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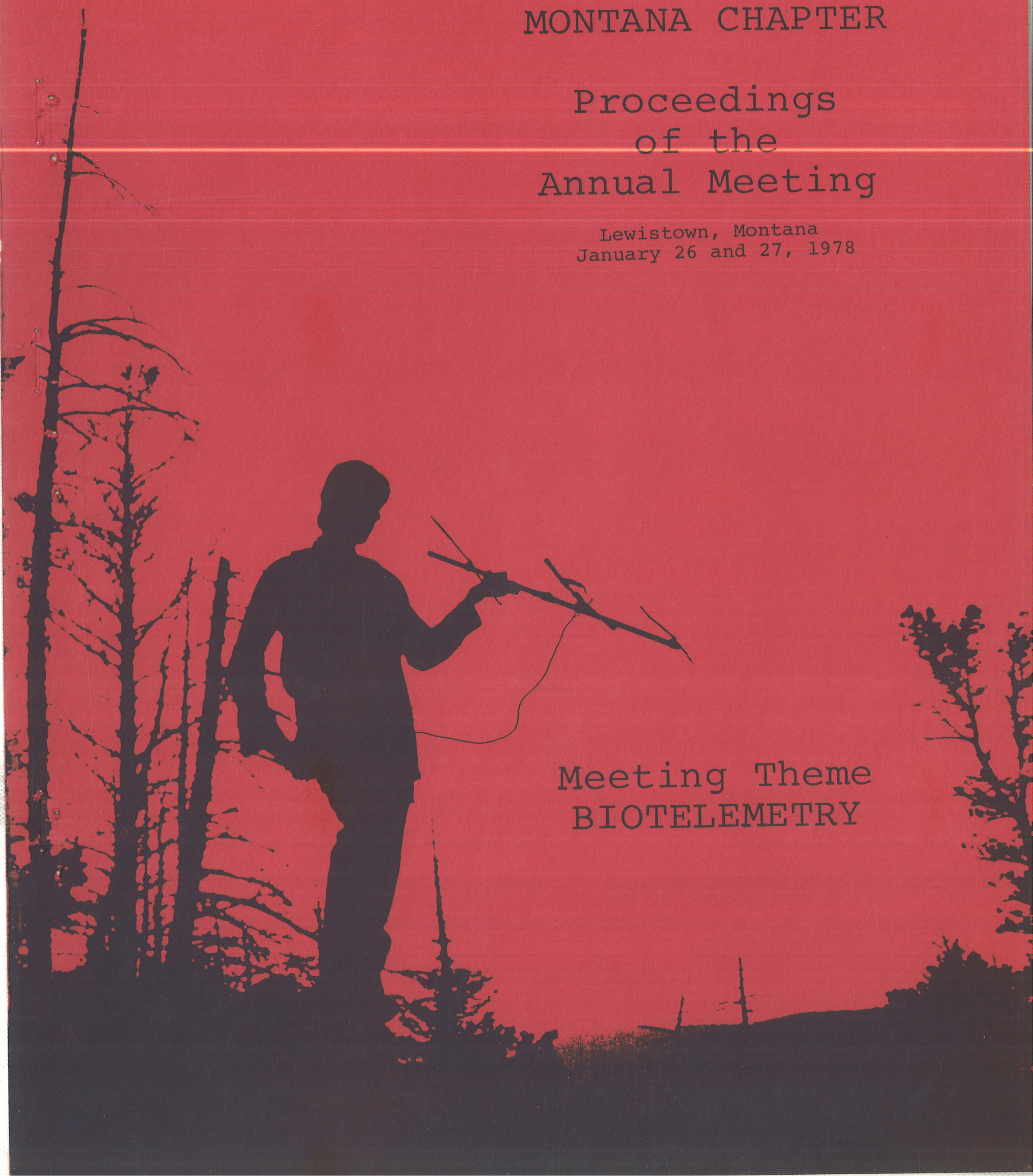

Meeting Theme
BIOTELEMETRY

F O R E W O R D

The program theme of the 1978 meeting of the Montana Chapter of The Wildlife Society was "Biotelemetry". Discussion ranged from its usefulness and application in wildlife management to very technical aspects of how biotelemetry equipment operates. There were 104 chapter members in attendance and the meeting lasted for two days (January 26-27). Two of the 18 reports planned for the meeting were not given, because bad weather prevented the speakers from attending.

These proceedings were compiled and edited by Terry Lonner; typing was supervised by Phyllis White.

The photo on the cover was taken by Paul Tarnauskas.

TABLE OF CONTENTS

BIRTH AND EARLY JUVENILE STAGES OF BIOTELEMETRY - AN OVERVIEW

Steven L. Judd[1]

The theme of this year's meeting is biotelemetry. So why biotelemetry for the theme of a whole chapter meeting? Is there even enough biotelemetry work going on to provide a 2-day program? These questions and others like them cropped up almost simultaneously with the announcement of the theme.

These questions and discussions are what prompted the title of my overview - birth and early juvenile stages of biotelemetry - and I suppose I should have added, as it applies to wildlife research and management; for in some fields biotelemetry has gone far beyond its juvenile period. The space program and some oceanographic work are far beyond the juvenile stages. But I think we are still in it.

Wildlife biotelemetry, per se, has actually been around quite awhile; for about 21 years now it has been used in gathering data on wildlife species. It was born, or I suppose I should say hatched, in 1957 when researchers Busser and Mayers developed and used a transmitter that would fit into a King penguin egg and would transmit the temperature of the egg. Their transmitter weighed 80 g, was powered by three mercury batteries with a 150-hour life expectancy, was accurate to 0.2° F, and had the awesome range of 80 feet. From this early stage we have progressed to a meeting like this one today. Much of the technology that made this beginning possible was developed in the budding young space programs and in the medical field.

Then a few farsighted people, biologists and engineers, teamed together to develop a tool that would allow us to gather certain types of data, in the quantity and quality that would not otherwise be obtainable. It has made many studies possible and forced changes in many concepts such as behavior and home range. There are probably going to be many changes of concepts that we will learn as our data proliferates.

The field began to grow rapidly after 1957, and by 1959 there were about 20 papers published on some phase of biotelemetry.

From these meager beginnings we have blossomed and have hung around, stuck on, sewn in, and otherwise attached transmitters to everything from *Peromyscus* to pachyderms, literally. Of course, the path has not been smooth. At first it was looked on as a rather expensive toy, a fad that would soon pass. However, it did not pass, and by 1963 conferences were being held on biotelemetry and a wildlife biotelemetry newsletter was being circulated.

Then a few people started to get some data, and the Buck Rogerish quality of this space age technique became a status symbol. If you didn't have someone in your organization with a couple of transmitters and a set of headphones, you just weren't doing up-to-date management and research. This helped some

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fish and game administrators for a year or two. When the local sportsmen club came in and put the heat on about the lack of game in Backwoods Creek, all the man had to do was give them the space program bit and about how they had a man on the area who would soon have all the problems solved and once again there would be a deer in every garage.

Well, it didn't quite go that way - biotelemetry is not a panacea but just another tool, albeit a very useful one.

Perhaps I should point out here what we are really talking about when we say biotelemetry. It has been defined thusly: "Biotelemetry, the instrumental technique for gaining and transmitting information from a living organism and its environment to a remote observer" (Slater 1965). Used in this context, a lot of us are generally not talking about what we thought we were talking about, which is often the case when a bunch of wildlifers get together. But we do have some people here who are going to talk about biotelemetry, the equipment, and the techniques; and I am sure we will all find this quite beneficial.

What I think most of us really want to discuss are the results of studies that have USED biotelemetry to gain insight into and definition of some basic biological phenomena, so that we will be better able to understand and manage our wildlife and other natural resources.

There are a few things, however, that still stand in the way of getting the most out of this technique. There still seems to be a kind of mystique that surrounds biotelemetry. Some managers and researchers using biotelemetry and the data gained with it are still somewhat awed by it. We are not awed by the plane we fly in to do our radio tracking nor are we awed by the car we use to get to the airport. These are accepted as everyday mechanical devices of which we know most of the capabilities and limitations. We are still learning the capabilities and limitations of our radio equipment. I don't mean to imply by that that we should become electrical engineers or even low grade electronics technicians. In fact, good biologists who are also good in electronics are few and far between.

Because of this lack of understanding of the mechanics, we don't always get the right equipment for the job; this can then make all biotelemetry work suspect to some people. I would like to quote from an article written in 1965 that I think is still pertinent: "It is clear that the future of biotelemetry, while exceedingly bright, rests firmly on the continued and strengthened liaison between engineers and biologists which ushered in the technique only a few short years ago. The notion that the biologist may work in isolation and some day purchase his biotelemetering units in bright new 'off-the-shelf' models becomes more and more wishful thinking as this technique gains in versatility" (Slater 1965). Well, we do now have bright new 'off-the-shelf' models, and in many cases these are just what the investigator needs. However, sometimes they are not, and I think we need to renew this rapport with the electronics people.

As an example, we are still running around for the most part just trying to figure out where the animals are. This is good information, but there is a lot more data out there that we desperately need and there probably is the technology available to get it. In fact, some studies are getting this data - things like active vs. inactive periods in wolves, and how varying water temperatures affect alligator movements and behavior. There have been extensive studies in both Minnesota and Wisconsin that amassed large quantities of data on primarily small- and medium-sized mammals. Fisheries research people seem to have more potential projects which lend themselves to remote sensing of environmental conditions surrounding the animal, especially in the laboratory, than do researchers on terrestrial species. Or perhaps they just have more imagination.

I have one last major item that I think has caused more problems in the use of biotelemetry and use of the data gathered, if any, than most of the inherent equipment problems all put together. Biotelemetry, remote sensing, radio-tracking - call it whatever you like - CANNOT be substituted for good scientific study design. Nor can it be used in place of well thought out objectives. In biological work it is a tool, a methodology; it is not a result.

Biotelemetry is a technique that has proven its worth, and one that will be around in its various and steadily improving forms until something better replaces it or we run out of species to study.

LITERATURE CITED

Busser, J. H. and M. Mayers. 1957. Radio thermometer that fits in a Penguin egg. Naval Res. Rev.:9-13.

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ANTENNA CONSIDERATIONS FOR BIOMEDICAL TELEMETRY

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SECTION I
DESCRIPTION

1-1. PURPOSE AND SCOPE

The purpose of this paper is to provide personnel not skilled in antenna design or, for that matter, electronics necessarily, with sufficient information that they may choose and operate VHF-UHF antennas in practical field work based on the theory and performance information provided. This is not a "how-to-buy" paper, and is not directed to particular manufactured products, but rather toward various antenna types and designs as applicable to current and very real field problems. However, prior to actual fielding of equipment, personnel should be briefed on translating study mission requirements into the selected antenna type(s).

This paper includes a section on factors to be considered when selecting antenna types relative to pattern coverage, gain, bandwidth, and polarization. Comparison charts are provided in the case of several design types, and fleeting dips into basic theory areas are made where essential to the knowledge of the researcher.

It should be understood from the outset that each major topic and characteristic brought out could easily fill volumes. Additional details are obviously beyond the scope of a paper of this type, but the writers will gladly provide additional information or reference sources to those interested. This is intended to be a working paper, through the use of which practical results can be obtained by field personnel with more important things on their mind than oddly configured arrays of tubing and plastic which deform readily upon impact.

Radio waves are electromagnetic in nature, and therefore invisible (in our frequency range of interest,) to the human eye. This generally makes it difficult to visualize the mechanisms by which they can be reflected, blocked, scattered, polarized, or impressed on a resonant element. In many ways radio waves behave like light however, and this analogy can simplify the learning process to some degree, and make sense of many otherwise confusing indications in the field.

Basically, the researcher has two main problems which he alone must solve when utilizing a telemetry system, once the animals have been released:

1.) Physically reaching or establishing a point where a signal can be received.

2.) Establishing a reliable data link between himself and the animal once a suitable reception location is established. In most cases at this stage in the development of telemetry this is done for the primary purpose of determining the relative direction of the animal from the receiving location. In a growing number of cases however, the direction is either not a primary concern, or of no concern at all, and the data link is required only to transfer activity or physiological information from the animal to data acquisition systems at the receiving site.

A basic understanding of receiving antenna characteristics will allow the researcher to solve (1) above almost immediately when coupled with knowledge of the animal's habits. Solving this problem also has the greatest impact on the <u>REAL</u> basic problem in research-the cost of data.

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A great deal is said about "ease of operation", "convenience in the field", etc., but what we are actually talking about is the financial investment required to gather the data. We must assume for the purpose of this discussion that the telemetry system with which we are dealing is composed of reliable components such that the major investment reduces to man and machine hours in the field. In such a case, the time-to-acquire signal, and the ability to maintain a reliable data link to the animal once acquired can easily result in the most significant expense or cost-saving area. The proper choice of receiving antenna at the onset of the study can very literally make, or break a study.

Unfortunately, most antenna designers are purists, in that the comparative data available on various antenna types is based on performance under "ideal" conditions. The writers have seen precious few "ideal" conditions in the field in the past 16 years, and it must be understood that while the technical information is very helpful initially- the final choice of antennas MUST include the actual field conditions to be encountered. This is because some antennas are quite temperature sensitive, some will not perform in high humidity, some will not achieve proper patterns or gain if near various surrounding objects, some become very fragile in cold weather, some cannot stand salt-water environments, some MUST have large ground-plane areas under them, others will not function if a ground-plane is present, etc., etc. It is therefore advisable to look into these areas also, after the basic antenna types have been reviewed.

1-2 ANTENNA CHARACTERISTICS

An antenna is a basic component of any electronic communication system which utilizes free space as the medium of propagation. Since, in general, antennas have reciprocal properties, the same antenna can be used to either transmit or receive. The antenna characteristics are an essential part of the overall operational characteristics of the system in which it is used. For example, an antenna can be designed so that it transmits or receives signals more strongly from one direction than another. It can also be designed so that it transmits or receives a signal essentially uniformly in all directions. Thus, by the proper choice of antenna, the system can be made directive to achieve "gain" and to reduce the possibility of interference from other systems. All antennas have certain basic defined properties that are a measure of their effectiveness and suitability for a particular application. The principal properties which are of specific interest to the reader are:

a. The radiation pattern character.

b. Polarization

c. Gain

d. Impedance at the antenna terminals.

e. Bandwidth

These characteristics are described in sufficient detail in the following paragraphs that the reader will have an insight into the trade-offs available for choosing a logical antenna type for a given application. These properties are identical for either transmitting or receiving. FOR THE PURPOSE OF EXPLANATION, THESE PROPERTIES WILL BE CONSIDERED IN THE TRANSMITTING SENSE.

1-3 ANTENNA PROPERTIES

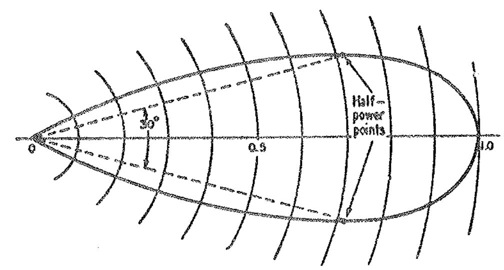
1-4 Radiation Pattern. The radiation pattern defines the way the radiated energy is distributed in space. The radiation pattern is usually the first property of an antenna that is specified once the operating frequency has been established. Two important characteristics of a radiation pattern to be specified are the beamwidth and sidelobe level. The beamwidth of a pattern is normally defined by the angular width of the pattern at a power level which is one-half of that at the peak of the main beam.

This is called the half-power, or "3 dB beamwidth". (A reduction in power to a point corresponding to ½ the original power level represents a relative change of 3.0 Decibels, or 3 dB.) (It might be well to note at this point, for those unfamiliar with the term DECIBEL or dB, that it is a very convenient term for expressing relative antenna gains, and signal levels in the field. Measurements of power levels are made logarithmically, and since the Decibel is a logarithmic term, we laymen can simply add or subtract dB's for the purpose of relative comparisons of power levels, or "densities".)

IT IS SIGNIFICANT TO NOTE THAT A CHANGE in Power of 6 dB (either times 4, or times ¼ of the original level,) represents an effective change in operational range by a factor of two. i.e., if the signal level at the receiving end of the system is increased by 6 dB, the transmitter can now be received at TWICE the original, or prior distance. Similarly, if the signal level at the receiving system is reduced by 6 dB, it will only be possible to receive the transmitted signal at one-half the original or prior distance. This relationship carries appropriately on through higher levels, a 12 dB change would vary the operating range by a factor of four (4), 18 dB varies the range by a factor of eight (8), 24 dB varies the range by a factor of sixteen (16), etc., etc.

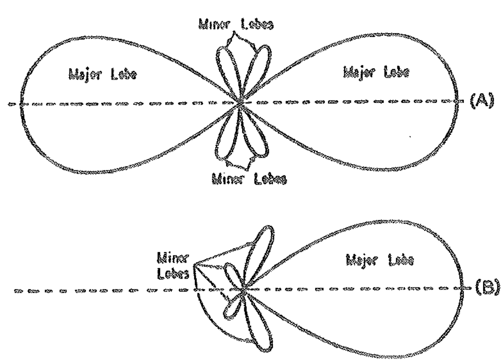
The illustration at the right serves to illustrate the half-power point concept as applied with a fairly directional antenna. In this instance, the 3 dB points as they are called, occur at points 15 degrees plus and minus of center direction, or a total 3 dB beamwidth of 30 degrees.

In addition to the main beam, antenna patterns have very definite SIDE LOBES which are often encountered, but seldom understood. An example of such lobes is given in the next illustration to the right. It may be seen that in the first case, a simple bi-directional antenna such as a DIPOLE has two main lobes, BUT it also has a number of "side", or "minor" lobes. Antennas actually have many more minor or side lobes of less significance, but they are seldom shown due to their relative insignificance, and the fact that the manufacturer would generally not wish them to be known!



— The width of a beam is the angular distance between the directions at which the received or transmitted power is one half the maximum power.

In a practical sense, these minor or side lobes are not evident when receiving a weak signal, as only the main lobe(or lobes), or "main beam" is capable of viewing the weak signal. The situation changes drastically however when a strong signal is present. (Such as in aircraft systems, or fixed sites with large antennas which command a good view of the study area.) In the latter cases, the side lobes are perfectly capable of receiving signals well, and one must be very careful not to confuse them with the main beam. The most confusing aspect of the side lobe problem is most evident WHEN REFLECTIVE SURFACES IN THE NEARBY GEOGRAPHY ARE PRESENT. (Study areas in foothills, near canyons, etc.) In that case, it is easy to see where a reflected signal might arrive on a more significant minor lobe such as is present in illustration (B) of the second figure. It is quite possible to receive the direct signal on the major lobe, and simultaneously receive a reflected signal on a minor lobe. Depending on the distance traveled by the reflected signal, the



— Typical bidirectional (A) and unidirectional (B) directive patterns. These drawings also illustrate the application of the terms "major" and "minor" to the pattern lobes.

combination of signals may add together and produce a falsely strong, and apparently very broad directivity, or in fact, can literally subtract from each other-thereby producing a false "null" or minimum signal condition-or any combination in between. IN ACTUAL PRACTICE, MANY MORE SIGNALS THAN TWO ARE ARRIVING AT THE RECEIVING ANTENNA AT ONCE, AND THE ALGEBRAIC SUMMATION OF THE SIGNALS IN VARIOUS PHASE RELATIONSHIPS WILL DETERMINE THE MAGNITUDE, OR APPARENT SIGNAL STRENGTH AT THE RECEIVER. These effects can either drive the operator to distraction, or if used properly, can be a great aid, and actually provide additional insight into the habits and activity of the animal.

WHAT ALL THIS BOILS DOWN TO is simply, that in our opinion, IT IS CERTAINLY POSSIBLE TO HAVE TOO MUCH ANTENNA GAIN AT THE RECEIVING SITE for some study situations. Again, the geographical area and study objectives must be considered.

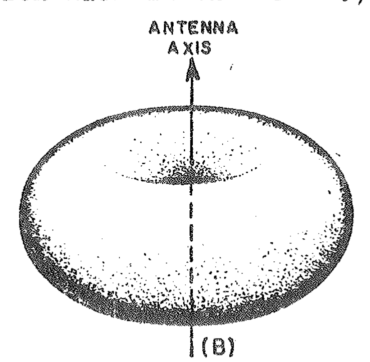
It may now be seen that the side lobes, or minor lobes are seperate and distinct from the main beam. Because they do not contribute to the principle direction of interest, it is desirable to keep the side-lobe level at a reasonably low value. The side-lobe level is generally specified with respect to the maximum of the main beam, and it is expressed in "dB down from the main beam". In practical designs, they should be 13 dB or more below the main beam peak. In directive antennas, the side lobes are a function of element placement and spacing. The user should be aware that MANY SUPPLIERS IN THE TELEMETRY FIELD DO NOT HAVE ANTENNA DESIGN CAPABILITY, OR EVEN MORE IMPORTANT PERHAPS, ANTENNA PATTERN TEST CAPABILITY. MOST SUPPLIERS SIMPLY CUT THE ELEMENTS OF STANDARD 2-meter AMATEUR ANTENNAS and supply them as-is. Such practices modify the characteristics of the antenna-in it's characteristic impedance, front-to-back ratio and over-all gain. An antenna thus modified cannot be expected to perform according to it's theoretical optimum design, and the user should in every case TEST EACH SUCH ANTENNA CAREFULLY PRIOR TO ACTUAL FIELD USE TO DETERMINE THE PARTICULAR CHARACTERISTICS IT EXHIBITS.

Over the years, many attempts to overcome these problems have been made, with so-called "PEAK/NULL" systems heading the list for a majority of applications. In many cases the results have been significantly better with such a set-up-but interestingly, NOT NECESSARILY THE SAME FROM STUDY-TO-STUDY. This seems to have lead to some controversy concerning the utility and application of "PEAK/NULL" and the many other approaches. It is unfortunate, but in many cases the comparisons were invalid, because the systems being compared were not equal in capability. As a case in point, the peak/null system is actually based on CRITICALLY PHASING two antennas together such that they ADD in gain in the PEAK mode, and NULL or CANCEL in the NULL mode. Again, one should not expect antennas cut to calculated dimensions to be electrically in phase, and THE PROBLEM OF MAINTAINING THE CRITICAL PHASE RELATIONSHIPS IN THE PHASING HARNESS fabricated of coaxial cable cannot be over stressed. The writers would not consider fielding such a system unless it was designed with phasing controls built-in which were aligned under dynamic test conditions wherein the actual response and phase relationships were visually apparent. The difference between such systems and so called "cut-and-hope" systems is dramatic in most cases. (Sometimes you get lucky, but most of us have enough problems with luck in the field.)

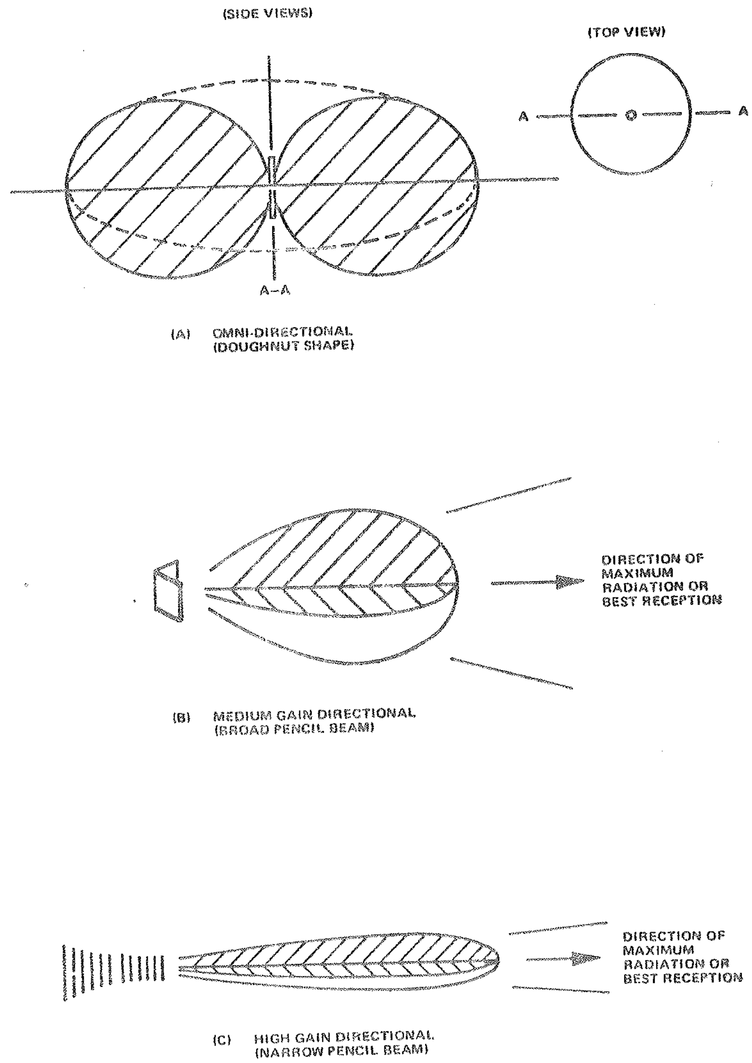
1-5 Types of Radiation Patterns. The types of radiation patterns of antennas described in this paper are namely:

a. Doughnut type pattern - omni-directional (uniform in all directions of a plane).
b. Broad pencil beam pattern - medium gain directional.
c. Narrow pencil beam pattern - high gain directional.

The figure at the right graphically illustrates the classic doughnut pattern:



The figure at the right depicts the three approximate shapes of the respective patterns.



Antenna Pattern Shapes

1-6 Doughnut Pattern. The doughnut or omni-directional pattern is used for applications requiring that the radiation be equal in all directions in the horizontal plane. In general, the pattern in the horizontal plane is nearly uniform or circular as indicated in the top sketch. In the vertical plane, the radiation pattern is maximum everywhere on the horizon, and zero overhead, hence, the name; "doughnut" shape.

1-7 Broad Pencil Beam Pattern. The broad pencil beam (medium gain directional) pattern is extremely useful for applications requiring that the pattern be concentrated in an angular sector. It is also the most practical for general hand-held use, and for situations requiring more gain than the smaller antennas, and less size and weight than that which is required with the larger antennas described next. (It may be evident that in general, antenna gain varies in direct proportion to size-as will be explained later.) For these applications blanket coverage is neither needed, nor desired. The middle sketch depicts a typical medium gain pattern, or "coverage". In general, this type of antenna is 2-3 times larger in volume than those having a doughnut (omni-directional) pattern. Antennas which exhibit a broad pencil beam pattern are the Corner Reflector Antenna, the Short Yagi, the Helix, and the Log Periodic Antenna.

1-8 Narrow Pencil Beam Pattern. The high gain directional pattern illustrated by the bottom sketch above is generally used for applications that require high gain and concentration of the beam in a very narrow angular sector. Examples of narrow pencil beam antennas in this paper are the "Yagi" and the Rhombic antenna.

By now, it is probably apparent that a graph showing the actual or relative intensity, at a fixed distance, as a function of the direction from the antenna system is called a radiation pattern. It MUST ultimately be understood that such a pattern is a three-dimensional affair, and therefore cannot be well represented in a plane drawing. The "solid" radiation pattern of an antenna in free space would be found by measuring the field strength (intensity) at every point on the surface of an imaginary sphere-having the antenna under consideration at it's center. The information thus obtained is then used to construct a solid figure such that the distance from a fixed point (representing the antenna) to the surface, in any direction, is proportional to the field strength from the antenna in that direction.

ISOTROPIC RADIATORS: If the reader is to fully understand the terminology given by various manufacturers as applied to antenna gain comparisons, the term "dBi" must at least be marginally understood. Many manufacturers use the term "dB" ONLY to signify the relative gain of an antenna. In the electronics field, this has come to generally mean the same thing as "dBd", which is THE RELATIVE GAIN OF A PARTICULAR ANTENNA-RELATIVE TO A "STANDARD" (single element) DIPOLE ANTENNA. Hence the term dBd, or dB-dipole. Partially through laxity (or purpose,) the term dBd has slipped into just dB in most cases. More reputable manufacturers and suppliers use this means of specifying relative gain relationships, while some less reputable firms use the comparison of a given antenna to what is called an ISOTROPIC POINT SOURCE, or ISOTROPIC RADIATOR. Since such comparisons are misleading, and serve to make the antenna look better than it would if compared in the conventional manner, it might be desirable to learn what an isotropic radiator is.

As you may have gathered, the radiation from a "real", or practical antenna is NEVER THE SAME in all directions. In fact, the radiation in some directions will even be zero, or in the case of antennas arrayed for gain, it will be greater than from an antenna that DID radiate equally in all directions. ALTHOUGH no antenna radiates with equal intensity in all directions, it is nevertheless useful to assume that such an antenna exists; for the purpose of comparing the properties of actual antenna systems. Such a hypothetical antenna is refered to as an ISOTROPIC RADIATOR. The "solid" (or 3-dimensional) radiation pattern of an isotropic radiator WOULD BE A SPHERE, since the field strength is the same in ALL directions. Therefore, in any plane containing the isotropic antenna (which may be considered as a "point source") the pattern is a circle with the antenna at its center. The isotropic antenna (or "radiator") has the simplest possible directive pattern; it has no directivity at all.

It is generally considered by the antenna industry that the relative variation between an isotropic point source and a "standard dipole" amounts to 2.2 dB (Decibels). Therefore, if an antenna is rated as having (for illustration,) 14.0 dBi, the manufacturer is stating that it exhibits 14 dB more gain than an isotropic point source. He might also go on to state that the same antenna is rated at 11.8 dBd, or 11.8 dB more gain than would be achieved with a standard one-element dipole antenna. Note that the differential between dBi and dBd is 2.2 dB. With this information at hand, the reader can easily convert either terms for comparison.

1-9 Polarization. The polarization of an antenna is another important property. It is imperative that the transmitting and receiving antennas of a communications or data link have the same polarization where possible. If they are not oriented in the same polarization a certain amount of effective power radiated from the transmitting antenna cannot be "captured" by the receiving antenna. This occurs due to the fact that an antenna (speaking in context of receiving usage,) exhibits what is called an "EFFECTIVE APERATURE" which may be thought of as sort of a "window" in free space, wherein all signals of usable magnitude are "captured" by the antenna. If one were to be able to visually "see" this "window" when standing in front of an antenna, with the antenna pointing directly toward him, it would appear to be symetrically oval, and slightly larger than the maximum frontal size the antenna as viewed (in the case of common types such as yagi, etc.). The electromagnetic waves radiated from the transmitter possess an identical configuration (or "envelope" as it is called,) in the ideal case. It is therefore desirable to match these two aperatures or "windows" in like polarization in order to transfer maximum energy from one to the other. One might also think of the situation in terms of two boxes placed in a darkened room, each box with a hole in the side shaped like a symmetrical egg. In one box is placed a light bulb, and the purpose of the experiment is to set the boxes close to each other in such a manner that a maximum amount of light is transferred from the box housing the bulb, to the other box in which a large light meter surface is placed. It follows that orienting the "receiving box" in the same manner or polarization as the hole from which the light is emanating affords maximu transmission of energy.

The transfer of electromagnetic energy works in essentially the same manner, however (as always,) there is a catch. In our particular application, the polarization of the transmitting antenna on the animal is both unknown and uncontrollable. Some manufacturers offer specialized transmitting antennas which offer relatively predictable patterns and polarizations, but most do not. Even on the best transmitting configurations the polarity of the "envelope" or "wave-front" as it is sometimes called, may be modified by terrain and vegetation prior to reception-resulting in even more variables. We are fortunate however, that in the vast majority of cases (in ground-to-ground terrestrial work,) the signals ultimately arrive largely VERTICALLY POLARIZED. This literally means that if you are putting in an array which cannot conveniently be optimized in polarization, you will generally fare far better if it is installed in the vertical plane as discussed below (tips of the elements pointing toward the sky).

It might also be well to point out that for our purposes, we are confining the discussion in this area to LINEAR POLARIZATION. There are many other forms used for spacecraft communication, high rate data links, and specialized applications such as Right-hand Circular Polarization, Left-hand Circular, Compound, Modulated Phase, etc. In such cases, the electromagnetic wave front is made to twist, or spiral as desired in space, however the antennas required to induce such phenemonon become impractically large in our frequency range of interest.

Most antennas in use for biomedical telemetry applications are special cases of the standard dipole, or single-element antenna. For those unfamiliar with the term "element", for our purposes, it is a length of conductive material (usually copper or brass, or aluminum,) used to "gather" the electromagnetic energy in the effective aperature of the particular antenna array of which it is a part. In our case, the element will be an ELECTRICAL half wavelength long. It is well to note that the ELECTRICAL LENGTH of a linear circuit such as an antenna element is not necessarily the same as it's PHYSICAL LENGTH in wavelengths, or fractions of a wavelength. Rather, the electrical length is determined by the TIME taken for the completion of an electromagnetic wave to occur along the element. Suppose for example that two different materials are used for elements, each having different electrical characteristics so that the speed at which an electrical charge flows along the surface (and by the way, it <u>does</u> flow <u>along</u> the <u>surface</u> at VHF and UHF frequencies, not <u>in</u> the metal,) is not the same in both. Now suppose we want to make both elements resonant at the same frequency, and for that purpose adjust the physical length of each, until a charge started at one end travels to the far end, is reflected, and completes it's return journey to the near end in EXACTLY the TIME of one RF cycle. We would find that the PHYSICAL LENGTH of the circuit or element with the <u>lower velocity of propagation</u> is SHORTER than the physical length of the other. The <u>ELECTRICAL LENGTHS</u> however are IDENTICAL, each being a half wavelength. For this reason, antennas made to perform at the same frequency will have different element lengths if fabricated of different materials and in different configurations. In general however, the departure from an electical half-wave is usually small, in the order of 10% or less. Only in the most advanced antenna designs will the variation be truly significant, in some cases reducing the physical length of an element to 1/100 wavelength.

One distinction remains to be made concerning antenna elements, and that is of course that elements serve different purposes-hence different names. In the most simple antenna, the dipole, the one and only element is the antenna proper. In the larger Yagi-type arrays, the principal element to which the output cable or "feedline" is attached is called the DRIVEN ELEMENT (again the terminology for transmitting is used for receiving,) or D.E. Other "passive" elements are placed in the array in such a manner that the signal impressed upon the driven element is reinforced in amplitude, effectively increasing the array's effective aperature or window in space, and thereby gathering more signal. (It follows-but is often overlooked that as the aperature is made larger, the array <u>must</u> be placed further and further from surrounding objects if the additional gain is to be realized.) The elements placed in front of the Driven Element in effect "DIRECT" the array, and are therefore called DIRECTORS. There is usually one longer element placed behind the Driven Element in medium to large arrays which is used to REFLECT signals such that they add in-phase on the D.E. and further increase the effectiveness of the antenna array. This element is aptly called the REFLECTOR. Some arrays employ even a second reflector, but little is gained by such an approach, and the unit is made more awkward with regard to turning radius and wind loading-some things we in this field don't need.

In discussing polarization in this field, it may be said that the antenna is oriented in horizontal polarization when the elements are parallel to the ground proper-and vertically polarized when the array is rotated about it's axis such that the elements are perpendicular to the ground (tips to the sky and ground). The variation from horizontal to vertical is 90 degrees, or multiples of 180° plus 90°. (The polarization employed directly effects beamwidth. The vertical-mode beamwidth is generally 20-40% more narrow.)

It is always considered an optimum situation when the antenna array has a means of optimizing the received signal via polarization.

In general, it may also be said that antennas used in telemetry applications of this type exhibit polarizations which are parallel to the Driven Element.

1-10 GAIN. The gain of an antenna can be considered as a figure of merit. The higher the gain, the more concentrated the radiation pattern. High gain values are associated with narrow pencil beamwidth and conversely, low gain with wide beamwidth. Speaking again in the reciprical or transmitting sense, it may be said that-if a certain amount of power is supplied to the terminals of an antenna by a transmitter and the antenna radiates equally in all directions, the power at a given point in space will be less for that antenna than for an antenna having gain. THE HIGHER GAIN ANTENNA COMPRESSES THE POWER INTO A SMALLER VOLUME AND THEREFORE IT CAN BE USED TO COMMUNICATE OVER LONGER DISTANCES THAN AN ANTENNA THAT RADIATES EQUALLY IN ALL DIRECTIONS. (Gain does not come free, there is no amplification available from a passive antenna, you simply trade off one pattern for another. Even in antennas, you can't get something for nothing.) However, since it is directive, it is necessary that it be pointed in the direction that communication is desired, or in our case, data is to be received. It follows that one would normally not choose a highly directional antenna for general searching, however there are times when maximum gain is needed for searching in all directions. In these cases special 3 dBd and 6 dBd, and even 9 dBd omni directional antennas are available depending upon the required installation.

Comparative charts are provided later in this paper for the various popular types of antennas.

1-11 IMPEDANCE. The output (or input-again bi-directional,) impedance of an antenna structure at the feed terminals connecting it to the transmission line (usually coaxial cable,) of the receiving system is an important factor. It determines to a large extent the efficiency of the system because it directly affects the energy transfer between the antenna and the system. In this paper, all antenna designs are typically based on the use of coaxial radio frequency transmission lines having 50 ohm characteristic impedance. Thus for the optimum transfer of energy to occur between the transmission line of the system and the antenna terminals to which it is connected, the impedance level at the antenna and receiver should both be 50 ohms. The reader should be aware that attempting to combine transmission lines from multiple antennas cannot be done without special impedance transformation devices if excessive power losses are to be avoided. For example one might imagine that two antennas with an impedance of 50 ohms might be combined by connecting their respective coaxial feedlines together in a "Tee", then feeding a 50 ohm input receiver. In actual practice, the resulting mismatch would result in a 3 dB loss at the receiver-oddly enough, 3 dB is exactly the amount of power gained by adding a second antenna (a factor of 2). So for all the trouble, nothing is gained. By using the proper impedance matching/combining techniques, the added received power of the second antenna could be used to advantage.

1-12 BANDWIDTH. Bandwidth of an antenna can be defined in several different ways with frequency being related to one of the aforementioned four characteristics. The bandwidth can be defined as where the pattern degrades beyond a useable condition as FREQUENCY IS VARIED, or where impedance conditions deterioriate, or gain, or polarization change drastically. Thus, bandwidth can be defined as THAT FREQUENCY BAND WITHIN WHICH THE ANTENNA MEETS A GIVEN SET OF SPECIFIED ANTENNA PERFORMANCE PROPERTIES.

Bandwidth might more properly termed "RF Bandwidth" to avoid confusion with BEAMWIDTH as discussed earlier in this paper.

Until recently, bandwidth was not really much of a consideration to the wildlife field, as the range of frequencies in use were relatively narrow as compared to the characteristic bandwidth of the basic antenna designs employed. This is now changing, and one would do well to assure that the antennas to be deployed on a particular study will <u>in fact</u> function at optimum as defined above over the entire range of interest. The recent advent of synthesized receivers capable of covering 2, 3, and even 4 MHz, coupled with intensive studies employing up to 300 transmitters indicate the direction of things to come.

SECTION II

CHOOSING THE ANTENNA TYPE

2-1 CHARACTERISTICS. Section 1 discussed the general properties associated with receiving antennas. This section briefly tabulates the particular characteristics of various antenna types in an attempt to assist in general choices for various applications, and environments.

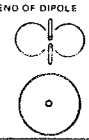
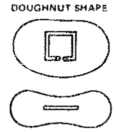
2-2 APPLICATION. Which of these antennas is most useful in certain applications depends upon several factors:

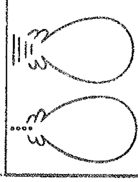
a. Pattern required, including gain and polarization orientation.

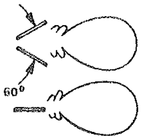
b. Installation limitations: volume allowed, pointing direction and obstructions, environmental restrictions, ease of mobility, ease of deployment, proximity of nearby objects, etc.

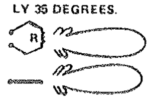
For the purposes of design and measurement, antennas are generally fabricated in test models at a common frequency, chosen for ease of construction and test. In this case 300 MHz was used. (Subsequent to fabrication and test, the most desirable antennas are scaled by frequency and factored by the velocity factors for the materials to be used and fabricated at the frequency of interest.) The 300 MHz test point is convenient in that the physical sizes noted in the tables may be doubled to obtain the approximate size in the 150 MHz range. This approximation is adequate for the range 146-175 MHz in general.

Only six antenna types are included in the following charts, in actual practice over twenty types might be considered. These choices were made because they generally bracket available types, sizes, and gains.

OMNI DIRECTIONAL							
ANTENNA TYPE	PATTERN DESCRIPTION	POLARIZATION	PEAK GAIN NUMBER	2.5 VSWR BANDWIDTH		ESTIMATED SIZE AT 300 MHz	REMARKS
DIPOLE	DOUGHNUT SHAPE NULL OR HOLES OFF END OF DIPOLE 	LINEAR AND SAME ORIENTATION AS DIPOLE ELEMENT USED MOST OFTEN IN VERTICAL ORIENTATION	2.1 DB ABOVE ISOTROPIC PEAK BROADSIDE TO DIPOLE	20%		FLAT AND THIN, MAXIMUM DIMENSION APPROXIMATELY 20 INCHES (51 CM) WIDTH EQUAL TO FOIL TAPE WIDTH	SMALL AND SIMPLEST ANTENNA TO BUILD PROVIDES GOOD VERTI CALLY POLARIZED COVERAGE
LOOP	DISTORTED DOUGHNUT SHAPE  DIFFICULT TO PREDICT HOW MOUNTING AFFECTS PATTERN.	LINEAR AND SAME ORIENTATION AS PLANE OF LOOP	APPROXIMATELY 1.5 TO 2 DB ABOVE ISOTROPIC PEAK OFF FEED END OF LOOP.	10%		FLAT AND THIN, DIMENSIONS APPROX IMATELY 7 INCHES BY 7 INCHES' (18 CM X 18 CM)	SMALL BUT NOT EASY TO OPERATE EFFICIENTLY. BEST USED WHERE HORI- ZONTALLY POLARIZED OMNI IS REQUIRED

MEDIUM GAIN DIRECTIONAL							
ANTENNA TYPE	PATTERN DESCRIPTION	POLARIZATION	PEAK GAIN NUMBER	2.5 VSWR BANDWIDTH		ESTIMATED SIZE AT 300 MHz	REMARKS
FOUR ELEMENT YAGI	BROAD PENCIL BEAM HALF POWER BEAM WIDTH APPROXIMATE LY 50 DEGREES 	LINEAR WITH SAME ORIENTATION AS THE YAGI ELEMENTS. USED IN EITHER VERTICAL OR HORIZONTAL ORIENTATION.	APPROXIMATELY 10 DB ABOVE ISOTROPIC. PEAK IS OFF END OP- POSITE FROM FEED END.	15%		FLAT AND THIN DIMENSIONS APPROXI- MATELY 20 INCHES BY 17 INCHES. (51 CM X 43 CM)	DIRECTIONAL ANTENNA. LIGHTWEIGHT, LOW VOLUME, MODERATE BANDWIDTH.

ANTENNA TYPE	PATTERN DESCRIPTION	POLARIZATION	PEAK GAIN NUMBER	2.5 VSWR BANDWIDTH		ESTIMATED SIZE AT 300 MHz	REMARKS
VEE	BROAD PENCIL BEAM, HALF-POWER BEAM WIDTH APPROXIMATELY 70 DEGREES. 	LINEAR AND SAME ORIENTATION AS THE PLANE OF THE ELEMENT. USED IN EITHER VERTICAL OR HORIZONTAL ORIENTATION.	ABOUT 7.0 DB ABOVE ISOTROPIC. PEAK GAIN IS OFF THE OPEN END.	50%		FLAT BUT REQUIRES RELATIVELY LARGE LENGTH. ARMS ARE 3 WAVELENGTHS LONG. AT 300 MHz, THIS IS 120 INCHES (OR 300 CM)	GOOD DIRECTIVE ANTENNA PROVIDED SPACE FOR ITS LENGTH IS AVAILABLE.

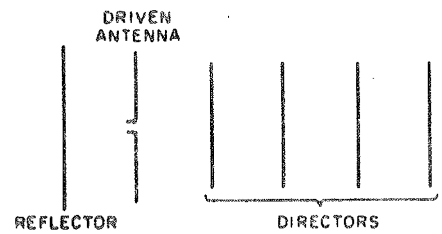
HIGH GAIN DIRECTIONAL							
ANTENNA TYPE	PATTERN DESCRIPTION	POLARIZATION	PEAK GAIN NUMBER	2.5 VSWR BANDWIDTH		ESTIMATED SIZE AT 300 MHz	REMARKS
RHOMBIC	NARROW PENCIL BEAM HALF-POWER BEAM WIDTH APPROXIMATE- LY 35 DEGREES. 	LINEAR AND SAME ORIENTATION AS THE PLANE OF THE ELEMENT. USED IN EITHER VERTI- CAL OR HORIZONTAL ORIENTATION.	ABOUT 13 DB ABOVE ISOTROPIC. PEAK OFF TERM- INATED APEX.	40%		FLAT BUT REQUIRES LARGE LENGTH. OVER- ALL LENGTH IS NEAR 6 WAVELENGTHS. AT 300 MHz, THIS LENGTH IS 240 IN.(OR 600 CM)	REQUIRES MUCH SPACE FOR LENGTH PLUS A TERMINATING RESISTOR.
TWELVE ELEMENT YAGI	NARROW PENCIL BEAM HALF-POWER BEAM WIDTH ABOUT 30 DEGREES. 	LINEAR AND SAME ORIENTA- TION AS THE PLANE OF THE ELEMENT. USED IN EITHER VERTICAL OR HORIZONTAL ORIENTATION.	ABOUT 15 DB ABOVE ISOTROPIC. PEAK IS OFF END OPPOSITE FROM FEED END.	15%		OVERALL LENGTH IS ABOUT 1.5 WAVE- LENGTHS. AT 300 MHz, THIS IS ABOUT 60 INCHES (OR 150 CM)	REQUIRES LONG FLAT SURFACE AND CAREFUL ORIENTATION POINTING BECAUSE OF RELATIVELY NARROW BEAMWIDTH.

SECTION III

ADDITIONAL INFORMATION

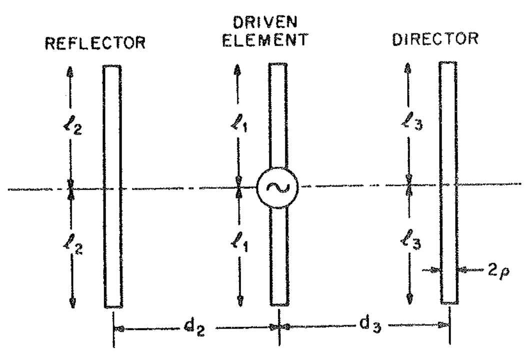
3-1 PHASE. The term "phase" has the same meaning when used in connection with the currents flowing on antenna elements as it does in ordinary circuits, or other applications. For example, two currents are "in phase" when they reach their maximum values, flowing in the same direction, at the same instant. The direction of current flow depends on the way in which signals are applied to the elements by positioning. In the case of a peak/null system, the currents from two stacked antennas are made to be IN-PHASE in the "peak" mode, and OUT-OF-PHASE in the "null" mode. In the latter case, the currents are made to cancel each other, producing a condition of minimum signal, or "null" directly ahead of the array.

3-2 "YAGI" (Yagi-Uda Array) BACKGROUND. The so-called Yagi antenna has been, and is currently a very cost-effective, and high performance antenna often used in wildlife telemetry studies. This antenna is composed of closely coupled arasitic arrays, where the parasitic element may function either as a director or reflector. In practice, it is common to use one reflector and one or more directors, up to 14 in number. The basis for the design dates prior to 1954 when it was officially introduced by S. Uda and Y. Mushiake of Japan. The description was subsequently translated to English by H. Yagi, after whom they have been referred for many years. In recent years however the term has reverted to "Yagi-Uda" array which seems a bit more fair. The first illustration depicts a high gain array, while the second shows the more popular and extremely effective three-element medium-gain array. This configuration has gained the widest acceptance in the wildlife field based on measured performance. The third figure shows the performance technically achievable for general information.

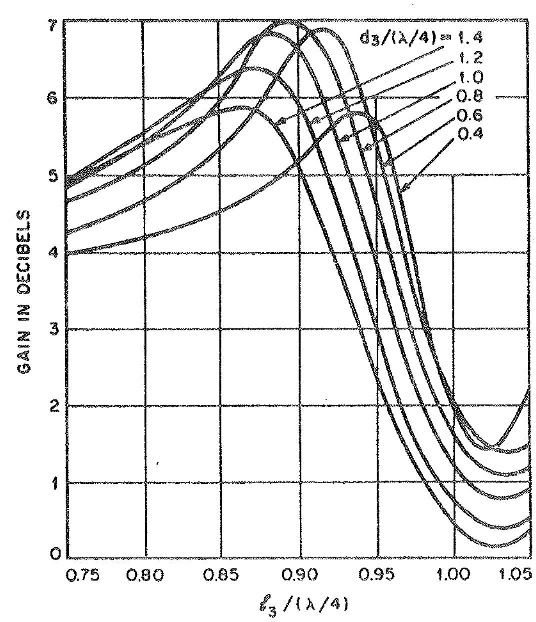


Yagi-Uda array.

* S. Uda and Y. Mushiake, "Yagi-Uda Antenna," Sasaki Printing and Publishing Co., Ltd., Sendai, Japan; 1954.



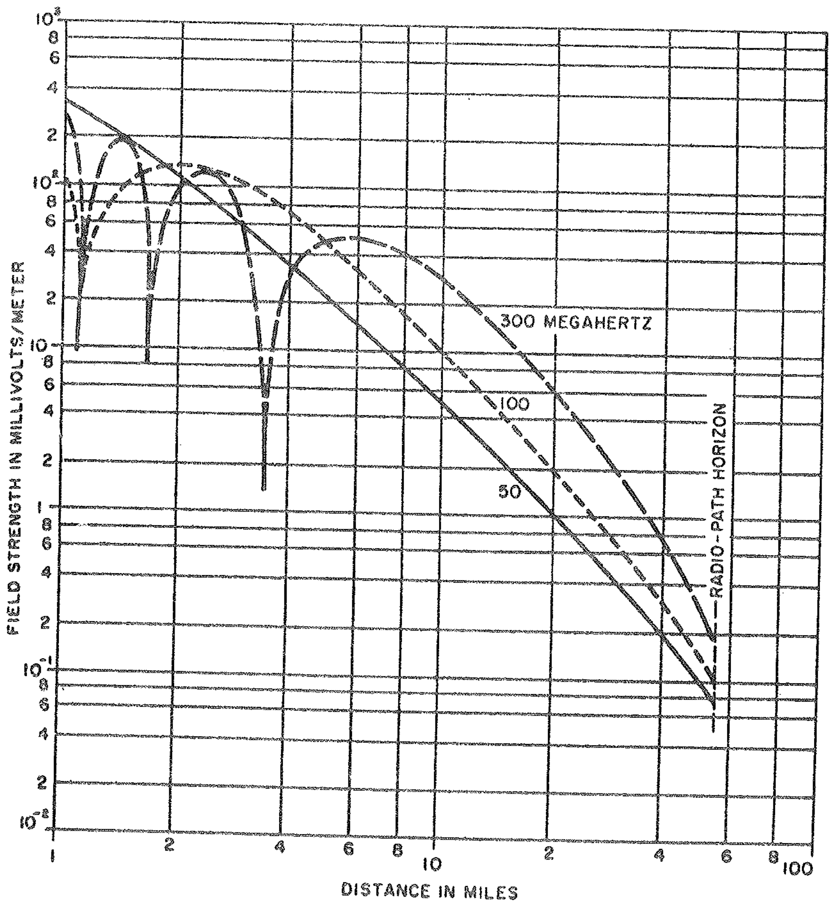
3-element Yagi-Uda antenna. *S. Uda and Y. Mushiake, "Yagi-Uda Antenna,"*



Calculated gain of 3-element Yagi-Uda antenna for indicated values of $d_3/(\lambda/4)$. $l_1=l_2=d_2=\lambda/4$ and $\rho=\lambda/200$. *S. Uda and Y. Mushiake, "Yagi-Uda Antenna,"* 3-3 ATTENUATION. The intensity of a radio wave in free space decreases directly in power with the distance from the source. As noted earlier (see page 3) the power density of the wave is reduced by 6 dB each time the distance from the transmitter is doubled. This decrease in field strength results from the fact that the energy in the wave progressively spreads out over larger and larger spheres as the distance from the source is increased.

In actual practice the attenuation of the radio wave may (and generally is,) much greater than this "inverse-distance" law would indicate. For one thing, the wave is not traveling in the empty vacuum of space, but in a rather dirty, and often humid atmosphere. For another, the receiving antenna is seldom situated such that a totally clear "line-of-sight" condition exists between it and the transmitting antenna. Since the earth is generally irregular in contour at short ranges, and spherical with regard to long distances where the so-called "radio horizon" comes into play, considerable vegetation loss and terrain scattering must be expected since the waves do not penetrate the ground to any extent at these frequencies. The general characteristic at the more popular VHF frequencies is virtually line-of-site. The lower frequencies in the HF range (30-50 MHz) exhibit some ability to "bend" over the terrain, but the beneficial effect is generally overshadowed by the high losses in both the transmitting and receiving antennas due to the excessively long wavelengths involved.

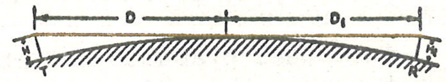
The chart at the right depicts graphically the variation in field intensity as the receiving antenna is moved away from the transmitting antenna. Note that the performance at 150 MHz and thereabouts will have more nulls than the 100 MHz line, and less than the 300 MHz line. These nulls are very real, and seldom understood. These characteristics will be discussed following the propagation charts.

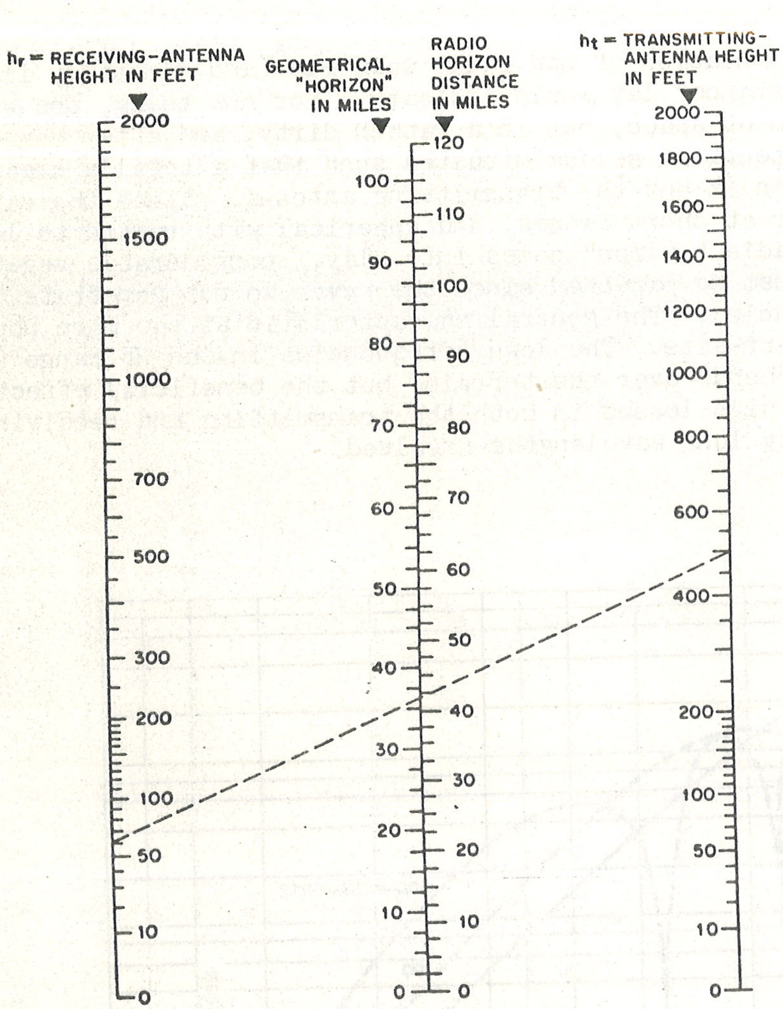


Variation of resultant field strength with distance and frequency. Antenna heights: 1000 feet, 30 feet; power: 1 kilowatt; ground constants: $\sigma = 5 \times 10^{-14}$ emu, $\epsilon = 15$ esu; polarization: horizontal.

The following nomagram may be used to determine the effective radio horizon on gently contoured terrain when the receiving antenna height is known, and the transmitter height can be approximated. It often proves to be an interesting excercise to compare the effect of an animal lying very close to the ground (particularly in damp weather,) as well as standing errect in a cleared area. The variation is extremely dramatic.

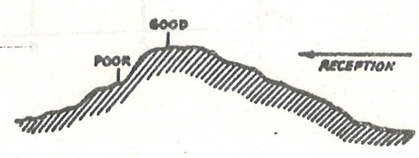
ELECTROMAGNETIC-WAVE PROPAGATION

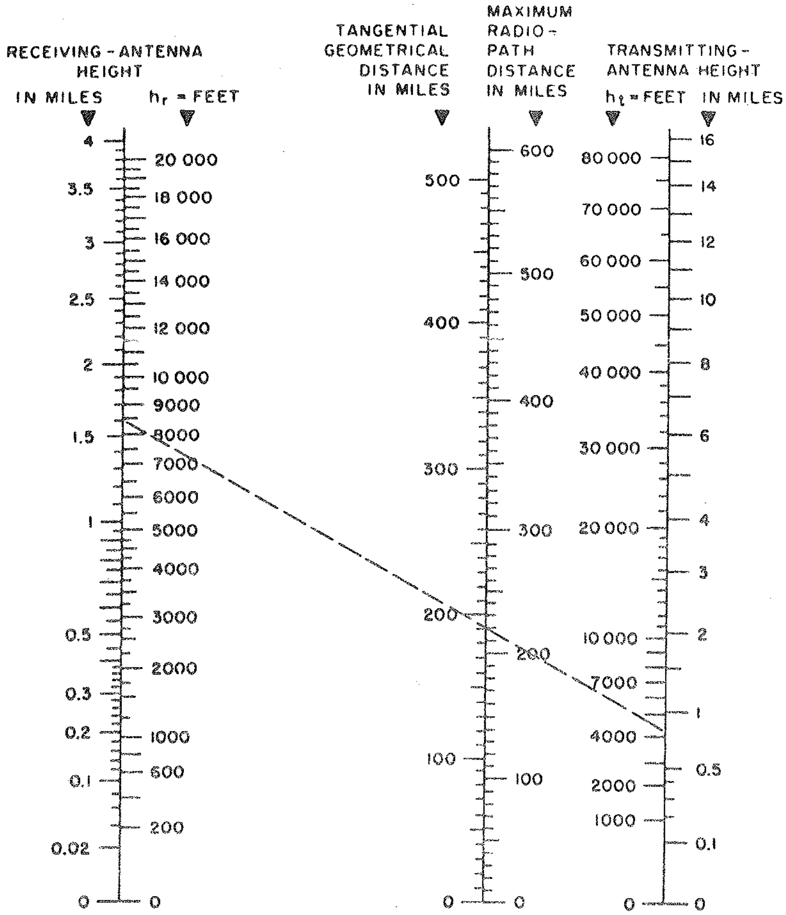




Nomogram giving radio-horizon distance in miles when h_r and h_t are known. Example shown: Height of receiving antenna 60 feet; height of transmitting antenna 500 feet; maximum radio-path length=41.5 miles. ($K=1.33$)

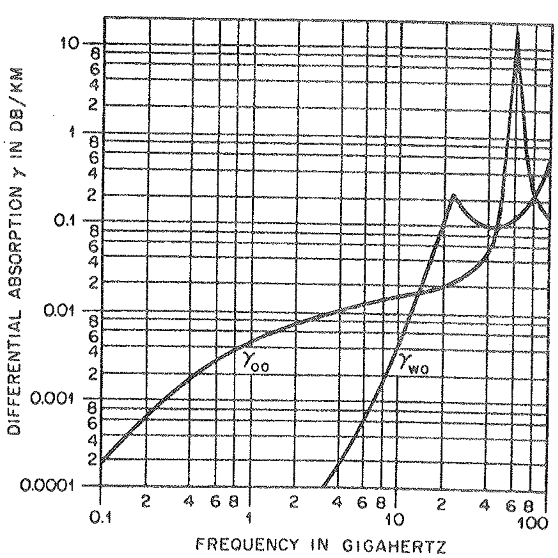
The nomogram which follows is designed for determining the radio-path length between two aircraft, however it is useful to compare the ideal path from an animal on the ground, or on the side of mountain from which the altitude can be approximated, to a receiving antenna system on an aircraft. Note in both cases the nomagrams show only the possible horizon or tangential path and DO NOT CONSIDER THE OTHER LOSSES OR TRANSMITTER POWER, OR ANTENNA GAINS AT BOTH THE TRANSMITTER AND RECEIVER.



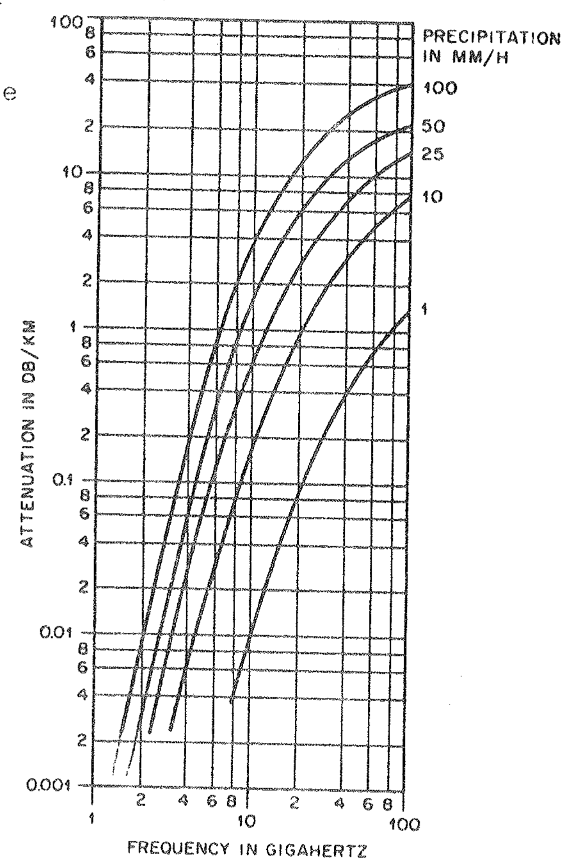


Nomogram giving radio-path length and tangential distance for transmission between two airplanes at heights h_r and h_t. Example shown: Height of receiving-antenna airplane 8500 feet (1.6 miles); height of transmitting-antenna airplane 4250 feet (0.8 mile); maximum radio-path distance = 220 miles. ($K = 1.33$)

Other factors which greatly effect the practical operating range of a system are the frequency range chosen, and various types of attenuation in the atmosphere. The frequency has been generally chosen to be in the VHF region due to the combined system trade-offs which easily occupy another paper of this length. The chart provided below offers a quick means of comparing absorption losses vrs wavelength. The chart at the right provides some insight into the effects of rain. Although no charts are provided, it can be stated with fact that the effect of snow is generally worse, however it will vary drastically with humidity. If it is very cold and snowing, the effect will be less than with a wet snow.



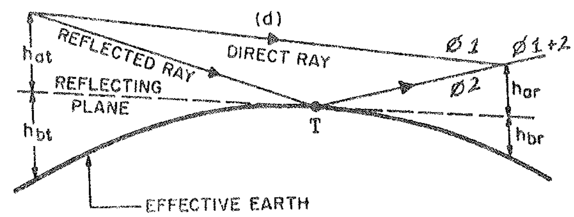
Atmospheric absorption versus wavelength.



Attenuation due to precipitation.

3-4 MULTI-PATH. Perhaps the most common problem in working with VHF frequencies in the field when working either on foot, or from vehicles is a phenomenon called (appropriately) "multipathing". The effect is more easily noted if the reader has experienced "FM flutter" when traveling in a vehicle while communicating by voice. The automobile continually passes through electrical wavelengths as it either approaches or travels from the transmitter. As each electrical wavelength is passed, the magnitude of the received signal goes through a maximum and a minimum condition, resulting in a "fluttering" volume level which is understandably a function of the car's speed. In addition to the wavelength fluttering, a second effect of greater magnitude is superimposed over the effect which if observed, would appear to have some relationship to the varying terrain, and will disappear suddenly, only to reappear later.

This second effect is due to interference between the direct, or "free-space" wave from the transmitter and the ground-reflected wave as these two components arrive at the receiving antenna in or out of phase as depicted in the figure to the right. The resultant voltage will vary drastically as the receiving antenna is moved only a fraction of a wavelength, which of course changes the the phase relationship of the two or more signals arriving at the antenna.



Interference between direct and reflected rays.

It is this effect that caused the signal from an animal to be "completely" (apparently) gone when the researcher is standing in one position, then magically, the signal appears suddenly, and is often very strong with movement of only a few feet, or several meters (multiples of fractional wavelengths).

As a result, it is wise to move a few meters in several directions when tracking on foot or via car if the signal is not where it should be.

Many other factors influence the reception of signals to a lesser degree such as various forms of fading and diversity, angle of incidence, reflection pertubation effects, etc., but require greater explanation than they merit. These effects are mentioned only to bring their existance to the attention of the reader.

CONCLUSION. Due to pressing schedules and committments, this paper was prepared in a very short time (12 hours), and in many cases does not delve into some important aspects in sufficient detail, and in other cases dwells excessively on some points which were felt to be important to the typical users of telemetry systems. Time did not permit the addition of a 10-15 page section which takes the concepts and properties discussed above and applies them in a greatly simplified manner to both ground, and particularly air-to-ground tracking and data acquisition. This paper is the first attempt by the writers to tailor specific technical information to a group of similar-interest researchers topically. Your reaction and comments would be greatly appreciated-depending upon the comments received, this information may be reorganized in other formats and expanded upon, or additional topics may be treated. Thank you for your time in studying the thoughts and information presented-we sincerely hope it was worth your while.

A TECHNIQUE FOR BIOTELEMETRIC MONITORING OF HEART RATE IN ELK

Dr. C. Les Marcum[1]

Because visual aids, including slides of both photographs and figures, were used in this presentation, the tape recording produced an unusable manuscript. The following revised version was submitted by the author as a brief summary of material presented.

Results of Montana Cooperative Elk-Logging Studies have indicated that elk are displaced by logging activities and subsequent human access along open roads (Anonymous, 1977). While we may presume that such disturbances are detrimental to the welfare of elk, we need better information on the factors which disturb elk, and the extent and duration of the disturbing effects. We also need information on the energy costs and possible population consequences of these disturbances on elk.

Heart rate shows an instantaneous response to disturbance, and Gessaman (1973), after a review of symposium proceedings on the ecological energetics of homeotherms, stated that "Heart rate is potentially the only practical method . . . for estimating the metabolism of a completely unrestrained animal weighing more than a few kilograms." With funding from the U.S. Forest Service, Intermountain Forest and Range Experiment Station; and the McIntire-Stennis Federal Forestry Fund, administered through the School of Forestry, University of Montana, we initiated a study to obtain and test repeater heart rate biotelemetry systems on elk.

Initial work is being conducted using confined animals at the National Bison Range, and at a private ranch west of Missoula, Montana. James Lieb, a Ph.D. candidate, is working on the project to fulfill part of his degree requirements.

A repeater heart rate biotelemetry system has been developed cooperatively by researchers at the University of Wyoming and the U.S. Forest Service, Rocky Mountain Forest and Experiment Station in Laramie, Wyoming (Cupal et al. 1976). This system has been tested on free-ranging elk in Wyoming. Under a cooperative agreement with the University of Wyoming, we are using a modified version of the earlier system. Modifications are in the use of hybrid microcircuits in both the collar and implant. This improved system has been described by Weeks et al. (1977).

Briefly, the heart telemetry system is comprised of: (1) an implantable package which detects heart rate and transmits a short range

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low frequency signal, (2) a conventional neck collar which receives the low power signal from the implant and retransmits a powerful signal, and (3) appropriate decoding circuits for analog recording of heart rate and signal strength.

The implant consists of a transmitter/battery package and two electrical leads. The two electrodes are separate loops of highly flexible cardiac pacemaker lead, which is teflon coated, stranded stainless steel wire. The electrodes key on the R wave of the animal's electrocardiogram. This signal is received and amplified by a microprocessor, and transmitted inductively to the neck collar receiver.

The implants were originally powered by four small mercury cells, but a single lithium cell is now used. Weight of the completed implant package is approximately 60 to 70 grams.

The neck collar contains a receiver which is coupled inductively to the implant. Low powered pulses received are converted and retransmitted by a high power pulse transmitter, also in the collar. Collar components are powered by two D sized lithium cells. The completed collar weighs about 0.9 kg.

The data display unit consists of a conventional receiver, a decoding unit, and a chart recorder. The decoding unit measures pulse frequency and signal strength which are recorded as heart rate and animal activity, respectively, on separate channels of a two channel chart recorder.

The transmission system is powered to operate for 1 to 2 years. Range varies, but Lieb has received signals at several miles distance from instrumented animals. For a detailed description of the entire system refer to Cupal et al. (1976), and Weeks et al. (1977).

In installing the implants in elk, we generally follow procedures given to us by Dr. Thomas Thorne (pers. comm.), D.V.M., of the Wyoming Fish and Game Department. We employ a local veterinarian to perform these procedures. The elk are anesthetized using approximately 6 mg M99 and ½ cc Rompun. Five mg atropine is used to reduce salivation. Hair is clipped as closely as possible from areas around and between the planned incisions at the base of the neck and along the sternum. The area is then cleansed several times using first surgical soap and hot water, then 95% alcohol. Finally, a coat of beta-iodine is applied.

Areas adjacent to the cleansed area are covered with clean cloths to prevent contamination.

The first incision is made through the skin close to the base of the neck, and a subcutaneous pocket to hold the implant is formed just posterior to the incision. The second incision, about 2.5 cm long, is made just posterior to the anterior curve of the sternum.

A catheter is then inserted into this incision and is pushed subcutaneously to the implant pocket formed previously. The stiff inner rod is then removed from the catheter, and a hooked rod is used to pull the electrodes to the sternal incision. The final incision is also made on the sternum, about 27 cm posterior to the second incision, and the catheter is again used to pull the longest electrode to the opening. The electrodes are then sewn to attached muscle tissue as close to the sternum as possible, and the implant is checked to make sure it is operative. If so, powdered antiseptic is then sprayed into the wounds, and the incisions are closed with surgical steel sutures. An antibiotic injection (lo cc penicillin) is given. After the working area is cleared of equipment, 6 mg M50-50 is given. At this point, workers move away from the animal so it does not become excited on arousal.

The systems we have used seem to work very well. Our major concern at this point is whether or not the installed units will operate for a reasonable time (about 6 months) without malfunction or power loss.

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AN EVALUATION OF A FIXED NULL-PEAK TRACKING SYSTEM FOR MONITORING BIG GAME MOVEMENTS IN MOUNTAINOUS TERRAIN

David F. Pac[1]

In the field of wildlife research, radio telemetry has recently gained widespread application as a tool for studying a variety of wildlife species. Several current studies in Montana employ radio-collared animals to collect data on distribution, movements, and habitat use. Data are commonly obtained from aerial relocations of radio-collared animals at one-week intervals. Researchers are now questioning whether weekly aerial fixes are representative of overall animal distribution, movement, and habitat use. A weekly aerial fix accounts for three or four minutes out of the 10,080 minutes in a one-week period, and as a result, data interpretation must be made with caution. In order to achieve a more complete understanding of animal habits and requirements, answers must be found to questions such as: How wide-ranging is the species on an hourly or daily basis as compared to that shown by weekly aerial fixes? Are nocturnal movements of big game more or less extensive than diurnal movements? Are low-security habitats more intensively used under cover of darkness? A stationary null-peak tracking system can assist in answering questions such as these.

Pioneering efforts with such a system were made in Minnesota by Cochran and Lord (1963) in the early 1960's. About this same time Craighead and Craighead (1965) used a null-peak system to monitor radio-collared grizzlies in Yellowstone National Park. Ruffed grouse were tracked with a fixed null-peak system by Marshall and Kupa (1963). Other investigators have employed vehicle-mounted null-peak systems (Hallberg et al. 1974, Verts 1963). At present, Robert Phillips and Fred Knowlton of the U. S. Fish and Wildlife Service are using fixed null-peak systems. Phillips is studying effects of coal development on wildlife in southeastern Montana. Knowlton has used the system since 1967 to study coyotes in Utah. Very few studies have utilized a fixed null-peak system for monitoring big game movements in mountainous terrain. During the summer of 1977 the system was tested in mountainous terrain on elk in conjunction with the Long Tom Creek Elk-Logging Study.

The study area, located 25 miles southwest of Butte, consists of a series of heavily timbered ridges of moderate relief, separated by the Long Tom, Johnson, and Jerry Creek drainages. Elevations range from 7,000 to 9,100 feet.

The objective for using the null-peak system was to obtain detailed information on individual radio-collared elk in an effort to enhance data from weekly aerial relocations. Data were collected on detailed animal movement at two-hour intervals on a round-the-clock basis over a one, two or three-day period. An attempt was made to determine if changes in intensity of movement occurred as a result of the breeding season.

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Three null-peak systems were purchased from AVM Instrument Co. of Champaign, Illinois. As received from the company each system consisted of two four-element yagi antennas, a cross boom, coaxial cables, and a switch box. Figure 1 shows the system as it appeared when outfitted for field use. The tracking system consisted of two basic units: a base station and an antenna assembly. The base station was made of a heavy metal pipe affixed to a board stand. At the top of the base pipe was attached a wooden table with a 360° compass rose sealed to its surface. The base station was erected at the tracking site and remained there for the duration of the field season. The mast which supported the antennas and the cross boom had a diameter which allowed it to drop down into the base station pipe. A pointer was attached to the mast, and together with the compass rose, they were used for bearing determinations on the signal source. Attached to the null-peak switch box were coaxial cables from both the antennas and receiver. On the switch box was a toggle-switch that could be flipped to either a null or peak position. Two handles were bolted to the mast. The upper portion of the mast was supported by three guy wires that were attached to a wooden block with a ball bearing embedded in it. The ball bearing permitted the mast to rotate freely while the block was held stationary by the guy wires. The antenna cross boom was bolted to the ten-foot mast. The antennas were reinforced by two wooden support dowels that prevented twisting and bending by strong winds.

The key component of the system was the null-peak switchbox. It determined whether a maximum signal or minimum signal would be heard when the antennas were pointing directly at the transmitter (Fig. 2). If the switch was in the null position, a minimum signal or dead spot would be heard. If it was in the peak position, a maximum signal would be heard. The switch set in the peak position was used to quickly determine the approximate direction of the incoming signal. As the antenna was rotated through 360° with the switch in peak position several signal peaks would be heard, but the loudest and strongest one would be received when the antenna was pointing toward the transmitter. The boundaries of this strongest peak signal are quite broad, and its width in degrees should be noted from the compass rose. To find the exact direction of the signal source the switch was then flipped to the null position, and the antenna rotated within these boundaries. At this time, a dead spot or null signal was heard between two signal peaks of equal intensity. The null was usually only a few degrees wide in contrast to the broad peak signal. The limits of the null in degrees were then determined, and the mid-point was used as the bearing to the signal source. When the bearing from each of the three stations are plotted on a map, their intersection is used as the location of the radio-collared animal. Ideally, the three bearings should fall on the same point (Fig. 3). Often, this does not occur, and their intersection results in the formation of an error polygon (Fig. 4). The mid-point of the polygon is then used as the location of the radio-collared animal.

Tracking systems were erected on three mountaintops surrounding an area extensively used by several radio-collared elk during summer and fall. A reference transmitter was placed at a central location within the perimeter formed by the three stations. The three tracking systems were standardized

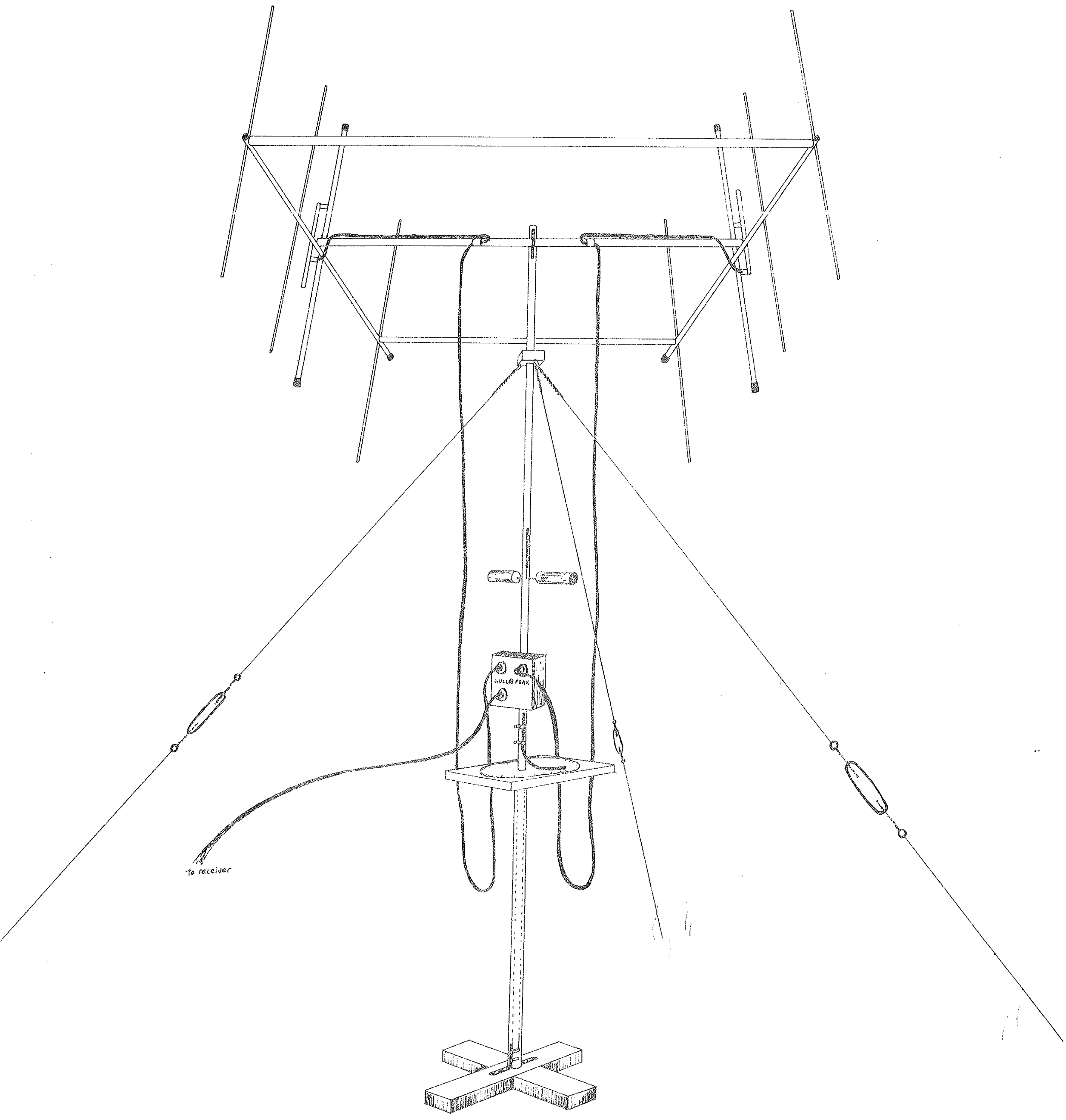

Figure 1. The fixed null-peak tracking system in field use.

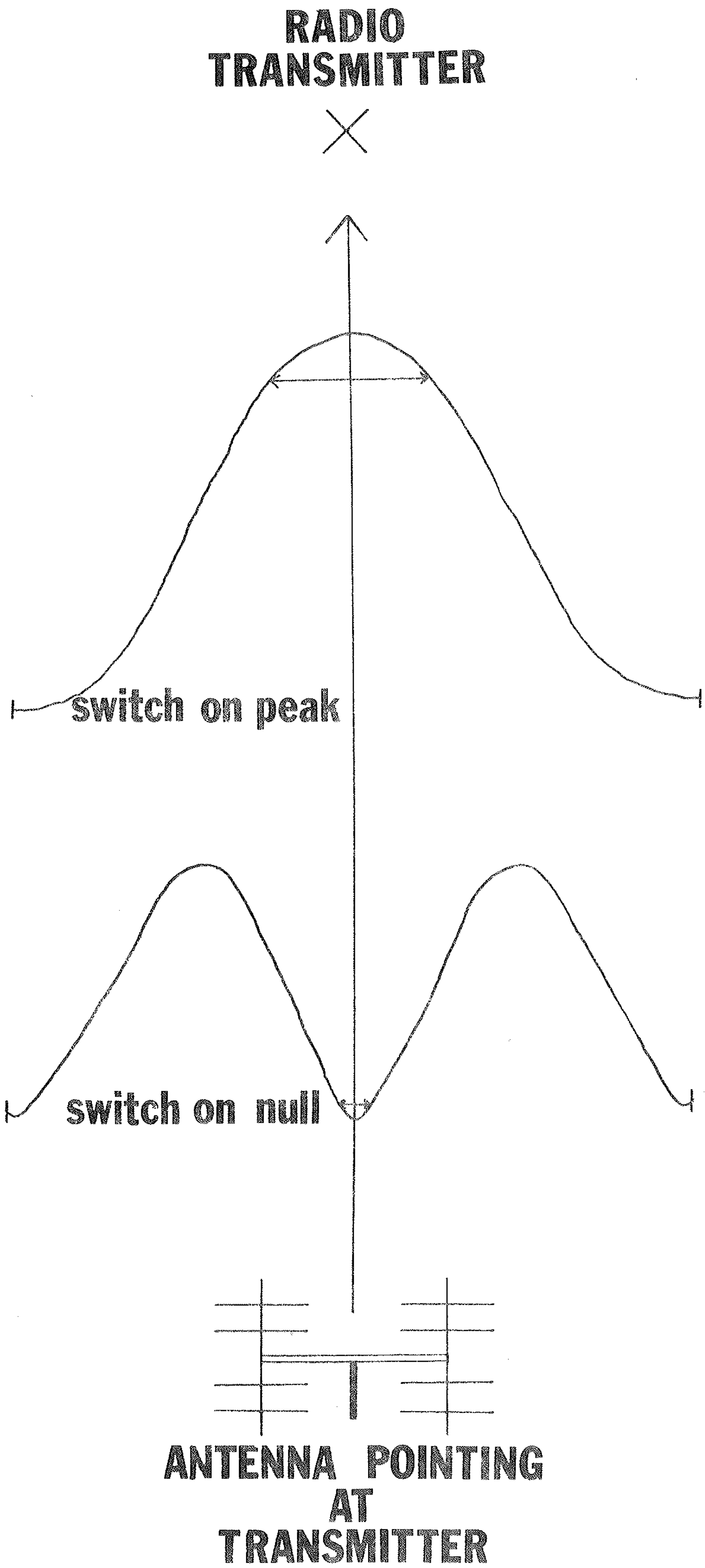

Figure 2. Signal patterns heard when switch box is set on null and peak.

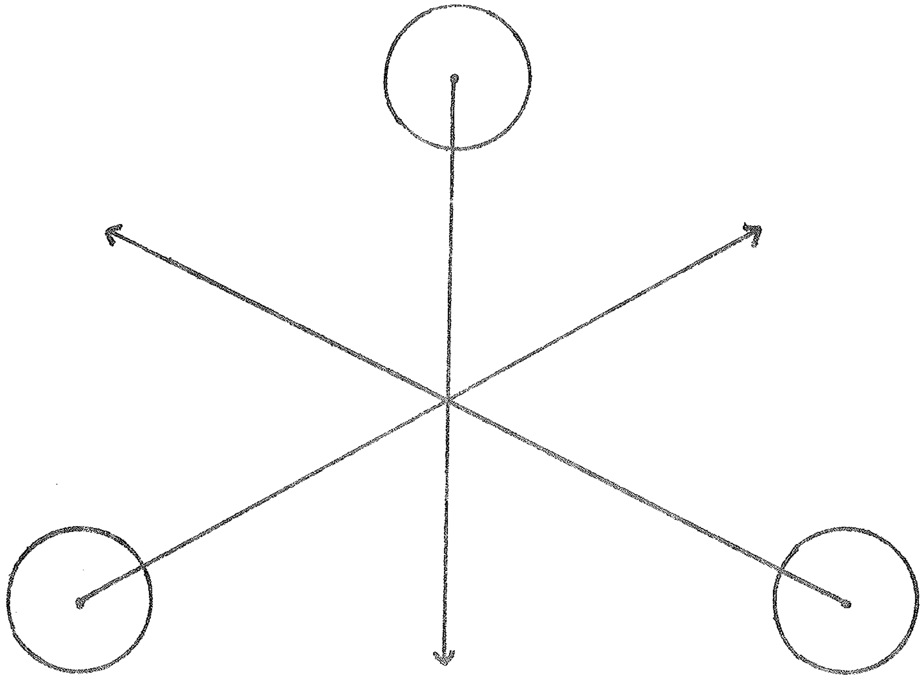

Figure 3. Ideal bearing intersection.

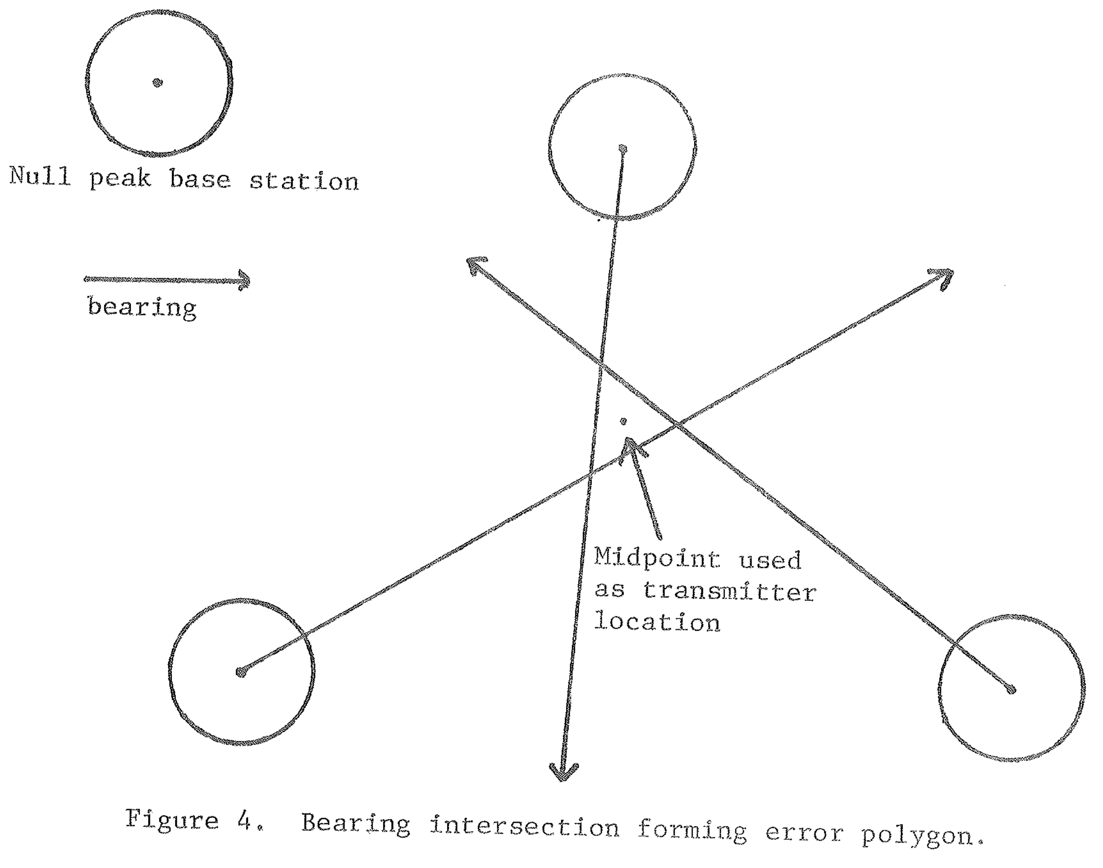

Figure 4. Bearing intersection forming error polygon.

on this reference transmitter. When the antennas were nulled on the reference signal, the compass roses were adjusted to give a bearing of 0^{o}. Bearings determined for radio-collared elk were made in reference to these standard bearings. As the null-peak system was used under field conditions, its favorable attributes and inadequacies became evident. These were determined from running a controlled test on the system to evaluate its capabilities. This was accomplished by driving through the study area in a vehicle carrying a radio transmitter. Stops were made at half-hour intervals at locations known only to the driver and recorded on a map. At the same time, operators of the three null-peak stations obtained signal fixes on the test transmitter at each half-hour interval. Accuracy of signal fixes was evaluated by comparing the fix locations with locations of vehicle stops.

The controlled test on the null-peak system helped determine what factors impaired the accuracy of signal fixes. Some of the errors in signal fix determinations were quite substantial as shown in Table 1. The data indicated that the chief factor affecting the accuracy of signal fixes was the mountainous terrain. A common problem occurred when topographical features blocked out signal reception by one or more stations. To fix the location of a transmitter a minimum of two stations must receive the signal, but error was generally less if three stations were able to receive. This problem occurred three out of the seven signal fixes made during the control test.

Table 1. A comparison of null-peak signal fixes to known locations of a test transmitter.

Fix No.	No. of Stations Making Fix	Distance Between Signal Fix Location and Actual Location of Transmitter
1	2	.38[1]
2	3	1.10
3	3	.21
4	2	.43
5	2	.30
6	3	.19
7	3	.14
AVERAGE		.39

[1]All distances in air miles

Terrain features caused other complications. The large error of 1.1 miles was primarily caused by signal bounce. The transmitter was out of line of sight with one of the stations, but a weak signal was received as it bounced back to the antenna off a high rocky cliff resulting in an erroneous bearing. The error for fix No. 4 (Table 1) was .43 miles. The error resulted from only two stations making the fix and one of these received the signal when the transmitter was out of line of sight. A weak signal was received that was reflected over an intervening ridge. As a result, the bearing determination was inaccurate.

Error was relatively large when fixes were made on a moving transmitter. During fix No. 5 the transmitter was in motion and only two stations received the signal. As the transmitter moved, the signal would fade in and out making it difficult to discern peaks and nulls. Since the location of the moving transmitter was never constant, an accurate fix could only be made if all three stations obtained a bearing on the signal simultaneously. If animal activity was great, the transmitter might move an appreciable distance in the time span required for the three stations to obtain bearings.

Other possibilities of error may include:

System imperfections. It was learned after the null peak system was field-tested that signal fix accuracy could be improved by substituting non-stretching nylon cord for the metal guy wires. Apparently, the metal guy wires caused distortion of incoming signals.

Human error. On a few occasions it was noted that the operator would choose the wrong signal peak resulting in a widely erroneous bearing on the transmitter location. Experience in equipment operation greatly reduced error of this type.

Airline communications and CB'ers. Frequencies similar to those we used would sometimes interfere with signal reception and increase the chances of error.

Receiver-transmitter distance. Error increased as distance increased between transmitter and receiver. The best fixes were made when bearings intersected at perpendicular angles or nearly so.

Weather and atmospheric conditions. During a snowstorm great difficulty was experienced in determining nulls. Moisture in the cable fittings and in the air between the transmitter and receiver may have distorted electrical impulses and changed the signal patterns.

The important lesson learned from the control test on the system was that characteristics of the signal can tell the operator a great deal about the kind of accuracy that can be expected. If the signal is either weak in intensity, seems to be non-directional, or tends to fade in and out, then the transmitter is in a situation that will most likely produce an inaccurate signal fix. If the signal is strong and distinct and does not flucuate in intensity then the transmitter is in line-of-sight and a good signal fix can be expected.

In the control test the average error for all seven signal fixes was .39 miles (Table 1). If the researcher is selective and uses fix numbers 3, 6, and 7, which were made when all three stations received good line-of-sight signals, then the average error would reduce to .18 miles. Compare this figure to the kind of error experienced in a good aerial fix. A good aerial fix is generally recorded to within 40 acres. This amount of area would be included in a circle with a radius of .14 miles. The error experienced with the null-peak system falls within a circle with a radius of .18 miles. If the researcher is selective and chooses the best fixes, then his performance is just a little worse than it is from the air. This selectivity is most important in mountainous terrain. What the null-peak system can do which aerial fixes cannot is to permit radio-collared animals to be monitored at frequent intervals around the clock.

Figures 5 and 6 illustrate the relocations of a radio-collared elk made with the null-peak system on two occasions during the summer of 1977. The numbers in Figure 5 represent fixes made on an adult cow elk every 2 hours over a 36 hour period on August 11 and 12. Numbers that are missing indicate a failure to make a fix at that time. The figure indicates the kind of movement recorded for a cool, clear summer day and a clear night with no moonlight. Figure 6 illustrates the movement pattern recorded for the same elk during the first of September. It was fixed every 2 hours for a 24 hour period. The tracking period occurred just before, during and after a snow storm.

The null-peak system can provide valuable information concerning animal movement as long as research objectives do not exceed the capabilities of the system. System capabilities will be greater in prairie or river bottom situations and least in mountainous terrain. The big advantage of this system is its ability to give insight into animal movements that can't be frequently monitored from the air.

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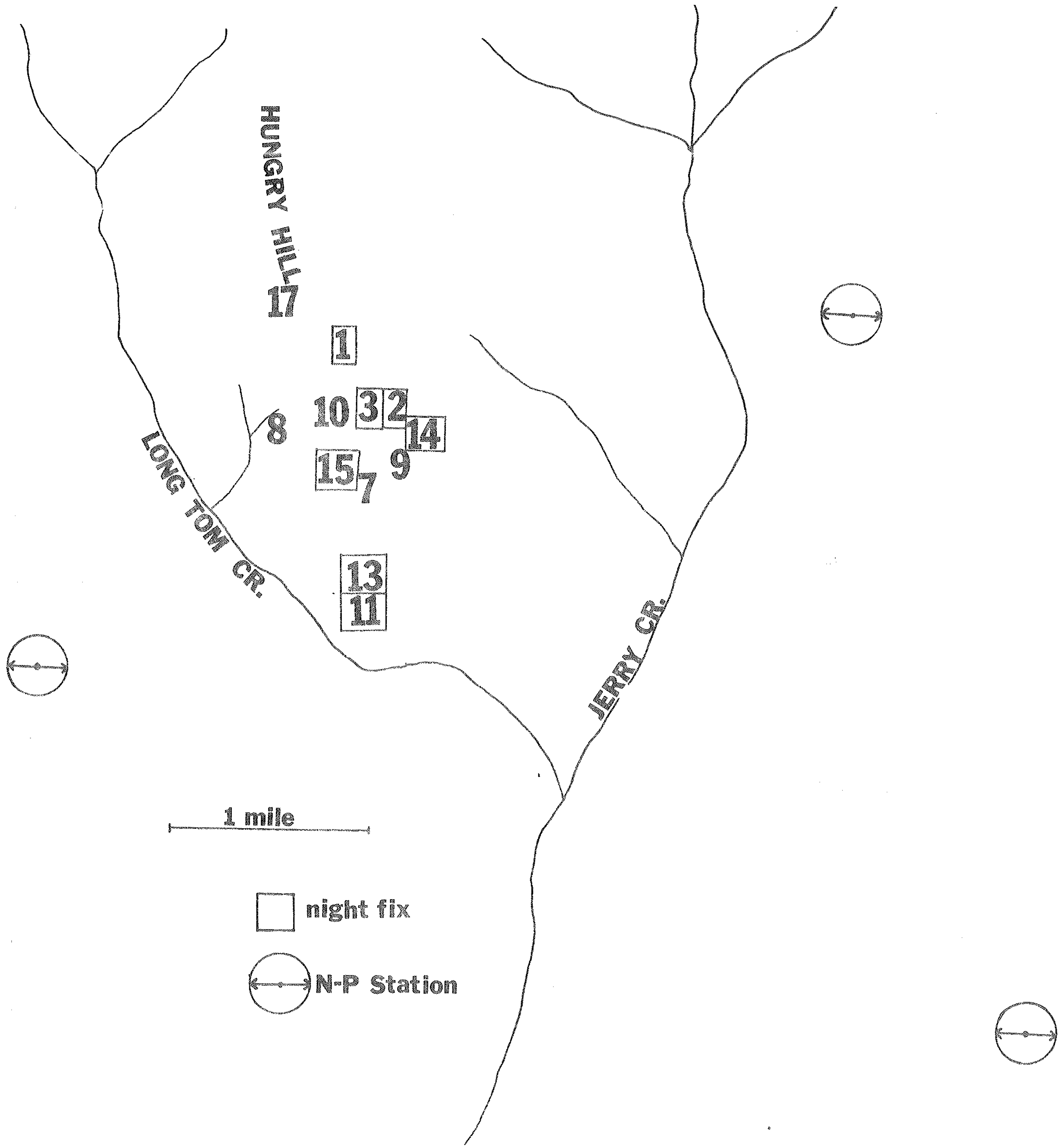

Figure 5. Null-peak relocations of an adult cow elk numbered in order of occurrence and made at two hour intervals between 2400 hours on August 11 and 1000 hours on August 12.

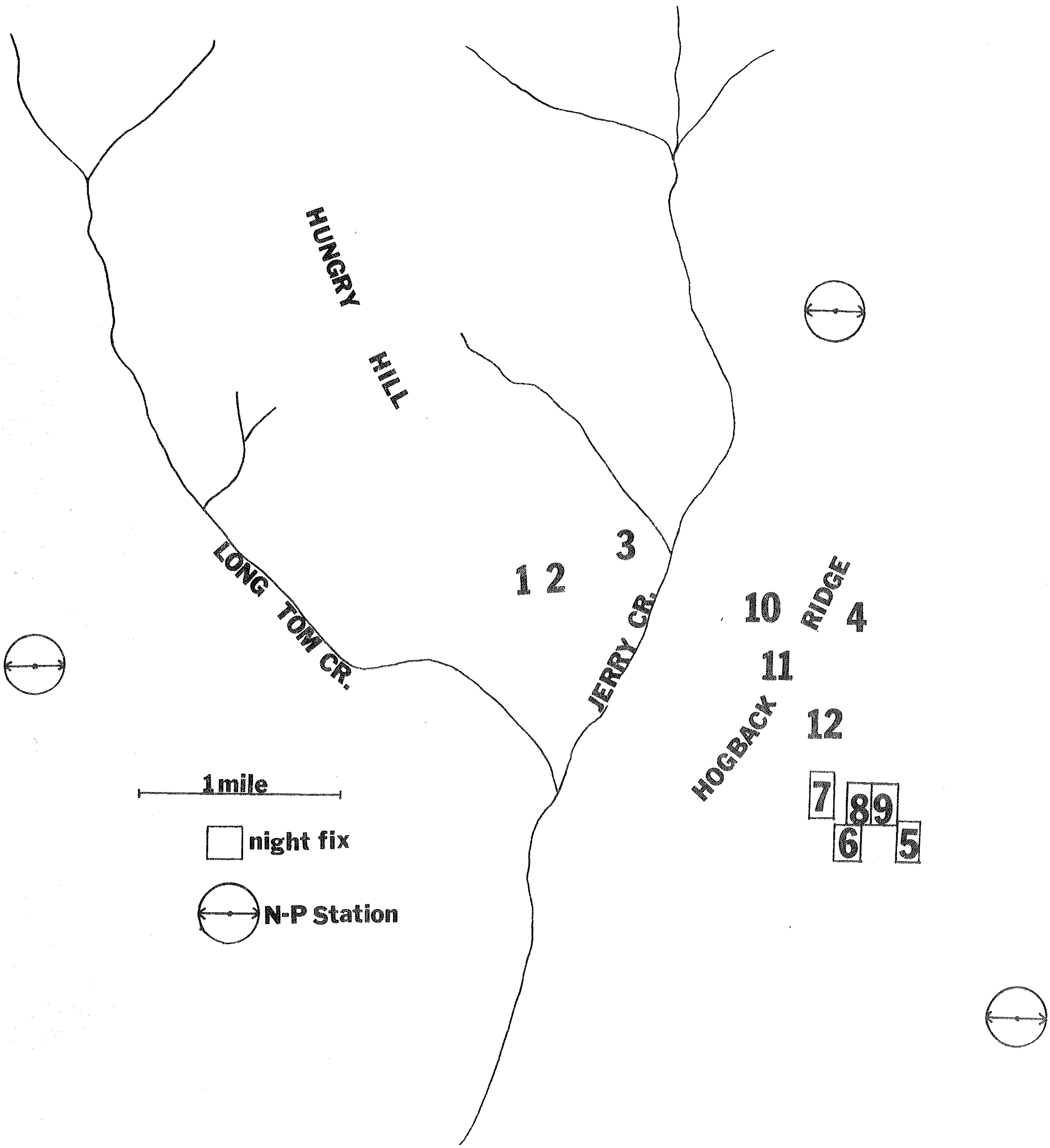

Figure 6. Null-peak relocations of an adult cow elk numbered in order of occurrence and made at two hour intervals between 1400 hours on August 31 and 1200 hours on September 1.

POSSIBLE APPLICATION OF BIOTELEMETRY FOR POPULATION SIZE ESTIMATION

Richard Knight[1]

Radio-telemetry gives the biologist the capability of determining the proportion of animals visible in any given area. Theoretically, with this knowledge, a census could be made by using a total count of visible animals and expanding by the known proportion of instrumented animals. In practice, observer bias and sample size prevent credible results.

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BIOTELEMETRY

Region One

Cliff Martinka[1]

(Report prepared and presented by Gayle Joslin[2])

Summary of the Region One Workshop held at Kalispell, Montana, December 2, 1977.

Between 40 and 50 people attended the Workshop. Five papers presented involved the topics of physiological retransmittal, radio-collar design, aerial tracking and general evaluation of radio-location telemetry by speakers Les Marcum, Charles Jonkel, Chris Servheen, Howard Hash and John Mundinger. Several major points came out of the meeting:

1. We must acknowledge that telemetry is a tool and not an end in itself and that the tool is only as refined as the data analysis.

2. Any time telemetry is a part of a research program, the program becomes a complex and costly operation. Careful planning, equipment maintenance and safety programs were emphasized especially where aerial tracking is involved.

3. Systematic methods of recording location data were discussed. One method gaining support for use during aerial tracking involves taking a photograph of the location site. This reduces observer bias and is a tangible record of the physical aspects of a given location.

4. Study design and the need to address statistical analysis on limited sources of data brings up the question of sample sizes of radio collared animals. Sample sizes, we deduced, had to be addressed on a case by case basis depending upon the objective sought.

5. In physiological telemetry programs, coordination and sharing should be increased to maximize research opportunities. In this vein, the group submitted to the TWS resolutions committee a proposal to designate a team of biologists which would develop a program to facilitate the current use of physiological retransmittal data and pool expertise in its development thus reducing duplication of effort and frustration. It was also noted that captive animals should be used to test techniques before using wild ones.

6. The group concluded that the abuses incurred through telemetry studies most often have come about through rough handling of the animals. It was the consensus of the group that before programs are initiated, it is the obligation of the researcher to be familiar with the specific herd which he plans to study. Recognizing that herds may have varying characters depending upon their history, location and seasonal influences, among other factors, the physiological and psychological state of the herd should be researched prior to trapping programs to avoid undue stress on the animals.

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[2]Fish and Wildlife biologist, Montana Dept. of Fish and Game, Libby, Montana

7. The problem of many users of telemetry equipment and the resulting pollution of the radio-airways lead us to submit for review to the TWS resolutions committee a proposal to form a radio-telemetry frequency committee. This, to help us police ourselves and hopefully avoid involvement of the FCC. This committee would compile a list of frequencies being used in the state and possibly surrounding areas. Such a list has already been started at the Border Grizzly Project, but is in need of updating and maintenance. This information would be readily available to researchers planning future studies and the Committee might make suggestions to the researcher regarding frequency use to avoid frequency conflicts.

8. A ramification of telemetry studies which might fall under the heading of "abuses" is the abuse which researchers themselves receive at the pens of popular journalists. To help alleviate this problem, which ultimately affects the resource, judicious public information efforts are necessary in explaining the concepts and positive results of telemetry programs.

BIOTELEMETRY
Region Two
Phil Schladweiler[1]

The Region Two workshop was held in Bozeman on December 15. Attendance was poor, as only about 15 people showed up. This made for a relatively short session, which included several papers on the use of telemetry in various big game studies and a general discussion period. Most of the papers presented will also be given at this meeting, and so will not be discussed further. The discussion centered on several points as follows:

1. Although the state of the art has advanced considerably, there are still major problems with transmitter failure due to poor batteries and/or components. Packaging is also a problem since big game especially are hard on collars.

2. In contrast to what Gayle just mentioned regarding costs, it was felt that for the benefit gained, the additional cost of marking an animal with a telemetry collar was not expensive. The cost of capturing a big game animal is generally high, with little or no assurance that you will see it again. Therefore, the added data that can be gained with telemetry is actually inexpensive and in many cases impossible to obtain in any other manner.

3. There was unanimous agreement that telemetry is a valuable wildlife tool, although it has also been used as a sort of status symbol by some.

4. Although only a small part of any population can be instrumented and followed, if used in conjunction with conventional marking, it can help find the answer to some of the questions being asked. If nothing else, the fact that most workers try to make frequent relocations of telemetry equipped animals often gets them into the field more often and thus more data is collected on all animals, not just those radio equipped.

5. One of the major points discussed was in making the most of the data collected. This should be considered when a project is in the planning stage, and the necessary time and money budgeted for analyzing and interpreting the data.

[1]Research biologist, Montana Dept. of Fish and Game, Bozeman, Montana.

BIOTELEMETRY
Region Three
Gary Dusek[1]

Introduction

The annual workshop for Region 3 was held in Billings on December 5 and 6. Forty-five individuals attended, a turnout similar to that of the previous two years. The program included 10 informal presentations. Four were concerned with studies employing telemetry on upland birds or raptors. The second session included six papers dealing with big game. Subject matter included methodologies, capabilities and limitations of telemetry in reaching research objectives, solving management problems, or assessing impacts of the mining of coal on wildlife.

Rather than summarize each presentation, I'll briefly discuss the major points made by the ten speakers.

Synopsis

The most obvious advantage of using radio telemetry, as opposed to individually marking animals, is that an animal may be located at will, whether it is actually observed or not. One speaker pointed out that the value of telemetry is inversely proportional to the relative visibility of an animal. Some of the fundamental information being sought in eastern Montana with the use of telemetry included patterns of travel by individual animals or segments of populations. In the case of prairie grouse, data most sought after were movements in relation to the use of dancing or strutting grounds. It was felt that use of telemetry enhanced locating nesting sites, and consequently locating nesting habitat. Data desired by those working with big game included that primarily associated with seasonal distribution, emigration, and identifying critical habitat. Daily and seasonal patterns of habitat use were also determined by some researchers. It was generally agreed that telemetry is capable of eliminating many of the bias's associated with direct observation in evaluating habitat use. Other uses of telemetry throughout the region included determining activity patterns, social interaction and estimating mortality.

It was pointed out that several assumptions are often made with reference to equipping animals with radio packages, or for that matter, with individual markers. These assumptions are as follows: 1) that animals, when marked, do not change their patterns of behavior; 2) that other animals do not change their patterns of behavior in relation to those that are marked; and 3) that marking does not reduce longevity. A literature review, prepared by one of the speakers, and observations of other individuals in attendance suggested, at least

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in the case of birds, that these assumptions do not always hold true. The weight and type of package used, or the conspicuousness of the package itself, was reported as being influential on behavior or longevity. Other problems encountered associated with equipping birds with radio packages were frequency drift and radio failure. One individual reported that transmitters put on sage grouse failed within 10-90 days with an average of 35 days. Earlier failures were usually associated with broken antennas or connections. Another individual reported that radio failures were minimal when solar cells were used.

Big game researchers also reported that the quality and type of equipment used was of fundamental importance. Perhaps due to differences in size and morphology between birds and large ungulates, and that radio packages for ungulates were mounted in neck collars, procedural problems differed somewhat between the two groups. Although the effects of marking on behavior and longevity of ungulates may not be as obvious as those on birds, some secondary effects were pointed out. For example, one speaker noted that tagging during late stages of pregnancy of mule deer does may induce lower production and/or survival of fawns, although there appeared to be little or no differential mortality between radioed and non-radioed newborn fawns.

Sample size poses an additional problem. Generally radioed animals comprise a very small proportion of the total population, and as the year progresses the sample becomes even smaller. The limitation here is that inferences tend to be made about large populations based on the activity of a few individuals. Here qualitative information is being gained at the expense of quantitative information, which poses an interpretational problem. It was also pointed out aerial tracking has advantages over ground tracking. The problem associated with this is that there is a tendency to track at convenient times such as early morning hours or during periods of favorable weather conditions. Our failure to take into account the effects of environmental factors in addition to different periods of the day poses an additional interpretational problem.

Conclusion

It appeared to be the concensus among the speakers and among those commenting on the presentations that telemetry can be an important tool in solving wildlife-related problems and has the potential to provide a wealth of information. However, we must consider the mechanical, procedural, and interpretational problems associated with this tool in order to derive the greatest benefit from it. We should not discredit the value of this tool because of these limitations, nor should we overlook the value of perhaps less sophisticated conventional means of gathering data. It was vividly pointed out at our workshop in Billings that telemetry is only a tool of wildlife management, and obviously a valuable one. When this perspective is lost, it tends to become a toy, or perhaps a crutch.

TELEMETRY AS AN AID TO THE STUDY OF GRIZZLY BEAR HABITAT

Joe Basile[1]

I'm going to tell you a little bit about how we use telemetry to ferret out the mysteries of grizzly bear habitat. And I do mean mysteries. At the Black Bear Workshop in Kalispell last winter, it was interesting to hear representatives from the various states and provinces tell the current status of bear management and research in their particular jurisdictions. It soon became very evident that there were two universal problems:

- how can we assess size and trend of bear populations?

- how can we characterize bear habitat?

We on the Interagency Grizzly Study were feeling some frustrations with this vexing problem of characterizing habitat. After listening to the workshop participants, it was somewhat comforting to know that our feelings of inadequacy were shared by so many others. On the other hand, its a bit frightening to recognize that there is no apparent solution in sight.

The difficulty of assessing population and characterizing habitat stem from several factors:

- the grizzly is non-gregarious, a loner. Finding one does not necessarily lead to others, as would be the case with a species that tends to group at least in part of the year.

- the bear is highly mobile, often covering tens of miles in a few days.

- the grizzly has a large home range. We hear about home ranges of 20-40 square miles in other areas, but we don't have any that small that we are aware of in the Yellowstone area. We're dealing with pretty big ranges of 100 to several hundred square miles.

- the grizzly has a nocturnal bent and a tendency to avoid man.

- the remoteness of its haunts provide us with logistical problems.

Combined, all of these factors serve to make the bear difficult to study. Telemetry helps to offset some of these hindrances.

How do we use telemetry in habitat study? The immediately obvious use is that of determining home ranges of bears and the plotting of these on habitat type maps. These plottings would show the kinds and amounts of the habitat types within the home ranges, the percentage

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of the radio fixes within each type, and the dates of the fixes, would reflect the relative preferences of the bear for each habitat type, and the seasonality of those preferences.

At best, however, this is but a crude characterization of habitat, because the habitat types commonly in use are based on climax vegetation, but the bears are using the areas for the vegetation now present. Furthermore, evidence is growing that the bears use niches not specific to habitat types (ponds, talus, anthills, etc.). Too, radio locations to date suggest the possibility that bears travel a circuit, feeding opportunistically on the way, with opportunity poorly related to habitat type.

To compensate for the shortcomings of habitat types alone we have been conducting feeding site examinations to identify specific food items. Candidate sites are indicated by radio fixes, and crews are sent to the sites as soon as possible after the fix while evidence of use is fresh. Our flights directed crews to 133 sites with evidence of feeding activity in 1977.

Feeding site examinations detect the more obvious feeding activities which leave long-lasting evidence: digging for roots, rodents, or rodent caches; torn logs and stumps; disrupted anthills; barked trees; animal carcasses. Less easily detected activities are probably missed, such as grazing, berry feeding, mushroom feeding. Here is where scat analysis comes into play, by providing information on the diet missed in feeding site examinations. For example, no use of grass or grass-like plants was evident on feed sites (except where ungulate sign was plentiful, and presumably ungulates were responsible for the grass use), but made up one-third of the scat content in a study reported by Mealey.

Many of the scats are collected on the feed sites, or enroute to them, which gives us a greater number of scats than chance collections alone would yield.

The area immediately surrounding a feeding site often provides additional information that would have been difficult to get without the direction afforded by telemetry:

- Scats, as already mentioned. Variously aged scats on a site would indicate a much visited area.

- Beds. Sixty-three beds were measured on 37 of the sites, with notes made on lining, visibility, type of nearby protective cover, etc.

- Tracks.

- Hair. Dr. Picton is doing some work for us, trying to age bears from hair samples. If successful, this would be a useful tool.

- Dens. We have also located and measured a number of dens with the aid of instrumented bears.

Absence of feeding evidence on a site to which crews are directed by telemetry is an indication that the bear was simply passing through the area. Repeated fixes in the same area, or much evidence of other sign, would suggest it to be a travel lane.

Additional uses of telemetry involve specific bears and their movements in relation to man's activities, such as:

- Bear movements in relation to domestic sheep operations on the Targhee National Forest.

- Bear in relation to logged areas in the Shoshone National Forest.

- Bear in relation to recreation activities on the Gallatin National Forest.

One big problem with all three of these attempts to relate bear activities to those of man is the difficulty of getting sufficient replications of bears for long enough time periods. Trapping difficulties, bear mortalities, and transmitter malfunctions are common occurrences.

One might argue that all of the information gained on the bears, as related above, can be gotten without telemetry. This is true, but the information certainly could not have been gained in the same time, nor over such a large and diversified area. Too, a good seasonal representation of activity would not have been possible without telemetry. Though no panacea, telemetry is an extremely useful tool.

SOME OBJECTIVES AND INTERPRETATIONS WHILE WORKING WITH BIOTELEMETRY

Terry N. Lonner[1]

Biotelemetry can have many applications and uses. At this meeting I am going to briefly discuss biotelemetry as a tool in game management as used to study the distribution and movements of free-ranging wild animals and some interpretation problems I've encountered. Biotelemetry gives us an ability that we've never had before--to frequently locate, at will and regardless of observability conditions, individual members of an animal population with very little disturbance to the animals involved, except for maybe the human being doing the work. For example, in making over 900 radioed elk locations from the air as part of the Long Tom Creek elk-logging study we actually saw the radio collared elk an average of only 25 percent of the time. Once the radio transmitter is on the animal it can be located only occasionally by a ground observer or if one has the manpower, money, and patience, it can be tracked continuously by satellite.

Some of the objectives that telemetry can help us attain in game management are:

1. Understand the annual and seasonal distribution and range of a given population of animals. This would help us understand traditional use patterns of a given area and dispersal rates and patterns from winter ranges. Of course, a major problem here is radio marking enough animals that would represent most of the population in question.
2. Assist in locating large numbers of animals of any given management area on a seasonal basis. This could be very helpful during the spring and summer while censusing and acquiring productivity indices.
3. To determine the mobility of a species and the variation of this mobility within and between populations and seasons.
4. Re-evaluate game management units for ecological continuity and hunting season regulations and quotas.
5. Study the behavior of animals in response to the various influences of man such as hunting, logging, livestock grazing, land development, etc.
6. Provide us with a better understanding of how weather and other natural influences such as predation affects animal distribution, movements and survival.
7. To better understand seasonal habitat use for any given species.

These objectives are much more easily thought of and written down than dealt with. Several problems can be encountered--some of which are economical, others physical, and still others interpretive. I am going to dwell on some of the interpretive problems. Interpretations must be held within the scope of the objectives. In other words, over-interpretation is not much different than misinterpretation.

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The accuracy and refinement of interpretations from a sample is often proportionate to sample size, especially when working with biotelemetry.

To illustrate various interpretation problems I chose as an example a radioed cow elk that we radio-tracked last year in conjunction with the Long Tom Creek phase of the Montana Cooperative Elk-logging Study.

First, I would like to compare home range as defined by tracking this elk on a daily, weekly, biweekly, and monthly basis. We actually tracked her on a weekly basis from late March to the middle of December, so daily locations within this time were filled in by my imagination and "best guess." Some weekly locations were also guessed. Alternating weekly locations were used for biweekly locations and every fourth weekly location was used to construct a home range based on 12 monthly locations. If each time we make a radio fix and it takes 4 minutes, then the percent of a year's time would be .35 for daily, .05 for weekly, .025 for biweekly, and .011 for monthly locations. Although these percentages seem very small, they are 100 percent better than nothing, especially in view of the poor success we've had in locating neckbanded animals.

"Home Range" has been defined as an area over which an animal normally travels (Burt 1943). If we radio tracked an animal continuously, its home range, or range as I prefer to call it, would not be a continuous area, but a network of various shaped lines (Fig. 1). Since it is almost physically impossible to track an animal continuously, even with biotelemetry, we make "snapshot" locations or periodic fixes of the animal while it is carrying on its living pattern. In general, the less frequent the locations the more caution one should use interpreting distribution and movement patterns; however, even when relocations are made on an infrequent but regular interval a good idea of an animal's annual home range can still be acquired (Fig. 1). Again, it must be emphasized that the sampling method and interpretation of results must be kept within the scope of the objectives and often research objectives are quite different than management objectives.

Home range is often defined by connecting the outside location points to form a polygon. The area of this polygon can then be measured and is called "minimum home range" (Mohr 1947). The area of a polygon formed by locating the radioed elk regularly on a daily, weekly, biweekly, or monthly basis was calculated to be 304, 200, 166, and 142 square miles, respectively (Fig. 1). This illustrates how closely interpretation error can be tied to sample size and technique. Another interpretive problem is illustrated by this example. If the center portion of the polygon was not used at all by the elk, then there were about 150 continuous square miles that were not even used within the polygon. This would then make the home range more of a doughnut shape and would then encompass an area of about 155 square miles instead of 305 square miles based on daily relocations. This demonstrates that by connecting the outside locations a false impression of the actual area covered can be made. It has also been argued that probably no two investigators, given the same set of data, would arrive at precisely the same results in determining home range size and shape by the polygon method (Hayne 1949).

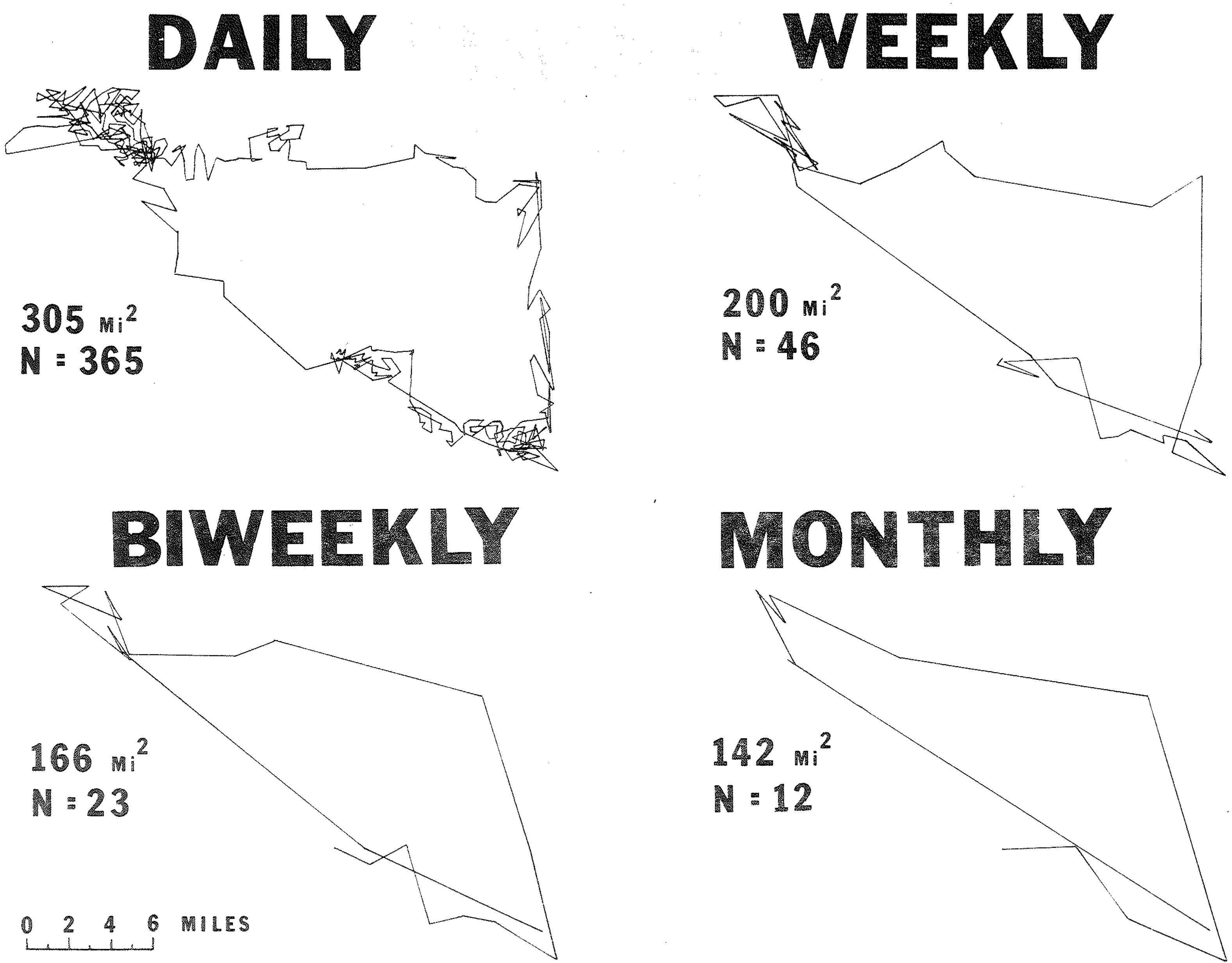

Figure 1. Comparison of home range size and shape between four sampling schedules (N=number of relocations).

Another way that has become popular to express an animal's range is called the standard diameter, which redefines home range to not include the whole range as encompassed by the polygon (which implies that the animal in question is confined to within the polygon boundaries), but that area within which the animal spends a suitable fraction of its time (Harrison 1958). The standard diameter is calculated from individual distance measurements from each relocation to a geographic activity center. This activity center is found by averaging separately all relocations along the vertical axis and all relocations along the horizontal axis. The two values which result are two coordinates of the point called the geographic activity center (GAC). This point may be viewed as a two-dimensional average of a group of points (Hayne 1949). It is purely a mathematical concept and may not necessarily have any biological significance. This is illustrated in figure 2 where the GAC fell within an area not even used by the elk.

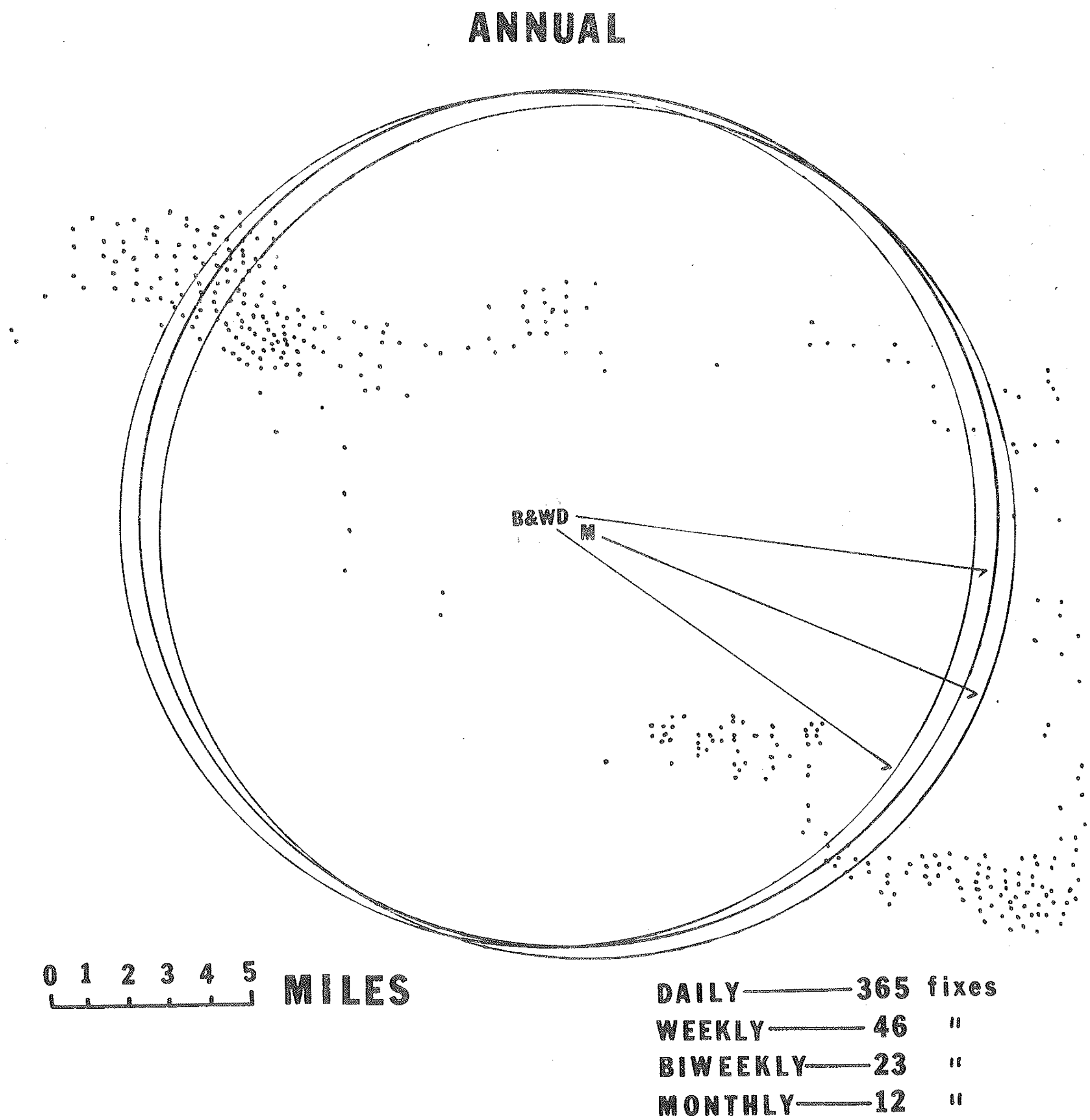

Figure 2. Comparison of standard diameter sizes as related to relocation positions and between four sampling schedules for annual movements.

The standard diameter is then calculated as follows:

$$SD = \sqrt{\frac{\Sigma D^2}{N}}$$

D = 2 times the distance from the GAC to each location

N = Total number of locations

It defines then, a "standard range" or a circle of one standard diameter, which will contain approximately 68.26 percent of all relocations.

The standard diameter method does not and was not meant to describe home range shape, but is a good index to home range size. For this method to be representative of home range size and shape it would be important that the relocations be evenly distributed about the GAC and throughout the time period or season being examined (Fig. 3). Sample size problems when interpreting home range size aren't as apparent when using the standard diameter method compared to the minimum home range technique. As given in the example above, annual home range size varied from 305 mi^2 for daily relocations to 142 mi^2 for monthly relocations using the minimum home range calculation, while standard diameter remained at 21 miles for all four sampling schedules (Figs. 1 and 2). This same relationship was apparent for seasonal measurements of home range size as well, although there was somewhat more variation in results from the standard diameter method but still large variation in results from the minimum home range measurements (Table 1 and Figs. 3 and 4).

The most dangerous misinterpretation problem with the standard diameter method I've encountered is the presumption that 68.26 percent of an animal's activity is within the circle defined. What about the 31.74 percent of the activity that falls outside the standard diameter? In some cases this activity could be far away from the GAC and may be critical during a season of high stress such as the winter (Fig. 4).

It appears, then, that trying to simplify animal distribution only through mathematical manipulation of data can oversimplify or overcomplicate the real situation. Plotting the real data on a map and made by someone who is familiar with the area in question is probably the best way to get started in making interpretations. Once this is done a mathematical manipulation of the data can be choosen to help summarize it and make it more subject to comparisons with other data from other studies. The best combination of methods I've found is to plot the relocations and then superimpose the standard diameter and GAC over these relocations. The standard diameter and GAC can then be used for data summarization and comparison.

Movement data or trying to express the mobility of an animal can also be subject to severe interpretive problems. This is especially true when comparing distances traveled between animals that were located at different time frequencies. For accuracy of interpretation when comparing two or more animal's mobility patterns, the time and interval between relocations should be as equal as possible. This assumes that each animal has an equal opportunity to make erratic or oddball movements at the same rate.

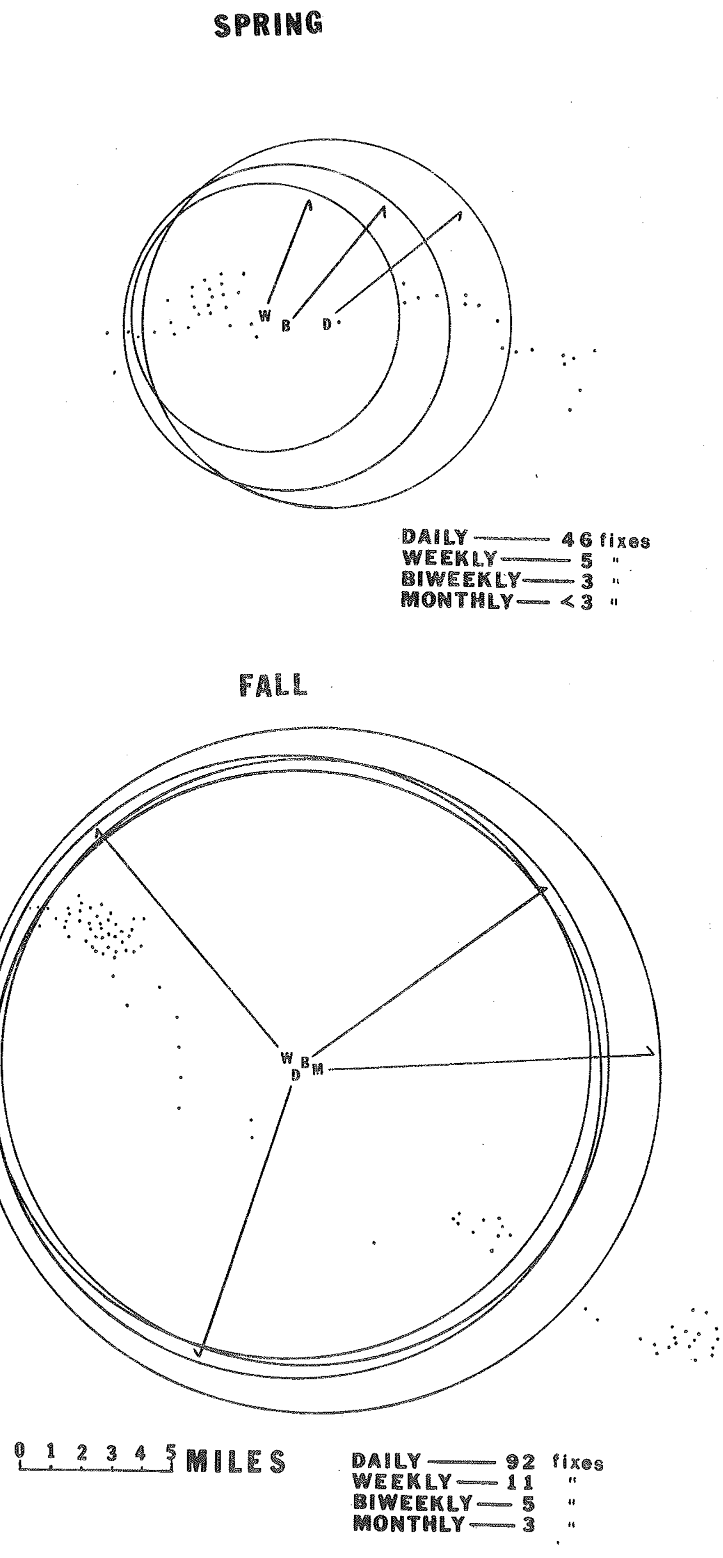

Figure 3. Comparison of standard diameter sizes as related to relocation positions and between four sampling schedules for spring and fall movements.

Table 1. Comparisons between standard diameter size and minimum home range size for four sampling schedules by season.

	SPRING (May 1-June 15)			SUMMER (June 16-Sept. 30)			FALL (Oct. 1-Dec. 31)			WINTER (Jan. 1-April 30)			ANNUAL (Jan. 1-Dec. 31)		
	No. of Fixes	Area[1]	SD[2]	No. of Fixes	Area	SD	No. of Fixes	Area	SD	No. of Fixes	Area	SD	No. of Fixes	Area	SD
Daily	46	65	12	107	28	5	92	98	20	120	118	9	365	305	21
Weekly	5	9	9	14	10	4	11	36	20	16	75	9	46	200	21
BiWeekly	3	6	11	7	6	4	5	24	20	8	32	8	23	166	21
Monthly	<3 Fixes			3	.4	2	3	2	23	4	11	9	12	142	21

[1]Polygon shape (mi^2)

[2]Standard Diameter (miles)

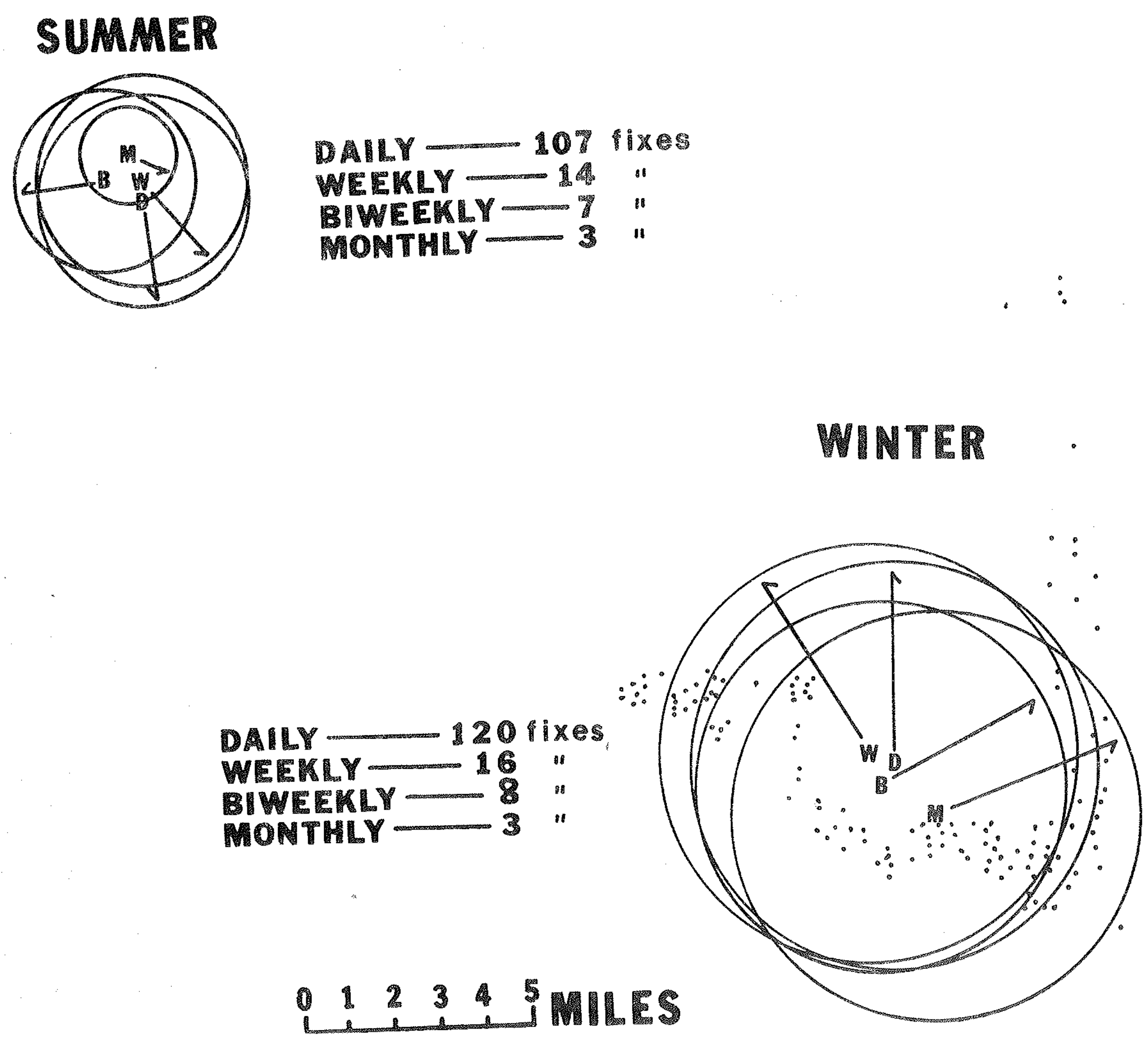

Figure 4. Comparison of standard diameter sizes as related to relocation positions and between four sampling schedules for summer and winter movements. (Summer relocations not plotted because of overcongestion.)

CONCLUSION

We must keep in mind that telemetry is just another tool and its cost, whether in time or money, should not outweigh the benefits we accrue from it. Biotelemetry has the potential to give us a very high benefit/cost ratio if used properly. Good results and their interpretation often hinge around good objectives and their follow through, and it must be kept in mind that the method should not become the objective and the objectives should not be tailored to fit the method. Interpretation of data is usually best initiated by displaying it at face value and then summarizing it to best fit the most realistic interpretation. As a final note, interpreting data from biotelemetry studies will always be at least a little frustrating based on Harvard's Law (Bloch 1978), which states:

> "Under the most rigorously controlled conditions of pressure, temperature, volume, humidity, and other variables, the organism will do as it damn well pleases."

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THE MOVEMENTS AND DISTRIBUTIONS OF RADIOED ELK IN THE MADISON-GALLATIN MOUNTAIN RANGE COMPLEX

John D. Cada[1]

Introduction

The management of the Gallatin Elk Herd has been one of the more complex and controversial problems faced by the Montana Department of Fish and Game. The primary difference between the Gallatin Herd and most other elk populations in Montana is that for six months these elk are in Yellowstone National Park and are not available for population control during the general elk hunting season, however, when winter comes they move out and then become the management responsibility of the State of Montana. Consequently, the movements and migratory patterns of the Gallatin Elk have been of major concern to game and land management agencies.

The first intensive biological studies of the Gallatin Herd were initiated by the U.S. Forest Service in the early 1920's. Crews of men would spend the entire winter season in the upper Gallatin Canyon collecting a variety of biological data on the herd. One of the main outcomes of this effort was the identification of travel routes used by elk as they migrated from summer range in the park to winter ranges outside (Figure 1).

By the late 1930's the Montana Department of Fish and Game had grown to sufficient size to begin taking over the reins of the biological studies in the Gallatin Canyon. At this time an elk calf tagging study was begun to gather data on elk dispersal from calving areas. During the 15 years that followed over 1000 elk calves were tagged and released in the canyon. Approximately 400 tags have since been returned to the department.

The next major movement study began in the early 1960's with the neckbanding of over 300 elk in the vicinity of the Park and on the Gallatin Game Range. Biweekly helicopter observation flights were made for the first two years to monitor the movements and distributions of the marked elk. Good information was gathered during this study, however, it fell considerably short of expectations. Elk neckbands were difficult to observe because of the elk's fear of the helicopter and the fact that the bands soon began to fade and tatter.

In the early 1970's an additional 40 elk were neckbanded at the Madison-Bear Creek Game Range, a winter range used by Gallatin Elk. These bands were to be observed from fixed-winged aircraft. This technique also was only partially successful.

This present study began in 1975 at a time radio telemetry had finally evolved into being reliable for use on big game.

The objectives of the study were:

1. To reinforce our knowledge of elk migration routes and seasonal distributions of migratory and resident (non-migratory, non-park elk);

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2. To determine proportions of migratory and non-migratory elk on each wintering area;
3. To determine the effects of regular and late hunting seasons on migrations and distributions of Gallatin elk;
4. To evaluate elk fidelity to each seasonal range;
5. To evaluate the effects of snow and weather conditions upon the timing and extent of migrations to winter ranges.

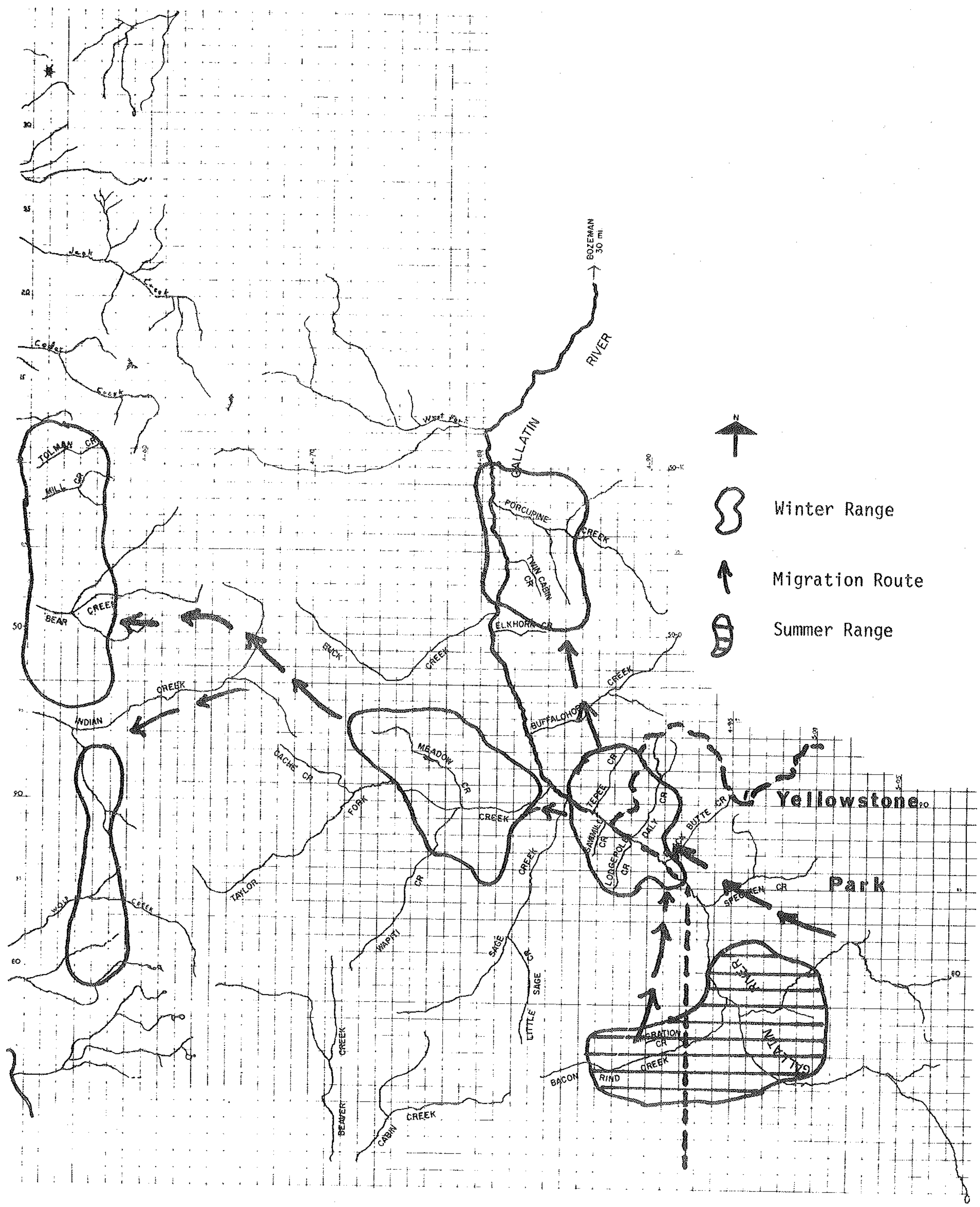


Figure 1. Winter and summer ranges of the Gallatin Elk Herd.

Methods

From December 1975 to January 1978 a total of 15 elk were immobilized, fitted with radio collars and released at the capture site. Twelve cow elk were collared the first winter on four elk winter ranges in the Gallatin and Madison Drainages and serve as the main data source for this study to date. All twelve elk were located by fixed-wing aircraft on a weekly or biweekly basis for the last two years. A total of 1008 radio relocations have been made of the original twelve radioed elk.

Weather conditions during the fall and winter seasons of the study varied considerably. The fall and winter seasons of 1976 and 1977, respectively, were of the mildest ever recorded, whereas the winter of 1976 and the fall and early winter seasons of 1977 were characterized by deep snows and cold temperatures.

The data was broken down into six seasonal activity periods: Winter, Calving, Summer, Rut, Hunting and Early Winter. The dates of the winter period for each radioed elk included only those dates that the elk actually spent on its most terminal winter range. For example, in 1977 radioed elk number 1-76 was first observed on the Porcupine Winter Range on January 25, 1977 and remained there through May 9, 1977. Thus those respective dates became the beginning and ending dates of the 1977 winter period for elk 1-76. Most of the radioed elk in this study were on their winter ranges by January of each year and remained there through April.

The Calving period was similarly defined as the period of time that an elk remained in its apparent calving area. Generally the calving periods for the radioed elk began in mid-May and ended by mid-June.

The Summer period began when the elk arrived on its summer range but did not overlap a portion of the Calving period. The summer period ended on August 31 so as not to overlap the Rut period.

The Rut period was defined as the period of time between September 1 and October 15 each year. Often the Rut would begin while the elk were still on summer range. Setting fixed dates for the Rut is based on the fact that rutting activities are more likely governed by photoperiodism than by climatic conditions or other factors.

The Hunting period began one relocation date prior to the opening date of the general big game hunting season and ended one relocation date following its closing. Generally these dates were from mid-October to early December.

The Early Winter period was bounded by the end of the Hunting period and one date prior to the beginning of the Winter period.

Points of relocation were used to calculate seasonal activity centers, home range sizes, average weekly movements, and average elevations. Seasonal home range sizes were determined by two methods, the "minimum home range" (Mohr 1947) and the "standard diameter" (Harrison 1958). One standard diameter is the diameter of a circle having its center at the seasonal activity center and includes approximately 68 percent of the points of relocation. The data was analyzed by a computer program developed by Lonner (1976) for the Long Tom Elk Study.

RESULTS

Seasonal variations in minimum home range sizes, standard diameters, and average distances moved between weekly radio locations for 12 elk during 1976 and 1977 are shown in Figure 2 and Table 1. Both methods of estimating home range size during the winter period showed greater values in 1977 than in 1976. Minimum home range sizes averaged 6.7 and 16.3 square kilometers for 1976 and 1977, respectively, whereas standard diameters averaged 4.7 and 6.8 kilometers for the same years, respectively. Thus, the more intense winter conditions of 1976 were more restrictive in the amount of area the elk covered. Winter period weekly movements for 1976 and 1977 were 1.2 and 2.8 kilometers, respectively, showing a similar relationship as the area calculations. Not only did the more severe winter restrict the amount of area used by elk, but it also apparently reduced their weekly movements.

The 1976 and 1977 Calving periods showed no appreciable difference in size, home ranges or movements. Home range sizes determined by both methods were similar to those of the Winter period. Weekly movements appeared to have increased only slightly from Winter to Calving. It is likely that the cow's association with a new calf, rather than snow conditions, had a suppressing effect on the sizes of home ranges and the length of weekly movements.

For the Summer period movements, minimum home range and standard diameters were larger than any other seasonal period, except for hunted elk during the Hunting period. Environmental and behavioral restraints are at their lowest annual level during the Summer period.

For the Rut period home range sizes, standard diameters and movements all declined somewhat from Summer values but were larger than those for Winter and Calving periods. The average minimum home range size for 1976 was smaller than that for 1977. Standard diameters also showed a similar but smaller apparent difference. Movements, however, showed no difference between years. This data suggests that movements were more linear in 1977 than in 1976. The apparent reason for this was that uniform summer-like climatic conditions existed in 1976 which allowed elk to remain on or near summer range throughout the Rut that year. In 1977 several storms occurred in September causing a shift in elk distribution towards winter range thus increasing home range sizes for the Rut.

For the Hunting period data for non-hunted elk (those in areas not open to elk hunting) and hunted elk (those in areas open to elk hunting) were analyzed separately for comparison purposes. Eight and seven of the 12 radioed elk in 1976 and 1977, respectively, were in non-hunting areas during this period. In all cases for both years average movements, home range sizes and standard diameters for hunted elk were substantially greater than those of non-hunted elk. Home range sizes as determined by both area methods were greatest for hunted elk in 1977. Since movements showed very little variation between years, it appears that the more wintery weather conditions during the early fall season of 1977 resulted in elk making more linear movements as was the case for the Rut that same year.

Figure 2. Seasonal variations in average home range sizes, standard diameters, and weekly movements for 12 radioed elk from winter 1976 through hunting season 1977.

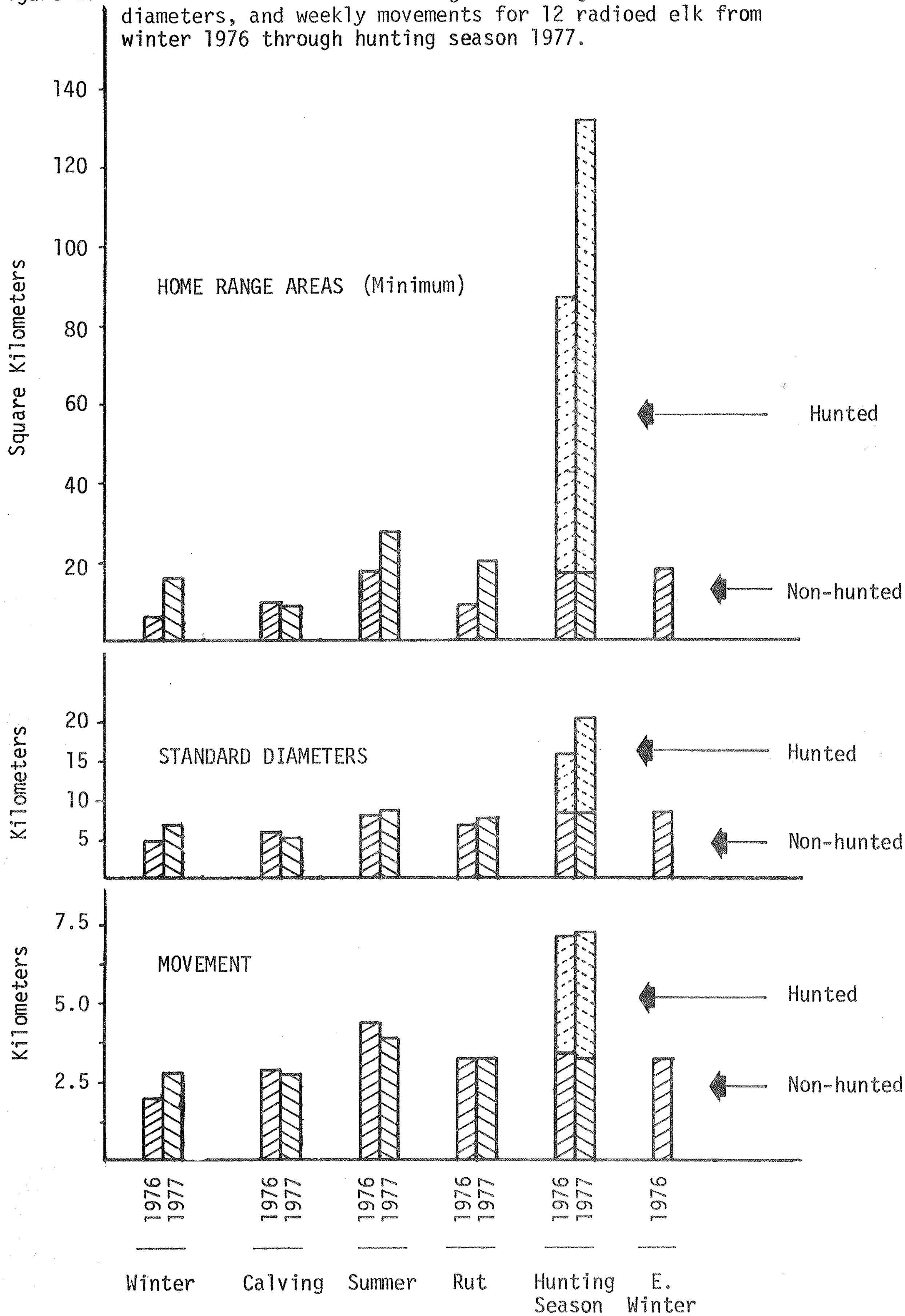
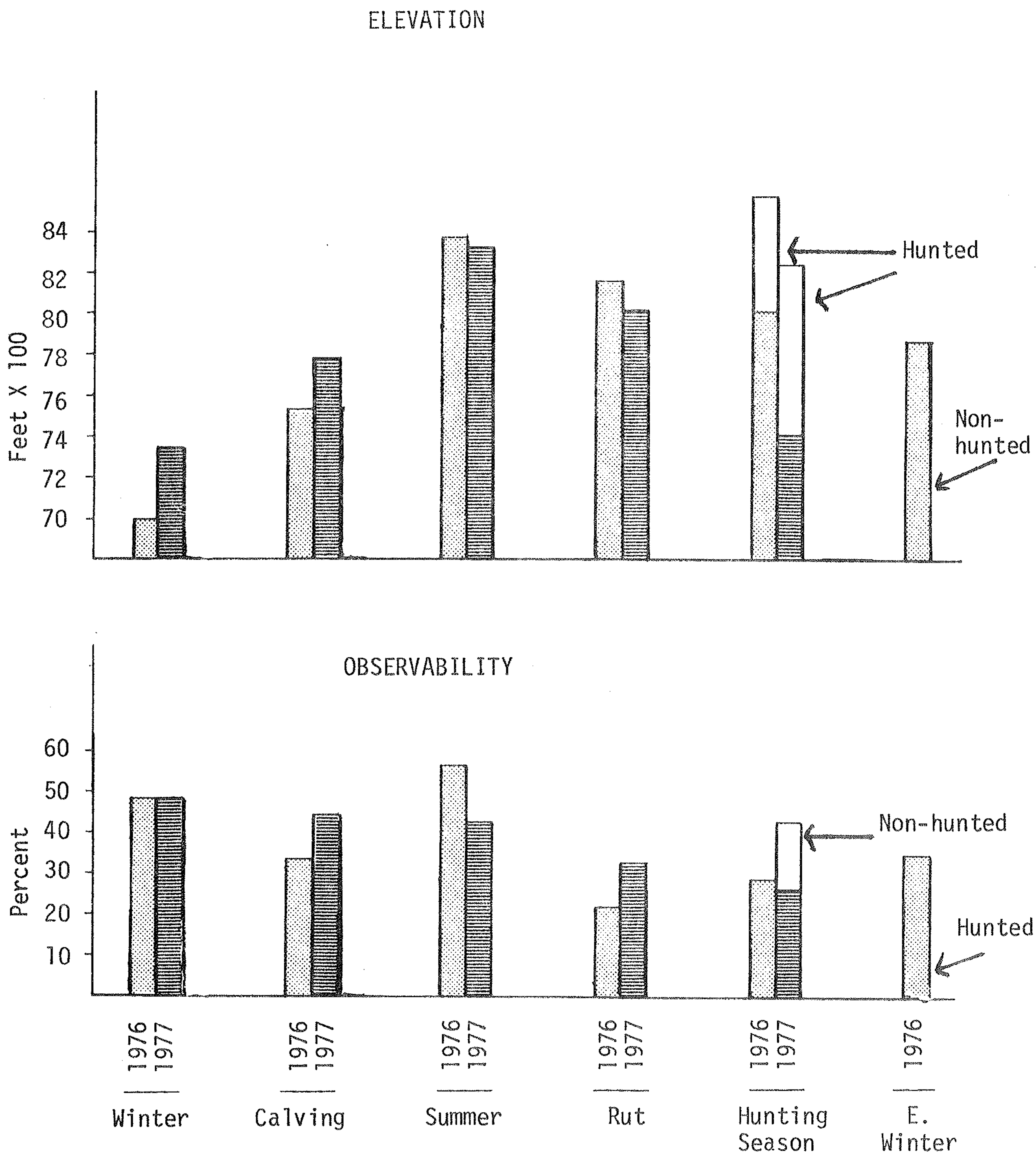


Table 1. Minimum home ranges, standard diameters, weekly movements, elevations and percent observability of 12 radioed elk for six seasonal activity periods during 1976 and 1977.

Seasonal Activity Period	Year	Home Range Area (Sq. Km.)	Standard Diameter (Km.)	Weekly Movements (Km.)	Elevations (Feet)	Observability (Percent)
Winter	1976	6.7	4.7	1.2	7001	49
	1977	16.3	6.8	2.8	7370	49
Calving	1976	9.1	6.1	2.9	7536	34
	1977	8.7	5.2	2.8	7792	44
Summer	1976	17.4	8.2	4.4	8383	57
	1977	19.4	8.6	3.8	8339	35
Rut	1976	8.8	7.1	3.2	8168	22
	1977	19.6	7.8	3.6	8013	33
Hunting	1976H 1/	86.9	16.1	7.1	8581	29
	N 2/	16.8	8.4	3.4	8103	29
	1977H	132.8	20.5	7.8	8231	26
	N	16.8	8.5	3.3	7424	43
E. Winter	1976	18.1	8.6	3.2	7870	49

1/ H = Hunted
2/ N = Non-hunted

Figure 3. Elevations and observability of 12 radioed elk for each seasonal activity period winter 1976 through hunting season 1977.



An Early Winter period was identified for the 1976 year only. In 1977 weather conditions were such that elk arrived on winter range shortly after hunting season was over. Movements and home range sizes for the 12 elk in the Early Winter period were very little different from those of non-hunted elk during the Hunting period. Thus it appears that there were no carry over effects from the Hunting period to the season that followed.

An obvious inverse relationship occurred between elevational usage of radioed elk and winter weather conditions (Figure 3 and Table 2). Elevations were least during the Winter period when snow depths were the greatest and weather conditions the most severe. As snow depths lessened, elevations increased. Elk, except hunted elk, were at their highest annual elevations during the Summer period but began a steady decline as the weather intensified toward winter conditions. The differences between years reflect the same relationships. The lower elevations during 1976 Winter and Calving periods as compared to those of 1977 were coincident with the more wintery climatic conditions of 1976. Likewise, the lower elevations of 1977 Summer, Rut, and Hunting periods also reflected the presence of more severe weather conditions those periods.

Another factor affecting elevational usage was hunters. Elk in areas open to elk hunting were at considerably higher elevations than were elk in non-hunted areas.

During the process of making radioed elk relocations attempts were made to observe the radioed elk. Many variables influence elk observability, nevertheless some reasonable comparisons were possible between the various seasonal activity periods (Figure 3 and Table 1). Differences in corresponding activity periods for both years are probably an indication of the magnitude of sampling error. Elk appeared to be most observable during Winter and Summer periods. Elk during the Calving periods were moderately observable whereas hunted elk and elk during the Rut were least observable.

The large distances separating Winter from Calving activity centers suggests that elk are anxious to leave winter range and get close to summer range to calve (Table 2). During mild years such as in 1977 the elk not only wintered but also calved closer to summer range.

Average distances between Summer and Rut activity centers were small both years indicating that elk rut on or very near their traditional summer ranges. Distances between Rut and Hunting activity centers were likewise small but those for 1977 were obviously larger than the previous year's. This larger difference in 1977 was the result of more wintery weather conditions during the fall of 1977 causing a general shift of elk distribution toward winter range that year.

Elk fidelity to their various seasonal ranges is illustrated by comparing distances separating seasonal activity centers for each of the 12 radioed elk during the years 1976 and 1977 (Table 3). Only six of the 12 radioed elk wintered on the same major winter range both years. The average distance separating activity centers of elk wintering on the same winter ranges both years was 4.4 kilometers whereas 21.9 kilometers separated activity centers of the six elk wintering on different areas. It appears that the mild weather conditions during the 1977 winter did not provide enough weather stimulus to encourage half of the 12 radioed elk to migrate to their most terminal winter range. These elk did not go out of their way to winter at different locations but simply stopped at one of the intermediate winter ranges along the way.

Table 2. Distances between succeeding seasonal activity centers for 12 radioed elk from winter 1976 through hunting season 1977.

Activity Periods	Radioed Elk Number												
1976	1	2	3	4	5	6	7	8	9	10	11	12	Ave
Winter - Calving	33.5	20.7	15.9	32.8	44.5	12.2	4.8	29.7	14.0	34.8	32.6	23.7	24.9
Calving - Summer	6.0	21.1	9.3	2.9	2.5	23.0	18.1	4.7	14.6	11.5	4.3	25.1	11.9
Summer - Rut	12.9	2.1	7.1	.6	5.7	.9	4.2	3.7	1.8	5.4	6.1	13.3	5.3
Rut - Hunting	1.4	.9	2.2	4.4	4.1	9.0	1.7	1.9	3.5	3.1	2.8	5.2	3.4
Hunting - Winter	14.4	18.0	13.0	10.1	8.9	40.2	10.0	16.6	10.2	38.3	11.8	26.7	18.2
1977													
Winter - Calving	13.9	22.6	15.3	10.2	15.5	20.6	12.8	16.8	7.6	31.7	13.2	26.4	17.2
Calving - Summer	10.5	2.2	3.4	.6	5.1	19.1	1.9	2.4	12.3	11.4	3.8	6.3	6.6
Summer - Rut	9.9	9.6	3.3	2.3	4.1	5.9	.6	2.8	5.6	4.2	10.0	7.2	5.5
Rut - Hunting	1.2	6.0	8.5	.8	.3	8.5	7.4	6.5	4.3	10.6	7.1	2.9	5.3

Table 3. Distances (kilometers) between 1976 and 1977 seasonal activity centers for 12 radioed elk.

Seasonal Activity Periods	Radio Channels												
	1	2	3	4	5	6	7	8	9	10	11	12	Ave.
Winter	3.3 1/	21.5 2/	2.6 1/	22.4 2/	33.3 2/	6.8 1/	8.4 1/	14.4 2/	4.9 1/	.5 1/	18.9 2/	21.4 2/	13.2 4.4 1/ 21.9 2/
Calving	16.4 3/	23.4 3/	1.7 4/	1.3 4/	2.4 4/	18.0 3/	18.2 3/	.7 4/	2.1 4/	2.7 4/	1.5 4/	24.5 3/	9.4 1.8 4/ 20.1 3/
Summer	6.2	2.5	4.3	3.2	3.4	2.6	1.4	4.9	1.7	2.3	8.3	6.8	4.0
Rut	1.1	5.0	4.5	2.0	1.6	3.4	3.5	3.5	4.8	2.1	12.3	7.1	3.9
Hunting	1.1	9.3	5.9	3.8	5.1	5.3	7.5	8.5	9.0	9.8	8.7	3.8	6.5

1/ Six elk wintered on the same major winter ranges both years
2/ Six elk did not winter on the same major winter ranges both years
3/ Seven elk calved on different major calving areas in 1976 and 1977
4/ Five elk calved on the same major calving areas both years

The Calving period activity centers also showed major variations in calving locations between years for 5 of the 12 radioed elk. Distances separating 1976 and 1977 activity centers for the elk calving on different major calving areas averaged 20.1 kilometers whereas there was an average of only 1.8 kilometers separating the locations of the 7 elk which calved on the same calving grounds. All of the five elk which calved at different locations did so by calving closer to summer range during the spring following the mild winter of 1977. The interesting thing is that the elk which did not winter in the same location both years were not necessarily the same elk which calved on different calving areas. Thus it appears that some half of the elk prefer to calve at traditional calving locations whereas the other appear to calve as close to summer range as the progression of the spring snowmelt allows.

Elk displayed the greatest fidelity to summer and rutting areas. The average distances separating the 1976 and 1977 activity centers for all elk during the Summer and Rut periods were 4.0 and 3.9 kilometers respectively. Climatic conditions vary the least during the Summer and Rut periods which allows elk to rely mostly upon tradition to determine where they are found during these periods.

Weather does become an influencing factor during the Hunting period, thus tradition in combination with weather conditions determine an elk's location during this period. The average distance separating activity centers for the 1976 and 1977 Hunting period activity centers was 6.5 kilometers.

Elk migrations from Yellowstone Park to winter ranges in the Gallatin and Madison drainages typically occur sometime during the month of December, however, the specific timing is keyed to the occurrence of winter weather conditions. Individual elk appear to require differing amounts of weather stimulus since elk arrivals on winter ranges commonly begin in early December but are not completed until January. By rank ordering radioed elk arrivals on their respective terminal winter ranges, a great deal of individual consistency was apparent from year to year (Table 4). Elk which were the first arrivals in 1977 were most likely to be the first arrivals in subsequent years. Conversely, those elk arriving late one year would likely arrive late, respective to other elk, in following years. The late arrivals also had the best chance of not reaching a terminal winter range during a mild year.

Table 4. Winter range arrival rankings for eleven radio collared elk in the Gallatin and Madison Drainages, 1976 through 1978.

Winter Range	Channel No.	Year 1976	Year 1977	Year 1978	Total	Average	Rank
Porcupine Cr.	1	1 1/	1	1	3	1	1
	4	1 1/	3 2/	2	6	2	2
	11	1 1/	3 2/	3 2/	7	2.3	3
Bear Cr.	2	1 1/	6 2/	6	13	4.3	5
	5	6	6 2/	5	17	5.7	6
	6	1 1/	3	3	7	2.3	3
	9	1 1/	1	1	3	1	1
	10	1 1/	2	1	4	1.3	2
	12	1 1/	4	3	8	2.6	4
Wolf Cr.	3	1 1/	1	1	3	1	1
	7	1 1/	1	1	3	1	1

1/ Elk were banded on their terminal winter ranges in 1976, thus arrival rankings were not possible for all but one.

2/ Did not reach terminal winter range for the year indicated

Summary

Weather conditions and traditional behavior in combination have the greatest influence on an elk's location at any one time. Individual elk use only a small portion of the habitat available to them each season of the year. Weather determines what portion of the habitat is physically available and usable, but tradition determines what part of the available range is used.

Considerable individual variation occurs among elk as to the influences of weather and tradition. Some elks' range usage seem to be mostly influenced by weather, whereas other elk appear to be more consistent and less influenced by weather.

Elk show the greatest fidelity to summer range and the least to winter range. In no case did elk change terminal winter range location but rather if a change was made it was done so within its previously established annual home range.

Hunting does have a major effect on elk elevational usage, weekly movements and hunting season home range sizes. However, hunting showed to tendency to retard elk migrations to winter ranges.

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IS TELEMETRY THE APPROPRIATE SALVE FOR GAME MANAGEMENT SORES?

Bruce Campbell[1]

No written report submitted.

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THE USE OF TELEMETRY TO EVALUATE THE IMPACT OF COAL DEVELOPMENT ON WILDLIFE

Robert L. Phillips[1]

Since 1975, personnel of the Denver Wildlife Research Center have been conducting studies on the effects of coal development on wildlife near Decker, Montana. This has been a cooperative effort with the Fish and Game Departments of Montana and Wyoming and the energy companies working in the area. Our major project goal is:

> To determine the long-term impact of coal development on wildlife populations indigenous to the Northern Great Plains.

Under the broad goal, we have six major objectives which are:

1. To measure and evaluate the significance of major habitat types of the Northern Great Plains to important wildlife species.

2. To establish basic population parameters for selected wildlife species unaffected by mining activity and to assess changes during and after the development period.

3. To develop methodologies for assessing impacts on wildlife populations from coal development and related activities.

4. To develop the capability to predict impacts to wildlife populations on similar areas being considered for coal development.

5. To determine the effectiveness of land reclamation procedures in the reestablishment of wildlife populations with primary emphasis on mule and white-tailed deer, antelope, and raptors.

6. To provide energy companies with recommendations for developing mining plans that will minimize detrimental effects to wildlife resources.

We have placed special emphasis on certain species or groups of species which in our best judgment appear to be sensitive to coal development activities or are of special economic and/or ecological significance to the area. During the past 2.5 years, we have conducted specialized studies on deer, antelope, sharp-tailed grouse, raptors, and bobcats. Table 1 shows the species we have been working with and the volume of data collected thus far. Our principal technique to accomplish the objectivies of all the studies has been radiotelemetry. We chose this method because it minimizes the biases in evaluating habitat use and

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allows the biologist to collect data obtainable in no other way. Perhaps I was prejudiced by previous experience, but I saw no other way of accomplishing project objectives without this method. We needed marked animals to assist us in defining migration routes, areas of critical habitat, and habitat use patterns of many wildlife species.

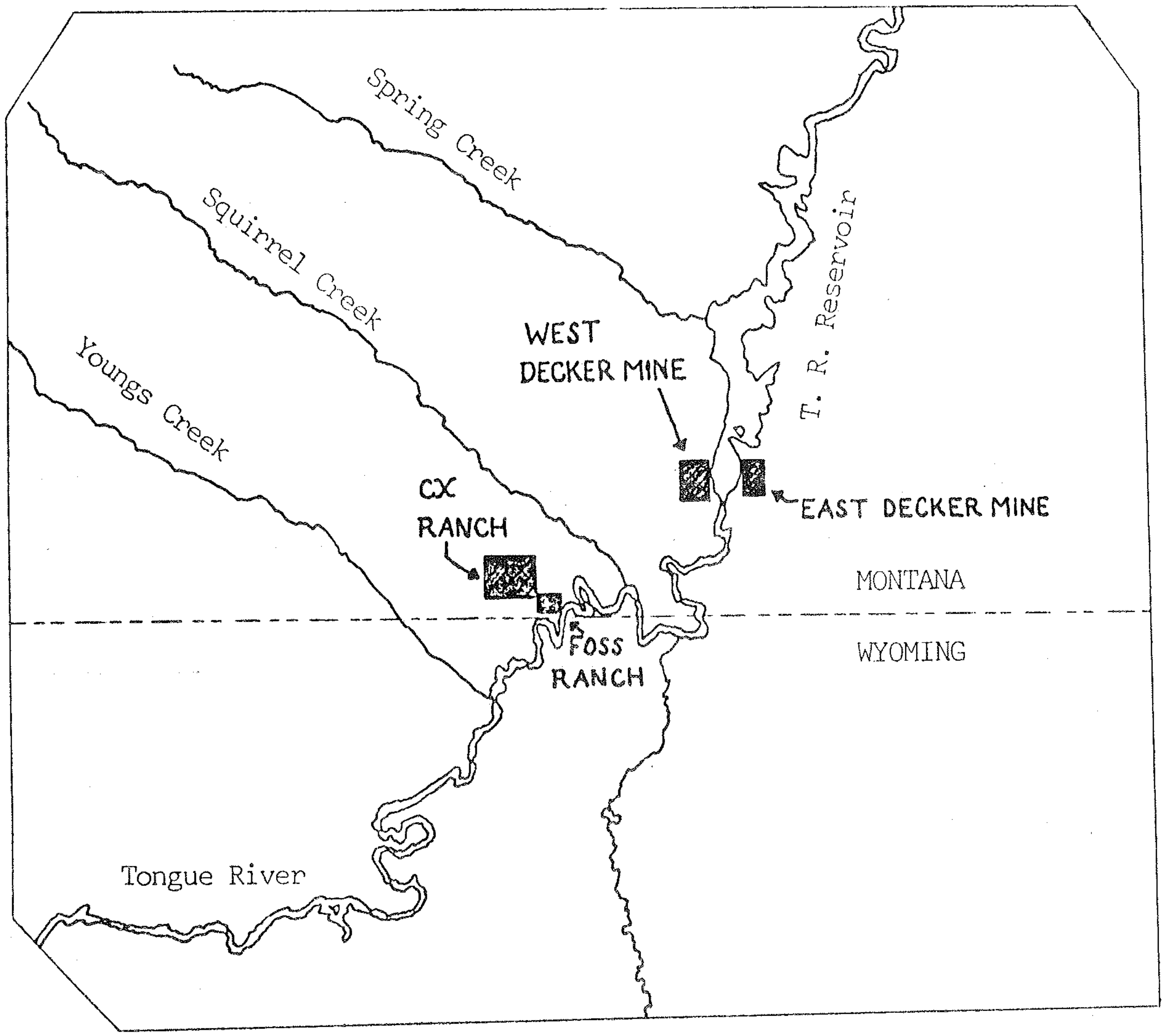
The Study Area

To accomplish our goals and objectives, we established a 500-square mile study area, 20 miles north of Sheridan, Wyoming (Fig. 1).

Table 1. Radio-telemetry data on wildlife species marked in connection with impact study near Decker, Montana.

Species	Number Radio-Marked	Number of Relocations
Antelope	38	3,000
Mule Deer	41	2,500
White-tailed Deer	12	250
Bobcat	11	300
Sharp-tailed Grouse	25	200
Golden Eagle	2	50

This site was selected because it contained the major habitat types of southeastern Montana and northern Wyoming that would be influenced by coal development activities in the immediate future. Three active coal strip mines are located within the area and at least four more are scheduled for development within the next few years. Major coal leases are held by Shell Oil, Decker, and Consolidated coal companies. The study area also contains the site of a proposed major coal-fired power plant.



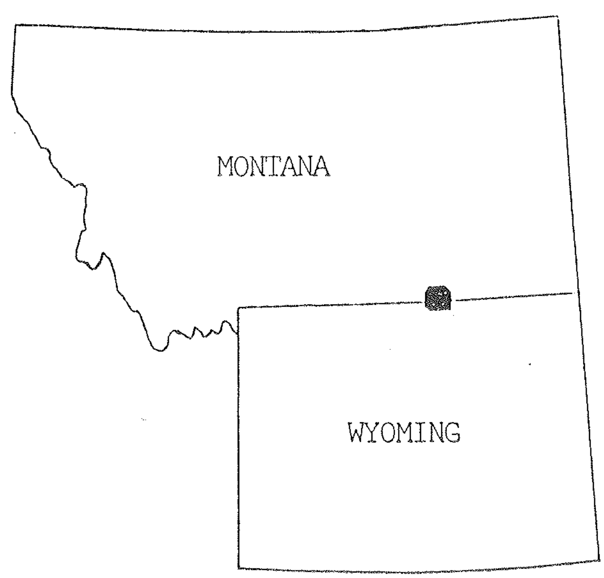


FIG. 1. Map of study area.

The Tongue River flows north through the eastern third of the area, and its tributaries flow southeast or northwest. Steep to moderately steep south or west aspects are characterized by xerophytic shrub/grasslands or ponderosa pine, and north or east aspects often feature ponderosa pine or mesophytic shrubs. Gently rolling areas between drainages are usually big sagebrush/grassland or grassland, with interspersed dryland crop fields. Drainage bottoms are a mixture of deciduous forest, riparian grasslands, and irrigated alfalfa or other crop fields.

Most of the sub-region is privately-owned. The dominant land use is agriculture, primarily cattle ranching. Human population is low. The only organized town in the study area is Decker, Montana (population about 50), although Ranchester and Sheridan, Wyoming (populations about 250 and 15,000 respectively) are within 5 miles of the area. Two town sites have been proposed along the Tongue River Reservoir in Montana.

Methods

During the course of our investigations, we have used a variety of telemetry equipment. Most of our gear has been obtained from commercial sources; however, we have had some assistance from the electronics lab of the Denver Wildlife Research Center. Standard radio-collar designs have been generally used on both deer and antelope. We did experiment with a pendant-type collar, but this effort proved unsuccessful.

Our principal method for relocating radioed animals has been triangulation from two known points. This has been accomplished with hand-held Yagi antennas and through the use of a tower system. If individual animals could not be readily located on the ground, we employed the use of fixed-wing aircraft.

The tower system has proved to be the most efficient and accurate method of relocating animals for a number of reasons. Normally using this system we can track 25-30 animals in a 2-3 hour period. This system can be operated in practically any type of weather without disturbing the marked animal.

All telemetry data have been recorded in a format suitable for future keypunching and computer processing. Relocations are plotted on 1:24,000 topographic maps and recorded as UTM coordinates. We plan to use a variety of programs to analyze the data at a future date.

Results

Now I will give a brief progress report on each of the studies involving telemetry work.

Deer

The deer study began with two broad objectives which were: (1) To establish baseline population data on mule and white-tailed deer in three experimental areas within the overall study area, i.e., data collection on population size and productivity, sex and age ratios, habitat use and movement patterns; and (2) to determine the direct effects of mining on deer by documenting changes in movement patterns, population size, and habitat use.

Since the initiation of field work in December 1975, we have captured and marked 90 mule deer and 30 whitetails in the Decker area. Forty mule deer and 12 whitetails have been instrumented with radio-collars. To date, we have obtained nearly 3,000 relocations from these animals. In addition to radio-collaring, we neckbanded 67 deer. These animals have produced approximately 530 relocations or 18 percent of the total relocations. It should be noted that many of the sightings of neck-banded animals were assisted by a radioed animal leading the observer to the area. Although the quantity of data generated by neckbanding was not great, it did produce valuable data on migration patterns and home ranges. Also, the combination of neckbanded and radioed animals was useful in assessing annual population changes in the experimental deer herds under study. Results of this phase of the project are preliminary, but we do have some tentative findings.

We have determined that at least a portion of the mule deer in south-eastern Montana is migratory. Traditional winter ranges are used by large numbers of deer. Movements from summer to winter ranges have been documented up to 25 miles. Home ranges of resident deer are found to be generally less than 3 square miles, with winter ranges being less than 1 square mile. Mule deer normally use upland sagebrush-juniper habitats in the fall and winter months. The riparian bottomland of the Tongue River is heavily used during the period June to October. Daily movements to the river bottom become more regular as the summer progresses. By September these daily movements cease and the deer become full-time residents of the bottomland. The return to the upland types normally coincides with the first heavy snow of winter.

Some mule deer appear to be compatible with strip mining operations. At least this has been evident at the West Decker mine which supported a resident population of 17 deer on 1.5 square miles in the summer of 1977. This population was drastically reduced shortly thereafter from a variety of causes. Only one mortality was directly attributable to mining. This was a fawn which was hit and killed by a coal hauler. The remaining mortalities came from highway kills and poaching adjacent to the mine.

We have some limited results from our efforts working with whitetails. Radiotracking has shown that they are most frequently associated with the agricultural land and deciduous woodland along the Tongue River. There is limited use of upland habitats during the summer months. Year-round home ranges are small--generally less than 2 square miles. Movements appear to be linear. Whitetails concentrate in the densely wooded areas during the winter and disperse to smaller drainages in the early summer.

Antelope

Our research efforts on antelope thus far have been concentrated in the Youngs Creek area along the Montana-Wyoming border and in the East Decker mine site area immediately east of the Tongue River Reservoir. The whole study area contains an estimated winter population of 500-600 antelope with the largest winter herd concentrated in the Youngs Creek area. We have individually marked 116 antelope in the two areas of study. These animals have provided a great deal of information concerning fawning areas, use of winter ranges, habitat use, and movement patterns. Thus far, we have accumulated nearly 4,000 relocations on marked antelope. Approximately 50 percent of the relocations have come from neckbanded animals. The neckbanding technique is more productive for antelope than deer primarily because the habitat they occupy allows this species to be more visible to the observer than deer.

Movement patterns for antelope do not appear to be traditional; i.e., different ranges are used in different years. This is probably related to changing weather patterns and existing snow conditions. Individual winter groups are not distinct social units and there appears to be a great deal of "mixing" from one year to the next. Movements are most erratic during the spring breakup. Studies in the Youngs Creek area have shown that approximately 24 percent of the herd is migratory. Distances from winter to summer ranges are up to 30 miles. Spring activity areas range from 13 to 73 square miles, whereas summer activity areas are generally from 4 to 20 square miles. All of the data on movements strongly suggest that antelope are more nomadic than traditional. The implications of this are of significance to wildlife managers and coal companies. It points out that while perhaps de-emphasizing the importance of the actual coal pit, it could magnify the significance of roads, railroads, and other potential impediments to movements. It also emphasizes the need for additional long-term research to gain a full understanding of the ecological significance of such movements in the face of changing land use practices. Most important, such movements emphasize the inadequacy of a "one mine at a time" approach to impact assessment.

There have been no big surprises as far as the type of habitat used by antelope in the area. They are strongly associated with sagebrush as they are in other parts of Montana and Wyoming. The sagebrush-grassland type was by far the most heavily used on a year-round basis. Croplands received a fair amount of use during the late summer and fall. We observed some use of timber types for shade purposes during the summer months. This suggested the importance of small patches of upland timber in breaking up the sagebrush-grassland community.

Sharp-tailed Grouse

We have conducted limited studies on sharp-tailed grouse. Our major objective was to evaluate the seasonal use of habitat types. General field observations suggested that sharptails seem to "disappear" during the brood rearing season, so it was obvious we didn't know much about the significance of different habitat types. The only way to keep them visible to the biologist was through telemetry.

To date, we have instrumented about 25 birds using a variety of attachment techniques. Avian predation has been a major problem for birds wearing backpacks. We have attempted to solve this problem by attaching the radio unit to a camouflaged poncho collar. This approach has worked fairly well.

Our limited results to date indicate that most nesting occurs within 1 mile of the lek. The few adult males that have been radiotracked have stayed in close proximity to the lek.

Eagles

Most of our raptor work has been baseline oriented, but we have done a limited amount of telemetry work with golden eagles. This has been in response to the need for data on the behavioral responses of eagles to industrial development close to nesting sites. Two adult birds were only recently instrumented so no results are available. Radios are attached to the eagle by securing the package to the central tail feather with monofilament line.

Bobcats

In 1975, we initiated work on bobcats in various parts of southeastern Montana. We were interested in gathering population data and information on the influence of man's activities on the population dynamics of the species. As a part of this study, we instrumented eight cats with coyote-type collars. The units worked well, but we found the life span of most Montana bobcats to be very short. Because this species was not classified as a game animal or furbearer, there was no state control over the harvest. The limited amount of data we gathered on this study strongly suggested that cats could and were being overharvested by hunters and trappers in several areas. However, due to changing research priorities, we discontinued further field studies on this species.

In summary I'll say that despite some problems and difficulties, we have still found telemetry to be one of the best techniques available to wildlife researchers.

THE USE OF RADIO TELEMETRY IN DETERMINING DEER FAWN MORTALITY

Arnold Dood[1]

The role of predation in regulating deer populations has long been debated. Most of the evidence of predation on neo-natal fawns to date has been indirect and, therefore, subject to considerable uncertainty. The advent and refinement of radio telemetry has provided a technique that allows for rapid detection of morbidity and mortality of deer fawns.

Methods of fawn capture

a) The first and most widely used method has been to use dam-newborn behavior to aid in locating fawns (White et al. 1972). Observers are posted in towers or on other high points and when the behavior of the dam suggests a fawn is in the vicinity a search of the area is initiated. When the fawn is located, it is captured by hand or with the aid of nets. This method has been used successfully on white-tailed fawns in Texas and Oklahoma, and on mule deer fawns in Oregon and Colorado. Problems associated with this method are that it generally requires a small area with a good density of deer and many observers on that area.

b) A second method which was used successfully on white-tailed fawns in Texas is spotlighting fawns at night. Details on this method were not available but a documented lack of nocturnal activity in fawns (Jackson et al. 1972) leads me to believe other methods are more effective.

c) A third method involved an attempt to use radioed adult females to aid in locating their fawns. This method proved ineffective and was eliminated.

d) The fourth method and the one employed on my study in the Missouri River Breaks was to use aerial surveillance to locate does with fawns at side. Only after a fawn had been observed bedding was capture attempted. Long handled hoop nets were used to assist with the capture. This method proved very effective. It is advantageous because it can be employed on large areas, but it is limited by a requirement for easy accessibility to that area.

Handling time for all these methods should be kept to a minimum to reduce disturbance to the fawn and doe and this in turn reduces the chance of abandonment.

Types of radio transmitters

a) Transmitters with a steady pulse rate are acceptable for mortality studies if fawns are to be relocated visually on a daily basis.

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b) Transmitters with a thermal or mortality switch are available. The body heat of the fawn keeps the collar warm and when mortality occurs the radio cools and pulse rate changes. This type of transmitter allows for monitoring of fawn mortality without visual relocations. The major problem associated with this type of transmitter is the warm ambient air temperatures of summer interfering with correct operation of the switch after mortality has occurred.

c) Mercury or activity switch transmitters are also on the market. In these transmitters pulse rate changes with changing position and this allows you to monitor a fawn's activity without visual sightings. In my opinion this is the best type of radio to use in fawn mortality studies because the status of the fawn can generally be determined by listening to the pulse rate and visual relocations need not be made as frequently.

d) Combinations of thermal and mercury switch transmitters are available but are not necessary due to the weaknesses of the thermal switch.

Fawn radios should be attached to the neck (vs. a harness type) with elastic, expandable collars. Fawns should be monitored on a daily basis by radio and observed visually every third day throughout the period of study. Range of fawn radios is generally 1/2 - 2 mi. and weights vary from 60 - 300 gr. depending on design. Radios used on my study in the Breaks had both mercury and thermal switches and weighed between 60-80 gr. Collars consisted of a 1 inch wide band of elastic with seams sewn in to allow for fawn growth. Average battery life was approximately 4 months.

Information that can be obtained from telemetered fawns

a) The cryptic nature of fawns their first few months of life makes habitat use difficult to determine , however telemetry allows for a more accurate determination of habitat use than do general observations or observations of visibly marked animals. Visual locations of telemetered fawns are necessary for an accurate determination of habitat use. Studies to date on fawn habitat use are few.

b) Radio telemetry of fawns allows for determination of fawn movements. Comparisons of movements between months and/or years are most valid if a constant time interval is maintained between relocations.

c) Radios with mercury switches make possible the monitoring of fawn activity on a 24 hour basis.

d) Radio telemetry provides a method for daily observation and examination of young fawns for rapid detection of morbidity and mortality. Rapid consumption of predator killed fawns makes other methods of attempting to determine mortality, much less cause of death, generally ineffective.

General patterns of deer fawn mortality

Studies to date have shown the majority of fawn mortality occurs during the first 45 days of life with predation usually being the most important source of summer mortality. During the summer of 1977 in the Missouri Breaks the majority of mortality occurred after 45 days of life and indicates periods of major mortality can occur at anytime the first summer of life. Males are generally more susceptible to mortality possibly due to higher activity levels. Generally, drought and other severe environmental conditions adversely affect fawn survival. The range and mean summer fawn mortality rates for white-tailed deer, mule deer, and black-tailed deer are listed in Table 1.

Table 1. The range and mean summer mortality rates for white-tailed, mule and black-tailed deer fawns (information summarized from approximately 15 studies on summer fawn mortality).

	Range	Mean
White-tailed deer	10 - 96%	50%
Mule Deer	7 - 88%	30%
Black-tailed deer	4 - 69%	40%

Problems associated with using fawn telemetry to determine mortality

a) Most often fawn studies have taken place on the same area where adults and/or other species were also being studied. Confusion can result from too many radios being placed on too small of an area or movements of animals may concentrate radios. I suggest the use of four band receivers with the capability of monitoring at least 48 channels. In addition, a good distribution of radios would also help to eliminate this problem.

b) There is also difficulty working on large areas to determine fawn mortality unless the area is readily accessible by vehicle or large numbers of workers are available.

c) The possibility exists that the radio marking of fawns might adversely affect fawn survival. The majority of studies to date have shown that adequate sample sizes of telemetered fawns provide accurate estimations of actual mortality which is occurring in the unmarked population.

Future Application

Advances in radio design and battery life along with other refinements in the technique will make possible a more detailed picture of neo-natal life.

Now and in the future telemetry equipment could be used to obtain information on such things as traditional use of an area, dispersal rate, recruitment, family group associations and other population parameters. Telemetry could also be used to determine fawn bedding site selection and cover requirements and possible relationships between these factors and mortality. Longer battery life will extend our knowledge of the causes, extent, and timing of mortality during the entire first year of life.

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DISCUSSION

Q: What percentage of the fawns that you tagged this year in the Breaks were affected by predators?

A: Five of 19 marked fawns, or 26%, were lost to coyote predation.

THE USE OF TELEMETRY IN DETERMINING THE DISTRIBUTION OF SHARP-TAILED GROUSE IN RELATION TO REST-ROTATION GRAZING

Lyn Nielsen[1]

Radio telemetry was used to help determine the distribution of sharp-tailed grouse in relation to rest-rotation grazing. The study was conducted on the West Hotchkiss Unit of the Cottonwood grazing association, 25 miles north of Malta, Montana. The West Hotchkiss unit is a four pasture, rest-rotation grazing system, comprimising 26,000 acres. The study was funded by the Bureau of Land Management and the Wildlife Management Institute.

During April, 1977, sharp-tailed grouse were captured on leks display grounds by using cannon nets. Solar powered transmitters with a residual Nickel Cadmium battery (telemetry Systems, Milwaukee, Wisconsin) were fitted to ten male grouse. Males tend to show a closer association to the display grounds. Therefore, a change in group distinction from cattle grazing would be more apparent. The transmitters were glued and stitched to a leather pad which was held on the bird's back by nylon laces. The total weight of the radio pack was 26 grams. All "radioed" birds experienced high mortality during the spring,1977. By mid-June, six of the original ten were found dead. The four survivors experienced no mortality throughout the summer and provided 136 relocations for plotting distribution. However, during September, three more birds were lost coinciding with their return to the display grounds in the fall. The remaining "radioed" bird was the only one that had not received a poncho marker.

Visual observations of poncho marked birds provided only 28 locations for the summer as compared to 189 locations provided by the four birds with transmitters. The 28 visual observations represent many hours spent in the field where as the "radioed" birds' locations required only two hours every fourth day.

During October 1977, sharptailed grouse were again trapped to place recovered transmitters on new birds. This time the "radioed" birds did not receive a poncho marker since birds both radioed and collared in the spring experienced heavy mortality. Some grouse required a period of about two weeks to adjust to the radio pack. During this period, they would not fly or would only fly a short distance and hide. These birds were easily caught by hand and consequently three were lost to predation. Jackson (1967) experienced the same problem in attaching back tags, the weight was insignificant, to sharp-tailed grouse. Therefore, I feel the weight of the transmitter packs was not the problem since the grouse flew very well once they became adjusted to the transmitter. Since most did adjust after a short

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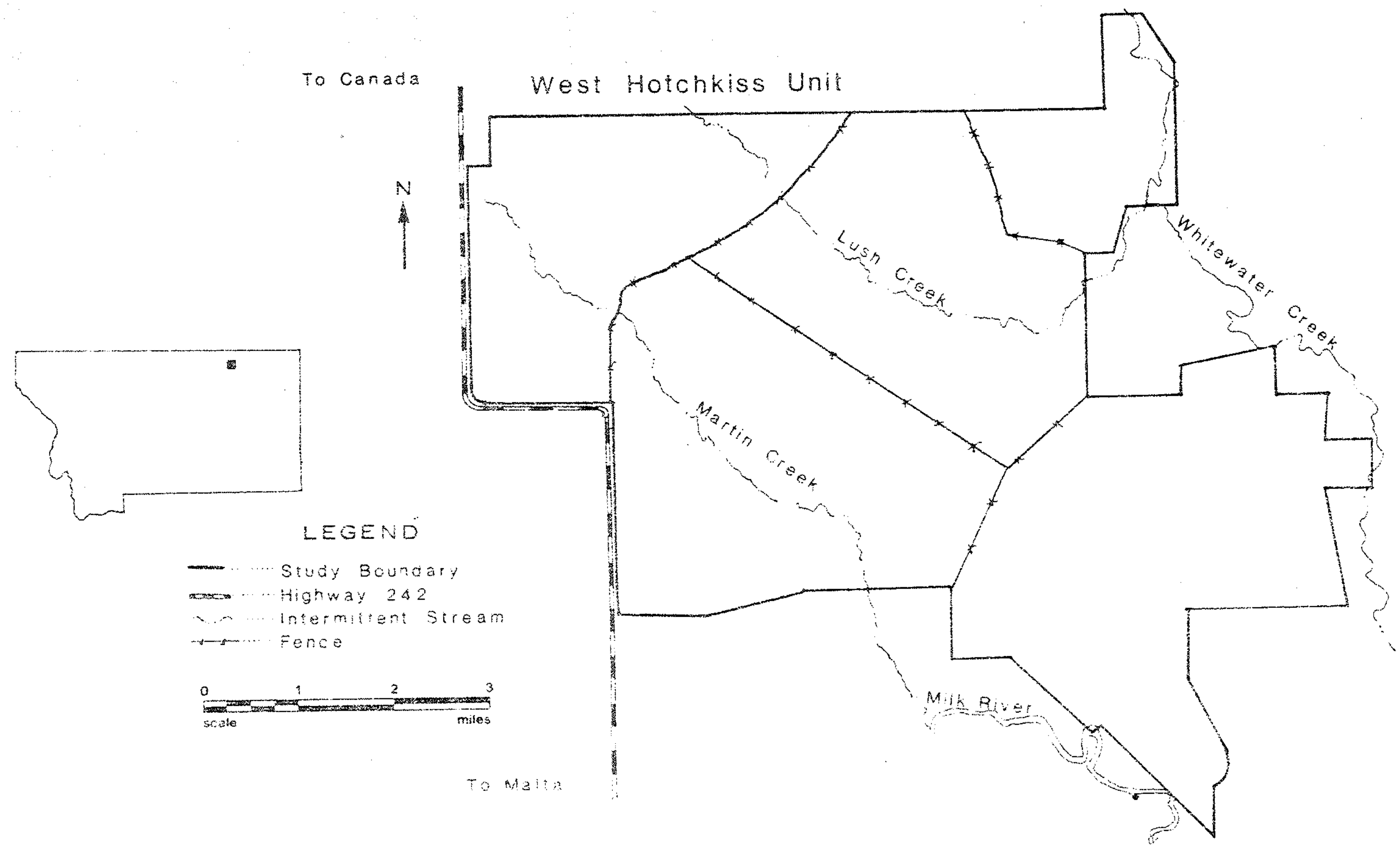

Figure 1. Map of the Study Area.

period, I feel the transmitter was not a physical impairment but a psychological one. Boag (1972) found red grouse showed decreased activity and food intake up to two weeks after they were fitted with transmitters.

At the end of the fall display, eight birds had adjusted to the radio pack and were doing very well. In November, the transmitters started to malfunction. They would only transmit if they were in direct sunlight making locations very difficult. In December, during a very cold period, all the transmitters basically stopped functioning. Since this cold period, a total of only seven signals have been received. These were received on warm, sunny days, therefore making the transmitters almost useless in this area during the winter.

In conclusion, the problems I experienced with the radio telemetry falls into two categories. One was the technical malfunctioning of the transmitters, which may be remedied by using battery-powered transmitters. The other was the mortality of the "radioed" grouse. Suggestions that may reduce or compensate for the mortality are:

1. Eliminating the poncho marker with the transmitter.

2. Trapping near the end of the display period since the grouse are vulnerable to predation during their display.

3. A different method of transmitter attachment might eliminate the adjustment period.

4. A large number of transmitters should be used in bird populations to allow for their high natural mortality.

The value of telemetry, in this study was the positive data it gave for the distribution of grouse from different leks. These results indicate no movement of the adjacent rest pasture on areas of taller grass. Therefore, the grouse selected for traditional use areas whether cattle were present or not.

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DISCUSSION

Q. Where do you lose your six birds from during the summer?

A. I lost 9 during the summer; three from the trapping. All losses were within 1 mile of their display grounds. The mortality was from coyotes, eagles, other reptors and one hunter kill.

Q. Also, you said in the spring they could fly fairly well, and fall they couldn't.

A. There was problems in flying from the spring trapping as well as in the fall trapping. A few birds released from the spring trapping wouldn't fly either.

Q. Did you have two birds from one ground, were they both males? Did those two hang out pretty close association with each other?

A. Yes, at least 50% of the time they were found together and they were both males.

Q. Did they continue together to be established?

A. At the start of fall display period, 21st of September, I lost one of the pair.

Q. Did you notice any difference in production in areas that had low grazing?

A. No. As a result of a large, heavy rain, the production was very low. Broods averaged 2-3 chicks on the entire area and there was no significant difference between the pastures.

Q. Did the poncho have any effect in their ability to strut?

A. No.

RADIO TELEMETRY - ITS ACCEPTANCE AND USE IN GAME MANAGEMENT TODAY

Arnold J. Foss [1]

Throughout the years the trends in gadgetree used by biologists very closely parallels women's fashions, or automobiles, changing abruptly at fairly regular intervals. In many instances, the innovator cast firm renouncement on the old, when he didn't know much about it, and not too much about the new. However, if one was not to be scorned or cast out of the group for outmoded paraphernalia, it was imperative that he get up to date. One need only look back for a few years through professional journals to get some perspective on the fashion parade.

We find trends in the type of work that was being done, and in the methods and tools applied. For example, age determination was big, at one time, we used skeletal measurements, tooth morphology, sectioning of incisors and a variety of other methods to get data. Many people worked relentlessly at this endeavor for a brief time span. At another point, virtually anybody worth his salt was measuring and weighing eye lenses, for a variety of reasons. Further down the road, those working with any form of ruminants were all collecting paunch samples. Studies dealing with the influence of pesticides on wildlife populations were grouped in a short time span. This in part related to a rapid increase in the use of those chemicals during a short time, but it also exhibits a tendency toward follow the leader. Telemetry currently is the big cog in the wheel, we could go on and on pointing out the trends or fads in our activities. It is apparant that the development of tools and techniques did come in surges, someone concocting an idea with a variety of followers and innovators adapting the concept to suit their needs. Some hungry for press copy would utilize his modest little improvisions as a means of getting a ride to the North American Wildlife Conference or some other gathering that provided a break in the routine. The majority of the tools and techniques have provided some very worthwhile advances in the field when applied as intended and many passed out of the picture as rapidly as they were developed. It probably doesn't serve any useful purpose to dwell further on their evolution. Without question, there have been situations where the desire for gadgets far out ranked the need and purpose, however, in large measure the majority of the work in this area was justified and reasonable. We rarely came up with a good tool or system on the first run. There obviously are some benefits in concentrating efforts in a given area of study to get the bugs worked out.

Tools and techniques are very much a necessary part of the wildlife profession. The need for more precision in dealing with wildlife populations has become more pronounced as demands on the populations and their habitats have occurred. The sophistication of tools is necessary to keep abreast with demands placed on our agencies and professionals.

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Biologists have devoted considerable time and energy to find a means that would provide data on the location of individual animals in various cover types, weather conditions and in various seasonal life processes. All systems have left a great deal to be desired. Radio telemetry has provided some new dimensions in this area, and has the potential to be one of the most useful tools developed to date.

With regard to acceptance and application of new innovations, I believe people involved in management activity make these decisions primarily on the basis of the results that are provided or on the anticipated results. The man time, cost, reliability, and the practicality of a system or tool have to be important considerations. The fact that we spent the past two days discussing telemetry is some indication of its acceptance. I see radio telemetry as a tool that can provide us with some very specific information on a limited number of animals. It can provide, as the discussions you have heard the past two days indicate, some very comprehensive data on movements and location of animals in relation to various seasonal life processes. It can provide some very specific data on mortality, something that has been particularly difficult to measure by previous study means. It has enabled us to gather information that would not have been possible in its absence. The cost of equipment, its installation and the follow-up observation that is required to obtain worthwhile data is not cheap. However, when those costs are considered in light of other survey methods, and in terms of the quality of the data obtained, they are not out of line. The application of telemetry has primarily been directed toward research oriented projects, however, if those projects are properly planned they will and do provide information needed in basic management. For example, we have a number of big game populations in the State that migrate considerable distances from one seasonal range to another. Several are associated with parks and preserves and are huntable only in limited situations. Establishment of hunting regulations that are effective in harvesting those populations requires knowledge relating to location of the animals at a given time. We have utilized neck bands, ear streamers, paint and other marking devises to keep tabs on movements. Those methods have provided some very useful data, however, they have not given us the detail we have obtained through the use of radio telemetry. The data obtained in those areas had made it possible to refine management programs, to reduce differential harvests on population segments, and to winter desirable numbers of animals on existing winter areas etc. I could site numerous examples of practical application of study results. I think it is well established that we gather some very specific and worthwhile data by the application of telemetry. It obviously is a very fashionable business to be in, since all up and coming biologists are grasping for all the transmitters and receivers they can wrangle. We probably have plans for more telemetry oriented work than field schedules and flying days allow. Should we be alarmed about this, or is the application of telemetry not likely to encounter some of the same misdirection and overconfidence we placed on other tools in the past?

We recently had a session similar to this one in which our deer management program was fairly intensely cussed and discussed. I believe these periodic evaluations of activities and of tools and techniques we utilize in those activities are healthy, provided we don't go completely overboard. I felt there was some tendency for this in our evaluation of the deer program. There were some things below par, however, it was my opinion that our greatest problem was not an inadequate browse survey technique, or that our basic approach and efforts to secure population and harvest data were poorly conceived. I feel the primary problem was our lack of constant evaluation of what we were getting in the way of data, proper interpretation and application, and more importantly what it was we're trying to do and how well we were doing it. Tools do not solve these problems. I feel we endeavered to make very precise predictions of what we thought we could do with very limited data and we were about as successful as we should have been. We wouldn't anticipate a very refined flight plan with modern day aircraft if our primary navigation tool was a magnetic compass. On the other hand an experienced and thoughtful pilot could do some responsible flying with a compass if he clearly understood its limitations.

At the mule deer workshop and in other circles, I have heard the Cole browse transect technique criticized because it didn't provide all the answers we needed. No one ever said it would - the people that initiated the browse surveys in the State with the Cole method pretty well understood what they were getting from the surveys and what those surveys were intended to provide. At the time they were initiated, with our state of knowledge, with plentiful browse supplies and deer numbers, the method provided some good data. The problem that developed 15 years down the road occurred because we continued to place too much emphasis on the browse surveys and a few other data sources. We became locked into our little world and were content to collect data and occasionally do a little serious analysis, but all in a rather closed fashion. We found it easier to run established surveys than to devote our major energy to thinking and constantly challenging our activities. Collecting data in the field is always more fun than solving problems. This is true if the tool applied is a Daubenmire Frame or a radio transmitter. Part of this is justified and a hazard of the profession. However, biologists like most other people feel a great deal more comfortable in familiar surroundings and have strong tendencies to justify their actions by the group think process - we're all doing it - it must be good.

We could deal with this situation for days and point out examples. We can look at the actions of various agencies. The clear-cutting techniques for some timber species gained considerable criticism in some quarters, not because it is an unworkable or poor timber harvest practice. The problem again was ahead in the sound application of the practice. Sage brush control, rest-rotation grazing, deer harvest surveys, or the application of any practice can wind up crashing and burning, if allowed to go indefinitely with no evaluation and adjustment.

What does all this have to do with radio telemetry? To me it indicates that we have the same opportunity to get hung up on telemetry oriented studies and to the same extent we have with any others. The tool is a good one, it can provide us with some very useful information, provided the results from the studies are not interpreted out of context, and provided the studies are designed to give us useful results.

One of the primary limitations of telemetry studies is that we currently are able to get data from a very limited sample of a given population. We have always concerned ourselves with sample size in vegetation, population, and harvest studies. These same concerns have to exist when telemetry is utilized. Some of the results we get are much more specific than those we have obtained by other means. I feel this tends to breed overconfidence in the value of the results. Even with some of the more intense telemetry studies, we only observe or record behavior of instrumented animals for a very narrow part of their activity spectrum both in time and space. I think the urge continually crops up to give more credence to the results or make more precise predictions from the data than we should. Game managers are as guilty in this regard as anybody, particularly when the torch is being applied, and we are attempting to dig up answers to problems that are pretty obscure, and a decision is due the next day.

Another major problem is the time consumed in monitoring instrumented animals. There is the tendency to give priority to these critters, because of the investment in the equipment, the time and cost of application etc. The biologist feels an obligation to get the most out of this investment and that's not all bad. It does set up the opportunity to dilute his time in a way that he doesn't adequately attend to many other important responsibilities, probably the most important of the responsibilities being his thought process, setting back and evaluating what it is he's getting, why he's getting it, challenging its worth and trying to fit the whole matter into the fundamental objective of his agency. He might even be concerned if he's providing the program funders with a fair return.

A problem with any new tool or system is the tendency for the users to get engrossed in its newness, the anticipated merits of it, and to shift emphasis to it and not make adequate use of back-up systems. I'm a firm believer in putting a bunch of neck bands and ear tags on elk as well as a dozen radio transmitters. I am aware that we don't get many relocations on banded or tagged elk relative to the number we mark. The combination of the two methods cannot help but provide more data than one. The radios assist the observer in locating elk that he wouldn't without them; it also will increase his opportunity to see more bands. Ear tags will far out last both and will provide some long term results not possible from the radio or the neck band. I think it is important that we continue to look at animals that aren't marked or programmed for specific study just as we should look at the broad spectrum of vegetation, not just the stuff under the plot frame. The more complex or intricate the system--the greater the opportunity to get hung up with systems.

I think we have an opportunity to make some outstanding progress in the wildlife field, through the application of radio telemetry. We don't ever want to forget that there have been some outstanding contributions made in the past utilizing a whole batch of tools many of which aren't popular today. None-the-less they had a great deal to do with where we are today. I feel we have strong tendencies to overlook the value and significance of things that were done in the past and don't spend enough time looking back at the lessons of history. I'm sure that the people that did some of the earlier work were equally as enthused about what they were doing and accomplishing as we are today. The person that put the first neck band on an elk expected that he would glean a great deal more useful data from the animal than history proved to be the case. I feel the use of telemetry, at sometime in the future, will verify many of the findings that were surfaced with other techniques. I'm also sure that its applications will uncover some findings and conclusions we would like to keep covered. Some very intense and dedicated thought would accomplish some of the same things.

In conclusion, I view radio telemetry in much the same light as I do airplanes, snowmobiles, the Lincoln index, the Cole browse survey method or a horse. If we have a clear picture of the type of information we need and the problems we're trying to solve, anyone of the above can be useful in helping us get it. To do this effectively, requires that we have a good working knowledge of the tool, its strong points and its limitations. Most important - realize it's a tool and nothing more.