AN ABSTRACT OF THE THESIS OF

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Title: SOME ASPECTS OF RABBIT ECOLOGY IN LYON COUNTY, KANSAS

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A radio-telemetry study of cottontail rabbit mortality was conducted on approximately 100 acres of Ross Natural History Reservation in Lyon County, Kansas. In addition, population estimates were calculated from trap-retrap data, condition indices for rabbits on the study area were calculated, and a daily roadside survey of cottontail activity was conducted. Data were gathered from 1 August 1974 to 1 May 1977. Trapping success was greatest during fall months. For the 274 different cottontails captured, the sex ratio was 1:1.21 in favor of females. A population estimate of 259 rabbits in July was calculated as the peak population density of 2.59 rabbits per acre. In 33 months, 105 cottontail mortalities were discovered. Thirty-seven were wearing

a functioning radio-transmitter at the time of death; 60 dead rabbits were discovered by personal observation and the remaining eight were discovered by dogs. Twenty deaths, 19.0 % of total mortality, were classified as research mortalities. Predation accounted for 42.9 % of total known mortality. Cottontail deaths attributed to tularemia represented 18.1 % of total deaths. In one case of cottontail mortality the cause of death was determined to be pneumonia. Condition indices were calculated for 122 rabbits captured from 1 May 1976 to 1 May 1977. The mean condition index was 5.60. There was no significant difference between indices of males and females. A daily roadside survey was conducted from 1 June 1975 to 1 May 1977. A total of 1,575 cottontails was sighted in 7,351 miles traveled, a rate of 21.4 rabbits per 100 miles. Peak roadside activity occurred in July.

SOME ASPECTS OF RABBIT ECOLOGY

IN

LYON COUNTY, KANSAS

A Thesis

Submitted to

the Division of Biological Sciences

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by

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INTRODUCTION

The cottontail rabbit, *Sylvilagus floridanus* (J. A. Allen), is important as a major food source for many vertebrate predators, as well as a major game animal of the eastern United States (Kirkpatrick, 1950; Reilly and Dell, 1955; Tiemeier, 1955; Scott and Klimstra, 1955; Lord, 1963; Craighead and Craighead, 1969; Gipson and Sealander, 1976; Beasom and Moore, 1977). During the years 1964-73 in Kansas, an average of 62,300 hunters harvested approximately 475,000 rabbits per season. It has been determined that an average daily bag of about 2.0 rabbits and a season harvest of at least 8.0 rabbits per hunter is necessary to satisfy Kansas hunter demand. Beginning in 1969 and continuing through 1976, the average daily bag has fallen below 2.0 rabbits per hunter. Thus it was generally felt that some factor was making cottontails less available to Kansas hunters (Peabody, pers. comm.).

The Kansas Forestry, Fish, and Game Commission (KFFG) personnel became concerned over numerous reports from sportsmen of the cottontail's apparent decline in numbers during the fall months of recent years (Peabody, pers. comm.). If such a decline had occurred in recent years, an investigation of cottontail ecology might provide information and understanding necessary for effective management of this animal.

As a result of concern over an important game animal, a radio-telemetry study of certain aspects of cottontail rabbit ecology was initiated in 1974 on Ross Natural History Reservation (RNHR) in Lyon County, Kansas. The project has yielded information on population levels, home range and movement, and mortality. From the inception of the project, it was recognized that the apparent decline in fall populations was possibly due to increased mortality resulting from disease or excessive predation (Watt, 1975). Changes in cottontail behavior and habitat usage patterns that affect observability and harvest may also cause an apparent decline in population when, in reality, none has occurred (Sheffer, 1972).

For two years KFFG funded this radio-telemetry project in order to establish whether or not a cottontail population decline was actually occurring in the fall months. They provided telemetry equipment, vehicle, operating expenses, and stipends for the study. During the 1976-77 phase of the project partial financial support was provided by the Division of Biological Sciences of Emporia State University, while KFFG continued to furnish telemetry equipment and use of a vehicle.

The technique of biotelemetry has been employed in animal movement studies since 1959. The first transmitter packages were designed for implantation into the body cavity of woodchucks (Le Munyan et al., 1959). Since

1959 many advances have resulted in improved equipment and increased accuracy, and rendered the overall technique more versatile in its application. In the past 20 years radio-telemetry techniques have yielded information on movement, behavior, home range, mortality, and disease ecology of various animals (Marshall et al., 1962; Storm, 1965; Cochran et al., 1965; Houseknecht, 1970).

If increased mortality resulting from disease or excessive predation is a factor in an apparent decline in cottontail population levels, then the role of radio-telemetry in monitoring mortality is particularly important. Marshall and Kupa (1963) saw the potential of radio-transmitters for investigating mortality, and since that time several researchers have employed some form of radio-telemetry to study mortality. Cook et al. (1971) used transmitters to monitor mortality of white-tailed deer fawns in Texas. Mech (1967) and Trent and Rongstad (1974) also utilized transmitters for locating cases of mortality in studies of cottontail rabbits.

Pulsing transmitters equipped with thermistors were later designed to change signals when the animal died and its temperature and that of the collar dropped. This improvement in equipment enhanced the role of radio-telemetry in mortality studies by providing fresh carcasses for cause of death determination, with less time and effort expended by the researcher (Cook et al., 1967; Houseknecht, 1970). It may be that radio-telemetry, in all forms, shows its greatest worth by providing more data per unit effort than are provided by most other current techniques (Houseknecht, 1970).

This study was conducted on approximately 100 acres of the Ross Natural History Reservation in west-central Lyon County, Kansas. RNHR has been maintained by the Division of Biological Sciences, Emporia State University, as a natural history area since 1960. Watt (1975) provided maps of major vegetational types found on the study area, and listed plants comprising these major vegetation types. Wilson (1963) provided an account of the flowering plants of RNHR. A detailed description of the study area, including geological, biological, and historical features can be found in Hartman (1960).

Since the project was initiated in May 1974, six Emporia State University biology graduate students have collected considerable data on radio-telemetry usage and the cottontail rabbit. The telemetry system used in this continuing study was designed and tested during the first year, 1974-75 (Hutton, 1975). Also during the first year, initial information on mortality, home range, movement, and population levels of cottontail rabbits was gathered and reported by Watt (1975). Beginning in May 1975, a second team of researchers collected additional data on mortality, home range, movement, and population levels. Gress (1976) reported on mortality and population levels for this period, while Clark (1976) reported on home range and movement.

The primary objective of this study was to monitor cottontail rabbit deaths by utilization of radio-telemetry equipment, which included thermistor-equipped mortality transmitters. Personal observations and a dog were also employed in locating dead rabbits. Additional objectives of this study were to calculate population estimates based on trap-retrap data, to calculate condition indices for rabbits on the study area, and to conduct a daily roadside survey of cottontail activity. It was also the intent of this study to compare current data with data previously collected by Gress (1976) in the same manner and on the same study area.

This report is concerned primarily with the third year of the project, beginning in May 1976, and focuses on the mortality and population aspects of the study. A compilation of all data gathered over the past three years is a future goal of the Kansas Forestry, Fish, and Game Commission which should greatly aid in the understanding of cottontail rabbit population dynamics in eastern Kansas (Peabody, pers. comm.).

MATERIALS AND METHODS

Rabbits were collected on the RNHR study area using two types of live traps. Approximately 20 single door Tomahawk wire traps were placed in foot trails or rabbit runs. Approximately 80 conventional wooden box traps, described by Forsythe (1974), were placed in areas which appeared to be good rabbit habitat, usually along boundaries between cover and open areas. Both types of traps were left unbaited, because Gress (1976) had reported no noticeable increase in catch in baited traps in an experimental baiting program. Traps were open continuously from 1 May 1976 to 1 May 1977, except for four days in December and five days in April.

Traps were checked each morning. Captured rabbits were transported to the laboratory where sex, weight, total length, general physical condition, reproductive status, and presence of ectoparasites were determined and recorded. Sex was determined using criteria described by Petrides (1951). Trap location for each rabbit was recorded on a map of the study area (Appendix A). Other information (sex, weight, trap type, physical condition) was recorded on a form on the back of the same map (Appendix B).

All captured rabbits were ear-tagged with #898 Tab End, Size 3, National Wing Bands. If for some reason a rabbit was not outfitted with a radio-transmitter, a numbered white plastic collar was placed on the rabbit. This marking procedure was recommended by Hutton (1975) and Watt (1975) after they found that coyotes did not ingest the collars when eating rabbits. Since plastic collars are more conspicuous than ear tags, and because they are not ingested and ear tags may be ingested, collars improve the chances of positive identification of the victim in cases of predation by coyotes.

Depending on the availability of transmitters and batteries and the number of rabbits already transmitting, rabbits weighting over 650 grams were fitted with radio-transmitter collars. Radio-transmitters were obtained from Sidney L. Markusen, Cloquet, Minnesota. A detailed description of collars, antennas, and receivers was provided by Hutton (1975) and Watt (1975). The procedure employed for instrumenting a rabbit was described by Clark (1976). He stated that transmitter leads and battery terminals were covered (potted) with Luxe-cure #60 Superfine Quick Repair self-hardening resin (dental acrylic) to compensate for inadequate factory waterproofing. This product was satisfactory for waterproffing, but became extremely hard so that removing it from the transmitter occasionally caused damage to the transmitter package and leads. Clark's method was modified when it was discovered that aquarium cement could function as a waterproofing agent and was easily removed when necessary.

After being subjected to the above procedures the rabbit was returned to the capture site and released. For animals outfitted with transmitters, the channel number, transmitter number, and capture points were recorded on a map of the study area (Appendix A). On this map the daily resting locations were recorded as they were determined. A separate map was used for each month that the rabbit was "on the air."

Cottontail rabbit mortality data were collected by the following methods:

1) Mortality radio-transmitters, equipped with thermistors designed to change signals when the temperature of the collar dropped below 75 F, were placed on captured rabbits. Receiving a "dead" signal alerted the operator that the animal had died, and a search of the area was conducted until the rabbit was found. This was the major method of monitoring mortality.

2) For the first five months of the study a beagle dog accompanied the researcher on the daily trapping route. This dog searched the area for dead rabbits, aiding in the location of mortality cases. The dog was not used to find dead rabbits during the last seven months of the study.

3) The third method for locating dead rabbits was personal observations. A daily walk over the study area to check traps provided considerable opportunity for field observations.

When a rabbit mortality was discovered, the immediate area was searched for clues to aid in assessing cause of death. Rabbit remains, if any, were also examined for evidence of death cause. When dead rabbits were suspected of being diseased, the carcasses were frozen and later taken to the Kansas State University Veterinary Diagnostic Laboratory at Manhattan, Kansas, where they were examined and cause of death determined. Two dead rabbits without signs of predation were sent to the University of Missouri at Kansas City for examination and diagnosis.

The 12-month period 1 March 1976 to 1 March 1977 was used to calculate a population estimate since March is the beginning of the cottontail reproductive year. Using trap-retrap data and applying the Maximum Likelihood Estimation (MLE) derived for cottontails by Edwards and Eberhardt (1967), a maximum population estimate was obtained. Then monthly population estimates were calculated using the MLE and a modified life table developed by Lord (1961).

Condition indices for individual rabbits were calculated using a method devised by Bailey (1968a). Then monthly mean condition indices were calculated in an attempt to evaluate the monthly physical condition of rabbits on the study area.

A daily roadside survey of the cottontail rabbit was conducted in addition to the trapping and mortality research. Two routes were established between Emporia, Kansas, and RNHR.

The two routes were traveled alternately while commuting to the study area. On a roadside survey map (Appendix C), the date, route followed, time, weather conditions, and persons conducting the survey were recorded. When rabbits were sighted, the location and number of rabbits seen were also recorded on the map.

Statistical analyses were made using the Student *t* test at the $p = .05$ level of significance.

RESULTS AND DISCUSSION

Trapping Results

Trapping was conducted from 5 August 1974 to 1 May 1977. Trapping results of the first segment of the project, 5 August 1974 to 20 May 1975, were reported by Watt (1975). Gress (1976) summarized the trapping record for the second segment of the project, 1 May 1975 to 1 May 1976. Table I is a summary of trapping results for the period 1 May 1975 to 1 May 1977. Data reported by Gress were included in this table so that the second and third segments of the project could be compared. Scientific names were obtained from Schwartz and Schwartz (1959), Robbins et al. (1966), and Conant (1975).

The following vertebrate species were trapped on the study area during the period 1 May 1975 to 1 May 1977: Eastern Cottontail Rabbit (*Sylvilagus floridanus*), Eastern Fox Squirrel (*Sciurus niger*), Woodland White-footed Mouse (*Peromyscus leucopus*), Common Cotton Rat (*Sigmodon hispidus*), Eastern Wood Rat (*Neotoma floridana*), Norway Rat (*Rattus norvegicus*), Opossum (*Didelphis marsupialis*), Striped Skunk (*Mephitis mephitis*), Raccoon (*Procyon lotor*), Bobwhite (*Colinus virginianus*), American Woodcock (*Philohela minor*), Common Flicker (*Colaptes auratus*), Catbird (*Dumetella carolinensis*), Brown Thrasher (*Toxostoma rufum*), Eastern Meadowlark (*Sturnella magna*), Cardinal (*Richmondena

Table I. Trapping record of all species for the period 1 May 1975 to 1 May 1977. Species are indicated by number in the following manner: 1. Eastern Cottontail Rabbit; 2. Eastern Fox Squirrel; 3. Woodland White-footed Mouse; 4. Common Cotton Rat; 5. Eastern Wood Rat; 6. Norway Rat; 7. Oppossum; 8. Striped Skunk; 9. Raccoon; 10. Bobwhite; 11. American Woodcock; 12. Common Flicker; 13. Catbird; 14. Brown Thrasher; 15. Eastern Meadowlark; 16. Cardinal; 17. Field Sparrow; 18. Harris Sparrow; 19. Unidentified Sparrow; 20. Ornate Box Turtle.

Species	Year	M	J	J	A	S	O	N	D	J	F	M	A	Total
1	1975-76	4	5	10	14	62	100	65	16	14	7	3	4	304
	1976-77	6	7	11	7	15	48	44	10	5	3	1	-	157
2	1975-76	-	-	-	2	3	3	-	1	1	-	-	-	10
	1976-77	-	2	1	-	4	1	1	-	3	1	-	-	13
3	1975-76	-	-	-	-	2	-	-	1	-	-	-	-	3
	1976-77	-	-	-	-	-	-	-	-	-	-	-	-	0
4	1975-76	-	6	2	3	4	1	-	1	-	-	-	2	19
	1976-77	4	8	-	2	5	2	-	-	-	-	-	1	22
5	1975-76	13	60	65	65	23	24	8	12	4	10	6	-	290
	1976-77	5	36	44	32	26	20	5	5	-	4	7	1	185
6	1975-76	-	-	-	2	1	-	-	-	-	-	-	-	3
	1976-77	-	-	-	-	-	-	-	-	-	-	-	-	0
7	1975-76	-	1	2	4	1	1	1	2	1	1	-	4	18
	1976-77	3	6	4	3	3	-	1	-	-	3	-	-	23

Table I. Continued

Species	Year	M	J	J	A	S	O	N	D	J	F	M	A	Total
8	1975-76	-	3	9	4	5	-	-	1	3	-	-	1	26
	1976-77	1	1	2	2	2	5	-	1	-	-	-	-	14
9	1975-76	-	-	-	-	-	-	-	-	-	-	-	-	0
	1976-77	-	-	1	1	-	-	-	-	-	-	-	-	2
10	1975-76	2	-	1	3	9	6	6	1	2	-	2	-	32
	1976-77	4	4	1	1	3	8	4	1	1	-	-	2	29
11	1975-76	-	1	1	-	-	-	-	-	-	-	1	-	3
	1976-77	-	-	-	-	-	-	-	-	-	-	-	-	0
12	1975-76	-	-	-	2	1	-	-	-	-	-	-	-	3
	1976-77	-	1	-	-	-	-	-	-	-	-	-	-	1
13	1975-76	1	-	-	-	2	-	-	-	-	-	-	-	3
	1976-77	2	-	-	1	-	-	-	-	-	-	-	-	3
14	1975-76	-	2	2	3	6	-	-	-	-	-	-	-	13
	1976-77	2	2	-	1	1	-	-	-	-	-	-	-	6
15	1975-76	-	-	-	-	-	1	-	-	-	-	-	-	1
	1976-77	-	-	-	-	-	-	-	-	-	-	-	-	0
16	1975-76	-	-	-	-	-	1	-	-	1	-	-	-	2
	1976-77	-	-	-	-	-	-	-	-	-	-	-	-	0

Table I. Continued

Species	Year	M	J	J	A	S	O	N	D	J	F	M	A	Total
17	1975-76	-	-	-	-	-	-	-	-	-	-	-	1	1
	1976-77	-	-	-	-	-	-	-	-	-	-	-	-	0
18	1975-76	-	-	-	-	-	1	1	-	-	-	-	-	2
	1976-77	-	-	-	-	-	-	-	1	-	-	-	-	1
19	1975-76	-	-	-	-	-	-	-	-	-	1	-	-	1
	1976-77	-	-	-	-	-	-	-	-	-	-	-	-	0
20	1975-76	6	6	11	23	11	10	-	-	-	-	-	-	67
	1976-77	13	20	7	6	3	11	-	-	-	-	-	1	61
Total	1975-76	26	84	103	125	130	148	81	35	26	19	12	12	801
	1976-77	40	87	71	56	62	95	55	18	9	11	8	5	517

cardinalis), Field Sparrow (Spizella pusilla), Harris Sparrow (Zonotrichia querula), Ornate Box Turtle (Terrapene ornata).

The total number of animals captured during the 1975-76 phase was 801. For the 1976-77 period a total of 517 animals was trapped (Table I). This indicates that overall trapping success was not as great in 1976-77 as in the previous year. In particular, the cottontail was trapped less frequently, representing only 30% of all animals trapped, and was second in frequency of capture to the Eastern Wood Rat. The wood rat represented 36% of all animals trapped. Gress (1976) found the cottontail to be the most frequently trapped species, representing 38% of all animals trapped.

A total of 93 different rabbits was trapped a total of 157 times during the 12-month period. The trapping record for cottontail rabbits for the period 1 May 1976 to 1 May 1977 is summarized in Table II. This table shows that a total of 157 rabbits was captured during 33,485 trap nights. Gress (1976) had a total of 304 captures in 31,064 trap nights (Table III). Using a Student *t* test at $p = .05$ to compare the two one-year periods, there was a significant difference between the total numbers of rabbits captured, while there was no significant difference between the total numbers of trap nights.

Table II. Trapping record of cottontail rabbits for the period 1 May 1976 to 1 May 1977. C/100 equals captures per 100 trap nights.

Month	Trap Nights	Total Captures	Recaptures	C/100
May	3,001	6	1	0.20
June	2,908	7	3	0.24
July	2,992	11	3	0.37
August	2,986	7	1	0.23
September	2,882	15	2	0.52
October	3,005	48	22	1.60
November	2,910	44	19	1.51
December	2,595	10	9	0.39
January	2,125	5	3	0.24
February	2,685	3	0	0.11
March	3,006	1	1	0.03
April	2,390	0	0	0.00
Total	33,485	157	64	
Mean C/100				0.47

Table III. Trapping record of cottontail rabbits for the period 1 May 1975 to 1 May 1976. C/100 equals captures per 100 trap nights (after Gress, 1976).

Month	Trap Nights	Total Captures	Recaptures	C/100
May	1,153	4	3	0.35
June	1,879	5	1	0.27
July	2,134	10	1	0.47
August	2,292	14	1	0.61
September	2,393	62	31	2.63
October	3,010	100	56	3.36
November	3,503	65	45	1.83
December	2,874	16	10	0.56
January	3,238	14	10	0.43
February	2,987	7	6	0.23
March	2,874	3	3	0.10
April	2,727	4	3	0.15
Total	31,064	304	170	
Mean C/100				0.98

Trapping success was greatest in the fall months, peaking in October and November (Table II). Gress (1976) reported greatest trapping success in the fall months, with a definite peak in October (Table III). Watt (1975) reported an October peak in trapping success on the same study area. However, he also found a secondary peak occurring in February and March which Gress did not report and which did not occur during the past year. Racey (pers. comm.), studying cottontails near Pittsburg, Kansas, found trapping success to peak in September. Chapman and Trethewey (1972) experienced greatest trapping success in January and February in Oregon. Bailey (1969) found peaks in cottontail trapping success occurring in October, November, and December in Illinois.

Table II shows that during the 1976-77 year, the lowest number of captures per trap night occurred in the winter and spring months, with the lowest catch in April, when no rabbit was trapped. April 1977 was the only month in which no rabbit was captured since the study began in 1974. Captures in March were also extremely low, with 0.03 captures per 100 trap nights. Gress (1976) also reported the lowest catch per trap night in the winter and spring, with the lowest point in March (Table III). Bailey (1969) reported a low in March, and proposed that his decline in trapping success was due, in part, to a decline in trappability of the rabbits.

Seasonal fluctuations in trap success are influenced by various factors and attempts have been made to describe some of these factors and to determine what roles they play in trap success. Hanson (1943), Crunden (1954), Johnson and Hendrickson (1958), and Huber (1962) studying trap response in relation to weather conditions, found that trap response increased with high barometric pressures. It has been shown that a lack of precipitation and cooler temperatures enhance trap success (Huber, 1962; Bailey, 1969). Bailey also found that low wind velocities were associated with increased trap success, whereas snow decreased trap success. Wood and Munroe (1977), working with snowshoe hares, attributed their October peak in trapping success to the greater ease of trapping and presumably the greater vulnerability to trapping in October, after leaves had fallen and vegetation had died back. If this is so, then the weather conditions associated with an early or late fall might affect seasonal trap response.

No attempt was made to correlate weather with trap success in this study; however, it may be that weather conditions were a factor in the significant difference in trapping success between the last two one-year periods of the study.

Another factor which may affect trap response is the possibility that individual animals within the population are not equally trappable (Geis, 1955; Krebs, 1966). This idea has been studied to the extent that Hilborn et al. (1976), working with voles, have devised a method to measure the trappability of any individual known to be a member of the population.

Chitty and Kempson (1949) and Tanaka (1956) have suggested that individual small mammals that have never been live-trapped tend to avoid traps, but once they have been captured they are more likely to be captured again. Bailey (1969) found juveniles four to five months of age most susceptible to trapping. This agrees with reports by Huber (1962), Eberhardt et al. (1963), and Chapman and Trethewey (1972), and could help explain fall peaks in trapping success since the per cent of the population in this age group would be high during the fall months. Huber also found that trappability of juvenile rabbits increased with the approach of winter, while trappability of adults declined.

Several studies have shown females to be more easily trapped than males (Schwartz, 1941; Huber, 1962; Bailey, 1969). However, Eberhardt et al. (1963), found that fewer females than males were captured during cold weather. By methods of collection other than trapping, Wainwright (1969) found the sex ratio to be nearly 1:1. Gress (1976) reported that of 187 cottontails captured since the project began in 1974, 101 were females and 86 were males. The sex ratio was 1:1.17 in favor of females. During the past year, 92 new rabbits were captured, 87 of known sex (five escapees were not sexed). Of the 274 (187 + 87) cottontails, 150 were females and 124 were males. The sex ratio was 1:1.21 in favor of females.

The 274 rabbits were captured a total of 571 times (Table IV). Individuals were captured from one to 13 times.

Wire traps were ineffective for trapping rabbits during winter months. From 28 October 1976 to 24 February 1977, no rabbit was captured in wire traps. Certain other species did occasionally enter the traps and several of these animals did not survive. Wire traps were a particular problem during weather conditions of snow and ice. In January, wire traps were often frozen shut and filled with snow. As a suggestion for future trapping efforts it is felt that wire traps could be removed from the study area for the months of November, December, and January.

Population Estimate

Since individual rabbits within a population are not equally trappable throughout the year, population estimates based on trap-retrap data for brief trapping periods reflect seasonal variations in trap response. The fact that the population itself goes through an annual cycle due to seasonal breeding also makes data collected for short periods of time unsuitable for estimating population levels.

Table IV. Frequency of capture, number of rabbits captured, and total number of captures for the period 5 August 1974 to 1 May 1977.

Frequency of Capture	Number of Rabbits Captured	Total Number of Captures
1	144	144
2	65	130
3	30	90
4	15	60
5	7	35
6	3	18
7	3	21
8	1	8
9	1	9
10	1	10
11	3	33
12	0	0
13	1	13
Total	274	571

Therefore, data collected over a one-year period should provide a more realistic means of population estimation.

Assuming that March is the beginning of the cottontail reproductive year (Lord, 1963; Evans et al., 1965), the 12-month period 1 March 1976 to 1 March 1977 was used to calculate a population estimate. A total of 100 different cottontails was trapped a total of 163 times during this period. Using trap-retrap data and applying the Maximum Likelihood Estimate (MLE) derived for cottontails by Edwards and Eberhardt (1967), a maximum population of 259 rabbits was estimated for the 100 acre study area. The number of animals captured in a given period of time represents the minimum population for that period. The 100 different rabbits trapped from 1 March 1976 to 1 March 1977 can then be considered the minimum population for the study area.

Edwards and Eberhardt (1967) tested the accuracy of the MLE by comparing estimates derived from trapping data with a known number of rabbits confined in a 40 acre pen. They found that the MLE had a tendency to over-estimate the zero capture class, giving a population estimate slightly greater than the true population. However, they suggested that the MLE should be useful in estimating rabbit abundance from livetrapping data until more suitable methods are devised. Although the MLE estimate of 259 rabbits may be slightly high, it will be used in this report as the total population of rabbits on the 100 acre study area.

Juveniles four to five months of age are most susceptible to trapping (Huber, 1962; Eberhardt et al., 1963; Bailey, 1969). Younger juveniles, it was found, rarely enter traps (Eberhardt et al., 1963). This, along with trap results, indicates that nearly all rabbits trapped were at least four months of age. Lord (1961), after compiling 3.5 years of data on cottontails in Illinois, found July to be the month with the greatest number of rabbits four months of age and older. For this reason the MLE estimate of 259 rabbits was assigned to the month of July.

Monthly population estimates were calculated using a modified life table developed by Lord (1961) (Appendix D). From the life table, the number of rabbits four months and older alive at the beginning of each month was determined (Table V). These figures from Lord's study were used to compare each successive month, resulting in a ratio between any two successive months. Using Lord's ratios, the present study was compared to Lord's study with direct proportions for each month. Starting with the MLE estimate of 259 rabbits in July, monthly population estimates were calculated as follows:

Calculation of August population estimate

$$\frac{(\text{August})}{(\text{July})} \quad \frac{2689}{3056} = \frac{x}{259} \quad \frac{(\text{August})}{(\text{July})}$$

$x = 228$ August population estimate

Table V. Number of rabbits four months of age and older alive at the beginning of each month, as determined from Lord's (1961) modified life table (Appendix D).

Month	Rabbits Four Months and Older Alive at Beginning of Month
March	1000
April	846
May	708
June	593
July	3056
August	2689
September	2369
October	2079
November	1824
December	1577
January	1355
February	1175

Table VI summarizes monthly population estimates and total number of rabbits captured for the period 1 March 1976 to 1 March 1977. As shown in the table, this study found a peak population of 259 rabbits and a low of 49 (animals four months and older). Gress (1976) reported 281 rabbits as a peak and 55 as a low for the period 1 March 1975 to 1 March 1976 (Table VII). It appears from the trapping data that the population of the study area during the past year was slightly less than in the preceding year.

If the estimate of 259 rabbits is relatively accurate, then 39 % of all rabbits on the study area were marked. Since the MLE estimate is probably slightly high (Edwards and Eberhardt, 1967), more than 39 % of the rabbits were marked. Gress (1976), using the same method of estimation, determined that 53 % of the total population on the study area were tagged in 1975-76. This difference (14 %) between two consecutive years on the same study area, seems to indicate that something other than a slight difference in actual population was exerting an influence on trapping success. A decline in total captures could be expected from a decline in total population (Tables II and III). However, it seems that approximately the same per cent of the population would be captured. Trapping procedure was the same for both years, running approximately the same number of traps, in the same places, over the same period of time. Except for a few

Table VI. Monthly population estimates of rabbits four months and older, and total number of captures for the period 1 March 1976 to 1 March 1977.

Month	Population Estimate	Total Captures
March	84	3
April	71	4
May	59	6
June	49	7
July	259	11
August	228	7
September	201	15
October	176	48
November	154	44
December	133	10
January	114	5
February	99	3

Table VII. Monthly population estimates of rabbits four months and older, and total number of captures for the period 1 March 1975 to 1 March 1976. (after Gress, 1976)

Month	Population Estimate	Total Captures
March	92	16
April	78	4
May	65	4
June	55	5
July	281	10
August	247	14
September	218	62
October	191	100
November	168	65
December	145	16
January	125	14
February	108	7

traps which were lost and a few new ones which were added, traps were not moved during the study. Wood and Munroe (1977) felt it was necessary to relocate traps continually in order to maintain randomness in both captures and recaptures. Since traps were not periodically relocated in either the 1975-76 or 1976-77 studies, it is not felt that this procedure accounts for the decline in trapping success during the second year. As mentioned previously, it is possible that differences in weather conditions could be in part responsible for differences in trap success. It was also established that there are differences in trappability of individuals relating to such factors as age and sex of the animal (Schwartz, 1941; Huber, 1962; Bailey, 1969; Chapman and Trethewey, 1972). If for some reason the age or sex structure of the populations was different from one year to the next (Edwards, 1964), this might account for some of the discrepancy in trap success for the two one-year periods.

The actual population of the study area probably lies between the minimum of 100 cottontails and the MLE estimate of 259. These estimates put population densities between 1.00 and 2.59 rabbits per acre. Gress (1976) found population densities between 1.49 and 2.81 rabbits per acre on the same study area. These estimates are close to those reported by Hill (1972) in Alabama. He found a population density of 2.42 rabbits per acre in an enclosure with abundant food, abundant cover, and limited predation. If these density criteria are applied to the 100 acre study area of RNHR, it may be considered excellent habitat for high cottontail populations (Gress, 1976).

<u>Transmitter Performance</u>

Sixty-six different transmitters were placed on 89 different cottontails a total of 107 times during the period 1 August 1974 to 1 May 1977. From 1 May 1976 to 1 May 1977, 35 different transmitters were placed on 37 different rabbits a total of 39 times. Two transmitters, which were placed on rabbits by Gress (1976), were still functioning 1 May 1976. Radio-transmitter performance during the 1974-77 period is summarized in Table VIII.

In 33 months of monitoring cottontail activity on the study area, transmitters operated a total of 3,798 transmitter days, with recorded rabbit mortality occurring at the rate of one death per 92.6 transmitter days. Of the 66 transmitters, 29 were recovered and kept for future use and 37 were not recovered.

Battery life averaged 37.2 days. Hutton (1975) stated that batteries of the type used in this study have a theoretical life of 120 days. The policy of replacing batteries in this study would help explain why the average battery life was far below the theoretical life. Any collar that was

Table VIII. Summary of radio-transmitter performance for all transmitters used since August 1974. (* indicates those transmitters used from 1 May 1976 to 1 May 1977)

Transmitter Number	Total Days of Operation	Number of Batteries Used	Fate of Collar
WMI	55	1	Recovered
1709	52	1	Not Recovered
1710	5	1	Not Recovered
1711	59	2	Not Recovered
1712	82	2	Recovered
1713	198	5	Not Recovered
1727	180	4	Not Recovered
1728*	160	4	Recovered
1729*	144	4	Not Recovered
1730	104	1	Not Recovered
1731	6	1	Not Recovered
1755	103	2	Recovered
1756*	77	2	Not Recovered
1757	125	2	Recovered
1758	7	1	Recovered
1759	60	2	Not Recovered
1760	18	1	Not Recovered
1761	63	3	Not Recovered
1762	121	3	Not Recovered
1763	16	1	Not Recovered

Table VIII. Continued

Transmitter Number	Total Days of Operation	Number of Batteries Used	Fate of Collar
1764	105	3	Not Recovered
1965	33	1	Not Recovered
1766	38	1	Not Recovered
1767	142	3	Not Recovered
1768	92	1	Not Recovered
1769	84	2	Recovered
1773*	159	3	Not Recovered
1774*	58	2	Not Recovered
1775	87	1	Not Recovered
1776	95	1	Not Recovered
1777	12	1	Recovered
1778	78	1	Recovered
1779	72	1	Not Recovered
1780*	90	3	Not Recovered
1781	19	1	Recovered
1782	40	1	Recovered
1809*	27	1	Not Recovered
1810*	5	1	Not Recovered
1811	19	1	Recovered
1812*	29	1	Recovered

Table VIII. Continued

Transmitter Number	Total Days of Operation	Number of Batteries Used	Fate of Collar
1813*	5	1	Not Recovered
1814*	76	1	Not Recovered
1815*	1	1	Recovered
1816*	60	1	Not Recovered
1817*	43	1	Recovered
1818*	1	1	Recovered
1819*	60	1	Not Recovered
1820*	117	2	Not Recovered
1824*	3	1	Recovered
1825*	66	1	Not Recovered
1826*	16	1	Not Recovered
1827*	10	1	Recovered
1856*	10	1	Recovered
1857*	58	1	Recovered
1858*	30	1	Recovered
1859*	2	1	Recovered
1860*	6	1	Recovered
1861*	60	1	Recovered
1863*	42	1	Recovered
1895*	21	1	Recovered

Table VIII. Continued

Transmitter Number	Total Days of Operation	Number of Batteries Used	Fate of Collar
1896*	20	2	Not Recovered
1897*	31	1	Recovered
1898*	29	1	Recovered
1899*	81	2	Not Recovered
1900*	10	1	Recovered
1901*	21	1	Not Recovered
Total	3798	102	

recovered from a dead rabbit had the battery replaced before the collar was placed on another rabbit. When collared animals were recaptured with a battery that had operated at least eight weeks the battery was replaced. These procedures were attempts to minimize transmitter loss as a result of battery failure.

The number of transmitters functioning per month for the 33 months from August 1974 through April 1977 is summarized in Figure 1. During times of peak trapping success (fall months), more animals were available for transmitter attachment. However, in the fall and winter of 1976-77, the number of instrumented rabbits was somewhat limited by the number of batteries available. Difficulty in obtaining batteries resulted in a shortage of batteries from the last half of October through the first half of February. The peak number of functioning transmitters in 1974 was nine in November (Watt, 1975). In 1975, the peak occurred in September and October with 14 and 13, respectively (Gress, 1976). In 1976, the peak occurred in October and November with 11 and 12, respectively (Figure 1).

Since August 1974, 89 different rabbits were outfitted with radio-transmitters. Forty-one, 46 %, of the 89 cotton-tails died with a collar attached, radio contact was lost with 39, 44 %, of the rabbits, and nine, 10 %, of the 89 rabbits had their collars removed by the researcher.

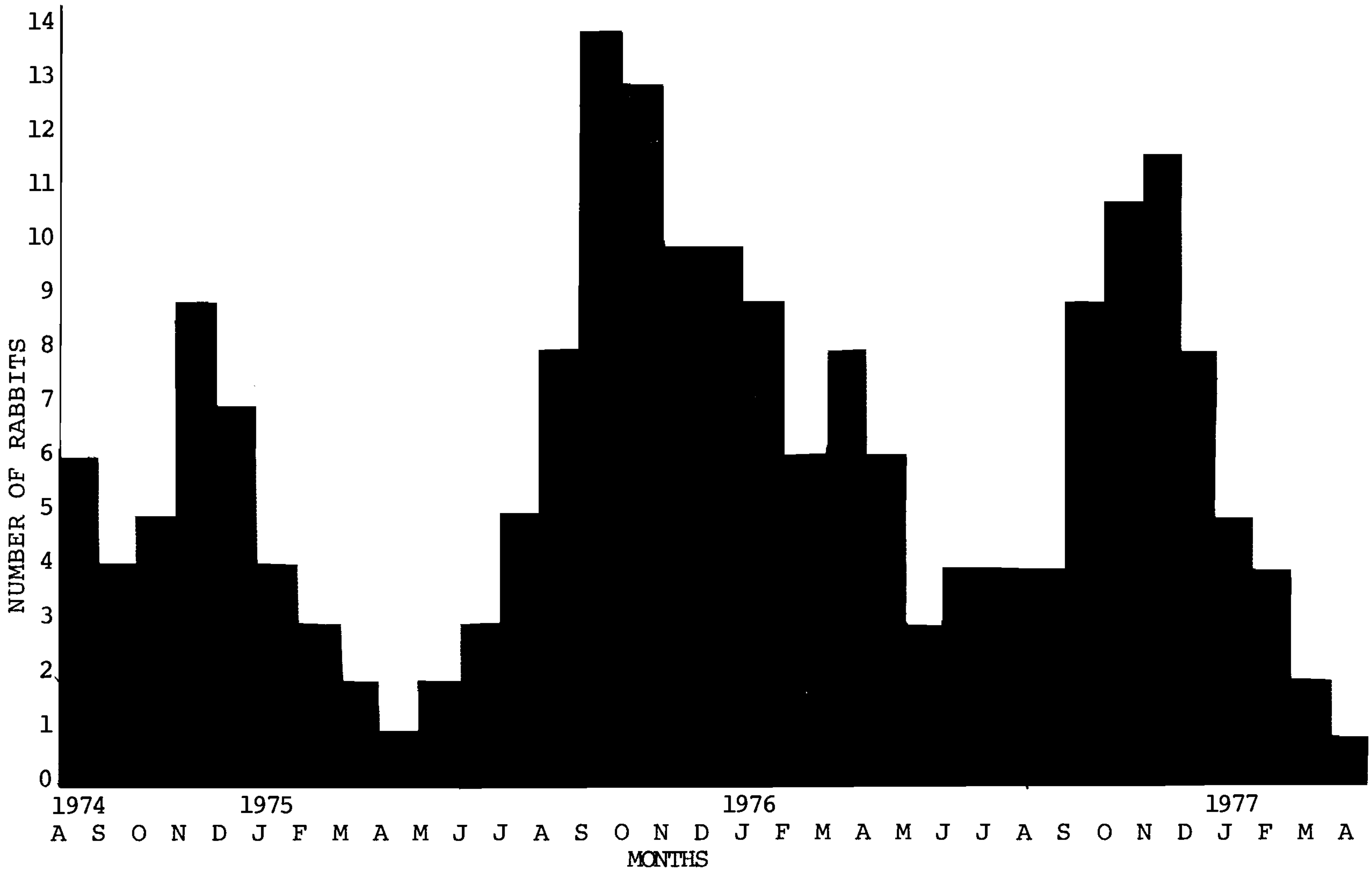

Figure 1. Total number of different rabbits equipped with functioning transmitters for at least one day during the month, for the period 1 August 1974 to 1 May 1977.

Mortality

Cottontail rabbit mortality was continually monitored on the RNHR study area from 1 August 1974 to 1 May 1977. Mortality information was collected on animals equipped with radio-transmitters and for any rabbit remains found on the study area. During the first segment of the project, 1 August 1974 to 1 May 1975, 21 rabbit deaths were discovered and reported by Watt (1975); 52 deaths were discovered between 1 May 1975 and 1 May 1976 and reported by Gress (1976); during the past year, 1 May 1976 to 1 May 1977, an additional 32 rabbit deaths were discovered. The total of 105 cottontail mortalities is summarized in Table IX and incorporates data reported by Watt and Gress.

Only one cause of death was assigned to each rabbit, since it was not possible to examine each and every animal for all possible parasites and diseases (Storm et al., 1976). The apparent causes of deaths were recorded, recognizing that identifying mortality factors in wildlife is not easy and may involve a complex set of factors (Errington, 1963; Davis, 1970).

In 40 of the 105 rabbit remains found it was impossible to determine the sex of the animal due to the extent of damages or decomposition. Of the remaining 65 mortalities, 31 were males and 34 were females (Table IX). Of the total deaths, 30 % were males and 32 % were females.

Table IX. Cottontail rabbit mortality summary, including date of discovery, rabbit number, method of discovery, sex, and cause of death for the period 1 August 1974 to 1 May 1977. (* indicates those deaths discussed in this report)

Date of Discovery	Rabbit Number	Method of Discovery	Sex	Cause of Death
(1) 8/ 6/74	-	Personal observation	-	Unknown, remains intact
(2) 8/31/74	-	Personal observation	M	Shot to recover radio-transmitter
(3) 8/31/74	265	Radio-transmitter	M	Coyote predation
(4) 9/ 6/74	254	Personal observation	M	Tularemia
(5) 9/12/74	-	Personal observation	-	Unknown, remains intact
(6) 9/16/74	-	Personal observation	-	Great Horned Owl predation
(7) 10/ 4/74	249	Personal observation	M	Trap mortality
(8) 11/ 2/74	-	Personal observation	-	Coyote predation
(9) 11/ 7/74	-	Personal observation	-	Coyote predation
(10) 11/13/74	-	Personal observation	-	Coyote predation
(11) 11/15/74	271	Radio-transmitter	M	Shot to recover radio-transmitter
(12) 11/19/74	236	Radio-transmitter	M	Avian predation
(13) 12/ 2/74	252	Radio-transmitter	M	Shot by hunter

Table IX. Continued

	Date of Discovery	Rabbit Number	Method of Discovery	Sex	Cause of Death
(14)	12/ 7/74	268	Radio-transmitter	F	Radio-collar
(15)	12/12/74	251	Radio-transmitter	F	Radio-collar
(16)	12/16/74	-	Personal observation	-	Coyote predation
(17)	2/17/75	205	Radio-transmitter	M	Coyote predation
(18)	3/ 3/75	-	Personal observation	-	Coyote predation
(19)	3/ 5/75	-	Personal observation	-	Coyote predation
(20)	4/12/75	239	Personal observation	F	Trap mortality
(21)	4/22/75	-	Personal observation	-	Avian predation
(22)	6/ 5/75	-	Personal observation	M	Hit by car
(23)	7/ 6/75	-	Discovered by dog	-	Mower mortality
(24)	7/21/75	-	Personal observation	M	Trap mortality
(25)	7/27/75	-	Personal observation	-	Mower mortality
(26)	8/ 6/75	331	Personal observation	F	Trap mortality
(27)	8/14/75	317	Radio-transmitter	M	Mammalian predation

Table IX. Continued

	Date of Discovery	Rabbit Number	Method of Discovery	Sex	Cause of Death
(28)	8/14/75	-	Discovered by dog	-	Mammalian predator
(29)	8/15/75	333	Personal observation	F	Trap mortality
(30)	8/20/75	-	Personal observation	-	Unknown, remains intact
(31)	8/27/75	329	Radio-transmitter	M	Coyote predation
(32)	8/30/75	-	Discovered by dog	-	Unknown, remains intact
(33)	9/ 6/75	343	Personal observation	M	Trap mortality
(34)	9/13/75	-	Discovered by dog	-	Unknown, remains intact
(35)	9/23/75	360	Personal observation	F	Tularemia
(36)	10/ 5/75	247	Radio-transmitter	F	Tularemia
(37)	10/ 6/75	349	Radio-transmitter	M	Tularemia
(38)	10/ 6/75	351	Radio-transmitter	M	Avian predation
(39)	10/ 9/75	393	Personal observation	F	Tularemia
(40)	10/11/75	-	Personal observation	-	Mammalian predation
(41)	10/13/75	-	Discovered by dog	-	Unknown, remains intact

Table IX. Continued

Date of Discovery	Rabbit Number	Method of Discovery	Sex	Cause of Death
(42) 10/19/75	399	Personal observation	M	Tularemia
(43) 10/21/75	389	Personal observation	F	Tularemia
(44) 10/22/75	347	Radio-transmitter	M	Tularemia
(45) 10/23/75	209	Personal observation	F	Tularemia
(46) 11/ 3/75	-	Personal observation	-	Mammalian predation
(47) 11/12/75	-	Personal observation	-	Marsh Hawk predation
(48) 11/14/75	-	Personal observation	-	Unknown
(49) 11/17/75	342	Radio-transmitter	F	Tularemia
(50) 11/29/75	310	Personal observation	F	Coyote predation
(51) 11/29/75	-	Personal observation	-	Coyote predation
(52) 12/ 8/75	-	Personal observation	-	Coyote predation
(53) 12/ 8/75	218	Personal observation	M	Tularemia
(54) 12/12/75	449	Personal observation	-	Tularemia
(55) 12/29/75	451	Radio-transmitter	F	Coyote predation

Table IX. Continued

	Date of Discovery	Rabbit Number	Method of Discovery	Sex	Cause of Death
(56)	1/ 3/76	372	Radio-transmitter	F	Dog predation
(57)	1/ 6/76	377	Radio-transmitter	M	Avian predation
(58)	1/12/76	246	Radio-transmitter	F	Coyote predation
(59)	1/23/76	335	Radio-transmitter	F	Dog predation
(60)	1/31/76	435	Personal observation	F	"Shock"
(61)	2/29/76	-	Personal observation	-	Coyote predation
(62)	3/ 6/76	369	Personal observation	M	Unknown
(63)	3/ 7/76	-	Personal observation	-	Coyote predation
(64)	3/21/76	-	Personal observation	-	Trap mortality
(65)	3/28/76	378	Personal observation	M	Mammalian predation
(66)	3/30/76	407	Radio-transmitter	F	Collar
(67)	4/ 6/76	340	Personal observation	F	Unknown
(68)	4/ 8/76	-	Personal observation	-	Coyote predation
(69)	4/ 8/76	419	Radio-transmitter	M	Avian predation

Table IX. Continued

	Date of Discovery	Rabbit Number	Method of Discovery	Sex	Cause of Death
(70)	4/ 8/76	-	Personal observation	-	Nest mortality
(71)	4/ 8/76	-	Personal observation	-	Nest mortality
(72)	4/12/76	-	Personal observation	-	Avian predation
(73)	4/26/76	457	Radio-transmitter	M	Coyote predation
(74)*	5/10/76	-	Personal observation	-	Trap mortality
(75)*	5/19/76	315	Discovered by dog	F	Tularemia
(76)*	5/31/76	338	Personal observation	F	Unknown, remains intact
(77)*	6/ 3/76	458	Radio-transmitter	M	Mammalian predation
(78)*	6/ 4/76	423	Radio-transmitter	F	Trap mortality
(79)*	6/ 8/76	-	Personal observation	-	Dog predation
(80)*	6/28/76	-	Personal observation	M	Trap mortality
(81)*	7/ 2/76	-	Personal observation	-	Unknown predation
(82)*	7/15/76	359	Personal observation	M	Tularemia
(83)*	7/31/76	472	Radio-transmitter	F	Avian predation

Table IX. Continued

Date of Discovery	Rabbit Number	Method of Discovery	Sex	Cause of Death
(84)* 8/ 6/76	-	Personal observation	-	Avian predation
(85)* 8/14/76	-	Personal observation	-	Trap mortality
(86)* 8/23/76	470	Radio-transmitter	F	Tularemia
(87)* 8/25/76	477	Radio-transmitter	F	Coyote predation
(88)* 8/29/76	480	Radio-transmitter	F	Trap mortality
(89)* 9/ 4/76	478	Discovered by dog	M	Tularemia
(90)* 9/ 6/76	483	Radio-transmitter	F	Dog predation
(91)* 9/ 8/76	-	Personal observation	-	Unknown, remains intact
(92)* 9/16/76	65	Discovered by dog	M	Tularemia
(93)* 9/26/76	489	Radio-transmitter	F	Coyote predation
(94)*10/ 4/76	490	Radio-transmitter	F	Tularemia
(95)*10/13/76	491	Radio-transmitter	F	Bobcat predation
(96)*10/20/76	411	Personal observation	F	Ruptured liver

Table IX. Continued

Date of Discovery	Rabbit Number	Method of Discovery	Sex	Cause of Death
(97)*10/21/76	-	Personal observation	-	Mammalian predation
(98)*11/ 1/76	499	Radio-transmitter	M	Tularemia
(99)*11/ 4/76	-	Personal observation	-	Coyote predation
(100)*11/10/76	784	Radio-transmitter	M	Coyote predation
(101)*11/12/76	779	Radio-transmitter	F	Mammalian predation
(102)*11/13/76	-	Personal observation	-	Mammalian predation
(103)*12/14/76	522	Radio-transmitter	F	Pneumonia
(104)* 1/ 1/77	370	Personal observation	F	Unknown, remains intact
(105)* 4/ 1/77	780	Radio-transmitter	M	Unknown, remains intact

In many cases the remains were destroyed to the point that it was impossible to find collars or ear tags. There is no doubt that some of the rabbits listed as unmarked in Table IX were, in fact, tagged rabbits. In 53 of the 105 mortality cases it was possible to determine that the animal had been previously marked. Table IX lists 62 rabbits identified by ear tag numbers. Nine of these were not previously marked, but their remains were ear-tagged for subsequent identification purposes at the laboratory.

Of the 105 dead cottontails, 37, 35 %, were wearing a functioning radio-transmitter at the time of death. Sixty rabbits, 57 %, were discovered by personal observation. The remaining eight mortalities, 8 %, were discovered by the dogs.

After 33 months (August 1974 through April 1977) of monitoring cottontail mortality on the study area, recorded mortalities ranged from zero to 10 per month. Figure 2 incorporates data reported by Watt (1975) and Gress (1976) to show the number of known cottontail deaths per month. From August 1974 through April 1975, mortality occurred at the rate of 2.33 deaths per month (Watt, 1975). Gress (1976) reported mortality occurring at the rate of 4.33 deaths per month, from May 1975 through April 1976. During the following year, from May 1976 through April 1977, 32 additional dead rabbits were discovered. Observed mortality occurred at the rate of 2.67 deaths per month.

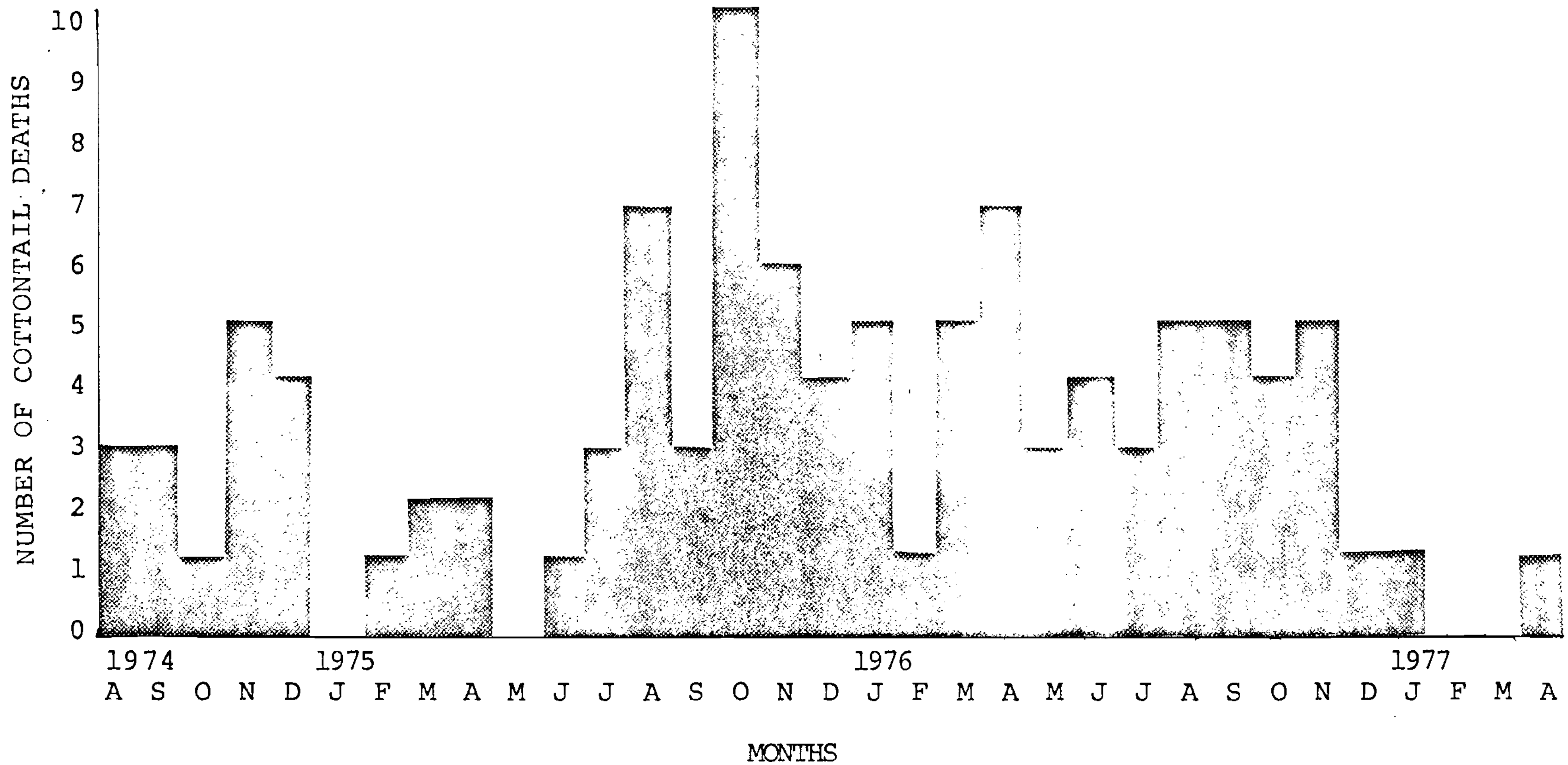

Figure 2. Total number of known cottontail deaths per month for the period 1 August 1974 to 1 May 1977.

The rate of 4.33 deaths per month reported by Gress (1976) for the period 1 May 1975 to 1 May 1976, was greater than either the 2.33 deaths per month reported by Watt (1975) or the 2.67 deaths per month reported in the present study. Gress offered possible explanations for differences between his data and that of Watt. Gress noted that more animals were captured in his study than in Watt's study due to an increase in number of traps used. As a result, more animals were available for radio-transmitter attachment. Gress used dogs to aid in discovery of dead rabbits, a procedure not employed by Watt. Gress stated that a tularemia epidemic or an excessive amount of predation on the study area might be another possible explanation for the increased number of deaths observed during the second year of the project.

Fewer rabbits were trapped during the present study than were trapped by Gress (1976) (Tables II and III). Since fewer animals were captured, fewer were available for radio-transmitter attachment. A shortage of batteries from the last half of October through the first half of February caused a further reduction in the number of animals equipped with radio-transmitters. Gress used a total of three dogs, singly or in combination, throughout the study to search for dead rabbits. One dog was used for the first five months of the present study, but not for the remaining seven months.

A combination of these factors may partially account for the decrease in observed mortality during the most recent 12 months on the project.

Lord's (1961) modified life table (Appendix D) which was used to calculate monthly population estimates, was also used to calculate monthly mortality estimates (Table X). The number of rabbits four months and older which died during each month was determined for Lord's study (from Table V). The per cent of each month's population which died during that month was calculated, and these percentages were applied to the present study. Monthly mortality estimates were based on monthly population estimates, calculated as follows:

Calculation of August mortality estimate

(from Table V) 2689 - 2369 = 320 rabbits died during August

$$\frac{320}{2689} \quad \frac{\text{(died during month)}}{\text{(alive at beginning of month)}} = 11.9\ \%$$

.119 (Aug. mortality rate) x 228 (Aug. population estimate) =

27.1 deaths (Aug. mortality estimate)

Calculations were made for the breeding year, 1 March 1976 to 1 March 1977, and include only rabbits four months of age and older. The peak population estimate of 259 rabbits was assigned to July, which corresponds with the peak

Table X. Monthly population estimates and estimated mortalities for rabbits four months of age and older, as calculated from Lord's (1961) modified life table.

	Population Estimate	Estimated Mortalities
March 1976	84	12.9
April	71	11.6
May	59	9.6
June	49	7.5
July	259	31.1
August	228	27.1
September	201	24.6
October	176	21.6
November	154	20.9
December	133	18.7
January 1977	114	15.1
February	99	14.7
Total		215.4

number of 31.1 estimated mortalities. During the one-year period an estimated 215 cottontails died (Table X). This represents 83.0 % of the total estimated population of 259.

Table XI shows monthly estimated mortality as compared to monthly observed mortality. Between 1 March 1976 and 1 March 1977, 35 cases of known adult cottontail deaths were recorded. This represents 16.2 % of the 215 deaths estimated for this period. Gress (1976) reported that 17 % of the estimated mortalities were discovered between 1 March 1975 and 1 March 1976.

Table XII gives the per cent of estimated mortalities discovered per month for each of the two one-year periods.

The number of discovered cottontail deaths fluctuated from month to month (Figure 2). No definite trend in mortality was obvious from these data. Gress (1976) noted that the chances of discovering mortality were not equal throughout the year. He stated that changes in ground cover probably affected chances of finding dead rabbits by personal observation. Monthly variation in numbers of functioning radio-transmitters (Figure 1) also influenced observed mortality. Examination of Table XII yields no definite monthly pattern in per cent discovery of estimated mortality. However, there was no significant difference (Student *t* test, $p = .05$) between the per cent of total estimated mortalities discovered for the two one-year periods.

Table XI. Estimated monthly mortalities (from Lord, 1961), observed mortalities of rabbits four months and older, and per cent of deaths discovered, for the period 1 March 1976 to 1 March 1977.

	Estimated Mortalities	Observed Mortalities	Per Cent Discovered
March 1976	12.9	5	38.8
April	11.6	5	43.1
May	9.6	2	20.8
June	7.5	2	26.7
July	31.1	2	6.4
August	27.1	4	14.8
September	24.6	4	16.3
October	21.6	4	18.5
November	20.9	5	23.9
December	18.7	1	5.3
January 1977	15.1	1	6.6
February	14.7	0	0
Total	215.4	35	
			$\bar{X}$ = 16.2

Table XII. Per cent of estimated mortalities discovered from 1 March 1975 to 1 March 1976 (from Gress, 1976), as compared to per cent of estimated mortalities discovered from 1 March 1976 to 1 March 1977.

	Per Cent Discovered	
	1975-1976	1976-1977
March	14.1	38.8
April	15.7	43.1
May	0	20.8
June	11.9	26.7
July	5.9	6.4
August	20.4	14.8
September	7.5	16.3
October	38.5	18.5
November	26.4	23.9
December	19.6	5.3
January	30.1	6.6
February	6.2	0
$\overline{X}$	17.0	16.2

Lord's (1961) modified life table (Appendix D) is a product of 3.5 years of data collection in central Illinois. Calculation of monthly population estimates and monthly mortality estimates based on Lord's table assumes that reproductive and mortality rates in Kansas and Illinois are identical. Whether or not this modified life table accurately reflects productivity and mortality of Kansas cottontails is a question open to confirmation or refutation by more data (Gress, 1976). Because of a lack of these data for Kansas cottontails, Lord's (1961) work was utilized in this study.

Research Mortality: From 1 May 1976 to 1 May 1977, 32 cottontail deaths were recorded. A summary of this mortality, by cause, is given in Table XIII. Six deaths, 18.8 % of total mortality, resulted from research interference.

Five rabbit deaths were classified as trap mortalities (Table IX). All five deaths occurred in wire traps. One trap mortality was an adult rabbit (no. 78) which sustained extensive injuries in the trap but was still alive when discovered. This rabbit was outfitted with a radio-transmitter and released. The next day it was found dead about six yards from the point of release. The carcass was sent to the Kansas State University Veterinary Diagnostic Laboratory for examination. When a report of "no disease"

Table XIII. Causes of cottontail mortality for the period 1 May 1976 to 1 May 1977.

	Deaths		Per cent of total deaths	
Research mortality	6		18.8	
Trap mortality		5		15.6
Dog		1		3.1
Predation	13		40.6	
Mammalian		10		31.3
Avian		2		6.3
Unknown		1		3.1
Disease	8		25.0	
Tularemia		7		21.9
Pneumonia		1		3.1
Ruptured liver	1		3.1	
Unknown	4		12.5	
Total	32		100.0	

was received from the lab, this rabbit was designated a trap mortality. Another adult rabbit (no. 88) died in the trap with no sign of trap injury or predator interference. This animal was sent to the University of Missouri at Kansas City for diagnostic examination and was also found negative for disease. Three juvenile rabbits (nos. 74, 80, 85) were victims of trap mortality due to predator interference. Mammalian predators were the probable causes for these deaths. Raccoons were numerous on the study area, and because of their manual dexterity, it seems that they were the probable trap raiders (Gress, 1976).

The other victim (no. 90) of research interference was an adult rabbit equipped with a functioning radio-transmitter. After the researcher had located the rabbit, it was pursued by the dog which accompanied the researcher on daily rounds. The dog chased the rabbit for about 40 minutes and eventually caught it. The remains of this rabbit were inadvertently discarded, so no lab report was available and this death was attributed to research interference. However, it is felt that the rabbit may have been weakened by disease since the beagle could not normally catch a healthy adult rabbit.

Predation: Of the 32 cottontail deaths recorded in the present study, 13 were due to predation (Table XIII). This represents 40.6 % of total deaths and 50.0 % of naturally occurring deaths. Thirty-two cases of mortality on the study area were accredited to predation from 1 August 1974 to 1 May 1976 (Gress, 1976). This was 43.8 % of total deaths and 54.2 % of naturally occurring deaths.

Table XIV summarizes known cottontail mortality for the period 1 August 1974 to 1 May 1977. In 33 months of monitoring mortality, predation accounted for 42.9 % of 105 total deaths. Other researchers (Mech, 1967; Stoddart, 1970; Trent and Rongstad, 1974), after studying mortality with radio-telemetry systems found predation rates greater than that found in the present study. Stoddart reported that 84 % of 25 jackrabbit deaths were due to predation. It is felt that 42.9 % of total deaths (Table XIV), 52.9 % of naturally occurring deaths, does not represent excessive predation on the RNHR study area.

During the present study 10 rabbit deaths, 76.9 % of all predation, were attributed to mammalian predators (Table XIII). Two cases, 15.4 % of all predation, were avian. The remaining one case, 7.7 %, was an unknown predator. Gress (1976) found that mammalian predators were responsible for 75 % of all predation. The remaining 25 % were due to avian predators.

Since August 1974, the maximum number of known deaths per month due to predation was four. These occurred in November, 1974, November, 1975, April, 1976, and November, 1976. No predation was recorded in October, 1974,

Table XIV. Causes of cottontail mortality for the period 1 August 1974 to 1 May 1977.

	Deaths		Per cent of total deaths	
Research mortality	20		19.0	
Trap mortality		12		11.4
Collar		3		2.8
Shot		2		1.9
"Shock"		1		1.0
Dog		2		1.9
Predation	45		42.9	
Mammalian		34		32.4
Avian		10		9.5
Unknown		1		1.0
Disease	20		19.0	
Tularemia		19		18.1
Pneumonia		1		1.0
Ruptured liver	1		1.0	
Mower activity	2		1.9	
Nest mortality	2		1.9	
Shot by hunter	1		1.0	
Hit by car	1		1.0	
Unknown	13		12.4	
Total	105		100.0	

January, May, June, July, and September, 1975, May and December, 1976, January, February, March, and April, 1977. No trend in monthly predation was apparent from these data.

Of the 10 cases of mammalian predation in this study (Table XIII), four (nos. 87, 93, 99, 100) were classified as coyote (Canis latrans) kills (Table IX). No tracks or scat were observed at any of the kill sites. These mortalities were assigned to coyote predation based on descriptions of coyote kills by Fitch and Packard (1955) and Stoddart (1970). Fitch and Packard described coyote kills as follows: "Ordinarily little remains of the rabbit except fur strewn over an area of several square feet to several square yards." Stoddard found that coyotes consistently consumed adult jackrabbits, leaving no trace of remains or leaving only the stomach.

Four more cases (nos. 77, 97, 101, 102) were simply designed as mammalian predation (Table IX), since they did not exactly conform to the above descriptions of coyote kills. However, it is conceivable that these deaths may have been due to coyotes. Mortality number 77 was discovered with head and collar intact and fur and some entrails were scattered over a five square yard area. Remains of rabbit kill number 97 consisted of the digestive tract, part of the liver, one hind foot, and a little fur. At the kill site of number 101, the head was untouched with the collar still attached. There was no sign of the remainder of the body. Rabbit mortality number 102 was represented by only one front leg remaining at the kill site. It is possible that any of these four mortality cases could have been due to dogs which frequently visit the study area.

The beagle dog was known to be responsible for one case of mammalian predation. Kill number 79 was a juvenile rabbit which was pursued and captured by the dog. This mortality was designated as mammalian predation rather than research interference because the dog was not participating in any research associated activity at the time of the incident.

Numerous studies have shown the importance of cottontails in the diet of coyotes. Fichter et al., (1955) found the volume of rabbits in Nebraska coyote stomachs to be 54 % of total contents; Korschegan (1957) found the cottontail in 54 % of all stomachs examined from Missouri coyotes. Gier (1968), studying Kansas coyotes, reported that rabbits occurred in 54.3 % of 1,988 stomachs, and made up over half of the total contents by weight. In another study of Kansas coyotes, Fitch and Packard (1955) concluded that rabbits were the major food item in coyote diets.

The remaining case of mammalian predation (Table IX) was attributed to a bobcat (<u>Lynx</u> <u>rufus</u>). Rabbit kill number 95 was found in a dense thicket below the pond dam. The head was completely gone, as was a large part of the viscera. The distinctive characteristic of this kill was the fact that the remains and the collar were completely covered by a pile of leaves which had been scraped into a circle approximately 2.5 feet in diameter. This feature provided the evidence for calling mortality number 95 a bobcat kill (Spencer, pers. comm.; Peabody, pers. comm.).

There was some evidence that another case of bobcat predation may have occurred on the study area, but no remains were found to confirm this death. On 16 January 1977 the radio-transmitter on rabbit number 950 was transmitting a "dead" signal. Bobcat tracks were observed in the immediate vicinity. The collar could not be located because of approximately seven inches of snow on the ground. After the snow had melted the area was searched again, but no rabbit remains was found.

An extensive study of bobcat food habits in Texas (Beasom and Moore, 1977) showed that cottontails were a major food item of this felid. They reported that when cotton rat (Sigmodon hispidus) and cottontail populations were high, these two species comprised 96 % of the bobcat's diet. Stomachs that contained solely these two species comprised 93 % of the sample with only six different species represented in all stomachs examined. When cottontail and cotton rat numbers were low, the total diet was composed of

21 different species, over 80 % of which was cotton rat, white-tailed deer, and cottontail rabbit. The importance of cotton rats and cottontails to bobcats is shown by the high occurrence of these two species in the diet even during years of scarcity (Beasom and Moore, 1977).

The bobcat is probably best classified as an occasional visitor to the study area, along with the long-tailed weasel (Mustela frenata), mink (Mustela vison), and red fox (Vulpes fulva) (Gress, 1976). Red foxes were not sighted on the study area and no rabbit mortality was identified as a red fox kill. However, on one occasion, tracks were observed which were thought to be those of a red fox, and red foxes have been found to have a predilection for cottontail rabbits (Scott and Klimstra, 1955).

Feral house cats, (Felis catus), were seen on the study area on numerous occasions. These animals are known to prey on rabbits. McMurray and Sparry (1941) found that 14 % of house cat stomachs contained cottontails. Parmalee (1953) found 13 % of feral house cat stomachs contained cottontails.

Mammalian predators sighted on the study area include the coyote (Canis latrans), dog (Canis familiaris), raccoon (Procyon lotor), badger (Taxidea taxus), striped skunk (Mephitis mephitis), and opossum (Didelphis marsupialis).

Table XIII shows that two deaths were assigned to avian predation. These two cases of mortality (nos. 83 and 84) were found in the same general area within a one week interval (Table IX). One rabbit (no. 83) had a neck wound and flesh stripped from one rear leg. The body cavity had been opened and both eyeballs had been removed. Another rabbit kill (no. 84) was partially decomposed when discovered, but it was still possible to determine that the eyeballs had been removed, the gut cavity had been opened, and some of the flesh had been stripped from the hindquarters. Both of these dead rabbits were found in open areas, a prerequisite for designating a kill to avian predators throughout the study (Gress, 1976).

The individual avian predator could not be identified positively in either case, but it is felt that the most likely suspect was a Great Horned Owl (*Bubo virginianus*). The researcher twice sighted a Great Horned Owl in the vicinity of these kills, within two weeks of their occurrence. It has been shown that these large owls feed extensively on cottontail rabbits (Fitch, 1947).

In addition to the Great Horned Owl, the following avian predators capable of feeding on rabbits have been signted on the study area: Marsh Hawk (*Circus cyaneus*), Rough-legged Hawk (*Buteo lagopus*), Ferruginous Hawk (*Buteo regalis*), Red-tailed Hawk (*Buteo jamaicensis*), and the Barred Owl (*Strix varia*) (Gress, 1976).

The remaining case of predation was assigned to neither mammalian nor avian predation (Table XIII). Rabbit mortality number 81 (Table IX) was found in an open area at approximately the same locality as the two cases of avian predation. The head had been chewed, the body cavity was gutted, and the limbs were still attached. This mortality was classified as unknown predation.

Discovery of rabbit remains in the field does not guarantee that the animal was the victim of predation. It is always possible that the animal died from some other cause and was scavenged (Stoddart, 1970). Eighteen of 45 animals placed in the field by Stoddart were never touched. The other 27 were eaten by birds. The extent of scavenging in this study was not known.

Disease: From 1 May 1976 to 1 May 1977 disease accounted for 25.0 % of total mortality (Table XIII), and 30.8 % of naturally occurring deaths. Disease in this study was represented by seven cases of tularemia and one case of pneumonia. Of the four cases of unknown mortality, three cases (nos. 76, 91, 104) were possibly caused by disease. All of these were largely decomposed when found, but the remains were intact (Table IX). This seems to imply disease rather than predation. One case of research mortality (no. 90) in which the rabbit was captured by the beagle may also have been disease related.

Known tularemia deaths accounted for 21.9 % of total deaths (Table XIII). Including the three cases of unknown mortality and mortality number 90, mentioned above, it is possible that as much as 34.4 % of known mortality was tularemia related. From August 1974 through April 1976, known tularemia deaths represented 16.4 % of total deaths on the study area. By including seven other questionable cases, it is possible that 26.0 % of recorded mortality was tularemia related in the first 21 months of this project (Gress, 1976).

Table XIV shows that in 33 months of monitoring mortality, known tularemia deaths accounted for 18.1 % of 105 total known deaths. Including the 11 questionable cases, as described above, it is possible that since the project began in 1974, 28.6 % of recorded mortality was tularemia related.

Between 1 May 1976 and 1 May 1977, 11 dead rabbits which showed no signs of predation were submitted to laboratories for examination and diagnosis. Two cottontails (nos. 82 and 88) were sent to Dr. John Stevenson, University of Missouri at Kansas City. The other nine (nos. 75, 78, 86, 89, 92, 94, 96, 103, 105) were transported to the Kansas State University Veterinary Diagnostic Laboratory where Mr. Dennis R. Howard examined them for disease.

Dr. Stevenson (pers. comm.) found number 82 positive for tularemia. He isolated the organism (*Francisella tularensis*) from the heart, blood, spleen, liver, and bone marrow. Reports from Kansas State University stated that five rabbits (nos. 75, 86, 89, 92, 94) had gross lesions of tularemia. Use of the fluorescent antibody technique confirmed the tularemia diagnosis (Howard, pers. comm.). A sixth rabbit (no. 98) was not sent to the laboratory, but was diagnosed by the researcher on the basis of gross lesions on the liver and lungs.

Of the seven deaths attributed to tularemia, three (nos. 75, 89, 92) were intact carcasses discovered by the beagle dog; one (no. 82) was an intact carcass discovered by personal observation; and three (nos. 86, 94, 98) were located with radio-transmitters. In two cases (nos. 86 and 94) the rabbits were dead but in a normal resting position with their eyes open when found. Another mortality (no. 98) was not completely dead when discovered but died on the way to the laboratory.

Reilly and Dell (1955) stated that in New York state countless pounds of perfectly good rabbit meat are discarded annually because of hunter concern over tularemia. They concluded that larvae of the dog tapeworm (Taenia pisiformis) probably accounted for 90 % of unnecessary waste of meat. With careful examination, a tularemic rabbit in the field can be recognized with reasonable certainty. Manifestation of the disease in rabbits was described by Kelly and Hite (1949):

> "The liver, spleen, lungs, and bone marrow are studded with small whitish lesions giving rise to the spotted appearance grossly typical of infection. These spots consist of necrotic tissue, accumulations of inflammatory cells, and small abcesses. Older lesions tend to be larger in size. Injury to small blood vessels is common. The animals are sluggish, obviously ill, and frequently die of the infection."

Although these characteristics are indicative of tularemia, they are not conclusive and must be considered as presumptive signs of the disease.

Seasonal trends in tularemia occurrence are important to the concerned hunter as well as to researchers in disease ecology studies. In Minnesota tularemia is primarily a spring and fall disease of the cottontail rabbit and snowshoe hare (Green, 1942). According to Green, tularemia in rabbits decreased rapidly during September when the ticks became scarce. He found tularemia to be uncommon among rabbits after the first of October. McGinnes (1964) reported that in Virginia cottontails, evidence of tularemia abated late in November and reappeared again in late March or early April. This seasonal influence substantiates the observations of Yeatter and Thompson (1952) in Illinois.

On the RNHR study area, tularemia was known to occur from May to December (Figure 3). The single case of tularemia reported by Watt (1975) was discovered 6 September 1974. Gress (1976) reported that tularemia occurred from 23 September 1975 to 12 December 1975. The present study found

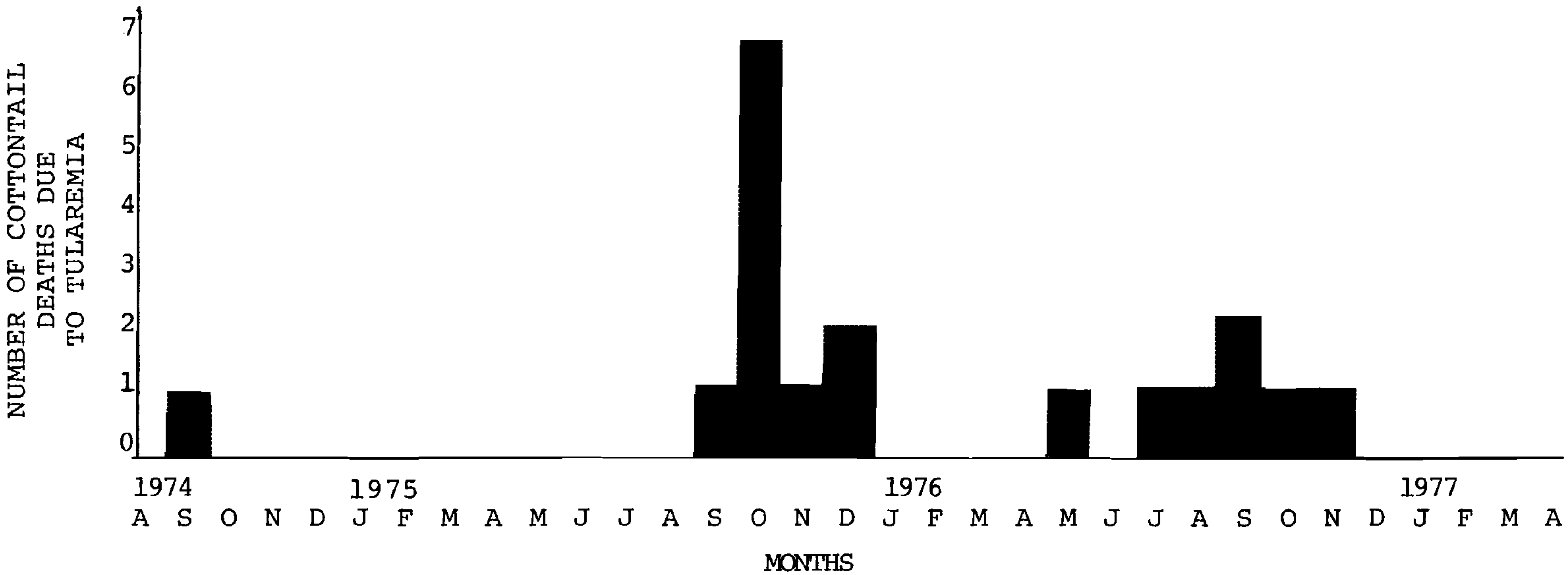

Figure 3. Total number of known cottontail deaths due to tularemia per month for the period 1 August 1974 to 1 May 1977.

tularemia occurring from 19 May 1976 to 1 November 1976. During this period one case of tularemia was discovered in each of the months of May, July, August, October, and November. Two cases were recorded for September.

Although the zoonosis tularemia is primarily a fatal, plaguelike disease of wild lagomorphs and rodents (Reilly, 1970), natural infection occurs in more than 38 mammals and birds native to the United States, with varying degrees of severity (McCahan et al., 1962). Tularemia is an acute, febrile, infectious septicemia caused by the bacterium, Francisella tularensis, formerly Pasteurella tularensis (Brooks and Buchanan, 1970).

Transmission of tularemia is accomplished directly by a variety of blood-sucking arthropods, including ticks, mites, flies, fleas, mosquitoes, and lice (Francis, 1929; Wayson, 1941; Hopla and Downs, 1953). The organism may also be transmitted by contact with infected vertebrates, aerogenically by inhalation of feces-contaminated dust, and by ingestion of infected carcasses or contaminated water (Burroughs et al., 1945; Gorham, 1949; Parker et al., 1951).

In rabbits, the disease is spread principally by the rabbit tick, Haemaphysalis leporis-palustris (Yeatter and Thompson, 1952). Lice and fleas may also contribute to the spread of the disease (Francis, 1937). Green (1942) found fleas present on rabbits in southern Minnesota during the winter; but, although these insects can transmit tularemia they appeared to do so rarely.

Green et al. (1938) reported that agglutinins for *F. tularensis* were never found in sera collected from apparently healthy, wild cottontails. They interpreted this as evidence that cottontail rabbits do not survive tularemia. Death usually comes within one week after contraction of the disease.

Tularemia also occurs in human populations. In 1939, 2,291 cases were reported in the United States. By 1967 this number had declined to 184 cases (Young and Sherman, 1969). Kansas reported 111 cases between 1960 and 1968 (Brooks and Buchanan, 1970). Jellison and Parker (1945) reported that in North America, cottontail rabbits, and in particular *S. floridanus*, are the direct source of over 70 % of all human cases of tularemia. McDaniels (1931) stated that in Illinois, which had reported twice as many cases of human tularemia as any other state, 98.3 % of the cases were due to handling infected rabbits. However, Green (1942) stated that the most common mode of infection was the bite of the American dog tick (*Dermacentor variabilis*) and the second most common was the cleaning of an infected rabbit.

According to Green (1942) the first symptoms of human tularemia are general, simulating an attack of influenza.

Also during the early days, a sore develops at the point of inoculation. The sore and a fever may persist for several weeks, usually accompanied by enlarged lymph nodes.

The impact of tularemia on rabbit populations is not fully understood. Cottontail population studies have suggested that pronounced year to year fluctuations do occur (Fitch, 1947; Bailey, 1968b; Preno and Labisky, 1971). Bailey reviewed population density statistics for cottontails in the Midwest and found indications of regular, synchronized highs and lows in cottontail populations; periods of peak abundance were recorded at intervals of eight to nine years. Numerous studies have employed various methods to determine the role of tularemia as a controlling factor in rabbit populations (McCahan et al., 1962; McGinnes, 1964; Jacobson, 1975).

McCahan et al. (1962) reported that an observed steady decline in rabbit activity on an estate in South Carolina occurred simultaneously with an epizootic of tularemia. This mortality was first noticed in October and November of 1961 when dogs began bringing in as many as five dead rabbits in a single day. At two Virginia military bases, cottontail population indices were recorded from 1956 to 1974 (Jacobson, 1975). These data revealed an abrupt decline in numbers in 1961. Tularemia was found in rabbits trapped during the decline. Further investigation of the area led Jacobson to conclude that tularemia was a factor in the 1961 population decline and may have continued as the primary limiting factor of the population.

That tularemia has the capability for effective population control has been demonstrated. In a 10.9 acre enclosure in Virginia, McGinnes (1964) found that 47 % of 60 native rabbits stocked in the pen, died of tularemia within one year. Action of the disease was rapid; in October 1956, 20 rabbits were stocked and one month later 10 had died.

The complexity of population controls makes it extremely difficult to assess the role of one factor. Fitch (1947) noted on one trapping area that the population had obviously undergone sharp reductions, but with no apparent cause. He found no dead or diseased rabbit on the area. Sadler (1969) investigated reported "dieoffs" and found dead rabbits had been suffering from high adrenal hormone output, often accompanied by stomach ulcers. He consistently found the cause of death to be the adrenal-ulcer pattern rather than death from disease.

Tularemia is definitely a factor in the ecology of the cottontail rabbit on the RNHR study area. The fact that 19 confirmed cases were discovered in 33 months of study warrants notice (Table XIV). At this point probably the most realistic assessment of tularemia is that of

Yeatter and Thompson (1952):

> "At times, tularemia may be a factor that contributes to the decline of rabbit numbers following population peaks. Local tularemia outbreaks that were the apparent cause of reduction of cottontail populations from high to low levels have been reported by Waller (1940) and Hendrickson (1943) in Iowa, Hicks (1942) in Ohio, and others. It seems safe to assume, however, that tularemia is but one of numerous factors that contribute to population control among cottontails."

The remaining case of disease related mortality (no. 103) was due to pneumonia (Table IX). This adult female rabbit was located with a radio-receiver on 14 December 1976. Since there was no evidence of predation, the carcass was sent to the Kansas State University laboratory for diagnosis, a routine procedure. The laboratory reported that the rabbit was negative for tularemia, but had lesions of pneumonia (Howard, pers. comm.). This was the first case of pneumonia recorded for the study area.

Three dead rabbits from McPherson County, Kansas, were submitted to the Kansas State University laboratory on 11 January 1977. Two of these were diagnosed as pneumonia. One additional rabbit, collection data unknown, was found by the lab to have pneumonia (Howard, pers. comm.).

Miscellaneous Mortality: Of the five mortalities not previously discussed, one (no. 96), was discovered to have a ruptured liver (Table IX). This adult female was active when trapped and appeared to be in good condition. She died in the laboratory approximately 10 minutes after being removed from the trap. The laboratory at Kansas State University found no disease, and diagnosed the cause of death as a ruptured liver (Howard, pers. comm.).

The four remaining mortalities were classified as having an unknown cause (Table IX). This represents 12.5 % of total deaths (Table XIII). As mentioned in the discussion of tularemia deaths, numbers 76, 91, and 104 were possibly caused by tularemia. These specimens were largely decomposed when found, but the remains were intact.

In the case of mortality number 105, the cause of death was still unknown even after laboratory examination (Table IX). This adult male was alive when located with a radio-receiver. When approached the rabbit moved about three yards and stopped under a cedar tree. He then allowed the researcher to capture him by hand, and subsequently died in the laboratory. This animal exhibited behavior indicative of tularemia. Green (1942) described tularemic cottontails as behaving oddly, appearing tame or in a stupor, and easily captured. The carcass of this rabbit was transported to the laboratory at Kansas State University for diagnosis. The report was negative for tularemia and the histopathology was negative. A small amount of staph infection was found, but the cause of death was not determined (Howard, pers. comm.). Therefore this rabbit remains a case of unknown mortality.

A summary of all known mortality which occurred on the study area from 1 August 1974 to 1 May 1977 appears in Table XIV. Detailed accounts of individual cases of mortality which are not presented in this report may be found in Watt (1975) and Gress (1976).

Condition Index

Bailey (1968a) devised a method for computation of a condition index in order to evaluate the physical condition of cottontails. This index is based on measurements of the rabbit's weight and length, and is a tool for evaluating differences in weights of cottontails collected at different times of year, from different habitats, and of cottontails experiencing various levels of parasitism or other stress. It reflects interactions of many genotypic, phenotypic, and environmental factors (Bailey, 1968a). In this study the condition index was used in an attempt to evaluate the monthly physical condition of rabbits on the study area.

As suggested by Bailey (1968a), female cottontails weighing more than 950 grams during the months of May through August were excluded in an attempt to minimize distortion due to pregnancy. Also excluded were those rabbits captured more than once during a 10-day period. Bailey (1968a) and Fitch (1947) found that rabbits captured more than once in a 10-day period had lost weight between successive captures.

Table XV shows monthly mean condition indices for 122 cottontails captured between 1 May 1976 and 1 May 1977. The mean condition index for the 122 rabbits was 5.60. An index greater than 5.60 indicates that an individual animal is heavier than average for its length class. An index below 5.60 indicates a below average condition. Gress (1976) found a mean condition index of 5.63 for 182 rabbits (Table XVI). Using the Student *t* test at the $p = .05$ level of significance, it was found that there was no significant difference between the mean condition indices for rabbits on the study area during the past two years.

Condition indices were calculated for 71 females and 51 males. The mean condition index for 71 females was 5.56, whereas the index for 51 males was 5.66. Using the Student *t* test at the $p = .05$ level of significance, it was found that there was no significant difference between the indices of males and females. Gress (1976) also found that there was no significant difference between the indices of males and females.

As shown in Table XV, the months of October and November had values equal to the overall mean condition index of 5.60. Six months, July, September, December, January, February, and March all had values greater than

Table XV. Monthly mean condition indices for cottontails captured during the period 1 May 1976 to 1 May 1977.

Month	Sample Size	Mean Condition Index
May	5	4.98
June	6	5.39
July	10	5.61
August	5	5.10
September	13	5.91
October	32	5.60
November	36	5.60
December	8	5.82
January	3	5.78
February	3	5.68
March	1	5.81
April	-	----
Total	122	x = 5.60

Table XVI. Monthly mean condition indices for cottontails captured during the period 1 June 1975 to 1 May 1976 (after Gress, 1976).

Month	Sample Size	Mean Condition Index
June	5	6.03
July	10	6.22
August	10	5.50
September	34	5.54
October	49	5.57
November	39	5.61
December	14	5.60
January	11	5.80
February	6	5.55
March	3	5.52
April	1	5.59
Total	182	$\bar{x}$ = 5.63

the overall mean. Only three months, May, June, and August had indices lower than 5.60. Gress (1976) found that three months, June, July, and January had values greater than the overall mean condition index of 5.63 (Table XVI). He found that the remaining eight months had indices slightly lower than 5.63. Because this index reflects complex interactions among many factors (Bailey, 1968a), it is not possible to determine which factors or combination of factors were responsible for these differences in monthly indices for the two years.

The month of September had the peak mean condition index with a value of 5.91, while the lowest value of 4.98 occurred in May (Table XV). Using the Student $\underline{t}$ test at the $p = .05$ level of significance, it was found that there was a significant difference in condition indices for the successive months of July and August. There was no significant difference in any other two successive months. Likewise, Gress (1976) found no significant difference between any two successive months, except for the months of July and August. In both years the significant difference between July and August mean condition indices was a drop from July to August, even though the September peak and May low found in this study did not correspond with the July peak and August low reported by Gress (1976) (Tables XV and XVI).

Gress (1976) stated that the August drop probably represented a return to an average condition and was not a drop to a critically low value due to some adverse factor. The monthly condition indices calculated in this study seem to support this opinion (Table XV).

Roadside Survey

Various studies by Voris (1956), Newman (1959), Lord (1961), Kline (1965), and others have employed roadside surveys to census cottontail rabbits. Roadside survey data have been used to determine relative abundance and distribution of rabbits, and have also served as a basis for speculation with regard to population fluctuations (Dahl, 1954; Lord, 1963; Collins, 1967). On 1 June 1975, a daily roadside survey was initiated in conjunction with the radio-telemetry rabbit project. Table XVII shows monthly roadside survey results from 1 June 1975 to 1 May 1977, and incorporates the first 11 months of the survey as reported by Gress (1976).

In 23 months of the survey, a total of 1,575 cottontails was sighted in 7,351 miles traveled. This was a rate of 21.4 rabbits per 100 miles. In the first 11 months reported by Gress (1976), a total of 465 rabbits was sighted in 3,267 miles, a rate of 14.2 rabbits per 100 miles. During the last 12 months of the survey, 1,110 rabbits were sighted in 4,084

Table XVII. Monthly summary of roadside survey for the period 1 June 1975 to 1 May 1977.

Month	Miles Traveled	Rabbits Sighted	Rabbits/ 100 Miles
June 1975	241	101	41.9
July	345	219	63.5
August	355	89	25.1
September	343	6	1.8
October	297	4	1.4
November	298	7	2.3
December	241	3	1.2
January 1976	298	13	4.4
February	287	1	0.3
March	253	4	1.6
April	309	18	5.8
May	364	25	6.9
June	349	340	97.4
July	379	475	125.3
August	337	193	57.3
September	303	20	6.6
October	349	16	4.6
November	362	6	1.7
December	326	5	1.5

Table XVII. Continued

Month	Miles Traveled	Rabbits Sighted	Rabbits/ 100 Miles
January 1977	325	9	2.8
February	326	2	0.6
March	350	9	2.6
April	314	10	3.2
Total	7,351	1,575	$\bar{x}$ = 21.4

miles, a rate of 27.2 rabbits per 100 miles. Using the Student *t* test at the p = .05 level of significance, it was found that there was a significant difference in total rabbits sighted for the two time periods. More rabbits (475) were sighted in July 1976, than the total of 465 that were sighted in the 11 months from June 1975 through April 1976.

In both 1975 and 1976, greatest roadside activity occurred in June, July, and August, with peak activity occurring in July. Using the Student *t* test at the p = .05 level of significance, it was found that there was a significant difference between the 1975 and 1976 rabbit sightings per 100 miles, for the months of June, July, and August. Roadside activity was significantly greater for these three months during the 1976-77 phase. Voris (1956) and Kline (1965) also reported peak activity in July.

Kline (1965) reported lowest activity in September and October. After 23 months of the present study it was found that little roadside activity was observed from September to April (Table XVII), at least during those hours of the day during which this survey was conducted.

As part of the roadside survey, the number of dead rabbits on the road was recorded. A summary of roadside mortality for the period 1 June 1975 to 1 May 1977 is given in Table XVIII. A total of 68 mortalities was recorded for

Table XVIII. Monthly summary of road killed cottontails for the period 1 June 1975 to 1 May 1977.

Month	Miles Traveled	Road Kills	Road Kills/ 100 miles
June 1975	241	1	.41
July	345	2	.57
August	355	2	.56
September	343	2	.58
October	297	1	.34
November	298	7	2.34
December	241	3	1.25
January 1976	298	5	1.68
February	287	-	----
March	253	2	.79
April	309	5	1.62
May	364	3	.82
June	349	3	.86
July	379	1	.26
August	337	5	1.48
September	303	2	.66
October	349	7	2.01
November	362	6	1.66
December	326	3	.92

Table XVIII. Monthly summary of road killed cottontails for the period 1 June 1975 to 1 May 1977.

Month	Miles Traveled	Road Kills	Road Kills/ 100 miles
January 1977	325	1	.31
February	326	2	.61
March	350	2	.57
April	314	3	.96
Total	7,351	68	$\bar{x}$ = .93

the 7,351 miles traveled, a rate of .93 road kills per 100 miles. In the first 11 months of the study, Gress (1976) reported a total of 30 mortalities for 3,267 miles traveled, a rate of .92 road kills per 100 miles. For the last 12 months of the study there was a total of 38 mortalities for 4,084 miles traveled, a rate of .93 road kills per 100 miles. Using the Student *t* test at the $p = .05$ level of significance, it was found that there was no significant difference between the overall rates of road killed cottontails for the two time periods. In 1975, peak mortality of 2.34 road kills per 100 miles traveled occurred in November. In 1976, the peak mortality of 2.01 occurred in October (Table XVIII).

Obviously, a census of this type reflects changing activity patterns of cottontails. Numerous efforts have been made to determine ideal conditions for roadside surveys by considering time of day, weather factors, and seasonal variations as they influence rabbit activity. Lord (1961) found that for eight months of the year (September through April), more rabbits were seen per mile during spotlight censuses than during early morning censuses. This could explain why the early morning censuses of this study showed little activity from September to April. Lord (1961) felt that an increase in morning sightings during summer months indicated a change in daily activity patterns for these months.

Weather can impair reliability of the roadside census by temporarily curtailing or increasing rabbit activity (Wight, 1959; Alkon, 1965; Payne and Provost, 1967). Alkon (1969) determined that the type of road also affects roadside surveys.

The present study did not involve rigid time schedules, and no attempt was made to correlate weather conditions with these data. However, this study did provide evidence of general trends in activity which seems to be supported by the results of previous research.

Conclusions and Recommendations

The cottontail rabbit was trapped less frequently during the past year, 1 May 1976 to 1 May 1977, than in the previous year, 1 May 1975 to 1 May 1976, even though trapping procedure was the same for both years. Fewer rabbit mortalities were observed on the study area during the 1976-77 phase of the project than during the 1975-76 phase. There are several possible explanations for a decrease in observed rabbit activity during the most recent year of the study.

It may be that fewer rabbits were trapped because fewer rabbits were present on the study area. Weather conditions could have influenced trap response, helping to produce the discrepancy between the two years. It has been established that there are differences in trappability of individuals relating to such factors as age and sex of the animal. If for some reason the age or sex structure of the populations was different from one year to the next, this might account for some of the difference in trap success for the two one-year periods.

Fewer animals were outfitted with radio transmitters in 1976-77 than in 1975-76, which could account, in part, for the fact that fewer dead rabbits were discovered in 1976-77. From one to three dogs were used throughout the 12-month period to search for dead rabbits in 1975-76. The present study used one dog for five months, but not for the other seven months. During the 1975-76 phase of the project two or three researchers walked the trapping route most of the time; occasionally only one observer was present on the study area. Throughout the present study a maximum of two researchers made the daily rounds and much of the time only one observer was present resulting in less opportunity for finding dead rabbits by personal observation.

A combination of the above factors may partially account for the decrease in observed rabbit activity on the study area during the most recent year of the project.

In 33 months of monitoring mortality on the study area, predation accounted for 42.9 % of total observed deaths, which does not seem to represent excessive predation. The other major cause of naturally occurring death was tularemia, which accounted for 18.1 % of total observed deaths since 1974. While predation and tularemia are definitely controlling factors in this rabbit population, it is not felt that they produced an obvious decline in rabbit numbers during fall months.

Wire traps were ineffective for trapping rabbits during winter months. No rabbits were captured in wire traps from 28 October 1976 to 24 February 1977. Therefore, as a suggestion for future trapping efforts it is felt that wire traps could be removed from the study area for the months of November, December, and January.

The number of rabbits outfitted with radio transmitters was limited by the number of batteries available during the fall and winter of 1976-77. Even though transmitters were available, approximately 20 rabbits were not collared because of a battery shortage. Some of the batteries which were used did not seem to function properly. A reduction in battery failure could enhance the ability of researchers to recover transmitters. If the difficulty in obtaining "fresh" batteries could be overcome, both time and equipment could be more efficiently utilized.

SUMMARY

1. A radio-telemetry study of cottontail rabbit mortality was conducted on approximately 100 acres of Ross Natural History Reservation in Lyon County, Kansas. Equipment was provided by the Kansas Forestry, Fish and Game Commission, and additional financial support was provided by the Division of Biological Sciences of Emporia State University. Data were gathered from 1 August 1974 to 1 May 1977.

2. Ninety-three different rabbits were trapped a total of 157 times during the 12-month period from 1 May 1976 to 1 May 1977. Trapping success was greatest in the fall months, peaking in October and November. Of 274 different cottontails captured since August 1974, 150 were females and 124 were males. This was a sex ratio of 1:1.21 in favor of females.

3. A population estimate of 259 cottontails in July was calculated as the peak population for the 100 acre study area. This was a population density of 2.59 rabbits per acre.

4. Sixty-six different transmitters were placed on 89 different rabbits a total of 107 times during the period 1 August 1974 to 1 May 1977. Of the 66 transmitters used, 29 were recovered and kept for future use and 37 were not recovered.

5. In 33 months of monitoring mortality, 105 cottontail mortalities were discovered. Of the total deaths 30 % were males and 32 % were females; sex could not be determined in the remaining 38 % of the cases. Of the 105 dead rabbits 37 were wearing a functioning radio-transmitter at the time of death. Sixty dead rabbits were discovered by personal observation and the remaining eight were discovered by dogs.

6. The peak population estimate of 259 rabbits was assigned to July, which corresponds with the peak number of 31.1 calculated deaths. An estimated 215 deaths occurred during the 12-month period 1 March 1976 to 1 March 1977. This represents 83.0 % of the total estimated population of 259. It is estimated that 16.2 % of the total mortalities were discovered.

7. In 33 months of this study 20 deaths were classified as research mortalities. This represents 19.0 % of the total mortality.

8. Predation accounted for 45 cases, 42.9 %, of total known mortality. Mammalian predators were responsible for 76 % of these while 22 % were due to avian predators. The remaining 2 % were the result of unknown predators. It is felt that cottontail predation was not excessive.

9. Nineteen cases of cottontail mortality were attributed to tularemia, representing 18.1 % of total

deaths. Since August 1974 tularemia has been recorded for the months of September, October, November, December, May, July, and August. The peak number of tularemia deaths for a single month occurred in October 1976, when seven cases were recorded. Based on these data it is felt that tularemia is not producing an abnormal fall decline in rabbit numbers. However, additional data are necessary to better understand the role of tularemia in controlling this rabbit population.

10. Thirteen mortalities were classified as having an unknown cause of death. It is possible that 11 of these were due to tularemia.

11. In one case of cottontail mortality the cause of death was determined to be pneumonia.

12. Condition indices were calculated for 122 cottontails captured during the period 1 May 1976 to 1 May 1977. The mean condition index was 5.60. There was no significant difference between the indices of males and females.

13. A daily roadside survey was conducted from 1 June 1975 to 1 May 1977. A total of 1,575 cottontails was sighted in 7,351 miles traveled, a rate of 21.4 rabbits per 100 miles. Peak roadside activity occurred in July of both years.

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APPENDIX A

Map of Study Area

Used

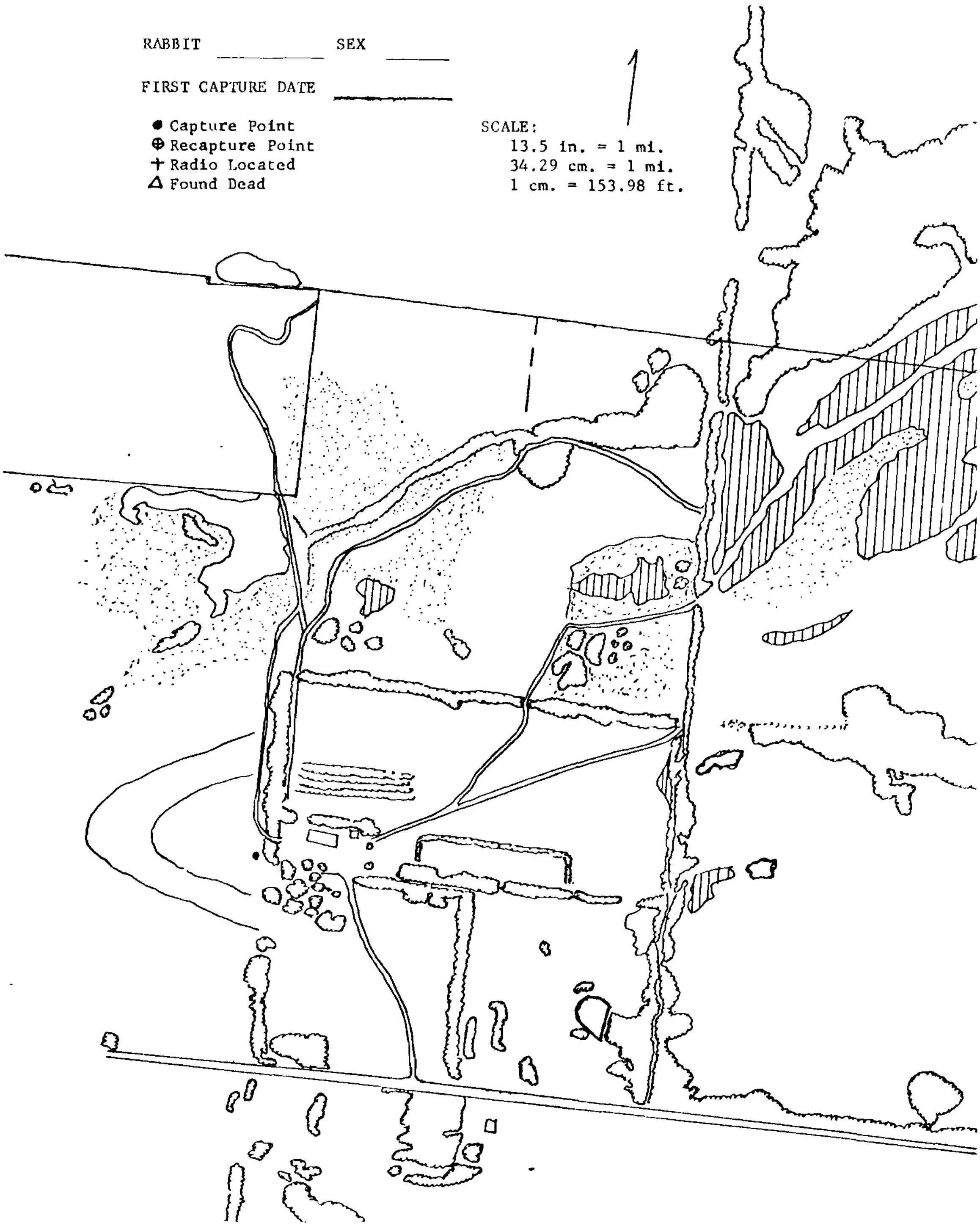
For Recording Locational Data Points

RABBIT ____________ SEX ________

FIRST CAPTURE DATE ____________

● Capture Point
⊕ Recapture Point
+ Radio Located
△ Found Dead

SCALE:
13.5 in. = 1 mi.
34.29 cm. = 1 mi.
1 cm. = 153.98 ft.



APPENDIX B

Rabbit Data Form

Used

For Recording Capture Data

______ SEX ____ DATE __________ B W

TRAP LOCATION ______________________________

WT. ________g. LENGTH ________cm. HIND FOOT ________mm.

REMARKS ______________________________

____

RECAPTURED __________ B W

TRAP LOCATION ______________________________

WT. ________g. LENGTH ________cm. HIND FOOT ________mm.

REMARKS ______________________________

____

RECAPTURED __________ B W

TRAP LOCATION ______________________________

WT. ________g. LENGTH ________cm. HIND FOOT ________mm.

REMARKS ______________________________

____

RECAPTURED __________ B W

TRAP LOCATION ______________________________

WT. ________g. LENGTH ________cm. HIND FOOT ________mm.

REMARKS ______________________________

____

MORTALITY DATE FOUND __________

LOCATION ______________________________

REMARKS ______________________________

____

____

APPENDIX C

Roadside Observation

Data Sheet

ROADSIDE OBSERVATION DATA SHEETS

ROUTE #1: ●●●●●● ROUTE #2: ▬ ▬ ▬

DATE:

TIME LEFT:

OBSERVERS:

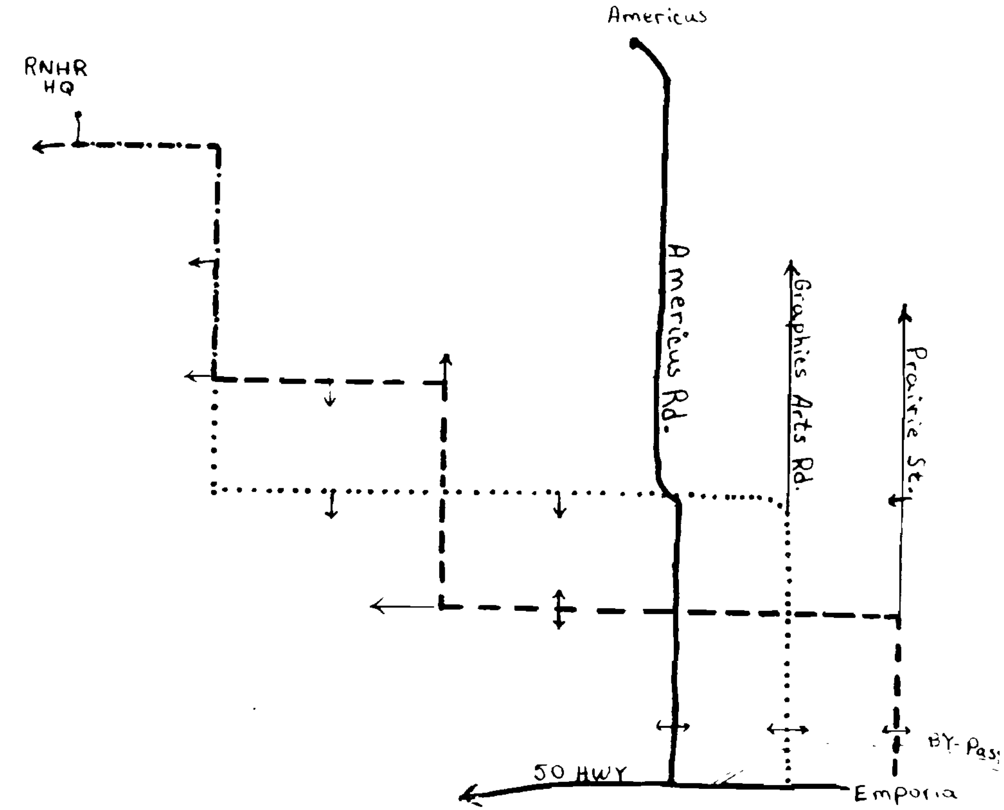
WEATHER CONDITIONS: TEMP.: PRECP.:

RABBIT SIGHTING=1

COYOTE SIGHTING=2

DEER SIGHTING=3

COMMENTS:



APPENDIX D

Modified Life Table

For

Cottontail Rabbits

Modified Life Table for Cottontail Rabbits (from Lord, 1961)

Month	Alive at Beginning of Month: Adults	Alive at Beginning of Month: Juveniles 0-4	Alive at Beginning of Month: Juveniles 4+	AT END OF MONTH: No. of Births by Adults	No. of Births by Juveniles	Total Increment	Deaths: Adult	Deaths: Juvenile 0-4	Deaths: Juvenile 4+	No. of rabbits alive
March-A	1000			2928		2928	154	545		3229
April	846	2383		1805		1805	138	881		4015
May	708	3307		1804		1801	115	1215		4486
June	593	3893		1004	104	1108	91	1423		4080
July	502	1024	2554	694	231	925	89	1050	278	3588
August	413	899	2276	564	335	899	76	881	244	3286
September	337	917	2032	248	278	526	54	643	236	2879
October	283	800	1796				36	436	219	2188
November	247	364	1577				50	265	197	1676
December	197	98	1380				36	98	186	1355
January	161		1194				20		160	1175
February	141		1034				23		152	1000
March-B	118		822							