ESTABLISHMENT AND TESTING OF A RADIO TELEMETRY SYSTEM

A Thesis

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by

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

INTRODUCTION

Radio telemetry has been used in wildlife investigations since 1960. Initially most of the work was done on movements and home ranges of vertebrates (Storm, 1965; Ellis, 1964). Subsequent studies have gathered data on physiology (McGinnis, et al. 1970), activity periods (Kjos and Cochran, 1970), habitat usage (Nicholls and Warner, 1972), behavior (Kuck, et al. 1970), and mortality (Stoddart, 1970; Cook, 1971). Radio telemetry is presently employed as a method for monitoring fluctuations in wildlife populations. It allows collection of information that is difficult, if not impossible, to obtain in any other way.

Although telemetry has been in use for 15 years, each system's performance must be evaluated before valid conclusions can be drawn from data gathered with that system. The objectives of this study were to: (1) set up a telemetry system which could monitor movements of cottontail rabbits, coyotes, and deer; (2) test accuracy and range of the system; (3) determine the actual life span and reliability of the transmitters; and (4) determine suitability of the transmitter collars for use on the respective animals.

This study was conducted on Ross Natural History Reservation (RNHR) (Appendix A) and 20 surrounding square miles in Lyon and Chase counties, Kansas from June 1974 to June 1975. RNHR has been maintained by the Division of Biological Sciences, Emporia Kansas State College, as a natural history area since 1960. The area is being invaded by woody vegetation except in those areas maintained as grassland by mowing and/or burning. It provides ideal habitat for cottontail rabbits and deer. Wilson (1963) provides an account of the flowering plants of RNHR.

Hartman (1960) described the physical, biological, and historical features of the area. The area surrounding RNHR is largely pastured, tall grass prairie with timber and brush along the streams. Weatherholt (1968) reported on the flora of Lyon county.

Vehicles, operating expenses, and stipends to support this study were provided by the Kansas Forestry, Fish and Game Commission (KFFGC). The Division of Biological Sciences, Emporia Kansas State College, provided maps, facilities at RNHR, and some telemetry equipment.

MATERIALS AND METHODS

The KFFGC purchased telemetry equipment from Mr. Sidney Markusen, Esko, Mn. The telemetry equipment included:

(1) Five continuous wave, mercury powered transmitters with whip antennas for cottontail rabbits. These transmitters were mounted on leather collars, weighed 78 grams, and had a theoretical life of 180 days.

(2) Five lithium powered, mortality transmitters with whip antennas for cottontail rabbits. These transmitters weighed 38 grams and had a theoretical life of 120 days. Mortality transmitters had a thermistor integrated into the circuit that caused the transmitter to change from a pulsed to a continuous signal when the thermistor sensed temperatures below 75° F. While the transmitter was on a live rabbit, the rabbit's body temperature maintained the thermistor above 75° F. When the rabbit died and cooled, the temperature dropped below 75° F and the transmitter switched to a continuous signal.

(3) Five pulsed, lithium powered transmitters with whip antennas for attachment to coyotes. These transmitters were mounted on dog collars, weighed 100 grams, and had a theoretical life of 180 days.

(4) Five lithium powered, mortality collars with whip antennas for attachment to deer fawns. These transmitters were mounted on dog collars, weighed 100 grams, and had a theoretical life of 180 days.

(5) Two pulsed, lithium powered transmitters with whip antennas for attachment to adult white-tailed does. These transmitters were mounted on webbed cloth collars, weighed 400 grams, and had a theoretical life of 24 months.

(6) One pulsed, lithium powered transmitter with whip antenna for attachment to adult white-tailed bucks. This transmitter collar weighed 400 grams and had a theoretical life of 24 months. The buck collar was designed to expand when the animal's neck enlarges during the rut, and to contract after the rut.

(7) One pulsed, mercury powered transmitter with whip antenna for attachment to cottontail rabbits. This transmitter was purchased from Wildlife Materials, Inc. It weighed 36 grams and had a theoretical life of 90 days.

(8) Three portable, 24-channel, crystal controlled, double conversion, superheterodyne receivers with channels spaced at .015 megahertz (MHz) intervals from 150.815 to 151.120 MHz.

(9) Four eight-element, Hy-gain, Yagi antennas adjusted to the 150 MHz range.

(10) Three two-element, hand held, Yagi antennas.

<u>Permanent Receiver Sites</u>

Two permanent receiver sites were constructed on elevated points at RNHR. A utility pole was set at each site by the Kansas Power and Light Company to serve as the main support for the antenna mast. A scaffold was erected beside each utility pole to allow maintenance and adjustment of the antenna. Station One (Fig. 1) is located directly north of the headquarters building along the northern boundary of the state-owned property (Appendix A, S1). A wooden shelter was constructed on top of the scaffold to provide minimal protection from the elements and to serve as an observation post. A compass rose was mounted on a table inside of the shelter. The antenna was 30 feet high and was mounted on a 1¼ inches x

Fig. 1. Receiver Station One.

11 feet mast that passed through the roof of the shelter and the compass rose table, and was seated in a base plate on the floor of the shelter.

Station Two (Fig. 2) was located immediately west of the headquarters building (Appendix A, S2). The antenna was 38 feet high. Its mast passed through the roof and compass rose table of a shelter at the base of the utility pole. Both receiver sites had a length of coaxial cable running inside of the mast from the antenna to the shelter.

Mobile System

The mobility and large home range of the coyote required that coyote mobility be matched with vehicle-mounted antennas. Some investigators (Slade, et al. 1965; Inglis, et al. 1968) who have used radio telemetry to monitor animal movements selected fixed-station radio telemetry systems rather than mobile units. There are advantages in using mobile units. Mobile tracking units eliminate the expense of establishing several permanent

Fig. 2. Receiver Station Two.

antennas to cover divergent ranges of test animals and allow tracking of periodic excursions of an animal outside its home range. They also reduce location errors which occur when animals are long distances from the fixed receiver sites by limiting that distance to 1.25 miles. The primary disadvantage of mobile units has been the inability to accurately orient the vehicle. Inaccurate vehicle orientation produces an error in any directional bearings taken from the unit.

Verts (1963) used roads or fences to orient the vehicle "With practice, . . . within limits of about one degree." Storm (1965) used mobile units to monitor movements of red foxes, but did not describe a method for orienting the vehicle or compass rose. However, he did report accuracy of $\pm$ 100 feet on level ground at ranges of between .125 and .250 miles; and accuracy of $\pm$ 300 feet when the receiver and transmitter were separated by ridges. Ables (1969) used a compensating compass rose mounted in the truck cab to obtain radio bearings of instrumented red foxes, but did not report on the accuracy of his mobile units. Anderson (1971) attempted to use aluminum rods set in the road to orient the compass rose, but found the 3^{o} error unacceptable. Thereafter, he used a beacon transmitter to obtain an accuracy of $\pm$ 1^{o} for his radio bearings. Hallberg, et al. (1974) used a compass mounted above a Datsun pickup and away from the antenna mast to orient the compass rose. Unfortunately, inclement weather severely limits the use of this method.

The mobile unit was composed of a 150 MHz, eight-element, Hy-gain Yagi antenna mounted on an International Travel-all. Instructions furnished by Wildlife Materials, Inc. (1974) were followed in mounting the antenna. The compass rose was mounted on a table in the rear of the vehicle. It could be rotated and then fixed in position. A piece of tape was affixed to the inside of the vehicle's windshield immediately in front of the steering wheel. A wooden dowel one inch x 30 inches was mounted on the front bumper, so that an imaginary line through the tape and the dowel paralleled the mid-line of the vehicle.

Receiver sites were established on hill tops along roads in the study area. At each receiver site, two stakes (Fig. 3, C and D) were set, using a surveyor's transit. If the road ran east-west at the site, the stakes were set on the left side of the road at bearings of 85^{o} or 265^{o}. If the road ran north-south at the site, the stakes were set on

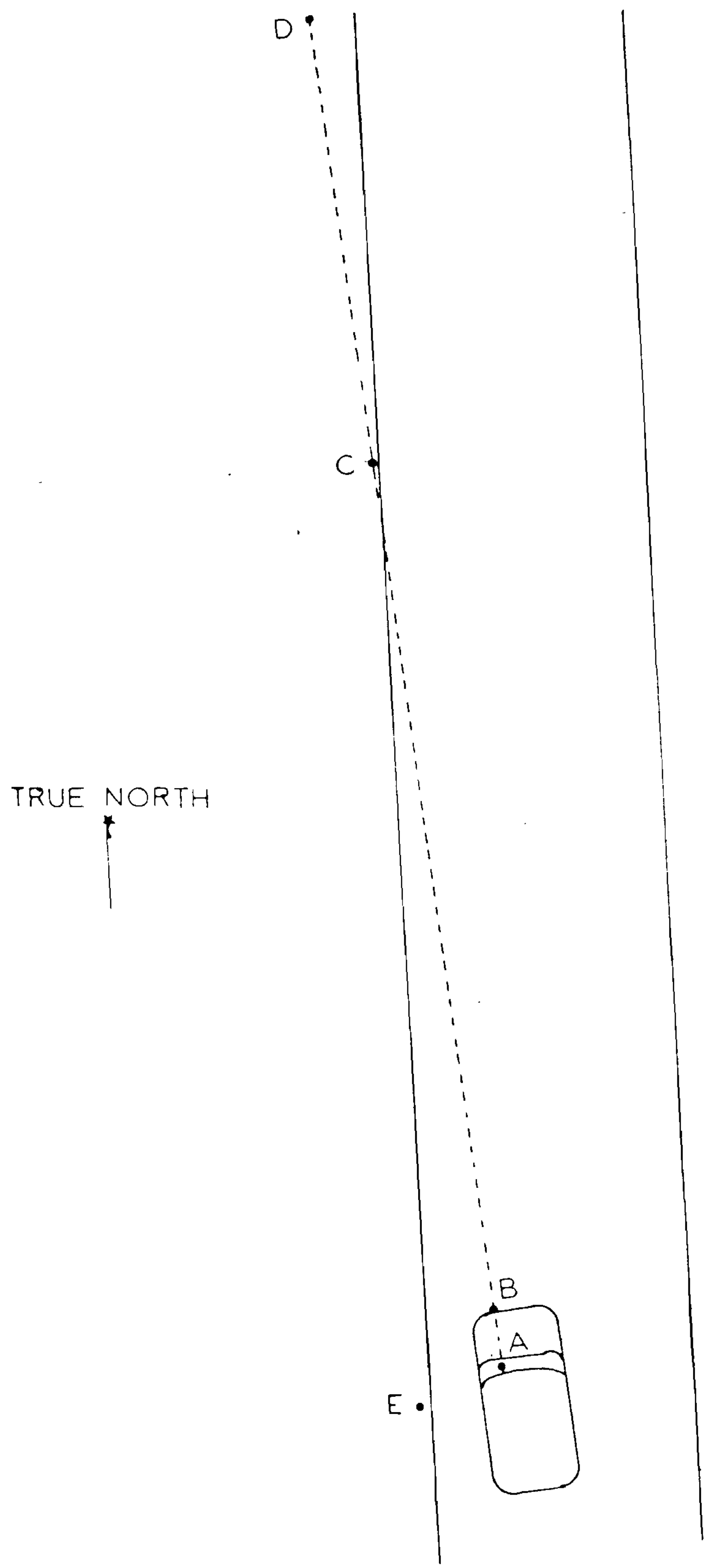

Figure 3. Method of alignment of the mobile unit.

the left side of the road at bearings of 175° to 355°. A third stake (Fig. 3, E) was used to mark the parking place of the vehicle. All stakes were painted white to facilitate night use.

The method for aligning the vehicle is illustrated in Figure 3. The driver lined up the tape (A), the dowel (B), the stake (C), and a second stake (D). The driver then looked to his left to see if he was in line with point E. If not, he adjusted accordingly.

After the vehicle was lined up with the two stakes of known bearing (85° or 265°; 175° or 355°), the compass rose was rotated so that the reading on the compass rose which corresponded with the known bearing was directed toward the front of the vehicle. The bearing 360° on the compass rose then corresponded with true north at each site.

<u>Accuracy</u>

With directional Yagi antennas, the strongest signal should be received when the open end of the antenna is pointed directly at the target transmitter. Signal strength is indicated audibly and by a strength meter. An operator's ability to judge audible signal strength is only precise enough to obtain the general direction of the transmitter. Although the signal strength meter is more sensitive, it indicates a peak signal over an arc of 10°. Approximately 35-40 degrees on either side of the peak there is a point where the signal nearly or completely disappears (a null). The bearing to a target transmitter is the arithmetic mean of the two nulls.

Accuracy of each permanent receiver site with the transmitter on line-of-sight was determined by two operators on two days. Each operator obtained three bearings for transmitter sites located 400-900 yards from the towers. The arithmetic mean of these three bearings was taken as the radio bearing for that trial. The radio bearings were later compared with transit bearings from those transmitter sites to determine accuracy.

Storm (1965) reported greatest error when the receiver and transmitter were separated by ridges. Accuracy of each permanent receiver site with the transmitter out of line-of-sight was determined by each of three operators on two days. Each operator obtained radio bearings for transmitter sites .5 to 1.0 miles from the receiver sites. These bearings were compared with bearings taken from aerial photographs to determine accuracy.

Assessment of the mobile system's accuracy was made by each of three operators on two days. Each operator aligned the vehicle and then determined radio bearings for a transmitter at 12 surrounding points located 400-700 yards from the vehicle. These radio bearings were later compared with transit bearings from those transmitter sites to determine accuracy.

Slade, et al (1965) inferred that there might be a correlation of error with distance of the transmitter from the receiver. They found, as did Marshal (1963), the greatest error when the transmitter was 1200-1800 feet from the receiver. To test this possibility, radio bearings for a transmitter were taken at successively more distant points directly west of Station Two. Radio bearings were compared with transit bearings from those transmitter sites to determine accuracy.

We know that the position of the transmitter in relation to the ground dramatically affects range. We tested the premise that the transmitter's relation to the ground affects accuracy. Each of two operators determined radio bearings for a transmitter held (1) six inches from the ground and (2) six feet from the ground at sites successively further from the tower. Slade, et al. (1965) held the transmitter 10 inches from the ground to simulate attachment to a prairie chicken. These radio bearings were then compared with transit bearings from those sites to determine accuracy for both positions.

Accuracy of the receivers with hand held antennas were determined by one investigator hiding an instrumented rabbit and allowing another investigator to locate it. Location of dead instrumented rabbits also provided information on accuracy with the hand held antennas.

Transmitter Life, Reliability, and Fit

Life, reliability, and proper fit of the transmitters were determined by attachment of the transmitters to captive and free ranging cottontail rabbits and coyotes, and to a captive deer fawn. The mortality transmitter was checked for proper operation by attachment to test animals. Reception of a continuous signal shortly after removal of the transmitter from the animal when the ambient temperature was below 75° F indicated proper functioning. Several actual rabbit mortalities also provided information as to the reliability of the mortality transmitters.

Range

Range of both the coyote and rabbit transmitters were checked in combination with the hand held, mobile, and permanent antennas by moving the transmitter away from the respective antenna until the signal was lost. Day to day operations also provided information on range under varying conditions.

RESULTS AND DISCUSSION

Transmitter Fit

Mercury powered rabbit transmitters were equipped with two batteries. Theoretical life expectancy of the transmitters with two batteries was 180 days. This life expectancy was seldom attained. A more realistic life expectancy was 90-140 days (Markusen, 1974). Markusen supplied two batteries to insure the 120 day life as requested. Unfortunately, weight of these transmitters represented eight per cent of an adult rabbit's weight. In previous cottontail rabbit telemetry studies the weight of the transmitters did not exceed five per cent of the rabbit's weight (Giles, 1971). Excessive weight could introduce unacceptable bias by affecting the rabbits' movements and chances of survival.

In addition to excessive weight, the second battery made it impossible to fit the collar snugly around the rabbits' neck. This allowed one rabbit to get its feet entangled in the collar. Removal of one battery resolved both of these difficulties.

Mercury powered transmitters were mounted on leather collars. Collars were attached to rabbits by fastening the ends of the collar together with split rivets. This was a cumbersome operation and proper fit was difficult. Markusen later supplied plastic collars with a built-in catch which greatly facilitated instrumentation (Fig. 4).

Plastic collars were numbered with metal tags. One instrumented rabbit hooked his lower incisors in one of the metal tags and apparently died from traumatic shock. Thereafter, plastic collars were numbered with a tatoo kit. Plastic collars were sturdy, easy to attach, and when properly adjusted caused little damage to the rabbits.

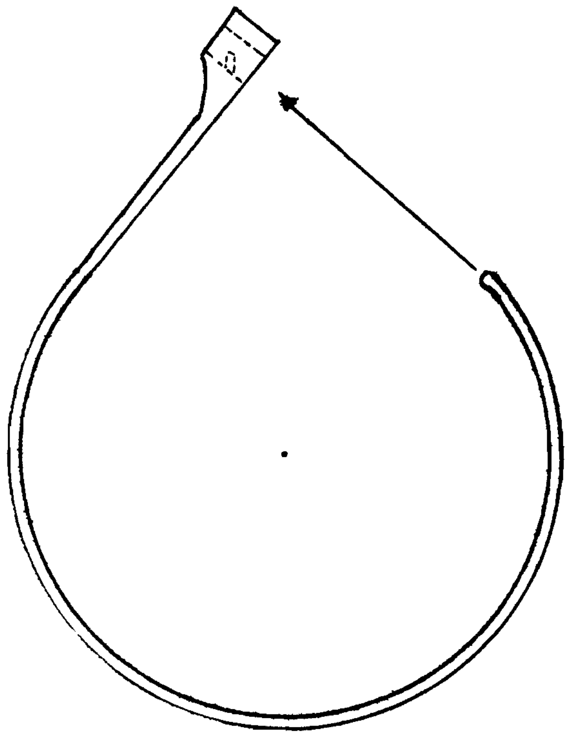

Fig. 4. Plastic transmitter collar for rabbits.

Proper fit of the collar was important. When in place, the collar had a tear-drop shape. One rabbit got the collar between his jaws. This prevented him from eating and he apparently starved to death. Another rabbit lost his collar. Since the transmitter was not recovered, it was impossible to say what caused the loss.

All rabbit transmitters were equipped with six inch whip antennas. Captive rabbits demonstrated that they could easily chew through the antennas. Loss of a large portion of an antenna drastically reduced the range of the transmitter. The antennas were protected by taping them along the collars. This reduced the range somewhat, but not as severely as the loss of a large portion of the antennas. A rabbit transmitter with whip antenna was later purchased from Wildlife Materials, Inc..

It had a ball point pen spring around the antenna (Fig. 5). The spring kept the antenna directed back along the side of the rabbit. This prevented the rabbit from chewing on the antenna and maintained the range of the transmitter. It is recommended that all rabbit transmitters be equipped with ball point springs.

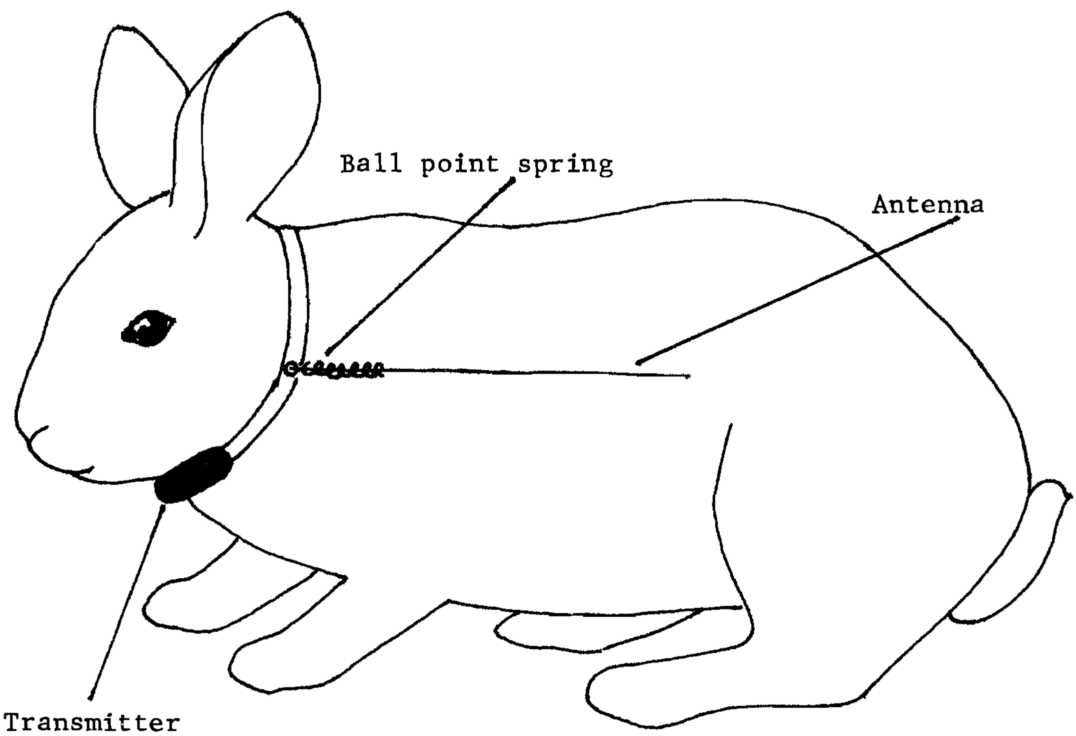

Fig. 5. Diagram of Wildlife Materials collar with ball point spring.

The lithium powered, mortality transmitters were mounted on plastic collars and required no extensive modification.

The coyote collars were marked for identification with metal ear tags. Captive coyotes demonstrated that the whip antennas would have to be taped along the collar to be protected. Chesness (1972) began using loop antennas on coyote collars when whip antennas were severely damaged. Two of the four transmitters recovered from free ranging coyotes were badly damaged. Evidently, other coyotes had been chewing on the collars.

The whip antennas were gone and the batteries and transmitter packages had been thoroughly chewed. The condition of these two transmitters indicated that better protected coyote collars should be designed.

The fawn mortality transmitters arrived from the manufacturer attached to leather dog collars. A properly fitted collar gave no consideration for the fawn's growth. Therefore, a length of ¼ inch surgical tubing was riveted to the inside of the collars opposite the thermistors (Fig. 6). The tubing kept the thermistor against the fawn's neck and also allowed for growth. A mortality collar was attached to a captive fawn for one month and worked well during that time.

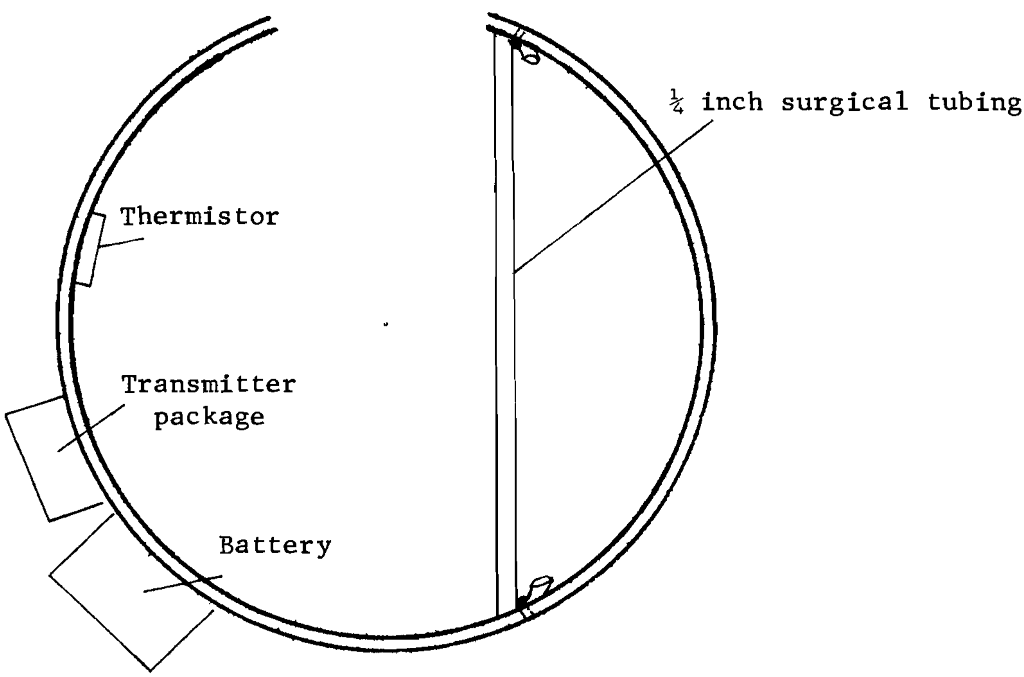

Fig. 6. Diagram of modified fawn mortality collar.

<u>Transmitter Life and Reliability</u>

The 10 rabbit transmitters purchased from Mr. Markusen functioned from 2-110 days. Four of the transmitters operated for the life of their battery; the other six malfunctioned before their theoretical battery life was exhausted. The mercury powered transmitters averaged 36 days of operation per battery. The lithium powered transmitters averaged 54 days of operation per battery. The transmitter purchased from Wildlife Materials functioned properly for 166 days on two batteries. It was on a free ranging rabbit 53 of those days. Figure 7 gives the history of each of the rabbit transmitters.

Stoddart (1970) reported malfunction of 25 of 75 transmitters used to monitor jack rabbit mortality. In view of that report and the performance of the Wildlife Materials' transmitter, Markusen's transmitters performed poorly. Wildlife Materials' transmitter performed best of those used and was preferred.

The coyote transmitters performed less effectively than the rabbit transmitters. The longest lived coyote transmitter, CT 987, functioned for 28 days. Three coyote transmitters which were attached to free-ranging coyotes had batteries which were not weatherproof. This may have contributed to their short life. In addition, Markusen (1974) indicated that the batteries may have been low in charge when he sent them. He had returned some of the same type batteries to the manufacturer because they had a low charge. CT 987's battery was weatherproof. On two occasions components within CT 987's transmitter package failed.

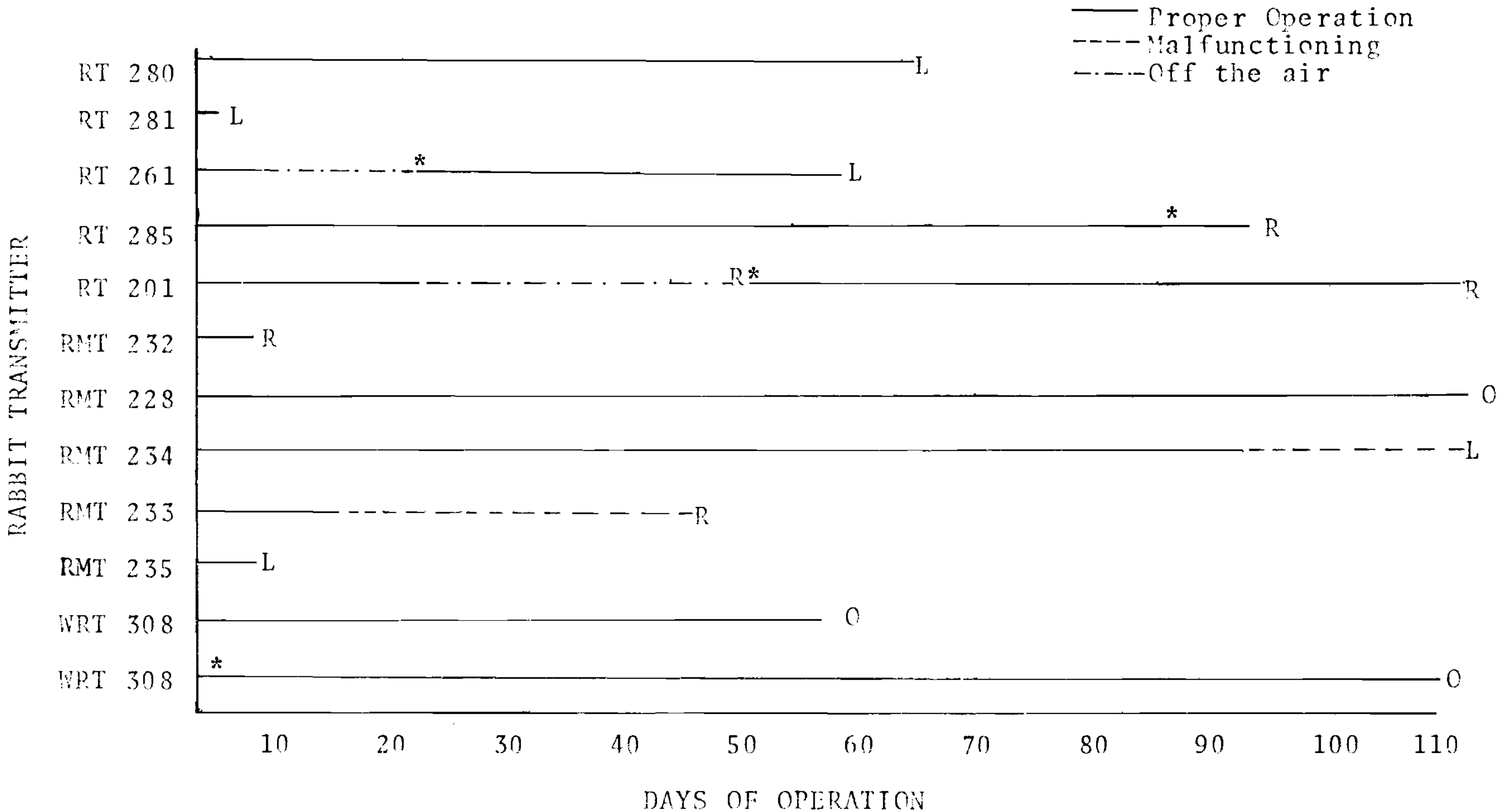

Figure 7. Performance of rabbit transmitters. RT= Regular Markusen transmitter. RMT= Markusen mortality transmitter. WRT= Wildlife Materials transmitter. L= Lost. R= Repaired. *= New battery. O= Still operating at end of study.

Accuracy

Hand held antennas: Instrumented rabbits could usually be located with the hand held antennas within 10 feet of their actual location. Signal reflection from vegetation caused difficulty at times. Cedar trees and dense vegetation often caused several peaks of equal strength in divergent directions. With care, the rabbit could still be located. On occasion, it was possible to locate instrumented rabbits only within 50 feet of their actual location. Six dead rabbits were located with little difficulty with the hand held antennas.

Mobile unit: It was possible for operators to orient the vehicle without previous experience. Seventy-two radio bearings obtained with the mobile unit had a mean error of $.59^{o}$, with a range of 0^{o} to 1.6^{o}. Table I reveals the mean error and standard deviation for each operator on each day. Mean error and standard deviation taken together are believed to be the most informative measure of a system's accuracy. A mean error of $.59^{o}$ was judged to be acceptable accuracy for mobile units. It compared favorably with the accuracy for a mobile unit reported by Hallberg, et al. (1974). The present mean error is less than that for fixed stations reported by Slade, et al. (1965), and the standard deviations are considerably less than those for fixed stations reported by Inglis, et al. (1968).

Figures 8 and 9 show the error of each operator for each transmitter site on November 22 and 23, 1974. No one operator had consistently larger error than the other operators. On three occasions one operator's error differed markedly from the other operators' error. This was probably due to a reading error on the part of the operator. In all other

Table I. Mean errors and standard deviations of radio bearings taken by three operators from the mobile unit.

Date	Mean Error (°)			Standard Deviation (°)		
	1st Operator	2nd Operator	3rd Operator	1st Operator	2nd Operator	3rd Operator
Nov 22	.555	.680	.702	.358	.483	.519
Nov 23	.362	.642	.578	.274	.335	.419

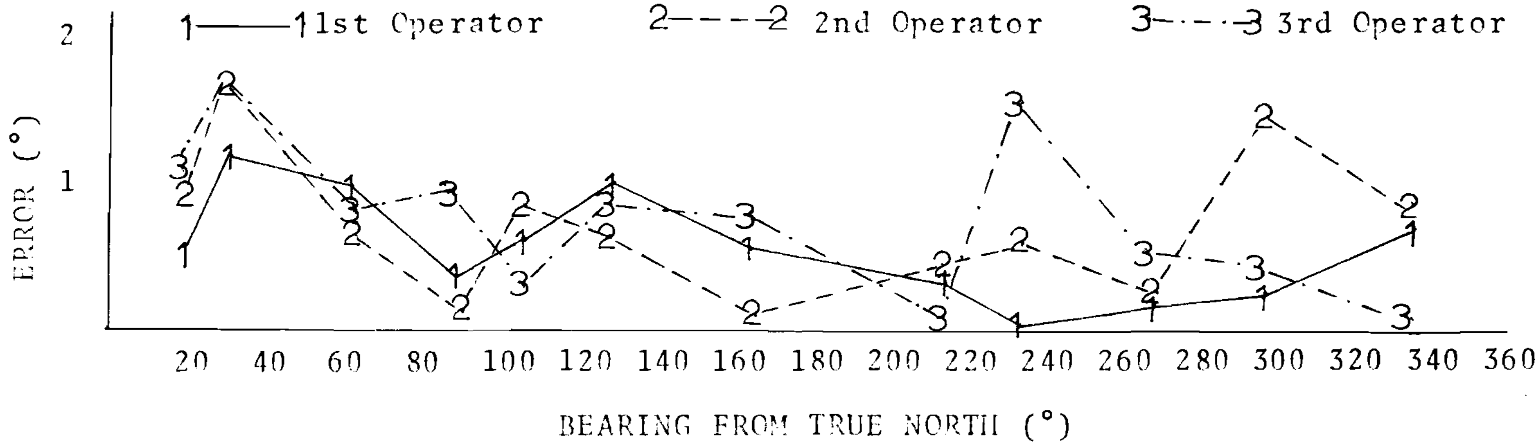

Figure 8. Each operator's error for each transmitter site from the mobile unit on November 22, 1974.

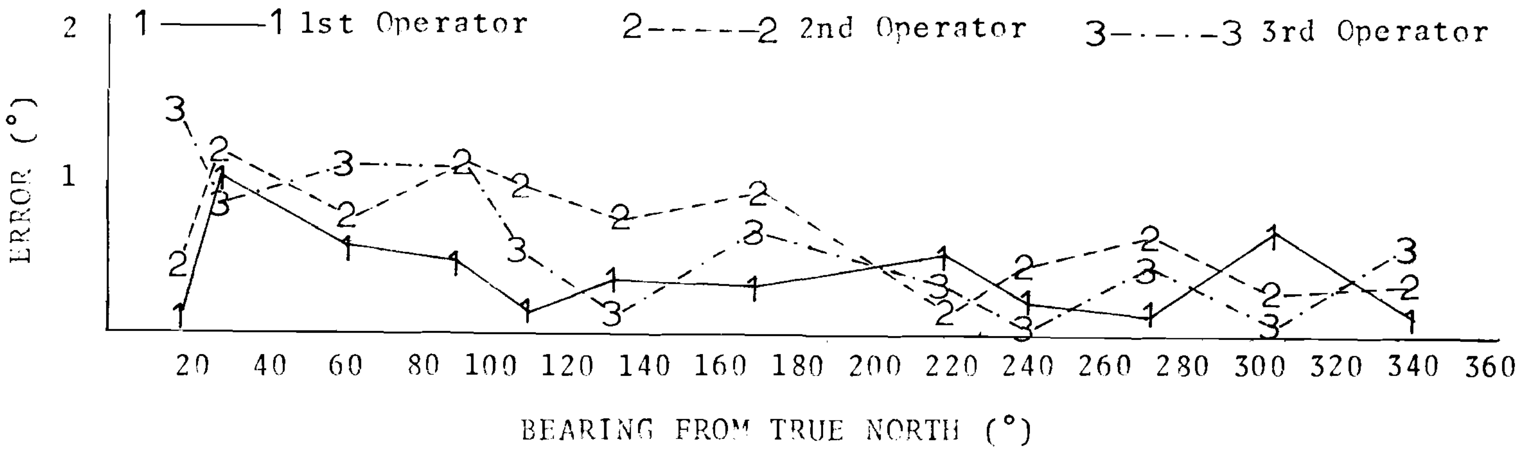

Figure 9. Each operator's error for each transmitter site from the mobile unit on November 23, 1974.

instances the operators had the same error, $\pm$ .37°.

Seven of the 72 radio bearings had an error greater than one degree. One transmitter site produced error in excess of one degree on four of six occasions. Since there were cedar trees along this bearing, this consistent error might be the result of signal reflection from vegetation.

Permanent receiver sites: Error from Station One with the transmitter on line-of-sight ranged from .09° to 3.96°. The mean error of all operators from the station was 1.65°. This is less error than was experienced by Slade, et al. (1965) using similar equipment. The mean errors and standard deviations for the operators on each day are given in Table II.

Table II. Mean errors and standard deviations of errors in radio bearings taken from Station One.

	Mean Error (°)		Standard Deviation (°)	
Date	1st Operator	2nd Operator	1st Operator	2nd Operator
October 8	1.87	1.70	1.41	.88
October 9	1.25	1.80	.93	1.05

Figures 10 and 11 represent each operator's error for each transmitter site from Station One on October 8 and 9, 1974.

Error from Station Two with the transmitter on line-of-sight ranged from .10° to 7.33°. The mean error of all operators from Station Two was 1.39°. Table III gives the mean error and standard deviation for each operator on each day.

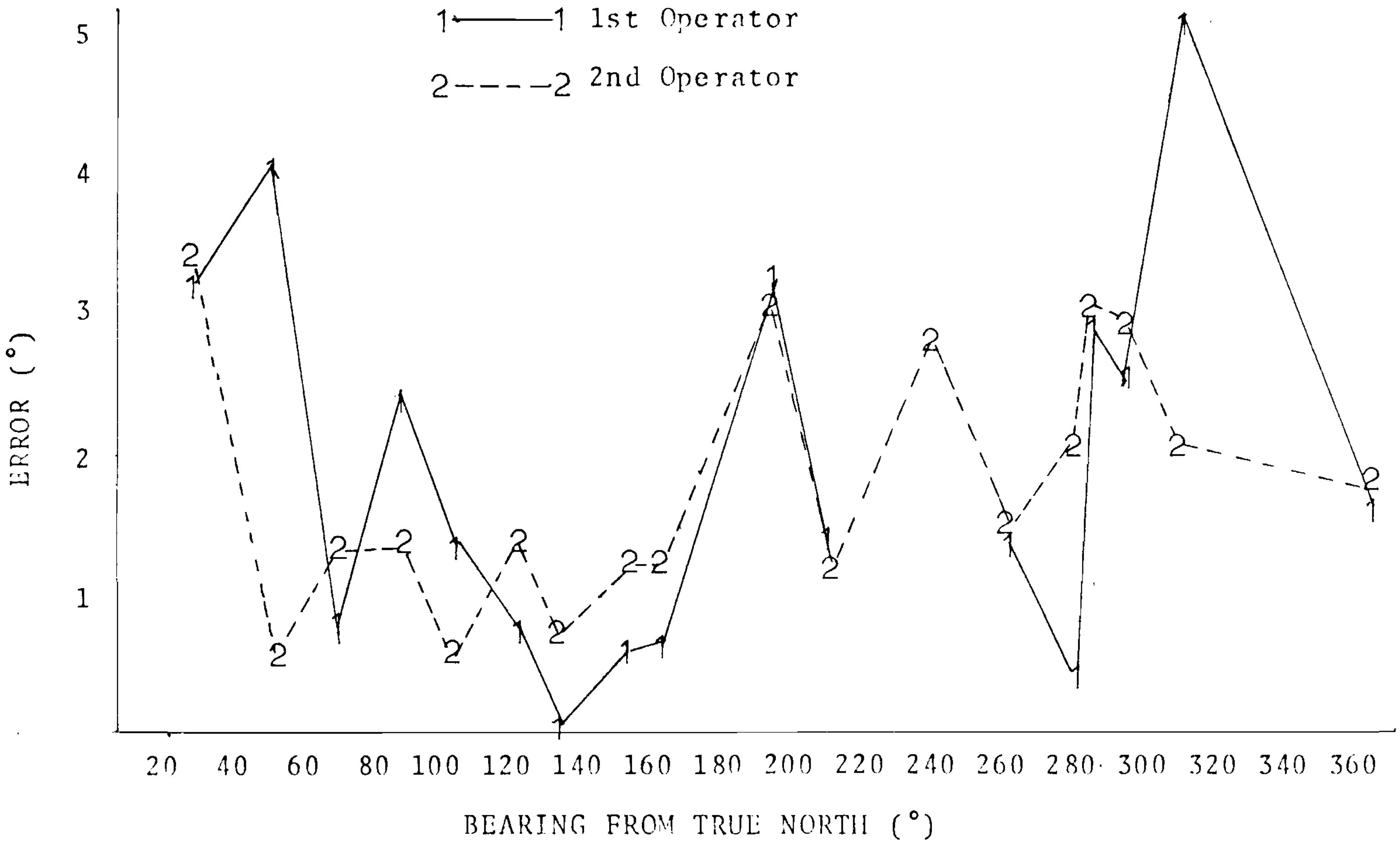

Figure 10. Each operator's error for each transmitter site from Station One on October 8, 1974.

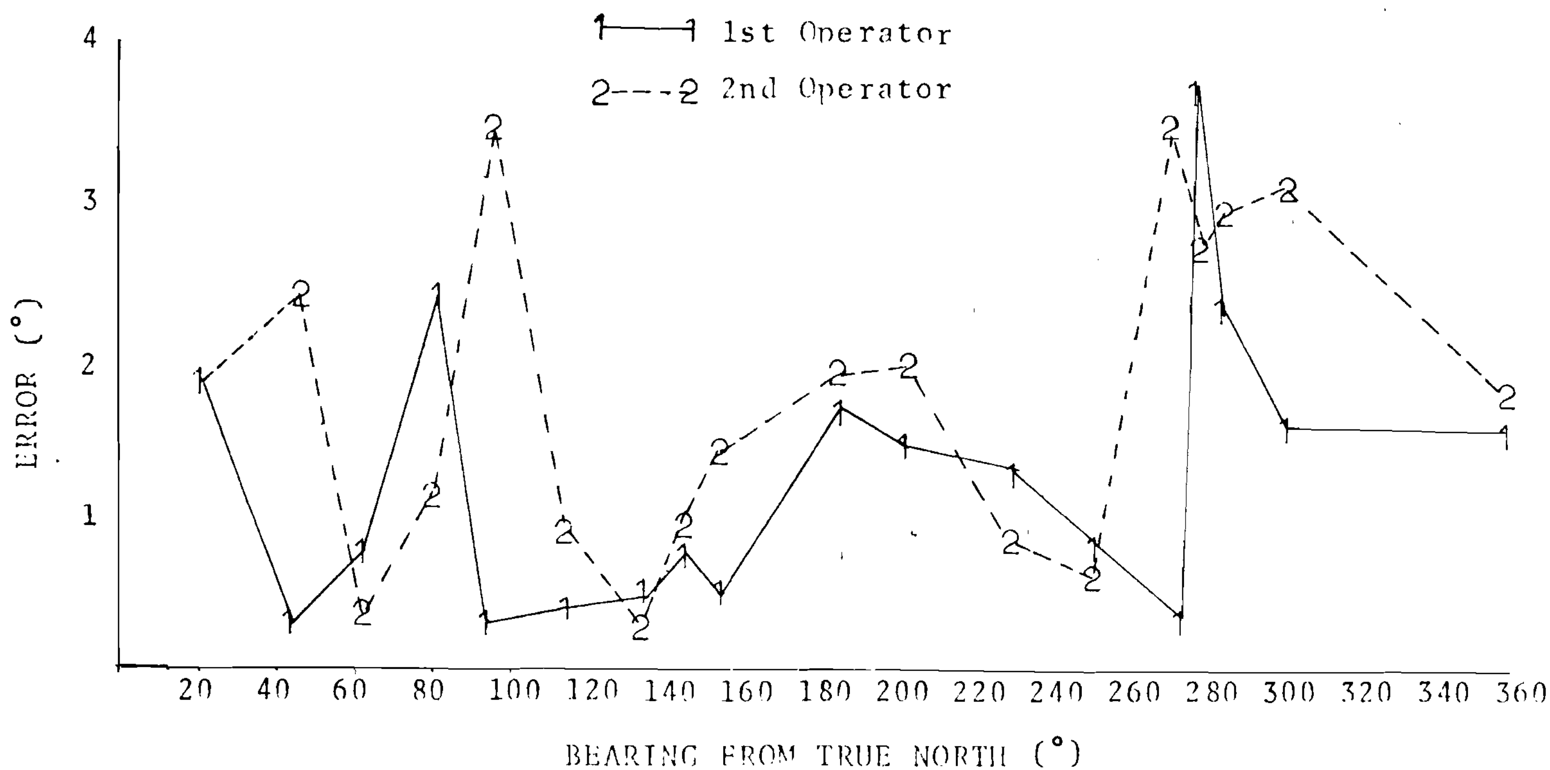

Figure 11. Each operator's error for each transmitter site from Station One on October 9, 1974.

Table III. Mean errors and standard deviations of errors in radio bearings taken from Station Two.

	Mean Error (°)		Standard Deviation (°)	
Date	1st Operator	2nd Operator	1st Operator	2nd Operator
October 14	1.37	1.18	1.35	1.40
October 15	1.59	1.40	1.57	1.90

Figures 12 and 13 represent each operator's error for each transmitter site from Station Two on October 14 and 15, 1974.

Overall, error from Station One was greater than error from Station Two. There were no large trees around Station One that could have caused the error. Although there are several exceptions, the operators had generally the same error for each transmitter site. During the trials on Station One, no attempt was made to orient the transmitter's antenna in the same plane as the receiving antenna. It has since been learned that if the receiving antenna is set up for receiving vertical polarization and the transmitter antenna is oriented horizontally, signal maximums and minimums may be obtained in unpredictable directions (Anonymous, No date). This might explain the inconsistency in error between operators (Fig. 10 & 11).

When the accuracy of Station Two and the mobile unit were assessed, transmitting and receiving antennas were oriented in the same plane. Following this procedural adjustment, results were more consistent in all trials (Fig. 8, 9, 12, 13).

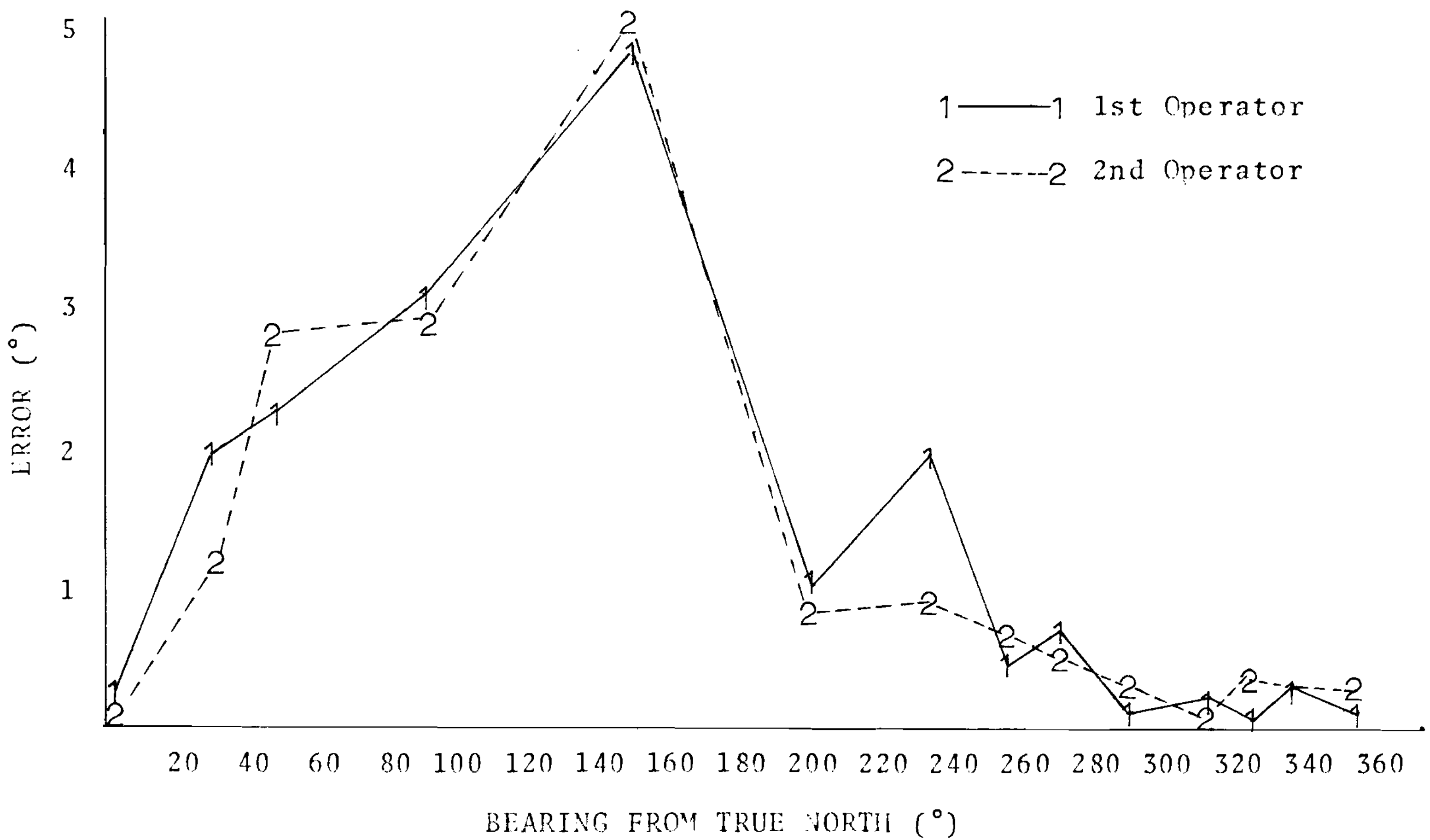

Figure 12. Each operator's error for each transmitter site from Station Two on October 14, 1974.

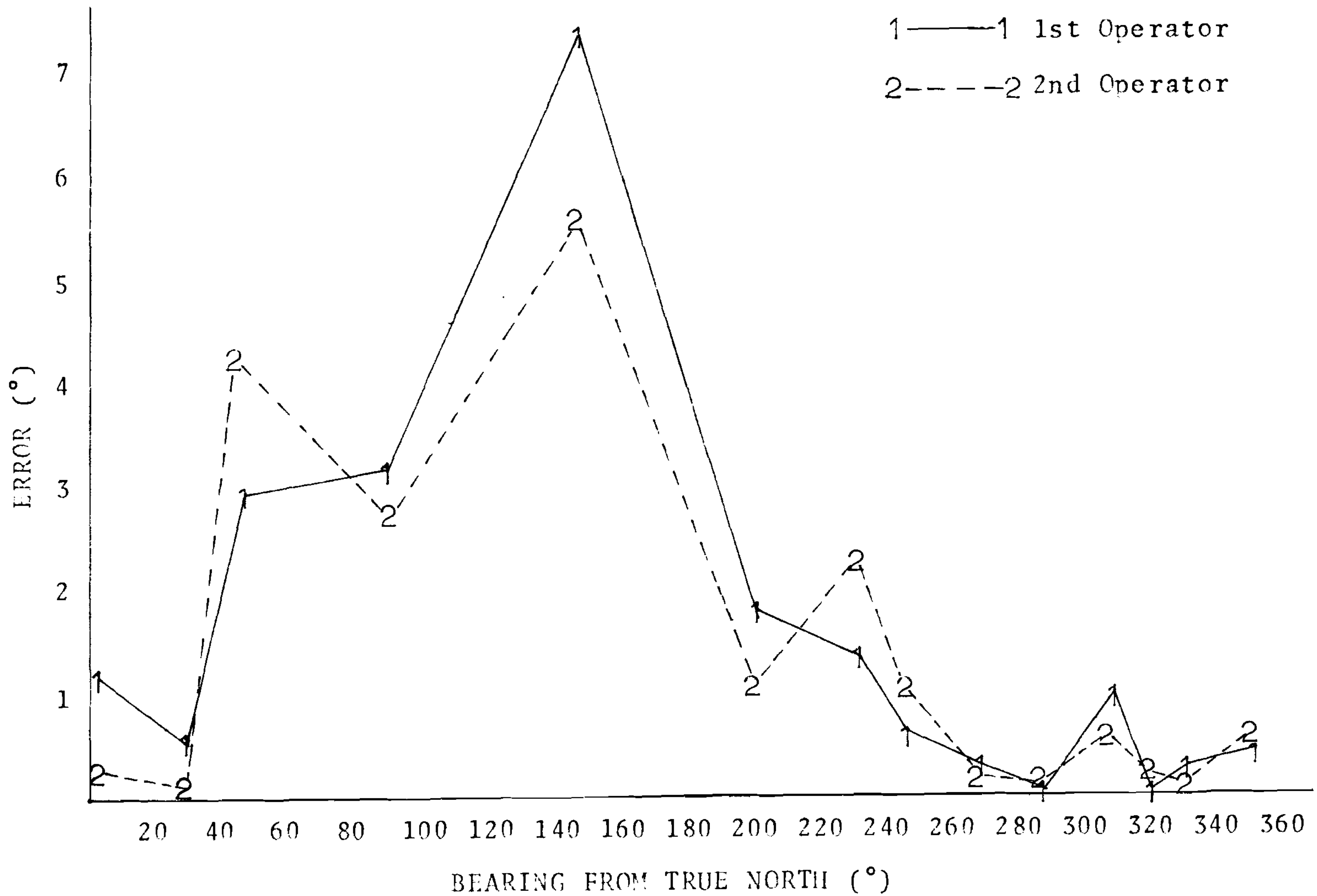

Figure 13. Each operator's error for each transmitter site from Station Two on October 15, 1974.

The larger error between bearings of 44° and 150° at Station Two corresponded closely with the occurrence of vegetation around the station. The large error at 150° was probably due to signal reflection from large cedar trees in that direction. Smaller errors from 195° to 5° represent transmitter sites on open grassland with few large trees. Marshall (1963), Ellis (1964) and Inglis, et al. (1968) also found that reflection from vegetation (especially pine and cedar trees), buildings, or topographic features are sources of error in telemetry operations. As Ellis (1964) and Cochran, et al. (1965) had reported, power line interference made reception poor, if not impossible, at some locations.

Error from Station One with the transmitter out of line-of-sight ranged from .04° to 3.17° with a mean error for all operators of 1.06°. Table IV gives the mean error and standard deviation for each operator on October 29 and November 1, 1974 from Station One.

Error from Station Two with the transmitter out of line-of-sight ranged from .12° to 3.16° with a mean error for all operators of 1.37°. Table V presents the mean error and standard deviation for each operator on October 29 and November 1, 1974, from Station Two.

A comparison of Tables IV and V with Tables II and III reveals that accuracy was generally better from both stations with the transmitter out of line-of-sight. Transmitters out of line-of-sight were located farther from receivers than transmitters on line-of-sight. This may have diminished the reflective effect of vegetation immediately around Station Two. Transmitter antennas were oriented in the same plane as the receiving antennas. This may have improved the accuracy from Station One.

Table IV. Mean errors and standard deviations of errors in radio bearings taken from Station One with the transmitter out of line-of-sight.

	Mean Error (°)			Standard Deviation (°)		
Date	1st Operator	2nd Operator	3rd Operator	1st Operator	2nd Operator	3rd Operator
October 29	1.12	1.19	.94	.73	.99	.77
November 1	.99	.80	1.00	.75	.90	.92

Table V. Mean errors and standard deviations of errors in radio bearings taken from Station Two with the transmitter out of line-of-sight.

	Mean Error (°)			Standard Deviation (°)		
Date	1st Operator	2nd Operator	3rd Operator	1st Operator	2nd Operator	3rd Operator
October 29	1.51	1.45	1.42	.73	1.19	1.05
November 1	1.33	1.45	1.06	1.08	.81	.77

If an animal is stationary, the procedure of averaging three bearings to obtain the radio bearing is workable. If an animal is moving, one bearing from each of two stations must be taken simultaneously to have meaning. An ordered sample was taken from all trials to determine if accuracy suffered when one, rather than three, bearings were used to determine a fix. These sample bearings were tested using the student t-test (P=.05) to see if the samples differed significantly from the averaged bearings.

In six instances the averaged bearings had a mean error greater than the sample bearings. In two instances the mean error was the same. In the other 17 instances, the sample bearing was greater. There were no statistically significant differences. The standard deviation of the sample bearings was greater in 19; the same in two; and less in four instances than the averaged bearings. The sample bearings were generally less accurate than the averaged bearings. Although sample bearings occasionally differed as much as 2^{o} from the averaged bearings, they usually differed less than $.5^{o}$.

The tests did not substantiate Slade, et al. (1965) and Marshall's (1963) finding that there was increased error when the transmitter was 1200-1800 feet from the receiver. Also, accuracy was comparable whether the transmitter was held six inches or six feet above the ground.

Range

The range of radio telemetry systems is highly variable. Topography, vegetation, sensitivity of the receiver, power output of the transmitter, height of the receiving antenna, and the distance from the transmitter to the ground, i.e., the size of animal and whether the animal is standing or lying down, all affect range. Table VI gives the ranges attained for coyote and rabbit transmitters with the various antennas under ideal conditions.

Table VI. Range of transmitters with each antenna.

	ANTENNA		
Transmitter	Hand held	Mobile	Permanent
Coyote	1/2 mi.	3 mi.	3 mi.
Mercury rabbit	1/4 mi.	3/8 mi.	1/2 mi.
Lithium rabbit	3/8 mi.	1/2 mi.	3/4 mi.

The ranges in Table VI are rarely attained in actual operation. Range for the coyote transmitters in Table VI is from hill top to hill top. There were many occasions when a coyote was lying down in a draw less than one mile away, and could not be located.

The mercury powered rabbit transmitters have good range in open grassland. However, if the rabbit was in its typical habitat, mercury transmitters were useless for monitoring from the permanent receiver sites. The lithium transmitters have a range of 1/2 mile in typical rabbit habitat. One half mile is workable range from the permanent receiver sites. If a rabbit can be received from one, but not both, permanent sites, a station can be set up for the mobile unit which allows coverage of that rabbit.

This study laid the groundwork for further telemetry studies on coyotes, rabbits, and deer. A workable telemetry system was assembled. The system's accuracy and range were assessed. The transmitter collars were modified so as to fit the subject animals better. Transmitter life and reliability were determined.

The limited number of transmitters, their poor performance, and their late delivery, limited the amount of data collected on the animals. A study that will provide meaningful information must be well equipped. It is recommended that additional transmitters be purchased in quantity from Wildlife Materials, Inc.

SUMMARY

A radio telemetry system was assembled and tested at Ross Natural History Reservation, Division of Biological Sciences, Emporia Kansas State College, from June 1974 to June 1975. Two permanent receiver sites were constructed on elevated points on RNHR. A mobile telemetry unit consisting of an eight-element, Yagi antenna mounted on an International Travel-all vehicle was assembled and a technique was developed for orienting the vehicle.

Transmitter collars supplied by the manufacturer proved inadequate. Rabbit transmitters were modified to reduce their weight and to improve their fit. Fawn collars were modified to allow for growth of the fawn and to keep the thermistors in contact with the animals' necks. Although the coyote collars were not modified, they needed to be more rugged to withstand the punishment received on free-ranging coyotes.

Transmitters performed poorly. The longest lived coyote transmitter functioned for 28 days. The mercury rabbit transmitters averaged 36 days of operation per battery, and the lithium transmitters 54 days. The mortality aspect of the lithium transmitters worked well. No data were collected on the life and reliability of deer transmitters.

Accuracies of Station One, Station Two, and the mobile unit with the transmitter on line-of-sight were determined by comparing radio bearings with transit bearings. Accuracies of Station One and Station Two with the transmitter out of line-of-sight were determined by comparing radio bearings with bearings taken from aerial photographs. Station One had a mean error of 1.65^{o} with the transmitter on line-of-sight and 1.06^{o} with the transmitter out of line-of-sight. Station Two had a mean

error of 1.39^{o} with the transmitter on line-of-sight and 1.37^{o} with the transmitter out of line-of-sight. The mobile unit had a mean error of .59^{o} with the transmitter on line-of-sight. Major sources of error were: (1) signal reflection from vegetation; (2) operator reading error; (3) non-alignment of transmitting and receiving antennas.

No correlation was found between accuracy and distance of the transmitter from the receiver, or between accuracy and the relationship of the transmitter to the ground.

Ranges of transmitters were highly variable and dependent on topography, type of antenna, and whether the animal was standing or lying down. A maximum of three miles was attained using the coyote transmitters and the permanent antennas under ideal conditions. A maximum range of .75 miles was attained with the rabbit transmitters under ideal conditions.

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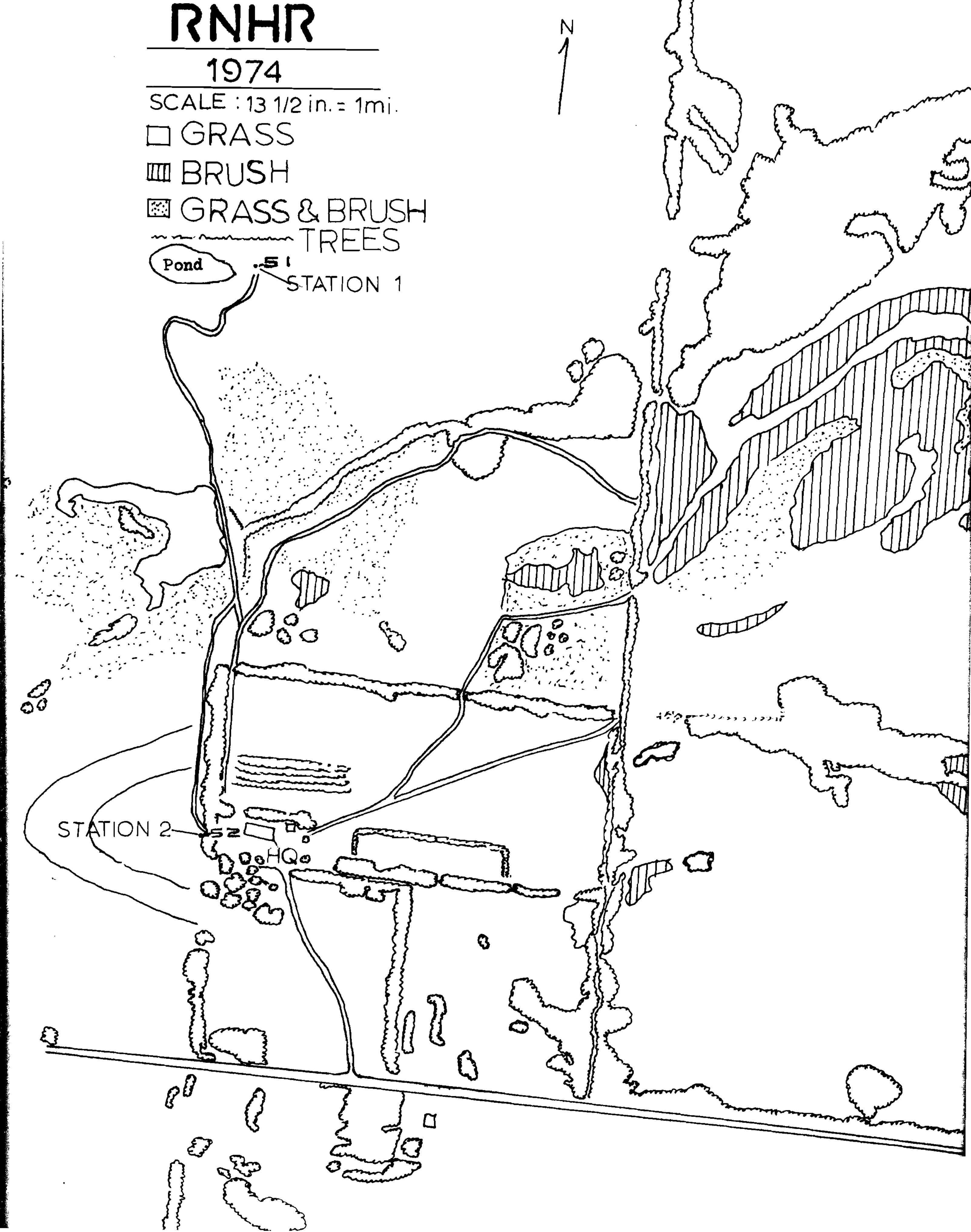
APPENDIX A


RNHR
1974
SCALE : 13 1/2 in. = 1mi.
N
GRASS
BRUSH
GRASS & BRUSH
TREES
Pond
STATION 1
STATION 2
HQ