A STUDY OF RABBIT SURVIVAL ON A PUBLIC HUNTING AREA

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Raymond Dale Schofield

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A STUDY OF RABBIT SURVIVAL ON A PUBLIC HUNTING AREA

By

Raymond Dale Schofield

AN ABSTRACT

Submitted to the College of Agriculture
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Approved Peter I. Tack

The cottontail rabbit, Sylvilagus floridanus mearnsii (Allen), has been studied at the Rose Lake Wildlife Experiment Station since 1938. The Rose Lake Station, located near East Lansing, is owned and operated by the Michigan Department of Conservation as a research area to study southern Michigan game management problems. Rose Lake operates as a public-shooting area during the hunting season. To obtain accurate information on hunting pressure and game yield a hunter registration system is used.

Cottontail rabbits were live-trapped periodically throughout the 1938 to 1955 period. A total of 3,223 individual rabbits were trapped, marked, and released. This thesis is based primarily on the rate of recovery for these tagged rabbits during the hunting season.

For the purposes of this study the data were analyzed by three periods: 1938-1945, 1946-1950, and 1951-1955. Because of the difficulty in field-aging male rabbits during the fall months, all males were analyzed together. Female rabbits were considered by age groups.

For the detailed analysis required, a Key-Sort individual record card was prepared for each rabbit handled. After the cards were punched mechanical sorting made possible a fast and accurate analysis of the records.

Rabbit survival rates were determined by two methods. The first (1) is based upon the difference in tag returns observed between animals handled the current year as compared to those handled the previous year. The second (2) depends upon the decreasing proportional returns from animals handled, the longer the time of handling precedes the hunting season each year. Here a linear regression technique allows estimation of the rate of natural mortality. The first method (1) yields an estimate of the total annual mortality, whereas, the linear regression technique (2) does not include the annual hunting mortality. With no allowance for crippling loss the latter rate was computed from the proportion taken by hunters of those rabbits handled immediately before the hunting season. Methods 1 and 2 can then be compared by converting surviving proportions from all three categories to instantaneous rates of mortality and adding the instantaneous rates found for hunting losses to those found by method 2. Thus, the latter values can be subtracted from the rates found by method 1 to yield a rough estimate of the hunting season crippling loss, as method 1 includes all annual mortality.

An analysis of covariance was used to compare natural mortality rates for the three year-groups studied. This analysis did not show any significant differences in survival. However, Chi-square tests applied to observed hunting mortality rates revealed that higher hunter numbers, during recent years, resulted in the taking of a greater proportion of the rabbit population. Chi-square tests also indicated hunting mortality rates for males and females are not significantly different, but juveniles are more vulnerable to hunting than are adults.

Considering the last five years of the study as typical of conditions today, the annual crippling loss appears to be about ten per cent of the pre-hunting population. The adult rabbit population suffers about a 70 per cent mortality from one breeding season to the next and the juveniles disappear at even a greater rate with only about 13 per cent surviving to their first breeding season.

Since there is no apparent difference in survival between sexes, a life table was prepared from the observed mortality rates for the female adult and juvenile rabbits. This table indicates that each female adult rabbit alive during the breeding season needs to produce nearly 12 juveniles (to the age at which they enter live-traps) in order to maintain the rabbit population at a year-to-year constant level. Also, a hypothetical population of 1,800 juvenile rabbits, present at the mid-point of the breeding season, dwindles to only about 800 animals by the opening of the hunting season.

It appears that an intensive habitat improvement program on the Rose Lake area has not increased rabbit survival. Additional studies of the effects of this management practice are recommended.

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[1]A contribution from Pittman-Robertson Research Project W-40-R, Game Division, Michigan Department of Conservation.

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INTRODUCTION

The cottontail rabbit, Sylvilagus floridanus mearnsii (Allen), has been studied at the Rose Lake Wildlife Experiment Station since 1938. A total of 3,223 individual rabbits have been live-trapped, ear-tagged, and released. This paper is based primarily on the rate of recovery for these tagged rabbits during the hunting season.

The Rose Lake Experiment Station, established by the Michigan Department of Conservation in 1937, has the following objectives: a) to provide an extensive area of publicly-owned land in southern Michigan where experimental game management can be conducted and accurate continuous records of the results secured; b) to develop practical, economical methods for increasing game and fur-bearing animals on farms; c) to determine the effect of farming practices on game and fur-bearers; d) to set up wildlife management demonstrations; e) to develop methods of censusing game populations and evaluating farm game range conditions to aid in state-wide game surveys and setting hunting regulations; and f) to permit the Department to appreciate and understand more fully the farmer's point of view, especially regarding hunters, and practicality of game management programs on Michigan farms.

Since Rose Lake is located in a glaciated area, the soils are naturally quite complex. Fox, Hillsdale, and Bellefontaine sandy loams and Coloma loamy sand are the predominant soils of the rolling upland. Rifle peak and Kerston and Carlisle muck are the principal poorly drained soils. Vermillion Creek with its related flood plain crosses the eastern portion of the station, providing most of the natural cover on the best rabbit area on the station.

Located 12 miles northeast of Lansing in Clinton and Shiawassee counties the station is available to a large number of sportsmen. Hunting has been very popular, averaging 280 gun-hours per 100 acres each hunting season since 1951. The hunting area has been increased by a land acquisition program from the original 1,545 acres in 1940 to the present 2,860 acres. A study of hunting near the station indicated that Rose Lake received about four times as much hunting per unit area as the surrounding private farm land (Rose Lake Wildlife Experiment Station, 1949). Hunters have been steadily increasing in numbers in recent years with no apparent detrimental effects on small game populations.

Throughout the study rabbit numbers exhibited a fairly constant pre-hunting density except for three "high" years -- 1941, 1942, and 1949. During 1947, 1948, and 1952 the lowest densities were observed (See Table 1, appendix).

REVIEW OF THE LITERATURE

The rapid turn-over rate of rabbit populations has been noted by several authors. Allen (1939) studied cottontails on the W. K. Kellogg Farm and Bird Sanctuary in Kalamazoo County, Michigan, and reported, "Of 70 rabbits marked in this study during the first 3 months of 1936, only 12 are known to have lived to the following November. Ten survived to the December shooting, and 5 of these were still alive after January 1 .... Two rabbits are known to have lived to an age of approximately 2½ years." Haugen (1942) in another study of the cottontail in Michigan found "a minimum of 25 per cent of the 1938 adult population lived to an

age of approximately 21 or more months." Ingles (1941) in a study of the Audubon cottontail, Sylvilagus audubonii, in California found, "A period of 19 months is the longest time recorded for any one of the 29 rabbits followed .... Only 7 rabbits are known to have lived longer than one year on this area." Kline and Hendrickson (1954) in a study of the cottontail rabbit in Iowa reported the apparent mortality or disappearance of about 85 per cent of 284 live-trapped rabbits between September 1 and January 1.

Southern (1940) reports from his study of the European wild rabbit, Oryctolagus cuniculus, "The main thing is the high disappearance rate which occurs at the beginning or soon after the beginning of the season .... This must be attributed mostly to a heavy mortality in the stages soon after weaning ...." Tyndale-Biscoe and Williams (1955) in their excellent study of the wild rabbit in New Zealand write, "The survival rate of young rabbits was found to be about 70 per cent per 26 days, or 20 per cent per annum, which was also the adult survival rate."

Thus, with several kinds of small rabbits, mortality appears to be high, through not all studies allow quantitative comparison.

PROCEDURE

Hunters using the Rose Lake Wildlife Experiment Station are required to secure daily hunting permits at the station headquarters. A personal hunting kill record card used for registering each hunter is appended, Exhibit 1. All game shot is autopsied at the station laboratory when the hunters leave the area at the completion of their hunt. Sex, age, weights, location of kill, and other pertinent information on each specimen bagged is recorded on an autopsy card (appendix, Exhibit 2). Accurate information on hunting pressures, game yields, and information on tagged-game bagged is secured by this check-in and check-out system as hunters have been very cooperative.

During the period 1951-55 a humerus from either front leg was collected from each rabbit to verify aging methods. These humeri were labeled by autopsy numbers and later separated into age groups without reference to the original autopsy. Based on the ages determined from humeri for known-aged rabbits, a high degree of accuracy was obtained, (Rose Lake Wildlife Experiment Station, 1954). Therefore, the humerus aging method, first reported by Thomsen and Mortensen (1946), was considered as completely reliable for this study.

Rabbits were live-trapped periodically throughout the period 1938 to 1955. A large share of the trapping took place in September and October immediately preceding the opening of the small game season. The standard live-trap described by Allen (1943) was used. Usually the trapping period was 11 days. Rabbits were tagged with numbered fingerling tags (size 3, National Band and Tag Company, Newport, Kentucky). Male rabbits were marked in the right ear, females in the left. As the tag was placed low and well-centered on the ear the loss of identifying marking was considered insignificant. A field trapping record is shown in the appendix, Exhibit 3.

Information from the field trapping record was placed on individual trapping record forms at the completion of the 11-day trapping period (appendix, Exhibit 4). Later trapping or autopsy information was entered on the individual rabbit's record.

Some difficulty was experienced in determining the ages of fall-trapped male rabbits. Nipple characteristics appeared to be fairly reliable indicators of age in females. Therefore, all male rabbits are

analyzed together and the female rabbits considered by age groups throughout this study.

For the detailed analysis required, a Key-Sort individual record card was designed (appendix, Exhibit 5). Data from all the rabbits live-trapped on the experiment station were transcribed from the old trapping record card to the Key-Sort card. These cards were punched according to the pre-established code given in the appendix, Exhibit 6. After transcribing and punching, these Key-Sort cards allowed a fast and accurate analysis of all trapping records.

For the purposes of this study the data were analyzed separately by three periods: 1938-1945, 1946-1950, and 1951-1955. These periods were selected to achieve larger samples and provide groups for comparative purposes. As very little field work was done in 1938, 1939, and 1945, these periods appeared to offer logical divisions.

Survival rates were determined by analyzing the recovery of tagged animals during the hunting season. Two relationships were used. The first is based upon the difference in returns observed between animals handled the immediate year as compared to those handled the previous year, and yields an estimate of total annual mortality. The second relationship depends upon the decreasing proportional returns from animals handled, the longer the time of handling is before hunting season. Here a linear regression technique allows estimation of the rate of natural mortality.

The first relationship is identical to that detailed by Ricker (1948) for analysis of returns from marked fish. The formula used is:

$$S = \frac{Ka\ Tb}{Ta\ Kb}, \qquad \ldots.(1)$$

where,

S = annual rate of survival,

Ka = kill in Year b of rabbits tagged in Years a,

Kb = kill in Year b of rabbits tagged in Years b,

Ta = number of rabbits tagged in Years a, and

Tb = number of rabbits tagged in Years b.

Because the data are relatively few for any one year, a weighted average rate has been computed for a period of years by using, in the formula, Years a and Years b as summations over several years. The following example will demonstrate the calculation of the survival rate for all male rabbits during the last five years of the study:

Years a = 1951-1954 incl.   Years b = 1952-1955 incl.

Ka = 20 (20 male rabbits tagged in Years a survived one hunting season and were killed by hunting the following year.)

Kb = 222 (222 male rabbits tagged in Years b were killed during the first hunting season following tagging.)

Ta = 560 (560 male rabbits were tagged in Years a.)

Tb = 588 (588 male rabbits were tagged in Years b.)

$$S = \frac{20 \times 588}{560 \times 222} = .095$$

Conversion of this rate of survival to an instantaneous rate of mortality, Ricker (1948), has two advantages: 1) instantaneous rates can be added algebracially; and 2) the instantaneous rate for a proportion of period is equal to the same proportion of the rate for the whole period. The instantaneous rate is defined here as the natural logarithm of the surviving fraction and in the case of mortality is always a negative value. The rate representing an addition to a population would be positive. For the example calculated above, male rabbits during the last five years of the study, the instantaneous rate of mortality is -2.354 (natural logarithm of 0.095).

Before illustrating the calculation by the linear regression technique it is necessary to have a basic understanding of the regression problem considered. If we prepare a graph with the abscissa "X" representing time in months before December (the mid-point of the hunting season) and the ordinate "Y" representing proportion of the tagged rabbits shot during the first hunting season following tagging, we find that a greater proportion of those rabbits handled immediately before the hunting season are taken by hunters. Correspondingly, a lesser percentage of the January, February, and March live-trapped rabbits turn up in the hunters' bag. If the logarithm of the proportion shot is plotted against time handled before hunting season, the points fall about a line, the slope of which is determined by the rate of mortality or disappearance of the tagged rabbits. Such a relationship holds if first, survival is at a uniform rate, and second, if hunters take animals in the proportion present.

Stated in a more form way, this relationship is:

$$\frac{Km}{Tm} = \frac{k(TmS^{tm})}{Tm} = kS^{tm}$$

where,

Tm = total number of rabbits handled during some particular month $\underline{m}$,

K = number of rabbits taken by hunters, out of Tm,

k = proportion of rabbits taken by hunters from all those alive during the season,

S = monthly survival rate, and

tm = time of the particular month before December.

Here a certain number of rabbits (Tm) are handled during some particular month m, say June, with tm for June being six months. Some of the rabbits (or TmS^{tm}) will survive until hunting season, when a fraction k will be taken by the hunters. We consider the ratio of those taken by hunters to those originally handled. Taking logarithms of both sides gives:

$$\log \frac{Km}{Tm} = k + (\log S)\ tm \qquad \ldots.(2).$$

The relationship is now in the form of a straight line:

$$Y = a + bX,$$

where,

Y = log proportion killed by hunters from those animals handled a particular month,

X = time, in months, from this particular month to December,

b = slope of the line = log monthly survival rate S, a negative quantity, and

a = log of k, the proportion taken of those animals present during the season.

The calculation of the survival rate for the same group of male rabbits, data from which illustrated use of the first method (1), by the linear regression method is presented as follows, using the standard regression technique as outlined by Snedecor (1956):

$$\text{Slope of the regression line} = \frac{SWXY - \frac{(SWX)(SWY)}{SW}}{SWX^2 \quad \frac{(SWX)^2}{SW}} \qquad \ldots.(2)$$

where,

S = summation, and

W = number of male rabbits handled during the particular month for the period 1951-1955, to allow computation of a weighted mean slope.

X and Y = see above.

$$\text{Slope} = \frac{-1943.85 - \frac{(3590)(-409.44)}{881}}{18898 \qquad \frac{(3590)2}{881}} = -.064 = \text{log monthly survival rate}$$

The proportion of male rabbits surviving each month of natural mortality is the antilog of -.064, or .862. This value, too, can be converted to an instantaneous rate of mortality of -.148 per month. Multiply this by 12 for the yearly rate of -1.782. The antilog will then give an annual survival rate of 16.8 per cent.

It should be noted that by the first method (1) the calculated annual survival for all males, .095, includes both natural and hunting mortality. These rabbits, recovered during their second hunting season, have survived one hunting season and a year of natural hazards. However, the linear regression method, (2) above, based upon survival for the months before the heaviest hunting kill, includes only the natural mortality (caused by disease, predation, etc.). To the natural mortality must be added the instantaneous rate of hunting mortality in order to offer a comparison to the results obtained by the first method.

The rate of hunting mortality may be computed roughly from the proportion taken by hunters from those rabbits handled immediately before the season. As well as ignoring crippling losses, this estimate neglects the effect of natural mortality and tends to underestimate hunting mortality by assuming the hunting to be over a larger population than in truth exists.

The September and October live-trapped rabbits were used in this manner to estimate the proportion of rabbits killed by hunting. Calculations for the same group of male rabbits follows:

611 males were live-trapped during September and October of 1951 through 1955.

238 of these rabbits were killed during the hunting season immediately following the period handled.

Proportion shot = .390 Surviving proportion = .670

Instantaneous rate of hunting mortality (assuming no crippling loss and ignoring the "competition" of natural mortality = -.494

Now we add this to the calculated natural mortality found by the linear regression technique, (-1.782) plus (-.494) = -2.276. We determine the antilog to find the surviving proportion, .108 per year. This compares very favorably with the 9.5 per cent survival computed by the first method, especially since the hunting mortality is probably underestimated.

Methods used for each sex and age class and year group discussed earlier were identical with the example cited above.

RESULTS

The basic data for the calculation of survival rates and the results obtained by the first method (1), are summarized in Table 1 since the values for males represent both ages, they must be compared to some value for females, intermediate between that for adults and that for juveniles. As mentioned earlier all males are grouped together because of the difficulty in determining accurate ages in the field. The nipple characteristics are considered fairly reliable for field aging of the females.

Table 1

Calculation of Rabbit Survival by a Formula from Ricker (1948)

	Ka*	Kb*	Ta*	Tb*	Surviving Proportion	Instantaneous Rate of Mortality
All males:						
1st period	16	110	471	562	.174	-1.749
2nd period	14	95	420	452	.159	-1.829
3rd period	20	222	560	588	.095	-2.354
Female adults:						
1st period	8	41	205	241	.229	-1.474
2nd period	11	35	172	186	.340	-1.079
3rd period	9	27	134	113	.281	-1.273
Female juveniles:						
1st period	9	72	247	317	.160	-1.833
2nd period	10	69	267	272	.148	-1.910
3rd period	18	155	371	409	.128	-2.056

1st period: Years a = 1938-1945 Years b = 1939-1946
2nd period: Years a = 1946-1950 Years b = 1947-1951
3rd period: Years a = 1951-1954 Years b = 1952-1955

*Defined on page 6.

The calculation of survival by the linear regression technique (2) yielded the values shown in Table 2.

Table 2

Rabbit Survival as Found by the Linear Regression Technique
(Does not include hunting mortality)

Sex and age group	Slope	S*/Mo	I**/Mo	I/Yr	S/Yr	Slope	S/Mo	I/Mo	I/Yr	S/Yr
	1938-1945					1946-1950				
All Males	-.058	.874	-.135	-1.616	.199	-.042	.909	-.096	-1.148	.317
All Females	-.058	.874	-.134	-1.610	.201	-.038	.917	-.087	-1.045	.352
Female Adults	-.049	.892	-.114	-1.368	.255	-.005	.990	-.011	-0.127	.880
Female Juveniles	-.060	.870	-.139	-0.975	.377	-.117	.763	-.270	-1.894	.151
	1951-1955					All Years				
All Males	-.064	.862	-.148	-1.782	.168	-.064	.863	-.148	-1.776	.169
All Females	-.039	.914	-.090	-1.082	.339	-.053	.885	-.123	-1.476	.235
Female Adults	-.029	.936	-.066	-0.797	.451	-.038	.916	-.087	-1.048	.351
Female Juveniles	-.073	.845	-.168	-1.179	.308	-.097	.800	-.223	-1.562	.210

*S = survival, **I = instantaneous rate of mortality

.874 S/Mo = 87.4 per cent survive each month of natural mortality

It should be noted that juvenile rabbits are not subjected to an entire year of natural mortality during their first calendar year of life. The figures in Table 2 are calculated on a 12 monthbasis to demonstrate the relative natural mortality rates between sex and age classes. However, since on paper the juveniles become adults January 1 (appendix, Exhibit 6) the adult mortality rate becomes effective. Thus rates of natural mortality are estimated for each of three sex-age classes (all males, juvenile females, adult females) and for each of three period of years (Table 2). To determine whether these rates differed among the sex and age classes considered, or among periods of years for any one sex or age class an analysis of covariance following Snedecor (1956) was computed. The rates of mortality were inferred from the records of tagged animals shot by hunters, comparing the representation in the hunters' bag of animals tagged successively longer times before the hunting season, in the manner already described. Since the rate of survival was established by a linear regression technique, an analysis of covariance is appropriate for comparing different regression lines in two ways: first, as to difference in slope (or rate of survival), and second, as to difference in position (overall proportion of tagged animals harvested).

The analysis of covariance used compares the reduction in unexplained variability achieved by fitting successively to the data, first, a single regression line; second, a separate regression line for each separate class and year group considered; and third, a separate line passing through the mean value for each of these nine groups, but all lines with a common slope. Separate lines, each with its own slope (the second case above), explain the most variability, and tests of whether the improvement thus effected is greater than that to be expected by chance furnishes a basis for deciding, first, whether there are any differences among the classes; and second, if lines do differ, whether they differ in slope (or rate of mortality).

Results follow in Table 3.

Table 3

Covariance Analysis of Survival Relationships (All Rabbits, All Years)

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square
Total	88	330.90	
Due to general regression	1	104.04	104.04
Deviations about general regression	87	226.86	2.61

(F = 39.86**, general regression is significant)

Question: Can one regression line be used for all observations or are there differences among all males, adult females, and juvenile females or year group differences?

Gain from nine separate regressions over general regression	16	73.29	4.58
Deviations about nine separate regressions	71	153.61	2.16

Answer: No. (F = 2.12*), for the nine classes differ in either survival rate or percentage harvested.

Question: Can a common slope be used within each class and year group for the separate regression lines?

[1]Gain from nine separate regressions	8	10.43	1.30
Deviations about nine separate regressions	71	153.61	2.16

Answer: Yes. (F = 1.66), the differences observed probably were due to differences in proportion of tagged animals harvested (probably differing with period of years, though this point is not specifically tested here).

*Significant at the 5 per cent level.
**Significant at the 10 per cent level.

[1]Gain by use of separate regressions for each class and year group over use of lines with common slope fitted through mean of each group considered.

This analysis of covariance test demonstrates that the method of analysis based on the recovery of tagged animals by hunting, does not show any difference in survival of the Rose Lake rabbits from natural mortality during the periods studied. However, as one regression line could not be used for all observations, a significant difference in proportion of tagged rabbits harvested occurred within the study, and further analysis shows that these differences occurred between periods of years.

Analysis of the rate of kill of September and October live-trapped rabbits demonstrate the effects of heavier hunting pressures, during the latter years, on the Rose Lake rabbit population. Calculations of the instantaneous rates of hunting mortality are shown in Table 4 where natural mortality is ignored for the short period between pre-season trapping, and the hunting season. Chi-square tests to determine the significant differences in these rates of hunting mortality are presented in Table 5.

The first Chi-square test in Table 5 shows that the hunting mortality rates for males and females are not significantly different. Several authors have stated that cold weather results in a greater harvest of males over females because of the tendency for females to "hole up." A large proportion of the Rose Lake rabbit harvest takes place during cold weather and it seems that if cold weather hunting produces an unbalanced sex ratio in the hunting kill, it would be more obvious.

The Chi-square test comparing juvenile females with adult females shows that juveniles are more vulnerable to hunting than are the adults. This probably applies to the males, also, as the first Chi-square test indicated homogeneity between the sexes.

Table 4

Calculations of Rabbit Mortality Rates Caused by Hunting
(September and October live-trapped rabbits)

Period	Tagged	Shot	Proportion Shot	Proportion Surviving	Instantaneous Rate of Mortality
All males:					
1938-1945	273	76	.278	.722	-.326
1946-1950	178	37	.208	.792	-.233
1951-1955	611	238	.390	.610	-.494
All years	1062	351	.330	.670	-.400
All females:					
1938-1945	321	80	.249	.751	-.286
1946-1950	181	52	.287	.713	-.338
1951-1955	530	204	.385	.615	-.486
All years	1032	336	.326	.674	-.394
Female adults:					
1938-1945	94	22	.234	.766	-.267
1946-1950	44	12	.273	.727	-.319
1951-1955	136	43	.316	.684	-.380
All years	274	77	.281	.719	-.380
Female juveniles:					
1938-1945	178	46	.258	.742	-.298
1946-1950	129	38	.294	.706	-.348
1951-1955	394	161	.409	.591	-.526
All years	701	245	.350	.650	-.431
All animals:					
1938-1945	594	156	.263	.737	-.305
1946-1950	359	89	.248	.752	-.285
1951-1955	1141	442	.387	.613	-.489
All years	2094	687	.328	.672	-.398

Table 5

Chi-Square Tests to Determine Significant Differences in Observed Hunting Mortality

(September and October Live-trapped Rabbits)

Test 1. Hunting mortality by sexes

	SHOT	NOT SHOT	TAGGED	
All males	351	711	1062	Degrees of freedom = 1
All females	336	696	1032	Total chi-square = 0.07

Test 2. Hunting mortality by female age classes

Juveniles	245	456	701	Degrees of freedom = 1
Adults	77	197	274	Total chi-square = 4.49*

Test 3. Hunting mortality of all males by years

1938-1945	76	197	273	
1946-1950	37	141	178	Degrees of freedom = 2
1951-1955	238	373	611	Total chi-square = 25.11**

Test 4. Hunting mortality of all females by years

1938-1945	80	241	321	
1946-1950	52	129	181	Degrees of freedom = 2
1951-1955	204	326	530	Total chi-square = 17.66**

Test 5. Hunting mortality of adult females by years

1938-1945	22	72	94	
1946-1950	12	32	44	Degrees of freedom = 2
1951-1955	43	93	136	Total chi-square = 2.22

Test 6. Hunting mortality of female juveniles by years

1938-1945	46	132	178	
1946-1950	38	91	129	Degrees of freedom = 2
1951-1955	161	233	394	Total chi-square = 13.91**

*Significant at the 5 per cent level.
**Significant at the 1 per cent level.

The rest of the Chi-square tests in Table 5 are designed to test the effects of higher gun pressures, during later years, on rabbit populations. Naturally, in recent years higher hunter numbers have resulted in a greater proportion of the rabbit population being shot and all of the sex and age groups except the adult females indicate higher hunting mortality rates for the later years of the study. The adult female class, perhaps because of the small sample size, does not demonstrate this difference. These Chi-square tests help explain the results shown by the analysis of covariance test presented in Table 3.

We have now illustrated all of the major calculations used for this study. In review, formula (1) provided survival rates which included mortality due both to hunting and to natural causes. The linear regression technique (2) estimated survival rate from natural mortality factors. The actual hunting mortality rate was estimated from the rate of kill of rabbits tagged and released during September and October, but is likely an underestimate of the true rate, since no allowance is made for natural mortality at the same time.

Table 6 compares the three methods with "Difference" representing the rate of mortality found by formula (1) minus the natural mortality from (2) for the same period. Therefore, it should approximate the hunting season mortality rates since formula (1) includes both rates and (2), linear regression method, includes all mortality except that during the hunting season. During the last five years of the study the two estimates of hunting season mortality are reasonably close, considering that one estimate is both biased downward and does not include crippling loss. It seems that the calculated survival rate from natural mortality for female adults during the period 1946-1950 may be too high and that all survival

Table 6

Comparison of Rabbit mortality Rates

	Natural Mortality[1]		Hunting Mortality[2]		Hunting + Natural		Mortality Found by Method (1)[3]		Hunting Mortality by Difference[4]	
	I	S	I	S	I	S	I	S	I	S
All Males:										
1938-1945	-1.616	.199	-.326	.722	-1.942	.143	-1.749	.174	-.133	.875
1946-1950	-1.148	.317	-.233	.792	-1.381	.251	-1.839	.159	-.691	.501
1951-1955	-1.782	.168	-.494	.610	-2.276	.108	-2.354	.095	-.572	.564
Female Adults:										
1938-1945	-1.368	.255	-.267	.766	-1.635	.195	-1.474	.229	-.106	.899
1946-1950	- .127	.880	-.319	.727	- .446	.640	-1.079	.340	-.952	.386
1951-1955	- .797	.451	-.380	.684	-1.177	.308	-1.273	.281	-.476	.621
Female Juveniles:										
1938-1945	- .975	.377	-.298	.742	-1.273	.280	-1.833	.160	-.858	.424
1946-1950	-1.894	.151	-.348	.706	-2.242	.106	-1.910	.148	-.016	.984
1951-1955	-1.179	.308	-.526	.591	-1.705	.182	-2.056	.128	-.877	.416

1. By regression of returns on time of handling, relationship 2.
2. By tag returns.
3. By differential tag returns, relationship 1.
4. Mortality rate found by formula (1) minus the rate found by the linear regression technique (2).

rates for female juveniles for the same period may be too low.

Figures for the last five years indicate the hunting season crippling loss may be about 10 per cent of the pre-hunting population. This loss is demonstrated in Table 6 by the "Difference" column exceeding the observed hunting mortality rate for each sex and age group during the last five years. Geis (1956) calculated a crippling loss for a public hunted area at about 20 per cent of the recovered kill. As 2,092 rabbits were shot at Rose Lake, 1951-1955, 20 per cent would be 418 lost as cripples. If we use 10 per cent of the pre-hunting population as the crippling loss, about 538 died as cripples during this period. These estimates appear to be in reasonable agreement.

Now that we have shown the various rates of mortalities for three sex and age groups and tested for significant differences it would be interesting to put the various instantaneous rates of mortality to work to show what happens to a hypothetical population of 1,000 rabbits present on the experiment station preceding the opening of the hunting season. Instantaneous rates of mortality for the past five years are used in order to make the situation up to date. For the purposes of this life table it is assumed that the different rates of mortality observed between age classes are significant. Results follow in Table 7.

Table 7

Mortality Suffered by a Pre-Hunting Population of 500 Female Rabbits*

	Juveniles	Adults
Pre-hunting population:	389	111
Natural mortality during hunting season:	-.168 x 3 = -.504	-.066 x 3 = -.198
Hunting season mortality:	-.526	-.380
Total:	-1.030	-.578
Proportion surviving hunting:	.357	.561
Number of rabbits surviving:	139	62
Total: (juveniles added to adults February 1)		201
Natural mortality to June 1 (considered mid-point of breeding season):	-.066 x 4 =	-.264
Proportion surviving February 1 to June 1:		.768
Number of rabbits surviving:		154
Production of female juveniles required to maintain population:	900	
Natural mortality (June 1 to November 1):	-.168 x 5 = -.840	-.066 x 5 = -.330
Proportion surviving to hunting:	.432	.719
Number of rabbits present pre-hunting:	389	111

*Assuming even sex ratios and equal mortality rates between sexes as this study did not reveal any real differences in natural mortality or hunting mortalities between sexes, the 500 figure can be enlarged to 1,000 and all corresponding population figures in the table doubled to account for the male rabbit population.

DISCUSSION AND CONCLUSIONS

This Rose Lake study has added emphasis to the fact that rabbit populations suffer huge annual losses. Considering the last five years of the study as typical of conditions today, our data indicated about 30 per cent of the adult population survive from one breeding season to the next. Juvenile rabbits may suffer even greater losses, but the recovery of tagged animals in the bag did not demonstrate significant differences in the natural mortality rate between the three sex-age groups studied. However, of the juvenile rabbits marked and released during this study only about 13 per cent survived to their first breeding season. It should be noted that these juvenile mortality rates are based on rabbits that were live-trapped and do not apply to nestlings or young juveniles before they reach the age at which they enter live-traps. Based on limited observations made on a few tagged nestlings, it is likely that mortality rates during the early periods of life are even higher than those observed for older live-trapped juveniles.

If it is assumed that the adult survival rate is actually 30 per cent per year and the juvenile rate is 13 per cent, each adult female rabbit alive during the breeding season would have to produce nearly 12 juveniles (to the age at which they enter traps) in order to maintain the rabbit population at a year to year constant level. If rates of mortality for the very small juveniles are higher, production would have to increase correspondingly.

The observation that natural mortality rates have not varied significantly over the periods studied raises many questions. Was the sample of rabbits studied a representative portion of the entire Rose Lake rabbit population? Did actual differences in natural mortality rates occur without the sampling methods noting these changes? If natural mortality rates have remained similar during Rose Lake's 18-year history, as the recovery of tagged rabbits indicated, does this mean that the intensive habitat improvement work completed at Rose Lake has not influenced rabbit survival?

One of the basic premises behind a habitat improvement program is to provide escape cover, thereby increasing the survival rate of the rabbit population. The station's early habitat development work certainly should have had an opportunity to show long-term results during the last five years, yet this study failed to note any significant change. Could the principal effect have occurred in the few early years, before data useful here were gathered?

Red foxes, Vulpes fulva, were much more numerous during the latter part of the study. However, it seems unlikely that the increased predator population could have exactly counterbalanced the beneficial effects of the habitat improvement work. Perhaps we do not understand what constitutes habitat improvement for cottontails. Possibly it is futile to attempt to improve cover which is already adequate. Certainly, more studies to appraise the effects of habitat improvement measures on game populations are urgently needed.

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A P P E N D I X

Table 1

Rabbit Population Levels
Rose Lake Wildlife Experiment Station
1940-1955

	Basic					Population Indices						
									Roadside Counts			
Year	Acres Hunted	Gun Hours	Total Kill	Trap Nights*	Individual Rabbits Caught*	Kill per 100 acres	Kill per 100 gun hours	Catch per 100 trap nights	Early Summer R/10 mi.	Late Summer R/10 mi.	Lincoln Index Computed Population	(with 95% confidence limits)
1940	1545	3421	233	2868	74	15.1	6.8	2.6			601	(443-935)
1941	1405	4262	335	5916	129	23.8	7.8	2.2			1060	(829-1470)
1942	1834	5256	404	4694	190	22.0	7.7	4.0			1568	(1248-2051)
1943	1784	2723	167	4115	100	9.4	6.1	2.4			753	(535-1275)
1944	1894	3113	162	--	---	8.6	5.2	---				
1945	1844	2858	139	--	---	7.5	4.9	---				
1946	2201	3702	176	4676	95	8.0	4.8	2.0			636	(468-994)
1947	2302	4110	97	2175	27	4.2	2.4	1.2			522	(326-1305)
1948	2567	5060	181	2710	75	7.1	3.6	2.8		0.6	847	(578-1815)
1949	2567	7209	511	1594	67	19.9	7.1	4.2		0.8	2304	(1589-4189)
1950	2570	6893	479	2027	35	18.6	6.9	1.7		1.9	1125	(750-2250)
1951	2860	6601	395	4355	169	13.8	5.3	3.9		1.8	1128	(902-1504)
1952	2860	7178	299	4764	163	10.4	4.2	3.4		1.0	930	(746-1232)
1953	2860	7899	456	4756	255	15.9	5.8	5.4	4.1	1.7	1204	(1027-1471)
1954	2860	8964	443	5287	231	15.5	4.9	4.4	3.8	2.6**	962	(827-1150)
1955	2860	9449	499	5601	280	17.4	5.3	5.0	4.0	---	1154	(1000-1364)

*September and October rabbit trapping only. Several additional rabbits were caught in traps set for squirrels.
**Route changed to eliminate unproductive areas in 1954. Route discontinued in 1955.

Exhibit 1

Personal hunting kill record.

SMALL GAME HUNTING KILL RECORD

AREA ____ DATE ____

- FILL IN BEFORE HUNT -	- FILL IN AFTER HUNT -
Name ____	Time in ____ Hours hunted ____
Address ____	Number of shots fired ____
Town ____ Time now ____	Game killed by you (use numbers 1,2, etc.)
What game are you hunting? (Check)	Pheasant ____ Rabbit ____
Pheasants ____ Rabbits ____	Fox Squirrel ____ Other ____
Fox Squirrels ____	Pheasants crippled by you and not recovered ____
Breed and number of dogs in party ____	Pheasants crippled by others and killed by you ____
Gauge of gun ____	Game seen by you (including kill)
	Rabbit ____ Cock pheasant ____
DO NOT CLEAN GAME. IT WILL BE WEIGHED	Fox squirrel ____ Hen pheasant ____
	Bob-white ____ Deer ____
RLWES	Waterfowl ____ Other ____

Exhibit 2

Autopsy card.

AUTOPSY CARD

Autopsy No. 16285

Species ____ Tag No. ____

Date ____ County ____ T. ____ R. ____ S. ____

Locality ____ Habitat ____

Sex ____ Age ____ Determined by ____ Initials ____

Weight ____ Length ____ Tail ____ H. Foot ____ Ear ____

Condition Uterus ____ Gonads (L) ____ (R) ____

Embryos (L) ____ (R) ____ Length ____ Weight ____ Age ____

Collector ____ Preparator ____

Notes ____

How taken ____ Cause of death ____

Exhibit 3

A field trapping record card.

DAILY TRAPLINE RECORD

Trapline No.............Date...............................Number of Traps.............Time.............Day.............

Weather.............Temperature.............Humidity.............Precipitation.............

Sky.............Pressure.............Wind.............Ground Conditions.............

Bait.............Operator.............

No.	Catch	Notes
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		
11		
12		
13		
14		
15		
16		
17		
18		
19		
20		

Exhibit 4

Individual trapping record card

Exhibit 5

Key-sort card

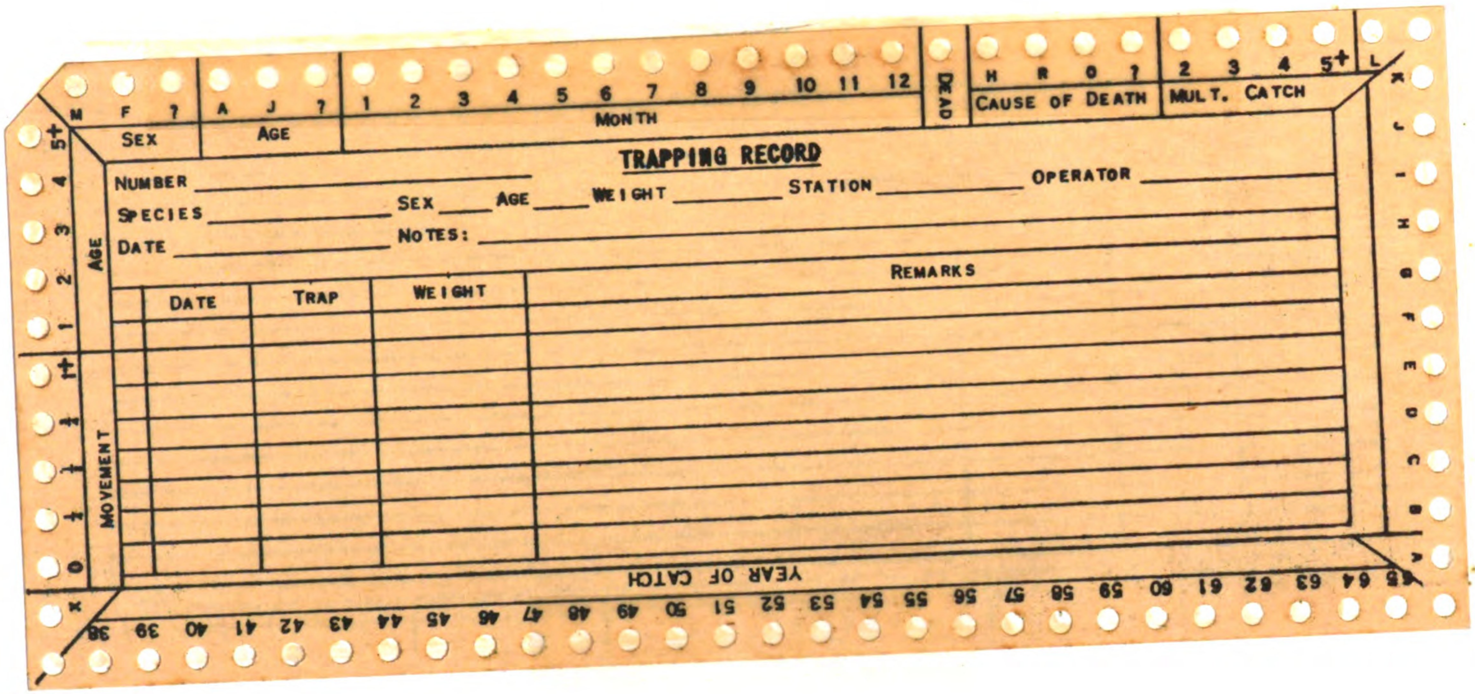

Exhibit 6

PUNCH CARD RULES

Top of Card

SEX: Punch sex of animal as recorded on trapping card except when autopsy record differs -- then use autopsy record.

AGE: Punch age at time of first trapping according to following rules:

(1) January 1 to March 31: All animals considered adults.

(2) April 1 to July 31: Accept age on trapping card unless obviously in error.

(3) August: Accept female aging. Males weighing 2-4 or less are considered juveniles. Males weighing 2-10 or more are considered adults. All other males are punched as (?).

(4) September 1 to December 31: Accept female aging. Males weighing 2-4 or less are considered as juveniles. All other males are punched as (?).

(5) Age by humerus is accepted as final in all cases if animal is autopsied by January 31 following year of first trapping.

MONTH: Punch all months during which animal was trapped or handled. Does not include autopsies.

DEAD: Punch when animal is autopsied.

CAUSE OF DEATH: Punch (H) for a hunting kill, (R) for a road kill, (O) for other kills when cause is known, and (?) for kills from unknown causes.

MULTIPLE CATCH:* Punch appropriate number each time animal is handled.

Right Side

LETTERS: Punch letter (A) when original catch is made from other than live-trapping operations. Punch letter (A) on all but one of

(Over)

a series of duplicates when an animal is represented by more than one tag number. Animals originally captured in other than live-trapping operations and represented by more than one tag number, have all cards punched at (A).

Animals requiring more than one card for trapping entries are represented in the regular key-sort file by one card which refers to the extra cards, located in a separate file.

Punch letter (B) if animal is autopsied between December 31 and April 1.

Bottom of Card

YEAR OF CATCH: Punch all years during which animal is handled. Does not include autopsies.

Left Side

MOVEMENT:* Punch number nearest to maximum distance moved by animal at time of each handling and when autopsied.

AGE (LONGEVITY OF YEAR CLASS):* Punch minimum year of life attained by animal at time of each handling and when autopsied. An animal trapped originally as an adult is considered to be in its second year of life at that time. An animal called (J) or (?) at first trapping is considered to be in its first year of life. If an animal is retrapped or autopsied at any time after December 31 of the year of first handling another year of life is punched on its longevity record. Any rehandling of an animal in a new calendar year is recorded as another year of life.

* All numbers must be punched up to and including the largest number pertaining to the animal.

Date Due

~~[illegible]~~			
~~NOV 26 1965~~			