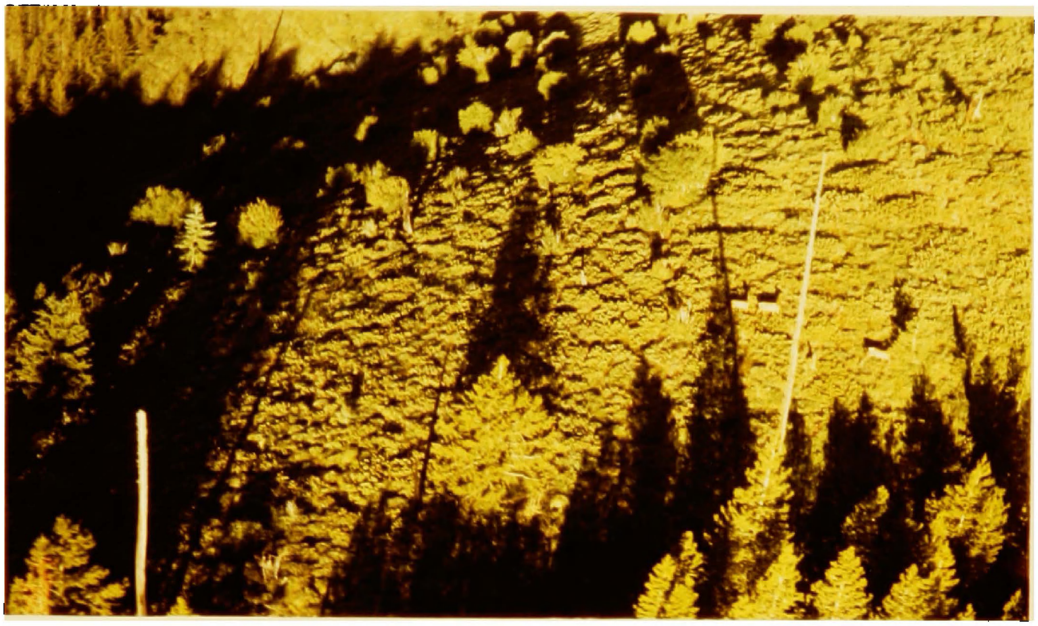

Fig. 13.--Coloration contrast of elk in open areas and lush green vegetation on evening spring (June) flights.

Fig. 14.--Color contrast of sunlight and shadows and difficulty in observing elk. Photo by Robert R. Ream.

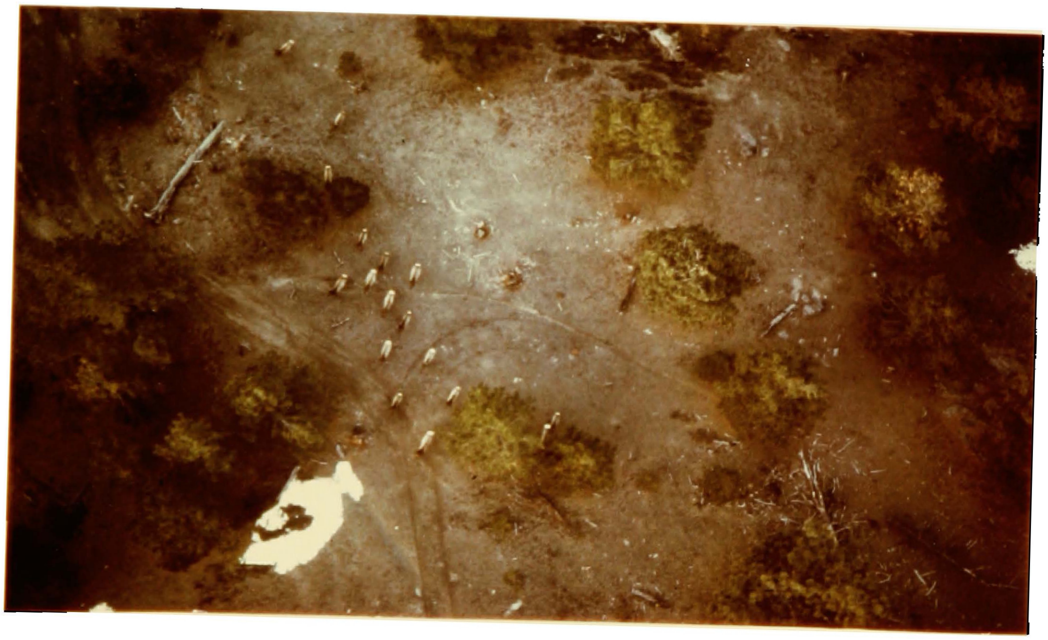

Fig. 15.--Uniform light on an overcast day. Photo by Robert C. Beall.

were made. The fifteen additional observations account for those animals without radio collars that were observed and located. An average of 1.42 visuals occurred per flight. Mean group size of those visual observations was 3.62 animals. In 1971, 4.09 radio approximations were made per flight.

In 1972, sixty-six flights were made between 3 June and 1 December with a mean of 6.12 locations per flight. There were 434 potential radio locations for radioed animals based on the number of functioning radios available each flight. Visual locations accounted for 223 (55.1%) of the 406 successful locations, while 183 (44.9%) were approximations. Including fifty-one non-radioed animal visuals, a total of 457 observations were obtained. Nine of these were questionable glimpses of animals making 448 positive total locations. These locations were obtained going to and from the airport, between radio locations, or associated with search phases for radioed elk. Twenty-eight were unassociated with intensive search patterns in 1972. An average of 3.39 radio visuals and 2.73 radio approximations were made per flight. The mean group size for visual observations was 4.04 animals.

Aerial Approximation Accuracy

A total of fifty-seven approximation trials were carried out. Of these, fifty (88%) were successful in having the transmitter within the approximated area. Thirteen locations were found on transmitters "planted" by co-workers in unknown locations. Forty-four were elk locations approximated and visually sighted moments later by passengers or observers. There was no significant difference ($X^2 = .05$ and $t_{\alpha} = .05$) between success and area of approximation respectively on elk locations and planted radio locations. A mean approximation area size of 10.621 acres resulted with a 95% confidence interval of 2.47 acres. A maximum of 36.8 acres and a minimum of 1.6 acres were located. Larger approximation areas above fifteen acres in size were on gentle slopes of homogeneous vegetation with no breaks in topography or on gentle, wide, sloping ridgetops. These areas averaged 18.5 acres in size. One approximation occurred in a large, uniform grassland area. The animal was located in a small gully moments later. These topographic and vegetational situations seemed to cause difficulty in pinpointing the signal source, especially with slow pulse rates. In small canyons, heads of draws, and around sharp ridges, flight patterns and signal blockage by topography allowed a mean approximation size of 6.45 acres. Midslope locations on high moderate-slope ridges averaged 9.2 acres while ridgetops averaged 10.7 acres for approximation area size. One can use knowledge of topography, animals, and signal reception to narrow down approximations. Approximations of these sizes allow an observer to define cover density from the plane. It was possible to find the actual site the animal was by on-the-ground observation with the aid of the flight locations (Marcum, pers. comm.). The smaller approximations were best used for this purpose. Of all 1971 radio approximations, 7.8, 47.1, and 45.1 percent were considered poor, fair, and good, respectively. In 1972, 15.9, 21.4, and 62.7 percent were considered poor, fair, and good, respectively (Table 5).

Habitat Cover

Visual locations are more desirable than approximations as more ecological data is obtainable. One of the major factors affecting

Table 5.--Aerial approximation habitat classes and rating by individual animal, 1971-1972

Year	Elk	No. successful radio locations	No. approx.	Habitat density of approx.				Relative accuracy of approx.			
				Heavy timber	Mod. timber	Open timber or open	Unknown or other	Poor	Fair	Good	Unrec.
1971	A	41	36	25	4	3	4	5	14	12	5
	B	48	37	26	5	1	5	2	14	19	2
	C	40	24	18	5	1	0	3	12	8	1
	D	44	33	19	10	0	4	1	22	9	1
	E	47	42	28	9	1	4	3	20	18	1
	F	33	23	7	11	1	4	1	8	12	2
	G	42	27	16	6	2	3	1	8	16	2
Total	7	295	222	139	50	9	24	16	98	94	14
Percent recorded				70.2	25.7	4.1		7.8	47.1	45.1	
1972	E	47	20	10	5	1	4	3	4	10	3
	G	41	20[a]	7	6	1	6	3	4	3	7
	H	57	20	10	3	1	6	0	2	16	2
	J	17	7	2	0	0	5	1	2	2	2
	K	59	22	12	5	1	4	2	3	6	11
	L	53	20	15	1	0	4	2	2	10	6
	M	36	28	22	1	0	5	2	5	14	7
	O	49	31	14	3	1	13	3	3	11	14
	P	47	15	9	2	0	4	1	2	7	5
Total	9	406	183	101	26	5	51	17	27	79	57
Percent recorded				76.5	19.7	4.8		15.9	21.4	62.7	

[a] It is suspected that the collar had fallen off on three of these approximations.

visual locations is overstory cover (Tables 5 and 6). Most visual sightings of non-radioed elk occur in moderate to open areas. This is the case with 28 sightings in 1972 (Table 6). The apparent difference in visual locations from 1971 to 1972 seems to be due to the cover utilized by animals. A greater proportion (62.2%) of locations was in heavy timber during 1971 than 1972 (43.7%). Approximations in heavy timber were 47.1% of the total observation in 1971 while only 24.8% in 1972. In 1971, 16.9% of approximate locations were in moderate timber and only 6.4% in 1972. Table 6 shows a decreased percentage (15.5%) of visuals in heavy timber, a slight increase (5%) of visuals in moderate timber, and a greater increase (10%) of visuals in open timber and roads. Approximations were 6.3% less, 6% more, and 0.4% less in heavy, moderate, and open timber respectively in 1971 than in 1972 (Table 5).

Ease of Observation Related to Cover Density

Individual animals vary in use of cover (Tables 5 and 6). Some are found more often in one type than another. For example, elk P and elk M were located more often in open timber and heavy timber respectively (Tables 5 and 6).

Animals sighted in heavy timber require a more intensive phase four search. Searches in heavy timber may take up to ten or twelve circles of phase four search. Often, a visual sighting results from the additional amount of search. Animals not sighted after 5-10 minutes of search were approximated. Aside from the fact animals are under dense overstory vegetation, they are also in the shade, rendering them more difficult to see. If animals are moving, an observer can spot

Table 6.--Aerial visual locations, habitat classes and animal behavior in response to aircraft

Year	Elk	Total successful radio locations	No. visual locations	Habitat density or character for visual locations						Elk behavior when air-craft circling					
				Heavy timber	Mod. timber	Open timber	Ecotone	Roads	Unrecord.	Standing	Feeding	Bedded	Travelling	Running	Unknown unrecord.
1971	A	41	5	2	1	2	..	..	..	..	1	1	1	..	2
	B	48	11	4	1	2	1	..	3	..	1	5	1	..	4
	C	40	16	5	4	5	2	..	..	..	1	2	1	..	12
	D	44	11	4	4	1	1	..	1	1	3	1	1	..	5
	E	47	5	2	2	1	..	..	..	..	1	..	1	..	3
	F	33	10	3	4	3	..	..	..	1	1	1	1	..	5
	G	42	15	4	7	3	..	1	..	..	3	1	2	..	9
Total	7	295	73	24	23	17	4	1	4	2	11	11	8	0	41
Percent recorded				32.9	31.5	23.2	5.5	1.3	5.5	6.4	34.3	34.3	25	0.0	
1972	E	47	27	4	14	6	1	..	2	5	10	1	8	..	3
	G	41	21	7	6	5	1	..	1	4	5	2	4	..	6
	H	57	37	3	11	13	2	6	3	2	9	6	12	2	6
	J	17	10	2	3	2	1	1	1	..	3	..	3	..	4
	K	59	37	6	14	11	1	3	2	6	13	8	3	..	7
	L	53	33	4	17	11	..	..	1	6	5	5	10	..	7

TABLE 6--Continued

Year	Elk	Total successful radio locations	No. visual locations	Habitat density or character for visual locations						Elk behavior when aircraft circling					
				Heavy timber	Mod. timber	Open timber	Ecotone	Roads	Unrecord.	Standing	Feeding	Bedded	Travelling	Running	Unknown unrecord.
1972	M	36	8	2	2	1	2	..	1	..	5	1	1	..	1
	O	49	18	3	4	10	..	..	1	..	6	4	3	2	3
	P	47	32	8	10	9	1	2	..	4	11	3	8	..	7
Total	9	406	223	39	81	68	9	12	13	27	67	30	52	4	44
Percent recorded				17.4	36.1	30.0	4.2	5.3	5.8	15.0	37.2	16.7	28.9	2.2	
1972	Ext. elk*	28	28	2	4	16	..	1	5	3	10	1	7	1	6
Percent recorded				7.2	14.4	57.6	0.0	3.6	17.2	10.7	34.4	3.6	25.0	3.6	21.4

*Elk not associated with search phase patterns 3 and 4 and unrelated to location of radioed elk.

them easily, but keeping them in view is difficult. Bedded animals are even more difficult to observe. Pilots cannot fly a circle small enough with timber so dense. Animals were sometimes observed only as a glimpse, and not seen again. These were not considered valid visual locations. The entire animal is seldom seen; rumps, heads and necks, and backs are the portions of animals observed most often in heavy timber. The only relatively easy observations in heavy timber are those in mature lodgepole pine stands. It is not so difficult to see between the tree canopies to the ground. Tall trunks, devoid of green branches allow greater visibility.

Animals standing or moving in moderate timber situations are readily seen. Animals bedded or standing near the bases of trees can be difficult to see, especially when in the shade. An observer can fly over an animal or a group of animals several times before seeing them. Others are not seen regardless of the time spent in search. Flying small circles allows an observer to watch the elk a large percentage of the time.

Elk in open timber and grassland situations (Fig. 13) are usually easily seen; however, animals in small gullies or bedded on areas blending with their coloration can be repeatedly flown over and not seen. In one instance, I flew over a group of eleven bedded cows and calves six times before several individuals stood up and were seen. Groups of bedded animals on ridgetops sometimes appear as outcrops of rock, especially when sunlight does not fall directly upon them.

Groups of elk in all situations are more easily seen than individuals. Usually when one or several are spotted, more circling sometimes lets an observer see several more in addition to those first seen. I do doubt that in heavy and moderate timber situations all the animals in a group are seen 100% of the time. Even in grassland situations stragglers behind the major group are missed.

Temperature Influences

It is not the purpose of this work to investigate annual differences relative to elk behavior and habitat use, but the flight days in 1972 that were cool and cloudy days were more numerous than in 1971 (Table 7). No long hot periods occurred in 1972 like the ten week period of ninety degree weather in July, August, and early September of 1971 (Table 7). This heavy-cover response to hot weather, by elk, is reflected in the relative percentages of approximations and visuals during July and August of both years (Table 7). In 1971, the number of visuals decreased a large amount during late summer; visuals decreased only a minor amount during the same time in 1972.

Observer Influences

I do not believe that the sightings of different observers from one year to the next to be an important factor. Once experienced, one observer can spot elk nearly as well as the next, but recording data accurately may differ between observers. I did, however, search for longer periods of time on search phase four than did C.L. Marcum in 1971 (pers. comm.). Table 8 shows that observers in 1971, when flying together, saw more elk, but this is a small sample size. During the 1971 hunting seasons, approximations by Dr. Ream, if located by standard procedure, probably would have yielded a percentage figure similar to C.L. Marcum's. The 1972 data bears this out. All 1972 observers showed increases in visual sightings approaching the 1972

Table 7.--Spring, summer and fall observation of radioed elk by month and related to temperature and cloud cover

Month	No. of flights		Elk observations						Flight weather							
			1971			1972			1971				1972			
	1971	1972	Percent radio visuals	Percent radio approx.	Total No.[a]	Percent radio visuals	Percent radio approx.	Total No.[a]	Mean max. daily temp.[b]	Mean min. daily temp.[b]	Percent overcast flights	Percent clear flights	Mean max. daily temp.[b]	Mean min. daily temp.[b]	Percent overcast flights	Percent clear flights
June	12	16	38.2	61.8	63	54.6	45.4	98	76.8	41.9	40	60	75.2	45.0	50	50
July	8	12	14.8	85.2	59	57.7	42.3	81	86.1	45.0	38	62	83.0	47.3	46	54
Aug.	8	10	18.4	81.6	51	51.0	49.0	80	91.0	46.0	0	100	84.7	46.5	20	80
Sept.	10	9	25.7[c]	74.3[c]	68	52.0	48.0	80	65.5	28.0	0[d]	100[d]	72.4	35.0	30[e]	70[e]
Oct.	10	7	27.0[c]	73.0[c]	48	56.6	43.4	56	....	....	..	...	60.2	35.0	0[f]	100[f]
Nov.	6	12	5.0[c]	95.0[c]	21	61.2	38.8	62	....	....	..	...	45.0	26.6	67	33
Total	54	66	24.8	75.2	310[a]	55.1	44.9	457[a]			25	75			40.8	59.2

[a] Includes non-radioed animal observations, these are called non-radio locations. These account for fifteen 1971 locations and fifty-one in 1972. These increase the percent total visual locations to 28.2% in 1971 and 59% in 1972. In 1972, 406 of 457 were valid radio locations; nine extraneous animal visuals were questionable, making 448 valid locations.

[b] Based on flight day maximum and minimum temperature, Stevensville Weather Station.

[c] Hunting season.

[d] Based on five of ten flights.

[e] Based on seven of nine flights.

[f] Based on four of ten flights.

Table 8.--Observer success, 1971-1972

1971				1972			
Observer	Observations	Percent visuals	Percent approx.	Observer	Observations	Percent visuals	Percent approx.
Marcum	237	26.3	73.7	Marcum & Denton	36	44.4	55.6
Ream	39[a]	15.4	84.6	Ream	51[a]	46.0	54.0
Marcum & Ream	19	42.0	58.0	Denton	319	56.9	43.1
Over-all	295	24.8	75.2		406	55.1	44.9

[a] These include hunting season approximations using different flight patterns than normal.

mean percentage of visuals. Dr. Ream, who served as an observer both years, shows a year to year increase in visual sighting. This is similar to the relatively greater number of visual sightings by Denton in 1972 as compared to Marcum in 1971. This leads me to eliminate observers as a major factor affecting numbers of visual sightings.

Seasonal Changes in Observability of Radioed Elk

Animal observability changes with seasons. Spring and early summer (June) were cool and rainy. Animals were often seen in moderate-to-open cover situations (Table 7). In rainy weather during July animals were seen in the same situations. In latter June calves appeared in the groups of elk. Early in August several small calves were also observed. Altman (1956), Brazda (1953), Harper (1964), and Picton (1960) all agree calves join the adult groups when three weeks of age. After mid-August, June calves became increasingly more difficult to identify as calves. From aircraft, the animals backs appear the same size. In early July animals became more mobile and were found anywhere from ridgetops to canyon bottoms in all types of cover. In 1971, animals were in canyon bottoms and heads of drainages in July and August. In late September the rut commences and animals were in groups. In 1972, more non-radioed bulls were visually observed, during the rut, than at any other time during spring, summer, or fall. Animals were found in bottoms, heads of drainages (Marcum, pers. comm.), and flat ridgetop areas. October and November were cooler than the previous months, and elk were seen on open and shrub areas near ridgetops (Table 7).

Background Coloration

The background color of the area which animals are in can hinder or help the observer. Snow gives a contrast that makes animals appear nearly black if no direct sunlight falls on the area, but stumps and rock outcrops appear similar. Standing or moving animals under this situation pose no problem and the whole body is usually silhouetted. Bedded animals, in the absence of sunshine, can appear as stumps. Observers must fly close enough to define outline of ears, head, and neck. If animals are on snow under bright sunshine, the tan back, dark head and neck, and orange rump patch stand out well enough to allow easy identification. Snow in heavy timber makes animals more readily seen. After the first snowfall of the year, an observer must learn how animals appear under new background conditions which differ from the understory vegetation background of spring, summer, and early fall.

June observations are characterized by a dark, lush, green background and usually cloudy days. Elk have just shed their winter coats and the new hair appears red under such conditions. The orange rump patch often gives their location away. Hair appears tan to blond on sunny days, but the background is still dark and green (Fig. 13). There is a good contrast of color on open slopes.

In the latter parts of July and August open area vegetation begins to turn brown or tan. These colors begin to blend with the colors of the animals and continue to do so until snow covers the ground. Moderate and heavy timber understory remains dark and green until it snows. Sunlight is particularly helpful in contrasting tan back and orange rump in these cover densities. When in shadows animals appear dark; dark sihlouettes, horizontal back lines, movement and the light rump patch catch the eye in this situation. One should not look for these characteristics, but look for the whole animal. Seeing those characteristics seems to be a matter of instinctive training rather than concentrated effort. Wide colored collars accompanying radio collars catch the eye on rare occasion (Fig. 16). When in dark shadows, the light collars contrast enough to catch the eye. These further serve to identify a radioed animal in a group of elk. Animals in heavy brush appear as a tan or brown island in a sea of green. Shrubs usually were not over six feet in height in this cover type.

Aircraft and Animal Response

Some hunters and others have contended that aircraft flight patterns of the sort used in this study harass animals. During 711 locations, 296 of which were visual, there were five recorded instances when elk apparently ran from the plane. Elk O and elk H each ran twice, and one group of non-radioed elk ran. The number of instances in which animals ran but were not recorded in 1971 is not known. Marcum (pers. comm.) states that isolated cases did occur but that they were very few in number. All the instances of running were recorded during the spring, summer, and fall of 1972. Two types of situations induced animals to run. The first involved flying low over an animal on the crest of a ridge. The second occurred when animals ran more than 300 yards to cover on logging roads. On sixteen occasions, small or large groups of animals were located far from cover in grasslands. After circling two or three times, these animals started walking and feeding toward cover. Small groups or

Fig. 16.--Color collared animals in dark shade.

individuals within larger groups would bolt 10-15 yards when the plane flew very close (20 yards). These groups of animals did not take the shortest path to cover except on one occasion. When the edge of cover was reached they stopped and watched the plane. One group thirty yards from cover had one animal bolt and the rest followed for fifteen yards and stopped. Aircraft caused 30% of the bedded animals to rise, but one walked to heavier cover. Bedded animals usually remained bedded, got up and fed, or stood and watched the plane. Feeding animals, unless far from cover continued to feed. Travelling animals frequently stopped, looked at the plane and continued the previous behavior. It is very unlikely that aircraft contributed greatly to elk harassment during the spring, summer, and fall of 1972. Observation of bulls E and G at fifty feet brought a response of antler shaking and stomping of the forefeet. Cows often viewed the plane with what I considered curiosity, before going back to whatever behavior they were involved in. Reaction to aircraft may depend upon species. Mountain goats (_Oreamnos americana_) hug cliffs or hide when aircraft pass (Chadwick, pers. comm.). More reaction from hunters about planes harassing elk occurred than the elk showed. I found out later of one case where a hunter had jumped and killed a bedded elk as I was flying 0.50 mile away. This hunter was on the trail of the animal before I arrived on the area, thus aircraft did not lead him to an elk or chase an elk to him. Flying during the hunting season apparently does not make elk more susceptible to hunters. One radioed elk was killed each year (C in 1971 and P in 1972) of the study. These were killed on days when no flights were made and in locations unrelated to the previous aerial flight location. Incidentally, those animals that were shot were observed visually more and approximated less often than any of the other radioed animals (Tables 5 and 6). I do not doubt that radioed animals habituate to aircraft, but many non-radioed animals with and without the company of radioed elk were observed. These animals apparently did not react differently than radioed animals.

Ground Telemetry

Accuracy in Mountainous Terrain

Two transmitters, with a steady signal and an 80 pulse/minute signal, were placed by a person for a total of 124 and 159 fixes, respectively. Of these 87 and 95 percent were "successful" fixes. Unsuccessful attempts occurred when receiver personnel were unsure of a signal, forgot to take a reading, or the transmitter man was unsure of his exact location. Mean error was 6. with a 95% confidence interval of 1.28 degrees and 5.89 with a 95% confidence level of 1.37 degrees for the pulse signal and steady signal respectively. There is no significant difference ($t_{\alpha} = .05$) between the error of azimuth bearing between the two transmitters. Error is the difference in degrees between the true azimuth bearing and receiver read azimuth bearing from receiver station to transmitter location. There is a possible 5 degree error in the equipment (Cochran, no date). Without visual locations of transmitters, error is inherent in any location system. Heezan et al. (1967) attribute wind twisting antennas, temperature, and improper reference settings as part of this error. A maximum error of 44 degrees and a minimum of zero degrees was the error range. The high maximum error occurred once and was probably due to signal bounce. It was not confirmed by further fixes. Only 7.9% of the mountain terrain bearings were greater than fifteen degrees. Many of these may have been due to special signal bounce situations, but were not tested with more fixes.

Accuracy on Level to Rolling Terrain

On level to rolling terrain forty-two radio fixes were obtained on the 80 pulse/minute transmitter. Of these, 95.5% were successful. A mean error of 2. degrees with a 95% confidence interval of .645 degrees resulted at a mean distance of 1.15 miles. Minimum distance was 3,300 feet and maximum 8,950 feet. Anderson (1971) found a mean error of three degrees at eight kilometers using a horizontal Yagi antenna. One degree conversions to feet are presented in Table 9.

Isolation of Error-Causing Factors

I found that trying to isolate the factor or combination of factors influencing the difference in error between different types of topography was difficult. The greater error occurred in mountainous terrain (Table 10). Data from mountainous terrain were analyzed for distance, topography, and the combinations thereof to determine significant combinations of factors responsible for lower accuracy (Table 11). I must conclude that the combination of timbered slopes, irregular topography, and distance together, contribute to a constant source of error and that I could not isolate a distinct factor or factor combination with the sampling I have done. I did not consider timber as a parameter as various densities and size classes of timber were always present between transmitters and receiver. Marshall (1963) reported signal reflection by evergreen trees. Anderson (1971) reported aberrant readings when the receiver was within four meters of large trees or

Table 9.--One degree error conversion to feet correlated to distance

Distance from receiver (miles)	1° approximates feet
0-0.25	24.75
0.50	49.50
0.75	74.25
1.00	99.00
1.25	123.75
1.50	148.50
1.75	173.25
2.00	198.00
2.25	222.75
2.75	272.25

Table 10.--Ground telemetry accuracy

Factor	No. of successful trials	Mean degrees ± 95% confidence interval	Coeff. of variation	$(t_\alpha = .05)$
Mountainous topography	143[a]	6. ± 1.28	.956	
Level-rolling topography	40[a]	2. ± .645	.689	yes

[a] 80 pulse/minute transmitter.

Table 11.--Irregular topography ground telemetry accuracy related to distance, topography, and distance and opposite slope topography

Factor	No. of successful trials	Mean degrees ± 95% confidence interval	Coeff. of variation	(Zm_{α} = .05)
Distance[a]				
0.00-0.50 mi.	10	4. ± 2.2	.90	No
0.50-0.75 mi.	17	6. ± 3.3	.73	No
0.75-1.00 mi.	21	7. ± 4.71	1.28	No
1.00-1.25 mi.	22	5. ± 1.7	.766	No
1.25-1.50 mi.	23	7. ± 4.0	.94	No
1.50-1.75 mi.	24	5. ± 1.8	1.02	No
1.75-2.00 mi.	11	5. ± 2.3	.74	No
2.00 mi.	9	4. ± 2.2	1.24	No
Topography				
Draws, lower one-half	44	5. ± 1.1	.90	No
Ridgetop	28	6. ± 2.4	1.11	No
Opposite slope	21	6. ± 2.7	.71	No
Adjacent slope	20	6. ± 3.3	.85	No
Ridgepoints	18	6. ± 2.8	1.31	No
Flats	6	7. ± 6.1	.64	No
Distance and opposite slope combined[b]				
0.00-0.50 mi.	12	7. ± 4.4	.88	No
0.50-0.75 mi.	19	5. ± 2.4	.76	No
0.75-1.00 mi.	11	5. ± 2.4	1.90	No
1.00-1.25 mi.	12	6. ± 3.2	.55	No
1.25-1.50 mi.	11	4. ± 2.0	.45	No
1.50-1.75 mi.	20	7. ± 4.2	.95	No
1.75-2.00 mi.	7	6. ± 4.6	.58	No
2.00 mi.	4	1. ± 1.3	.54	No

[a] Compared as subsamples of large population from mountainous topography.

[b] Similar results occur for ridgetop and distance, ridgepoint and distance, adjacent slope and distance, moderate timber, heavy timber, and open timber.

brush. Ellis (1964), Mackay (1968), and Verts (1963) noted that topography and vegetation affected signal accuracy. Slade et al. (1965) and Mackay (op. cit.) noted that power lines affect accuracy. Heezen and Tester (1967) found that heavy timber affected radio signals. Studies done in relatively level country by Marchinton and Jeter (1966) and Slade et al. (op. cit.) did not note any error due to topographic features or vegetation. This study noted signal blockage when transmitters were below line of sight off the crest of a hill up to 100 yards of the receiver station. Refraction and reflection of radio waves contribute to signal bounce; thus the amount of bounce may depend upon the frequency of transmitters used (Craighead et al. 1963). Signal bounce situations were not tested in the field. A bounce situation was related to me by C. L. Marcum (Fig. 17) that can occur in mountainous topography. The transmitter was located at location (1). The signal was received and located correctly at site (2) in the head of the adjacent draw. A reading taken in the bottom of the draw (3) located the animal in the opposite direction. A third reading (4) was taken on the ridge opposite the transmitter and located correctly. Multiple fixes seem to be the solution to eliminating bounce error (Marshall 1963; Stehn 1973; and Verts 1963). Tester (1971) states that letting observers evaluate bounce in their own way in their particular area is best. When transmitters are behind a ridge in relation to the receiver and the receiver was located at or near the same elevation as the ridge, no signal or a sporadic one was heard. Upon moving the receiver to a higher elevation or a greater distance, the signal was received.

Receiver station operator bias was minimal. Tom Stehn (pers. comm.) noted that varying transmitter operation, location, and activity

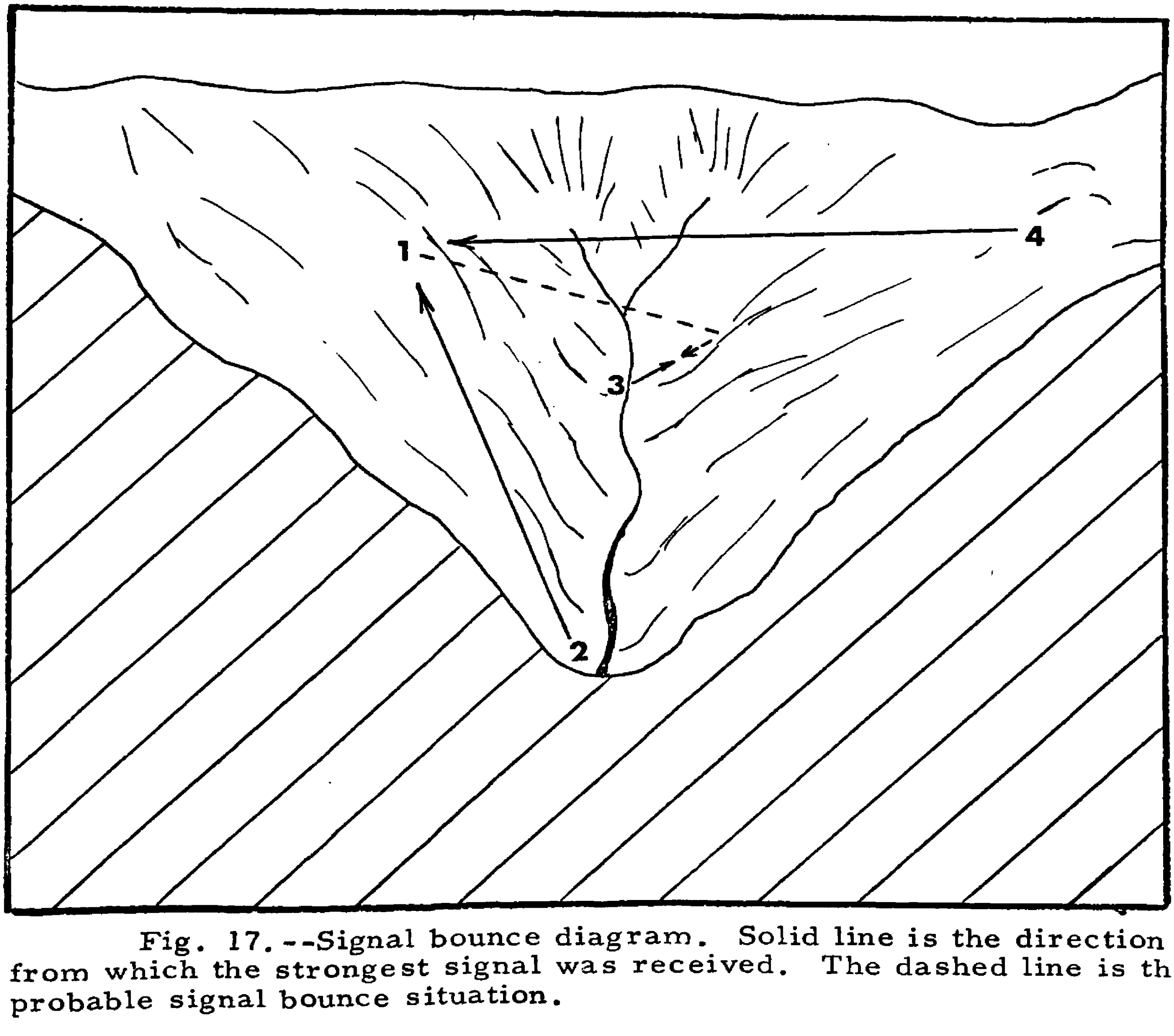

Fig. 17.--Signal bounce diagram. Solid line is the direction from which the strongest signal was received. The dashed line is the probable signal bounce situation.

did not allow a preconceived bearing direction. Due to the distance limitations of hiking the general area of activity did allow a bias, but did not affect the precise bearing reading. Bearings were taken using audible signal strength instead of the receiver signal strength indicator. Stehn had trained himself in the use of the system in this manner. The signal strength meter was used as a check, and was more valuable for the steady signal transmitter (Stehn, pers. comm.).

Varying activity of the transmitter was designed to test the receiver operator's ability to discern changes in activity. On two occasions, the transmitter was stationary and the operator labeled it as in motion. On one of these, the transmitter man was in motion around the stationary transmitter. The transmitter was in motion on two occasions and labeled stationary. On eleven occasions the transmitter was correctly labeled in motion. Four unsuccessful fixes were in motion. Erratic signals were responsible for three of these; the other was not taken in time. This data, though scanty, leads me to believe that activity determination may be marginal using audible signal exclusively. Stehn (1973) was trained for audible signal activity determination with the aid of a Rustrak recorder similar to that described by Gilmer (1971) and the pulse height detector (Varney 1971). When a variety of topographic and vegetative situations occur between transmitter and receiver, an irregular signal indicating activity (Stehn 1973) may be caused by movement of vegetation in wind or movement of other animals in the vicinity of the transmitter instead.

Radioed animals were approached on the ground using a three element Yagi antenna with the same receiver. The animal is usually disturbed when human presence becomes known. The animal leaves the immediate vicinity. The probability of animals habituating to the constant presence of a person tracking was not tested.

Using ground telemetry for elk is limited by the natural movements of the animals themselves. Movements may be great enough to render use of permanent triangulation stations useless. Following animals at a distance and triangulating upon them from high points can be done, but Stehn (pers. comm.) had difficulty in consistently finding and locating animals on a day-to-day basis, especially in inaccessible terrain.

CHAPTER VI

SUMMARY

A double whip-dipole antenna receiver system utilized in this study is practical, and adapts well to tracking elk in mountainous terrain in Western Montana. There are several advantages involved. The receiver system is easy to use after a relatively short training period. Locations can be plotted accurately on aerial photographs, depending on the ability of the observer. Many bits of data are possible for each location; behavior during visual observation, meteorlogical conditions, habitat parameters, time and topography for both visual and approximate locations are examples. This system allowed an observer to locate seven elk and nine elk, in 1971 and 1972, respectively, into often times remote and inaccessible areas spread over 200 square miles of mountainous terrain. It took two hours flying to accomplish this. This would be difficult for one person on the ground, because individual animals may be separated by as much as fifteen airline miles at any one time. Approximations of unseen radioed animals are accurate enough, on occasion, to facilitate finding the exact site of animal activity by ground search. Equipment is dependable as long as an observer is knowledgeable in its use and care. Minor problems of dirty connections, power loss, or loose components can occur and be corrected promptly. Reuse of most recovered transmitters is an advantage; however, recovering transmitters from radioed animals or from where they may have fallen off after malfunctioning is difficult. Animals do not appear to be harmed by radio collars nor harassed from aircraft.

No system is without its limitations. Loss of transmitters occurs. Transmitter malfunction is a problem difficult to solve without recovering transmitters as soon as they malfunction. An observer cannot observe elk any time of the day or night nor in all weather conditions. A number of locations are necessary for training pilots and observers to familiarize them with flight patterns required and use of equipment. Stormy, windy, cloudy, or excessively hot weather does not allow aircraft use in the desired manner or danger to aircraft and human life becomes a factor. Ratios of visual and approximate observations depend upon habitat use by elk under varying environmental conditions. The decision to use aerial telemetry should be made, based on the species to be studied and the type(s) of observations required to meet the objectives of the study.

The telemetry system, with an eight element Yagi antenna, is reasonably accurate for ground work on flat to rolling terrain, but error is two to three times greater in mountainous terrain. Multiple fixes and realization that greater error exists allow approximate locations only. The ground system does not allow frequent visual observation, nor can it locate several animals over 200 square miles of mountainous terrain. Determination of activity pattern changes and gross movements of animals is feasible from the ground; however, elk movements in inaccessible areas hinder triangulation work.

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