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Mortality and Population Density of Cottontail Rabbits at Ross Natural Reservation, Lyon County, Kansas

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Rhonda J. Baker, Robert J. Gress, and Dwight L. Spencer*

ABSTRACT

A radio-telemetry study of cottontail rabbit mortality was conducted on approximately 100 acres of Ross Natural History Reservation (RNHR) 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 completed. 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 85 males : 100 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. One cottontail death was attributed to 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 condition 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.

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INTRODUCTION

The cottontail rabbit, *Sylvilagus floridanus* (J. A. Allen), is important as a major food source for many vertebrate predators and 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). In Kansas, during the years 1964-73, an average of 62,300 hunters harvested approximately 475,000 rabbits per season. An average daily bag of about two rabbits and a season harvest of at least eight rabbits per hunter is necessary to satisfy Kansas hunter demand. From 1969 through 1976, the average daily bag was less than two rabbits per hunter, and an increasing number of hunters expressed alarm about a decline in the cottontail rabbit population in Kansas (Peabody, per. comm.).

In 1974, the Kansas Fish and Game Commission contracted personnel of the Division of Biological Sciences at Emporia State University to conduct a radio-telemetry study of certain aspects of the ecology of the cottontail rabbit which could be used to improve rabbit management. A second objective of the project was to verify whether the rabbit population had actually experienced a decline.

Reduced observability and harvest of rabbits resulting from changes in behavior and habitat usage patterns might be interpreted as a population decline when, in reality, none had occurred (Sheffer 1972).

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, technological 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). 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, and Mech (1967) and Trent and Rongstad (1974) 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 body 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).

This report summarizes data on mortality and population density of the cottontail rabbit observed on the Ross Natural History Reservation during the final year of a three year study and compares results between the second and third years. Hartman (1960), Wilson (1963) and Spencer (1981) have provided detailed descriptions of the study area.

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 rabbits runs, and approximately 80 conventional wooden box traps, described by Forsythe (1974), were placed in areas considered to be good rabbit habitat, usually along boundaries between cover and open areas. Both types of traps were left unbaited because Gress (1976) reported no noticeable increase in catch in baited traps during an experimental baiting program conducted during the second year of the project. 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 and 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; sex, weight, trap type, and physical condition were also recorded.

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) who found that coyotes did not ingest collars when eating collared rabbits. Plastic collars were more conspicuous than ear tags, and were not ingested while ear tags may be ingested; use of collars improved chances of positive identification of a victim in case of coyote predation.

Depending on transmitter and battery availability and the number of rabbits already transmitting, rabbits weighing 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 that described by Clark (1976), except we used aquarium cement instead of dental acrylic resin to waterproof transmitter leads and battery terminals. The aquarium cement could be removed from the transmitter package with less danger of damaging equipment than was the case for resin.

After being subjected to the above procedures, rabbits were returned to the capture site and released. For animals outfitted with transmitters, the channel number, transmitter number, and capture points of each rabbit were recorded on separate maps of the study area, and daily resting locations of each rabbit 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 was conducted until the carcass was found. This was the major method of monitoring mortality.

2) For the first five months of the study a beagle dog accompanied researchers on the daily trapping route. The 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, 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. Monthly population estimates were then 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 cottontails was conducted in addition to 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. Date, route followed, time, weather conditions, and persons conducting the survey were recorded. When rabbits were sighted, 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.

Table 1. 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. Opossum; 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
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
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

RESULTS AND DISCUSSION

Trapping Results

Trapping was conducted from 5 August 1974 to 1 May 1977, and trapping results from the first segment of the study, 5 August 1974 to 20 May 1975, were reported by Watt (1975). Table 1 compares trapping for the last two years of the project, 1 May 1975 to 1 May 1977. Vertebrate species trapped were: 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 cardinalis)*, field sparrow *(Spizella pusilla)*, Harris sparrow *(Zonotrichia querula)*, and ornate box turtle *(Terrapene ornata)*.

The total number of animals captured during the 1975-76 phase was 801; for the 1976-77 period the total was 517 animals (Table 1), which 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 it was second in frequency of capture only to the eastern wood rat. Wood rats represented 36% of all animals trapped. During 1975-1976 the cottontail was the most frequently trapped species, representing 38% of all animals trapped.

Trapping records for cottontail rabbits for the period 1 May 1976 to 1 May 1977 showed 157 rabbits captured during 33,485 trap nights compared to 304 captures in 31,064 trap nights during the preceding year of the project (Table 2). There was a significant difference between the total numbers of rabbits captured, and no significant difference between the total number of trap nights for the two periods.

During both years trapping success was greatest in the fall months, peaking in October and November. Watt (1975) also reported an October peak in trapping success during the first year of the project. However, he also found a secondary peak occurring in February and March which was not apparent during either the 1975-76 or 1976-77 segments of the study. Racey (per comm.), while 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, and Bailey (1969) found trap success peaks occurring in October, November, and December in Illinois.

Table 2 shows that during the 1976-77 year, the lowest number of captures per trap night occurred in 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. March captures were also extremely low with 0.03 captures per 100 trap nights; 1975-76 results were similarly low in winter and spring, with the lowest catch per trap night occurring in March. Bailey (1969) proposed that his observed decline in trapping success during March in Illinois was due, in part, to a decline in rabbit trappability.

Table 2. Comparison of trapping success for the cottontail rabbit on Ross Natural History Reservation during 1975-76 and 1976-77. C/100 equals captures per 100 trap nights.

Month	Trap Nights		Total Captures		Recaptures		C/100	
	75-76	76-77	75-76	76-77	75-76	76-77	75-76	76-77
May	1,153	3,001	4	6	3	1	0.35	0.20
June	1,879	2,908	5	7	1	3	0.27	0.24
July	2,134	2,992	10	11	1	3	0.47	0.37
August	2,292	2,986	14	7	1	1	0.61	0.23
September	2,393	2,882	62	15	31	2	2.63	0.52
October	3,010	3,005	100	48	56	22	3.36	1.60
November	3,503	2,910	65	44	45	19	1.83	1.51
December	2,874	2,595	16	10	10	9	0.56	0.39
January	3,238	2,125	14	5	10	3	0.43	0.24
February	2,987	2,685	7	3	6	0	0.23	0.11
March	2,874	3,006	3	1	3	1	0.10	0.03
April	2,727	2,390	4	0	3	0	0.15	0.00
Total	31,064	33,485	304	157	170	64	$\bar{X}$ = .98	0.47

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) while studying trap response in relation to weather conditions, found 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), worked with snowshoe hares and 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 or become dormant. If this is so, then weather conditions associated with an early or late fall might affect seasonal trap response.

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

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 hypothesis has been studied to the extent that Hilborn et al. (1976), working with voles, devised a method to measure trappability of any individual known to be a member of the population.

Chitty and Kempson (1949) and Tanaka (1956) 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 population percentage in this age group would be high during 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. Of 187 cottontails captured on the RNHR between 1974 and 1976: 86 were males and 101 were females, yielding a sex ratio of 85 : 100. During the third year of this study 92 new rabbits were captured, 87 of known sex (five escapes were not sexed), so that a total of 274 cottontails was captured during the duration of this project of which 124 were males and 150 were females, a sex ratio of 83 : 100. These 274 rabbits were captured a total of 571 times (Table 3), and frequency of capture varied 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

wire traps and several of these animals did not survive. Wire traps were a particular problem during and following snow and ice storms. In January, wire traps were often frozen shut and filled with snow. It is suggested that wire traps should not be used at this latitude during November, December, and January.

Table 3. 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

Estimating Population Standing Crop

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 variation in trap response. Because the population goes through an annual cycle, due to seasonal breeding, data collected over short periods are unsuitable for estimating population standing crops. Therefore, data collected over a one-year period should provide a more realistic estimate of population density.

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 estimate the study area cottontail population. One hundred different cottontails were trapped a total of 163 times during the 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 established for the 100 acre study area. If number of animals captured in a given time period

represents the minimum population for that period, then the minimum population of rabbits for the study area from 1 March 1976 to 1 March 1977 was 100 rabbits, an average density of one rabbit per acre.

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 was useful in estimating rabbit abundance from livetrapping data until more suitable methods were devised. Although the MLE estimate of 259 rabbits may be slightly high, it is 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; Eberhard et al. 1963; Bailey 1969). Younger juveniles, it was found, rarely enter traps (Eberhardt et al. 1963). This, along with trap results, indicated that nearly all rabbits trapped were at least four months of age. Lord (1961), after compiling 3.5 years of data on Illinois cottontails, 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.

Table 4. Life table for Cottontail rabbits in Illinois, from Lord (1961).

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

Monthly population estimates were calculated using a modified life table developed by Lord (1961). From the life table, the number of rabbits four months and older alive at the beginning of each month was determined (Table 4). It was assumed that the relative

proportion of rabbits alive at RNHR during any two successive months would be the same as the proportions exisiting between Lord's values. Starting with the MLE estimate of 259 rabbits in July, monthly population estimates for the cottontail rabbits on RNHR were calculated as follows:

Calculations of August population estimate

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

$$x = 228 \text{ rabbits}$$

Table 5. Monthly population estimates of rabbits, four months and older, and total number of captures for the period 1 March 1975 to 1 March 1976 and 1 March 1976 to 1 March 1977.

Month	Population Estimate		Total Captures	
	75-76	76-77	75-76	76-77
March	92	84	16	3
April	78	71	4	4
May	65	59	4	6
June	55	49	5	7
July	281	259	10	11
August	247	228	14	7
September	218	201	62	15
October	191	176	100	48
November	168	154	65	44
December	145	133	16	10
January	125	114	14	5
February	108	99	7	3

Table 5 compares monthly population estimates for the study area and total rabbits captured for the two years from 1 March 1975 to 1 March 1977. The rabbit population for 1975-76 ranged from 281 rabbits in July to 55 in June, while monthly populations for 1976-77 ranged from 259 to 49 rabbits. There were fewer total captures during 1976-77 than during the preceding year which was probably a reflection of the slightly smaller standing crop of rabbits that existed at that time.

If the 1976-77 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), it is assumed that more than 39% of the rabbits were marked. At least 53% of the total population on the study area was tagged in 1975-76. The difference (14%) between two consecutive years

on the same study area, indicates that something other than a slight difference in actual population was exerting an influence on trapping success. Although a decline in total captures would be expected from a decline in total population (Table 2), it seems that approximately the same per cent of the population should be captured. Trapping procedure was the same for both years, using approximately the same number of traps, in the same places, over the same period of time. Except for a few traps which were lost and a few replacements 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. Traps were not periodically relocated during either 1975-76 or 1976-77 but, it is not felt that this procedure accounted 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 trapping success. It was also established that there are differences in trappability of individuals relating to such factors as age and sex (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 trapping success between two one-year periods.

The actual cottontail population in the study area during 1976-77 probably fell between the minimum of 100 cottontails and the MLE estimate of 259. These estimates represent population densities between 1.00 and 2.59 rabbits per acre. Estimated population densities for the same area ranged from 1.49 and 2.81 rabbits per acre during 1975-76. 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 2.4 rabbits represents an optimal density then the 100 acre study area of RNHR may be considered excellent cottontail habitat.

Transmitter Performance

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. During 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 used, 29 were recovered and kept for future use and 37 were not recovered.

A collar recovered from a dead rabbit had the battery replaced before the collar was used on another rabbit; and when collared animals were recaptured with a battery that had operated at least eight weeks, the battery was replaced. Such procedures minimized transmitter loss due to 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), several animals were available for transmitter attachment. However, in the fall and winter of 1976-77, the number of instrumented rabbits was limited by the number of batteries available. A battery shortage occurred from the last half of October through the first half of February. The maximum number of functing transmitters in 1974 was nine in November (Watt 1975). In 1975-76, the peak occurred in September and October with 14 and 13 transmitters operating, respectively. In 1976, peak operation occurred in October (11 transmitters) and November (12 transmitters).

During the three years study, 89 different rabbits were outfitted with radio-transmitters. Forty-one (46%) of the 89 cottontails died with a collar attached, radio contact was lost with 39 (44%) rabbits, and nine (10%) had their collars removed by project personnel.

Mortality

Cottontail rabbit mortality was continuously monitored on the RNHR study area from 1 August 1974 to 1 May 1977. Mortality information was obtained from animals equipped with radio-transmitters and from 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 (Watt 1975); 52 deaths were discovered between 1 May 1975 and 1 May 1976; and between 1 May 1976 to 1 May 1977 an additional 32 rabbit deaths were discovered. Apparent causes of deaths were recorded, recognizing that identifying mortality factors in wildlife may involve a complex set of factors (Errington 1963; Davis 1970).

It was impossible to determine sex of 40 of 105 rabbit carcasses examined due to the extent of anatomical damage and decomposition. The remaining 65 cases of mortality consisted of 31 males and

34 females. Methods of discovery, sex, and most probable cause of death for 62 carcasses located during the course of this study were recorded and this information can be obtained from Baker (1977).

In many cases, rabbit remains were destroyed to the point that it was impossible to find collars or ear tags. No doubt some unmarked rabbits were, in fact, tagged rabbits. In 53 of the 105 mortality cases it was possible to determine that the animal had been previously marked.

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

During 33 months of monitoring cottontail mortality on the study area, recorded mortalities ranged from zero to 10 per month (Figure 2). From August 1974 through April 1975, average monthly mortality was 2.33 deaths per month (Watt 1975). Mortality averaged 4.33 deaths per month for the period May 1975 through April 1976. During the following year, May 1976 through April 1977, 32 additional dead rabbits were discovered, and observed mortality was 2.67 deaths per month.

Gress (1976) offered possible explanations for differences in mortality between the first and second year of the project. He noted more animals were captured during his phase of the study due to an increase in number of traps used. As a result, more animals were available for radio-transmitter attachment. Gress also used dogs to aid in discovery of dead rabbits, a procedure not employed by Watt. Gress hypothesized that either a tularemia epidemic or excessive predation could also account for the increased number of deaths observed during the second year of the project.

Fewer rabbits were trapped during 1976-77 than during 1975-76 (Table 2). Since fewer animals were captured, fewer were available for radio-transmitter attachment. A shortage of batteries which existed the last half of October through the first half of February caused a further reduction in the number of animals equipped with radio-transmitters during the final year of this project. Three dogs, singly or in combination, were used throughout the second year to search for dead rabbits, but only one dog was used for the first five months of the last year of the study. A combination of the above described factors may partially account for the decrease in observed mortality during the final 12 months of the project.

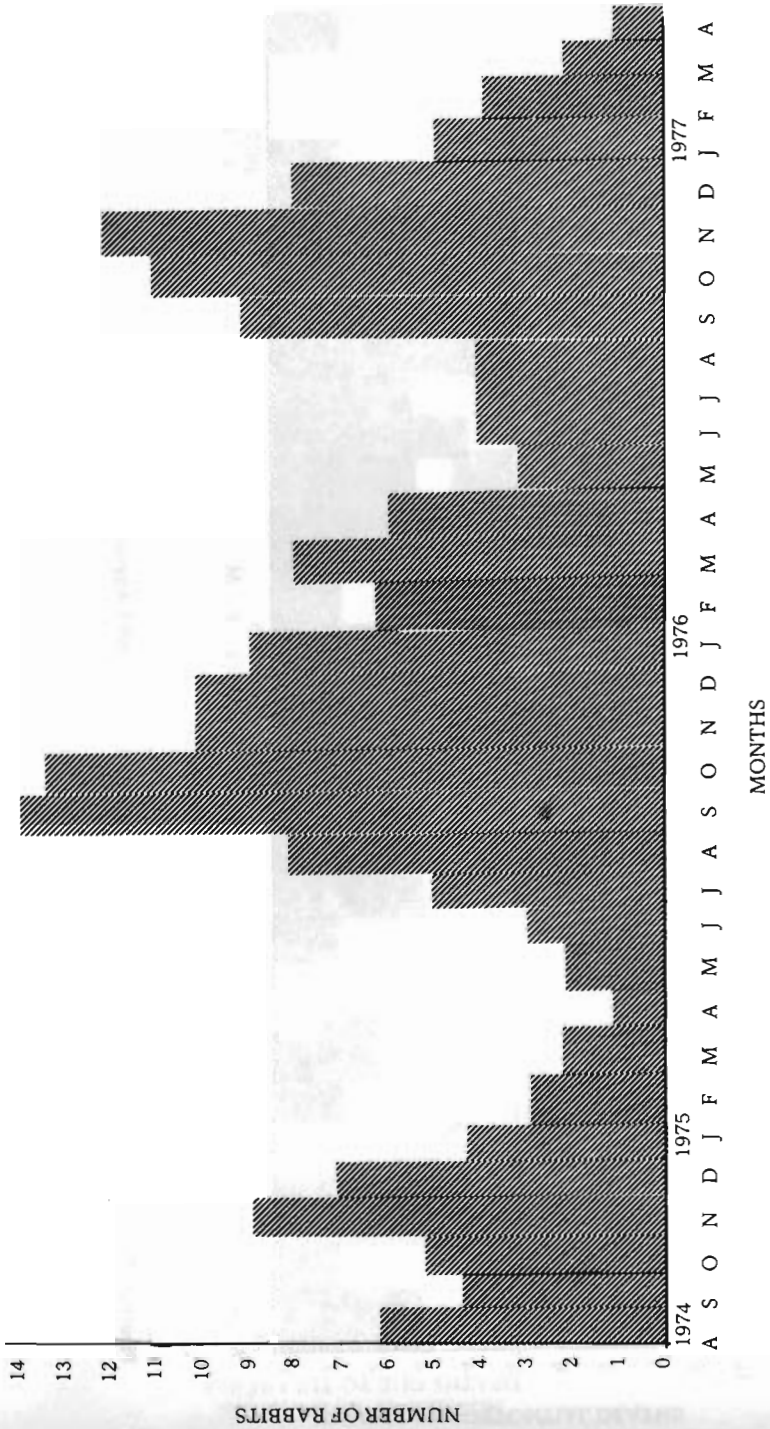

Figure 1. Total number of different rabbits equipped with functioning transmitters for at least one day during the month, for the period 1 August 1974 to 1 May 1977.

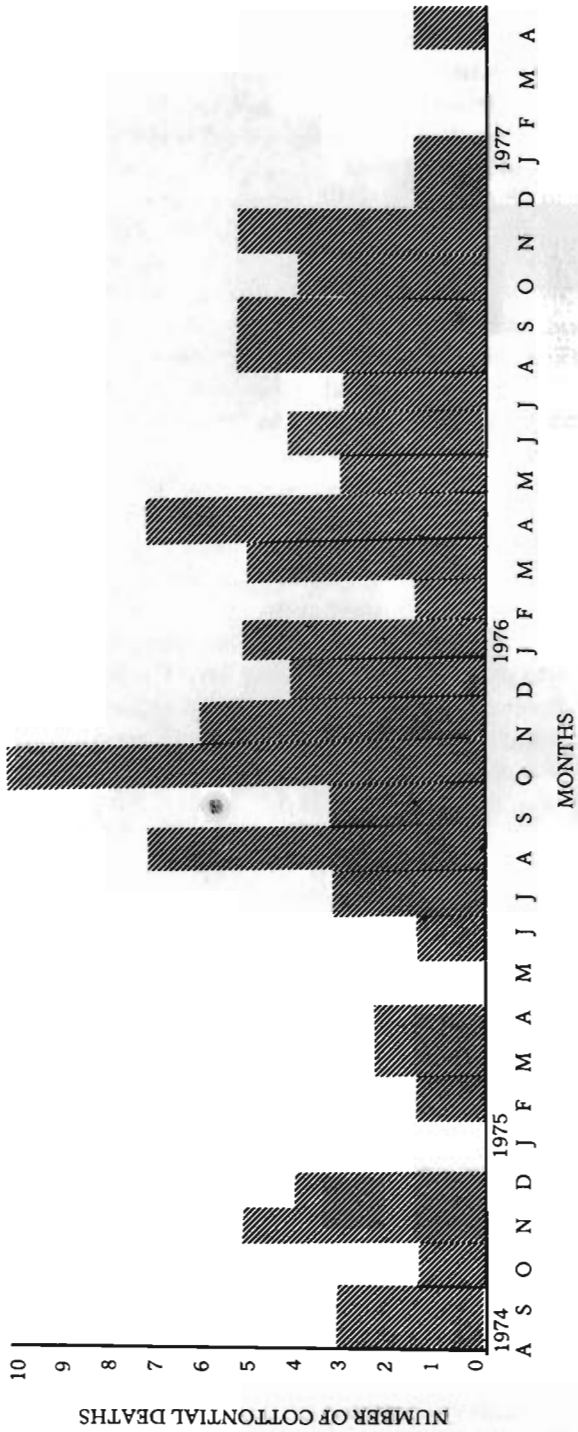

Figure 2. Total number of known cottontail deaths per month for the period 1 August 1974 to 1 May 1977.

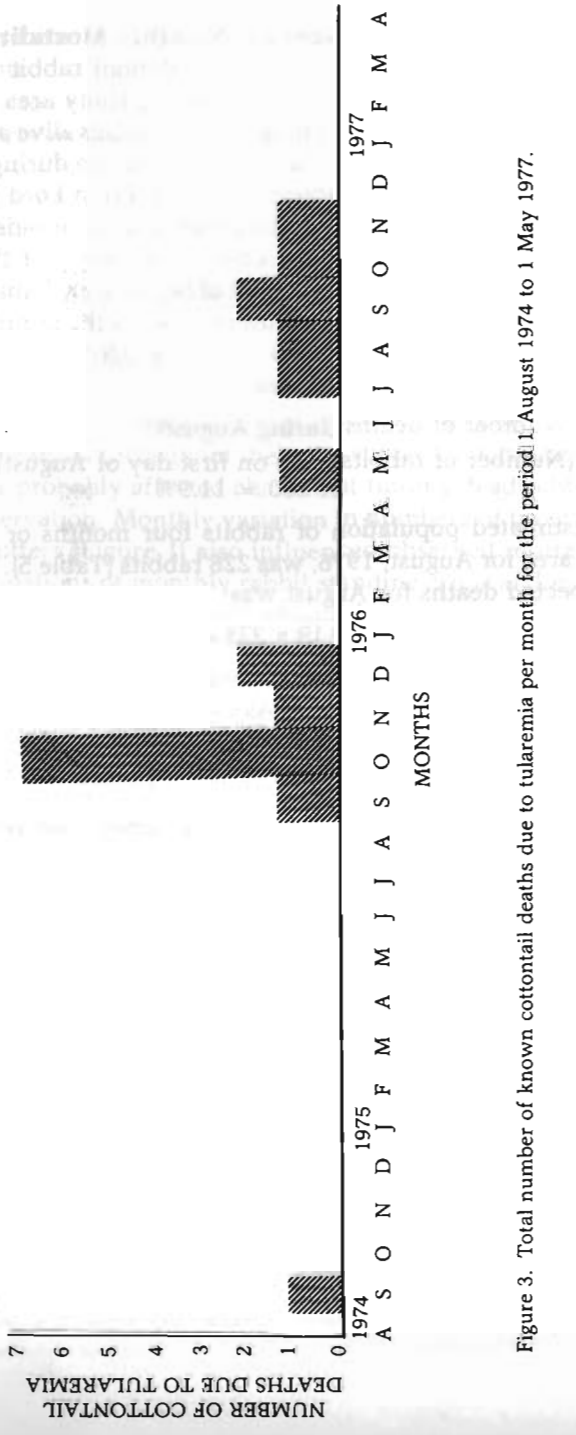

Figure 3. Total number of known cottontail deaths due to tularemia per month for the period 1 August 1974 to 1 May 1977.

Estimating Expected Monthly Mortality

Lord's (1961) life table for the cottontail rabbit was used to estimate monthly mortality values for the study area for 1 March 1976 to 1 March 1977. Percentage of individuals alive at the beginning of a given month which was expected to die during that month was determined in the following manner. From Lord (1961) it had been determined that 2689 rabbits four months or older were alive on the first day of August but only 2369 rabbits of the same age classification were alive on the first of September (Table 4). The difference between these two values represents the number of deaths occurring during August (2689 - 2369 = 320). Percentage of the August population that died was:

$$\frac{320 \text{ (Number of deaths during August)}}{2689 \text{ (Number of rabbits alive on first day of August)}} \times 100 = 11.9\%$$

The estimated population of rabbits four months or older in the study area for August, 1976, was 228 rabbits (Table 5). The number of expected deaths for August was:

$$.119 \times 228 = 27.1$$

This method was used to generate the expected monthly mortality values listed in Table 6. As can be seen, expected mortality was greatest during July when the estimated population of rabbits was greatest in the study area. Total expected mortality for this

Table 6. Expected monthly mortality, observed mortality, and percentage of expected deaths discovered for rabbits four months and older on RNHR.

	Expected Mortalities 1976	Number of Deaths Observed	Per Cent of Expected Deaths Discovered 1976*
March	12.9	5	38.8
April	11.6	5	43.1
May	9.6	2	20.1
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	15.1	1	6.6
February	14.1	0	0
Total	215.4	35	$\bar{X} = 16.2$

*Data from Gress (1976)

period, 215 rabbits, represented 83.0% of the estimated standing crop of rabbits in the study area.

Table 6 also compares monthly expected mortality to monthly observed mortality. Between 1 March 1976 and 1 March 1977, 35 known adult cottontail deaths were recorded. This represented only 16.2% of the 215 deaths expected for this period; 17% of the total estimated mortalities for the second year of the study were discovered. There was no significant difference between the per cent of total estimated mortalities discovered for the two one-year periods.

The number of discovered cottontail deaths fluctuated from month to month, (Figure 2), and no definite trend in mortality was apparent. Gress (1976) concluded that 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.

Our calculations of monthly rabbit standing crops and mortality were based on Lord (1961) and assumed that reproductive rates and mortality of Kansas and Illinois cottontails were identical. It re-

Table 7. Causes of cottontail mortality for the period 1 August 1974 to 1 May 1977.

Cause of Death	Number of Deaths Observed	Per Cent of Total Deaths Observed
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	**1**	**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

mains to be determined that such is actually the case, but this approach provides a useful method of generating values for study.

Causes of Rabbit Mortality

Table 7 summarizes causes of 105 rabbit deaths observed during the 33 months of this project. Predation, disease, and trapping were the major causes, accounting for approximately 80% of documented deaths.

The pattern and causes of rabbit deaths during the final year of the project, 1 May 1976 to 1 May 1977, are summarized in the following sections of this paper to represent conditions experienced throughout the 33 months of this project, since a description of the causes of all 105 cases of mortality would be excessive in length. Persons interested can obtain the additional information from the authors.

Table 8. Causes of cottontail mortality for the period 1 May 1976 to 1 May 1977.

Cause of Death	Number of 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

Research Related Deaths

During the final 12 months of the project five rabbit deaths were classified as trap mortalities, with all five deaths occurring in wire traps (Table 8). One trap mortality was an adult rabbit 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" was received from the lab, this rabbit was

designated a trap mortality. Another adult rabbit died in the trap with no sign of trap injury or predator interference. It was sent to the University of Missouri at Kansas City for diagnostic examination and was also found negative for disease. Three juvenile rabbits were victims of trap mortality due to predator interference. Raccoons were numerous on the study area, and because of their manual dexterity, it is highly probable that they were the trap raiders.

The sixth victim of research interference during 1976-77 was an adult rabbit equipped with a functioning radio-transmitter. This rabbit was pursued by a beagle which accompanied research personnel on their daily rounds. The dog chased the rabbit for about 40 minutes and eventually caught it. Remains of this rabbit were inadvertently discarded, so no lab report was available and death was attributed to research interference. However, the rabbit may have been weakened by disease since the beagle was usually unable to catch healthy adult rabbits.

Predation

Of the 32 cottontail deaths recorded in 1976-77, 13 were due to predation (Table 8). This represents 40.6% of total deaths and 50.0% of naturally occurring deaths.

In 33 months of monitoring mortality, predation accounted for 42.9% of 105 total deaths (Table 7). Other researchers (Mech 1967; Stoddart 1970; Trent and Rongstad 1974), after studying mortality with radio-telemetry systems found predation rates greater than that observed in this study. Stoddart reported that 84% of 25 jackrabbit deaths were due to predation. We believe that 42.9% of total observed deaths, actually 52.9% of the naturally occurring deaths, does not represent excessive predation on the RNHR study area.

Ten rabbit deaths, 76.9% of all predation, were attributed to mammalian predators (Table 8). Two cases, 15.4% of all predation, were avian. The remaining one case, 7.7%, was an unknown predator. Gress (1976) concluded that mammalian predators were responsible for 75% of all observed predation on the study area during 1975-76. The remaining 25% was due to avian predators.

Throughout the 33 months of this study, the maximum number of known deaths per month due to predation was four, which occurred in November, 1974, November, 1975, April, 1976, and November 1976. No predation was recorded on October, 1974; January, May, June, July, and September, 1975; May and

December, 1976; and January, February, March, and April, 1977.

Of the 10 cases of mammalian predation during 1976-77, four cases were classified as coyote (*Canis latrans*) kills. No coyote tracks or scat were observed at any of the kill sites, but 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." Stoddart found that coyotes consistently consume adult jackrabbits, leaving no trace of remains or leaving only the stomach.

Four more cases of predation were simply designated as mammalian predation, since they did not exactly conform to the above descriptions of coyote kills. However, it is conceivable that these deaths may have been due either to coyotes or to dogs which frequently pass through the study area. One rabbit was discovered with head and collar intact and fur and some entrails were scattered over a five square yard area. Remains of another kill consisted of the digestive tract, part of the liver, one hind foot, and a little fur. In one case, the head was untouched with the collar still attached. There was no sign of the remainder of the body. The last of the four was represented by one front leg remaining at the kill site.

The beagle dog was known to be responsible for one case of mammalian predation. The specimen, a juvenile, 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 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 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 was attributed to a bobcat (*Lynx rufus*). A dead rabbit 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 remains and collar were covered by a leaves which had been

scraped into a circle approximately 2.5 feet in diameter. This feature provided the evidence for calling the mortality a bobcat kill.

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 one rabbit 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 were found.

An extensive study of bobcat food habits in Texas (Beasom and Moore 1977) showed that cottontails were a major food item of the felid. They reported that when cotton rat (*Sigmodon hispidus*) and cottontail populations were high, these two species comprised 97% of the bobcat's diet. Stomachs that contained only these two species comprised 93% of the sample with only six other 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, fox tracks were observed 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 14% of house cat stomachs contained cottontails and 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)*.

The two cases of avian mortality were found in the same general area within a one week interval (Table 8). One rabbit 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 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, prerequisite for assigning a kill to avian predators throughout the study (Gress 1976).

The individual avian predator could not be identified positively in either case, but the most likely suspect was a great Horned Owl *(Bubo virginianus)*. Researchers 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 sighted 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 predators; the rabbit 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 disturbed. The other 27 were eaten by birds. Extent of scavenging in this study was not known.

Disease

Disease caused at least 19% of the 105 known deaths (Table 7). From 1 May 1976 to 1 May 1977 disease accounted for 25.0% of total mortality, and 30.8% of naturally occurring deaths (Table 8). Disease was represented by seven cases of tularemia and one case of pneumonia. Of the four cases of unknown mortality, three were possibly caused by disease. All of the carcasses were partially decomposed when found, but the remains were intact, which seems to imply disease rather than predation. One case of research mortality 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 in 1976-77. Including the three cases of unknown mortality, and the one dog induced mortality 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 7 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, described above, it is possible that since the project began in 1974, 28.6% of recorded mortality was tularemia related.

Diagnosis of Rabbit Diseases. Between 1 May 1976 and 1 May 1977, 11 dead rabbits showing no signs of predation were submitted to laboratories for examination and diagnosis. Two cottontails were sent to Dr. John Stevenson, University of Missouri at Kansas City. The other nine were transported to the Kansas State University Veterinary Diagnostic Laboratory where Mr. Dennis R. Howard examined them for disease.

Dr. Stevenson (per comm.) reported one of the two rabbits he examined 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 had gross lesions of tularemia. Use of the fluorescent antibody technique confirmed the tularemia diagnosis (Howard, per comm.). A sixth rabbit was diagnosed by one of the authors (Baker) on the basis of gross lesions observed on the liver and lungs.

Of the seven deaths attributed to tularemia, three were intact carcasses discovered by the beagle dog; one was an intact carcass discovered by personal observation; and three carcasses were located with radio-transmitters. In two cases the rabbits were dead but in normal resting position with their eyes open when found. One rabbit was not 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 tularemia occurring from 23 September 1975 to 12 December 1975. Baker (1977) found 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 *Haemaphyalis 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) noted 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. One of the authors (Spencer) can attest to the accuracy of Green's description as a result of contracting the disease during the course of this study.

Ecological Effects. 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 roles of tularemia as a controlling factor on rabbit populations (McCahan et al. 1962; McGinnes 1964; Jacobson 1975).

McCahan et al. (1962) reported an observed steady decline in rabbit activity on an estate in South Carolina occurred simultaneously with an epizootic outbreak 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 founded 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 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 make 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 infectious disease.

Tularemia is definitely a factor in cottontail rabbit ecology on the RNHR study area. The fact that 19 confirmed cases were discovered in 33 months of study warrants notice. At this point probably the most realistic assessment of tularemia is that of Yeatter and Thompson (195):

> "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."

Other Diseases. The remaining case of disease related mortality was due to pneumonia. The 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 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 1976-77.

Of the five mortalities not previously discussed, one, was discovered to have a ruptured liver. 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 unknown causes. This represents 12.5% of total deaths. As mentioned in the discussion of tularemia deaths, they were possibly caused by tularemia. These specimens were largely decomposed when found, but the remains were intact.

In one case of mortality, cause of death was still unknown even after laboratory examination. 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.

Condition Index

Bailey (1968a) devised a method for computation of a condition index in order to evaluate cottontail physical condition. 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 rabbits captured more than once during a 10-day period. Bailey (1968a) and Fitch (1947) found rabbits captured more than once in a 10-day period had lost weight between successive captures.

Table 9 shows monthly mean condition indices for 122 cottontails captured between 1 May 1976 and 1 May 1977 and 182 rabbits taken from 1 June 1975 to 1 May 1976. The mean condition indices

Table 9. Monthly mean condition indices for cottontails captured during the period 1 June 1975 to 1 May 1977.

Month	Sample Size		Mean Condition Index	
	75-76	76-77	75-76	76-77
May	-	5	-	4.98
June	5	6	6.03	5.39
July	10	10	6.22	5.61
August	10	5	5.50	5.10
September	34	13	5.54	5.91
October	49	32	5.57	5.60
November	39	36	5.61	5.60
December	14	8	5.60	5.82
January	11	3	5.80	5.78
February	6	3	5.55	5.68
March	3	1	5.52	5.81
April	1	-	5.59	-
Total	182	122	$\bar{X}$ = 5.63	5.60

for the two groups were 5.60 and 5.63, respectively. 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. 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 females and males, but there were no significant differences ($p = .05$) between the indices of the sexes during either year.

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 difference in monthly indices for the two years.

Differences between the values of the condition index for successive months were analyzed and there was a significant difference in condition indices for the successive months of July and August, but there were no significant differences between any other two succesive months.

Roadside Survey

Various studes 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 conjuction with the radiotelemetry rabbit project. Table 10 shows monthly roadside survey results from 1 June 1975 to 1 May 1977.

During 23 months of the roadside survey, 1,575 cottontails were sighted in 7,351 miles traveled, a rate of 21.4 rabbits per 100 miles. During the first 11 months of the survey 465 rabbits were 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 miles, a rate of 27.2 rabbits per 100 miles. There was a significant difference in total rabbits sighted for the two time periods. More rabbits (475) were sighted in July, 1976, than the 465 rabbits sighted in the entire 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. 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 10), 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 also recorded. A total of 68 mortalities was recorded for the 7,351 miles traveled, a rate of 0.93 road kills per 100 miles. In the first 11 months of the study, Gress (1976) reported a total of 20 mortalities for 3,267 miles traveled, a rate of 0.92 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 0.93 road kills per 100 miles. 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 occurred in November. In 1976, peak mortality of 2.01 occurred in October (Table 10).

Table 10. Monthly summary of roadside survey for the period 1 June 1975 to 1 May 1977.

Month	Miles Traveled	Rabbits Sighted	Road Kills	Rabbits/ 100 Miles	Road Kills/ 100 Miles
June 1975	241	101	1	41.9	.41
July	345	219	2	63.5	.57
August	355	89	2	25.1	.56
September	343	6	2	1.8	.58
October	297	4	1	1.4	.34
November	298	7	7	2.3	2.34
December	241	3	3	1.2	1.25
January 1976	298	13	5	4.4	1.68
February	287	1	-	0.3	-
March	253	4	2	1.6	.79
April	309	18	5	5.8	1.62
May	364	25	3	6.9	.82
June	349	340	3	97.4	.86
July	379	475	1	125.3	.26
August	337	193	5	57.3	1.48
September	303	20	2	6.6	.66
October	349	16	7	4.6	2.01
November	362	6	6	1.7	1.66
December	326	5	3	1.5	.92
January 1977	325	9	1	2.8	.31
February	326	2	2	0.6	.61
March	350	9	2	2.6	.57
April	314	10	3	3.2	.96
Total	7,351	1,575	68	$\bar{X}$ = 21.4	$\bar{X}$ = .93

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 reliablity 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.

We did not employ rigid time schedules, and no attempt was made to correlate weather conditions with these data. However, our roadside survey 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 1 May 1976 to 1 May 1977 than during 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 their age and sex. If for some reason population age or sex structure was different from one year to the next, it 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 fewer dead rabbits 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 1976-77 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 1976-77.

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 effort it is recommended that wire traps 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.

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