POPULATION DYNAMICS, MOVEMENT AND
HOME RANGE OF BLACK-TAILED JACKRABBITS (*LEPUS*
CALIFORNICUS) IN CURLEW VALLEY, NORTHERN UTAH

Progress Report

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Abstract

The long-term objective of the jackrabbit study in Curlew Valley, Utah and on the Idaho National Engineering Laboratory is to describe observed changes in rabbit density in terms of mortality and natality rates and to relate changes in these two population parameters to variation in environmental factors. Spring rabbit-density in Curlew Valley has been observed to change by a factor of 60; changes appear to be largely determined by variation in mortality rates, as shown with K-factor analysis. Mortality of the population from fall-spring and of adults from spring-fall is correlated with the coyote/rabbit ratio. Coyote numbers in the ratio are modified to reflect variations in coyote feeding behavior with changes in rabbit numbers as indicated by coyote food habits studies in Curlew Valley. Juvenile loss from birth-fall is correlated with the coyote/rabbit ratio and some yet unknown density related mortality factor(s). Evidence also exists of "carry-over" in juvenile mortality. High loss rates from density related factors were observed for 2-3 years after the population declined. Controlled experiments are now being designed to investigate genetic and/or behavioral changes associated with the high rates of juvenile mortality.

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1. Introduction

Population ecology of the black-tailed jackrabbit population on a 250-square-mile area in Curlew Valley, Utah has been studied from 1962-1975. In spring 1975 the studies were expanded to include a 450-square-mile portion of the Idaho National Engineering Laboratory, INEL. The main objective is to describe observed changes in jackrabbit density in terms of mortality and natality rates, to relate changes in these two parameters to variation in environmental factors, and to integrate the results into a mathematical model describing population change. Controlled experiments are now being designed to investigate genetic and/or behavioral changes associated with observed high rates of juvenile mortality.

The jackrabbit study in Curlew Valley is dependent on the U.S. Fish and Wildlife Service's Predator Ecology and Behavior Project for rodent and coyote density estimates and coyote food habits data for Curlew Valley. Conversely the rabbit project is providing the Fish and Wildlife Service with important data for its coyote ecology and coyote population modeling studies. On the INEL site, the rabbit project is supplying the estimates of coyote and rodent density. Coyote food habits data will be provided by Colorado State University under contract with the ERDA.

The present document describes findings from the 1974-1975 contract period along with some data obtained since the initiation of the project. In this way data obtained this year can be kept in perspective and demonstration made of their contribution to the long-range objectives of the study.

2. Population Measurement

Curlew Valley rabbit density indexes.-- October 1974 and March 1975 density indexes for the 250-square-mile study area in Curlew Valley were obtained using 68 one-mile foot transects. As in previous years, flushing angles and flushing distances of observed rabbits were recorded. Since flushing behavior of jackrabbits changes with density and between spring and fall, the absolute number of jackrabbits seen on the transects cannot be used as an index to density. Instead, we have utilized the flushing angles and distances and an equation derived by Gates (1969) to correct the transect results for observed changes in flushing behavior (Stoddart 1972).

Transect results over the years of study (Table 1 and Fig. 1) show a slow, continuous decline in density from an index of 61 in fall 1963 to 21 in fall 1967. In the following 3 years density increased rapidly to 190 in fall 1970, an increase over the 3-year period of 9-fold. The next 3 years saw a very rapid decline in density to a low in October 1973 of 15, the lowest fall density we have measured. The fall 1974 index of 25 indicated an increase in density over fall 1973 of 67 percent. However, the spring density index continued to fall to 2.2, the lowest index we have observed, and less than one half of that observed in spring 1974. This value is only 1.7 percent of the observed spring high in 1971.

Table 1. Results of Curlew Valley Jackrabbit Population Transects

Census date	No. Rabbits observed	Density index	Percent Density Change	
			Oct.-March	March-Oct.
Oct. 1962	29	40		
March 1963	19	14	-65	336
Oct. 1963	66	61		
March 1964	26	26	-57	62
Oct. 1964	49	42		
March 1965	30	18	-57	83
Oct. 1965	28	33		
March 1966	15	12	-64	100
Oct. 1966	20	24		
March 1967	9	7.4	-69	184
Oct. 1967	12	21		
March 1968	15	9.2	-56	606
Oct. 1968	81	65		
March 1969	75	43	-34	179
Oct. 1969	192	120		
March 1970	173	67	-44	184
Oct. 1970	268	190		
March 1971	181	130	-32	23
Oct. 1971	191	160		
March 1972	107	87	-46	-26
Oct. 1972	68	64		
March 1973	17	18	-72	-17
Oct. 1973	8	15		
March 1974	5	5.5	-63	355
Oct. 1974	16	25		
March 1975	2	2.2	-91

Fig. 1. Spring and fall jackrabbit population trends and fall coyote population trends in Curlew Valley. Closed dots indicate fall rabbit density, open dots spring density. Closed squares indicate fall coyote density indexes (see text). Open squares are spring and fall coyote indexes obtained using 4 scent post lines. The open triangle is the coyote density index for the INEL.

Rates of change from one census period to the next are indicated in the last 2 columns in Table 1. During this reporting period, the rabbit population increased 355 percent from March 1974 to October 1974. This is the second highest observed rate of increase over a breeding season. The over-summer increase was followed by an October 1974 to March 1975 decline of 91 percent, the highest over-winter rate of loss we have observed. Demographic mechanisms underlying these rates of change will be discussed below.

INEL rabbit density index.-- A 450-square-mile portion of the INEL has been selected for the jackrabbit study area. This portion will henceforth be termed the "INEL study area". The INEL study area was selected in cooperation with the U.S. Fish and Wildlife Service which will be conducting coyote studies in the same area. The INEL study area is shown in Figure 2 as the unshaded portion of the map of the INEL. Eighty one-mile foot transects were randomly located in the area (Fig. 3). For the rabbit transect locations, the study area was stratified into 6 vegetation types as determined utilizing INEL vegetation analyses of Harniss and West (1973) and McBride (1968).

The 80 rabbit transects on the INEL study area were first walked in April 1975. Only 1 jackrabbit was observed on the transects. Using Gate's equation for transect data, a density index of 1.0 was obtained. This compares with the record low April 1975 index in Curlew Valley of 2.2.

3. Natality

Each month approximately 50 adult rabbits are collected from the Curlew Valley study area. An autopsy is performed on each female to determine percent females breeding, litter size (Table 2), age of fetuses, and conception dates. Female jackrabbits in Curlew Valley generally produce four synchronized litters spaced about 40 days apart during the breeding season. Usually the breeding season ends during the conception period of the fourth litter so that not all females produce this last litter (Table 2, column B). In two years, 1968 and 1969 all females produced the fourth litter and some produced a fifth. In 1972 for the first time during the study not all females bred for the third litter, and none produced a fourth. The end of the breeding season was not well defined in 1973 as in previous years. Essentially all females produced the first three litters, 14 percent produced a fourth, but then 12 percent went on to produce a fifth. In 1974 mean litter sizes (Table 2, column C) for the four littering periods were 2.0, 4.7, 5.5, and 3.7 respectively. This compares with the mean over all years of study of 1.6, 4.6, 5.7, and 3.9.

Production of fetuses per female surviving the breeding season (Table 2, column D) has varied independently of density during years of spring population decline, 1964-1967 (Fig. 4). However, during the 4 years (1968-1971) of spring population increase, production decreased continuously from 18.9 to 11.3. The trend of decreasing production continued in 1972 to a low of 7.5 even though spring density decreased that year. This may have been due to a "carry-over" effect or have been simply a result of the record low rainfall in Curlew Valley in spring 1972. In 1973 and 1974 production increased markedly to 13.2 and 15.4 respectively. Figure 4 indicates a slight trend toward increased production with decreased spring density.

Fig. 2. INEL jackrabbit study area indicated by the unshaded portion of the INEL maps.

Fig. 3. Location of 80 one-mile jackrabbit transects within 6 major vegetation types in the INEL study area.

Table 2. Percentage of January 1 female population alive, percentage littering, mean litter size, number of fetuses per female, and number of fetuses per female alive January 1 in each littering period for each year

Year	Littering period	(A) Percentage of Jan. 1 female pop. alive	(B) Percentage littering	(C) Mean litter size	(D) Fetuses per female (BXC)
1963	1	66	13	1.0	0.1
	2	49	95	4.8	4.6
	3	39	100	5.2	5.2
	4	30	70	5.1	3.6
Totals				16.1	13.5
1964	1	66	100	2.1	2.1
	2	49	100	4.3	4.3
	3	33	100	5.5	5.5
	4	23	100	3.4	3.4
Totals				15.3	15.3
1965	1	66	100	1.6	1.6
	2	54	100	4.5	4.5
	3	43	100	5.2	5.2
	4	33	50	3.5	1.8
Totals				14.8	13.1
1966	1	66	100	1.6	1.6
	2	51	100	4.2	4.2
	3	41	100	5.8	5.8
	4	33	16	3.8	0.6
Totals				15.4	12.2
1967	1	59	100	1.4	1.4
	2	45	100	5.2	5.2
	3	37	100	6.8	6.8
	4	30	100	4.5	4.5
	5	25	29	3.5	1.0
Totals				21.4	18.9
1968	1	69	100	1.8	1.8
	2	60	100	5.3	5.3
	3	60	100	6.3	6.3
	4	59	100	4.2	4.2
	5	58	40	2.5	1.0
Totals				20.1	18.6
1969	1	88	94	1.6	1.5
	2	76	100	5.3	5.3
	3	64	100	6.4	6.4
	4	56	24	3.8	0.9
Totals				17.1	14.1

Table 2. Cont'd.

Year	Littering period	(A) Percentage of Jan. 1 female pop. alive	(B) Percentage littering	(C) Mean litter size	(D) Fetuses per female (BXC)
1970	1	78	93	1.4	1.3
	2	67	100	4.8	4.8
	3	64	100	5.4	5.4
	4	61	45	3.6	1.6
Totals				15.2	13.1
1971	1	85	96	1.4	1.3
	2	76	100	3.3	3.3
	3	67	100	4.9	4.9
	4	59	52	3.5	1.8
Totals				13.1	11.3
1972	1	74	100	1.7	1.7
	2	63	100	4.3	4.3
	3	48	33	4.6	1.5
Totals				10.6	7.5
1973	1	52	92	2.1	1.9
	2	36	100	4.9	4.9
	3	26	93	6.2	5.8
	4	21	14	3.5	0.5
	5	12	12	1.0	0.1
Totals				17.7	13.2
1974	1	66	100	2.0	2.0
	2	55	100	4.7	4.7
	3	55	100	5.5	5.5
	4	55	86	3.7	3.2
Totals				15.9	15.4

Fig. 4. Number of fetuses produced per female in the population surviving the breeding season plotted against the spring rabbit index.

4. Mortality

Mortality rates for three stages of the jackrabbits' life history were calculated:

A. Fall-spring mortality of total population. Mortality of the total population from October-March (Table 3, column 2) was calculated by dividing the spring density index by the preceding fall index, subtracting the quotient from 1, and multiplying by 100. October-March mortality rates have varied from 32 percent in 1970-71 to 91 percent in 1974-75. The unweighted mean for the 13 fall-spring periods was 59 percent. There are some indications (see below) that the estimated population mortality over the October 1974-March 1975 period of 91 percent is higher than that actually sustained by the population.

B. Spring-fall mortality of adults. Adult jackrabbit mortality rate from March-October (Table 3, column 3) was estimated for each year by dividing the fall adult density index by the spring index, subtracting the quotient from 1, and multiplying by 100. The fall adult index was obtained by multiplying the fall population index by the fraction of adults (Table 4) in a collection of 100 rabbits made in October of each year. March-October adult mortality rates have varied from 0-87 percent with a mean over the 12 summer periods of 55 percent. Adult mortality for the March-October 1974 period was calculated at 0 percent. This estimate is obviously low and will be discussed in a following section.

C. Mortality of juveniles from birth to October census. Mortality of juveniles from birth to October census was calculated each year by dividing the fall juvenile index by the index to juveniles born into the population, subtracting the quotient from 1, and multiplying by 100 (Table 3, column 4). Fall juvenile indexes were calculated by multiplying the October population index of each year by the fraction of juveniles in the October collection (Table 4). Indexes to juveniles born were obtained by multiplying the January 1 female indexes (Stoddart 1972) by the number of fetuses born per January 1 female (Table 5, column C). Postpartum mortality rates varied from 22-88 percent with a mean of 64. Postpartum mortality in 1974 was 56 percent.

5. Population Density Change

The pattern of events observed so far during the study of jackrabbit population dynamics in Curlew Valley indicates that density changes are largely due to annual variation in mortality rates and that changes in natality have had little effect on density trends. Table 5 shows the relative contribution of natality rate (column A) and combined mortality rates to the production of fall juveniles by females alive at the beginning of the breeding season, January 1 (column D). Natality rate as measured by the number of ova produced per female surviving the breeding season has varied from 8.1-19.8 with a mean over all years of 15.6. Except for the low value of 8.1 in 1972, the range in natality rate has been less than ± 30 percent of the mean. Fall 1972 density index was 64, a decrease of 60 percent from the fall 1971 index of 160. Had the 1972 natality rate been an average value of 15.6 the fall 1972 index would have been approximately 90, still a decrease of 44 percent from 1971. Though the low natality rate in 1972 did affect density, the basic trend of decreasing density would not have been greatly altered by a mean natality rate for that year.

Table 3. October-March Mortality Rate of Total Jackrabbit Population, March-October Mortality Rate of Adults and Birth to October Mortality Rate of Juveniles

Year	Percentage mortality		
	Oct.-March	March-Oct.	Birth-Oct.
1962-1963	65		
1963		70	22
1963-1964	57		
1964		87	69
1964-1965	57		
1965		74	69
1965-1966	64		
1966		70	67
1966-1967	69		
1967		65	67
1967-1968	56		
1968		9	38
1968-1969	34		
1969		60	61
1969-1970	44		
1970		23	68
1970-1971	32		
1971		50	85
1971-1972	46		
1972		67	88
1972-1973	72		
1973		87	85
1973-1974	63		
1974		0	56
1974-1975	91		
Unweighted means	59	55	64

Table 4. Percentage of Adults in October Rabbit Collections from 1963-1973

	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974
% Adults	7	8	14	15	12	13	14	28	40	45	16	22

Table 5. Mean number of ova and fetuses produced per female in the population surviving the breeding season, mean number of fetuses produced and mean number of juveniles alive at fall census per female alive January 1, and percent of potential juveniles actually observed at time of fall census from 1963-73

Year	(A) Ova/ female	(B) Fetuses/ female	(C) Fetuses per Jan. 1 female (AXD Table 4)	(D) Observed juv. in fall per Jan. 1 female	(E) Percent potential juv. obser. (D/Ax100)
1963	15.4	13.5	5.4	4.1	27
1964	19.1	15.3	6.1	1.9	10
1965	14.6	13.1	6.3	2.1	14
1966	13.2	12.2	5.8	1.9	14
1967	19.3	18.9	7.3	2.4	12
1968	19.8	18.6	11.2	6.9	35
1969	16.1	14.1	9.9	3.9	24
1970	14.2	13.1	8.7	2.8	20
1971	13.4	11.3	8.0	1.2	9
1972	8.1	7.5	4.7	0.6	7
1973	16.6	13.2	4.4	0.7	4
1974	17.8	15.4	8.7	3.9	22
Means	15.6	13.8	7.3	2.7	17

The number of ova produced per female is reduced through prepartum mortality to give the number of fetuses produced per female surviving the breeding season (column B). This number is further reduced by mortality of females during the breeding season to give an estimate of the number of young born per female starting the breeding season (column C). Finally, the number is reduced through juvenile mortality from birth to October to produce the number of juveniles at times of fall census per female starting the breeding season (column D). This number varied from 0.6-6.9, a range of about ± 200 percent of the mean 2.7. Therefore, through changes in mortality rates, variation in the number of ova produced per female compared to variation in the number of juveniles in fall per female starting the breeding season has increased from 30 percent to 200 percent of the respective means. The conclusion is that in most cases annual changes in mortality rates have overshadowed variation in natality. A multiple regression analysis (Fig. 5) indicates that 91 percent of the variation in population change from October-October is accounted for by changes in adult mortality rate from October-October and changes in juvenile mortality rate from birth-October.

K-factor Analysis.-- Changes in jackrabbit density from generation to generation, as indicated in Figure 1 by spring density indexes, occur only through mortality or natality in the population. Since variation in natality rate has had little effect on rates of population change, we have concentrated mainly on mortality in the analysis of population change. The purpose of K-factor analysis is to learn in which temporal period of a jackrabbit generation, i.e. spring-spring, mortality is most important in determining population numbers (cf. Varley et al. 1973).

A k-value for any time period is defined as the $\log_{10}$ of the population density at the beginning of the period divided by the $\log$ of the density at the end of the period or stage. Thus k-values express mortality on the basis of a life stage rather than as a function of time. The greater the percentage loss during the period, the larger will be the k-value. Generation mortality, K, is defined as the sum of the k-values for all periods into which the generation has been divided.

Since the jackrabbit population has overlapping generations, the population was divided into 2 generations. The first is adults from spring-spring and the second is juveniles from conception to the following spring. Adult generation mortality, K_1 , and juvenile generation mortality, K_2 , are plotted in Figure 6. The adult generation was divided into 2 periods: spring-fall mortality, k_4 , and fall-spring mortality, k_3 . It is apparent from the figure that the 2 mortality periods, i.e. k_3 and k_4 , have contributed about equally over the years to the generation mortality, K_1 , and are thus both important in the analysis of adult mortality.

The juvenile generation was divided into 3 periods: prenatal mortality, k_1 , birth-fall mortality, k_2 , and fall-spring mortality, k_3 (k_3 is the same for both the adult and juvenile generations). It is clear from Figure 6 that prenatal mortality has been insignificant over the years in terms of the juvenile generation mortality and thus is not considered any further in the analysis of mortality.

Fig. 5. Multiple regression of October-October instantaneous rate of jackrabbit density change on the October-October population mortality and the percent juvenile mortality from birth-October.

$$y = 4.2066 - 0.0254X_1 - 0.0333X_2$$

$$r^2 = 0.91$$

Fig. 6. Jackrabbit mortality during 4 life stages expressed in terms of k-values. See text.

From 1964-1968 k_3 and k_4 were about equally important in determining k_2 . However, from 1968-1973, while the rabbit population was increasing, and for 2 years following the peak (cf. Fig. 1), birth-fall mortality, k_2 , became markedly more prominent. The significance of this will be discussed in a following section.

Analysis of Mortality.-- It is apparent from the above section that analysis of environmental factors affecting k_2 , k_3 , and k_4 is necessary to obtain an understanding of jackrabbit population change.

A. Fall-spring population mortality, k_3 . Jackrabbit instantaneous mortality rates (instantaneous rate = $\log_e$ of the survival) for the October-March periods were plotted (Fig. 7) as a function of the independent variable, $(\text{coyote/rabbit})_E$, where $(\text{coyote/rabbit})_E = (\text{coyote/rabbit})_F$. The term $(\text{coyote/rabbit})_F$ is the observed coyote to rabbit ratio and $F = 1 - e^{-kd^x}$. F is a variable that relates the rate at which a single coyote eats jackrabbit as a function of rabbit density, d . The other terms, k and x , are constants which are determined empirically from coyote food habits studies. The rate at which F changes with rabbit density is determined by x , where k moves the curve up or down the F axis as a function of density of rodents or other buffer species. We have used values of 0.3 and 0.45 for k and x respectively. The values were determined from food habits studies in Curlew Valley under contract with the U.S. Fish and Wildlife Service, Predator Ecology and Behavior Project. The food habits studies are as yet incomplete.

The regression (Fig. 7), excluding the 1974-1975 data point, accounts for 83 percent of the observed variation in October-March mortality. October-March mortality in 1974-1975 was 91 percent, by far the highest so far observed (cf. Table 1). It is apparent from Figure 7 that the close relationship between rabbit mortality and coyote predation will not account for this high mortality in the 1974-1975 period. There are two possibilities: (1) some other factor was accounting for a large part of the rabbit mortality during the past winter, or (2) random experimental error in the density estimates during this period of low density (cf. Fig. 1) resulted in erroneous mortality estimates. The latter possibility is most likely. If the fall 1974 density estimate were too high (a good possibility since it broke the downward trend in density which we actually still seem to have; Figure 1) we would expect to over estimate the October-March loss since it is calculated from $1 - (\text{spring density/fall density})$. Also, if the fall 1974 density estimate were too high we would expect to under estimate March-October 1974 mortality. In fact, this was the case since the over summer adult mortality estimate was 0, obviously a low estimate (cf. Table 3). Another possibility which would explain the observed results, i.e. the 91 percent mortality over winter 1974-1975 and the 0 percent loss over summer 1974, would be March 1974 and March 1975 density estimates that were too low. This could easily have occurred with the low densities existing during 1974 and 1975 (Table 1). Observation of just one rabbit more or less on the transects would have made substantial difference in the density estimates. The potential for large experimental error was great.

During the operation of coyote scent posts in Curlew Valley, jackrabbit tracks in the scent post were also recorded. The frequency of rabbit tracks was used to obtain a second index to rabbit density. Figure 8 shows a comparison of rabbit indexes from the scent posts and from the rabbit transects. Except for the spring 1973 values, the trends of the two indexes are very comparable. The spring 1973 scent post index is probably low. This was the first time the scent posts were operated and the surfaces were not prepared in such a fashion as to adequately reveal rabbit tracks. The scent post

Fig. 7. Linear regression of instantaneous rabbit mortality rate from October-March on the effective coyote/rabbit ratio over the study area.

Fig. 8. Jackrabbit density indexes obtained using transects and scent posts.

results indicate less rabbit density change from spring 1974 to fall 1974 and from fall 1974 to spring 1975 than do the rabbit transects. This adds weight to the possibility that the summer 1974 mortality estimate was too low and the winter 1974-1975 estimate too high.

The coyote/rabbit ratio used in the calculation of $(\text{coyote/rabbit})_E$ in Figure 7 was calculated for each October-March period by dividing the estimated number of coyotes/square mile on the study area in October by the October rabbit index. Coyote densities (Fig. 1) were obtained from studies contracted with the U.S. Fish and Wildlife Service in Curlew Valley.

B. Spring-fall adult mortality, k_4 . Adult jackrabbit instantaneous mortality rates for the March-October periods were plotted, again, against the coyote/rabbit ratio multiplied by F (Fig. 9). The regression excludes the 1974 data point of 0 mortality discussed above. Error about the regression line is quite large giving an r^2 value of only 0.41. Apparently other factors besides coyote predation are responsible for a large part of the observed variation in March-October adult mortality rate.

C. Birth-fall juvenile mortality, k_2 . Mortality of juveniles has been of particular importance because of the great effect it has had on density change (discussed above). Juvenile survival was plotted as a function of two variables, the coyote/rabbit ratio multiplied by F and the mean rabbit index for the March-October period (Fig. 10). The multiple regression equation was calculated using data from 1964 through 1970 only. The 1971-1973 data do not fit the model well. Even though density had decreased in 1971-1973, mortality remained high. Possibly in these years we were observing some "cumulative" and/or "carry-over" effect of density on juvenile survival which Christian and Lemunyan (1957), Chitty (1967), and Krebs et al. (1973) have postulated might result from changes in behavior and/or genetic composition. The discussion above concerning the high rate of adult survival during the summer of 1974 also applies to the observed high juvenile survival in 1974 (Fig. 10).

Analysis of k-values.-- The regression equation for October-March mortality in Figure 7 can be used to partition k_3 into 2 k-values, k_{32} and k_{31} (Fig. 11). k_{32} represents mortality due to coyote predation while k_{31} is a combination of a constant mortality indicated by the intercept of the regression equation and experimental error at each of the data points. The straight, broken line in Figure 11 is the constant mortality of the intercept; the deviation of the dashed line, k_{31} , from this line is the experimental error. The figure depicts graphically our best estimate of the contribution of coyote predation, unknown mortality factors, and experimental error to the total October-March mortality, k_3 . It also shows that for most years change in October-March mortality is a result mainly of change in the rate of coyote predation.

The same procedure was used to partition k_4 into mortality due to coyote predation, k_{42} , and mortality due to unknown factors plus experimental error, k_{41} (Fig. 11). It is evident that much of the variation in March-October mortality of adults, k_4 , is a result of unknown mortality factors, even though mortality due to coyote predation does follow the same basic trend as k_4 .

In the same manner, birth-October mortality of juveniles, k_2 , was partitioned into mortality due to coyote predation, k_{21} , density related mortality, k_{22} , and mortality due to unknown factors, k_{23} (Fig. 12). From 1964-1968 juvenile mortality was closely associated with coyote predation, but in 1969-1971 this mortality factor was replaced, as the dominant cause of mortality, by density

Fig. 9. Linear regression of instantaneous rabbit mortality rate from March-October on the effective coyote/rabbit ratio over the study area.

$$r^2 = 0.78$$

Fig. 10. Multiple regression of percent juvenile survival from birth-October on the effective coyote/rabbit ratio and mean rabbit index during the March-October period.

k_3 = October-March population mortality
 k_{32} = Coyote predation mortality
 k_{31} = Mortality due to unknown factors plus experimental error

Fig. 11. k_3 and k_4 partitioned into mortality due to coyote predation and mortality due to unknown factors.

Fig. 12. k_2 partitioned into mortality due to coyote predation, into density related mortality, and mortality due to unknown factors.

related factors. Then in 1971-1973, k_{23} , representing density "carry-over" effect, became an important part of k_2 .

Since coyote predation mortality rates, k_{32} , k_{42} , and k_{21} , have been partitioned from the total mortalities, k_3 , k_4 , and k_2 , they can be plotted against rabbit density (Fig. 13) to determine the relationship of coyote predation to rabbit density. In all three cases an inverse relationship is evident indicating that loss due to coyote predation increases as rabbit density declines.

6. Controlled Studies

Four 5-acre pens of 4-foot chain link fence have been constructed this year on land being leased by the U.S. Fish and Wildlife Service near Logan. The pens have been equipped with water and electrical power lines and an observation tower at the center of the pens will be constructed this summer. By fall the pens should be ready for stocking.

The first phase of the penned studies will be to observe basic behavior of jackrabbits from a low density population. Particular emphasis will be placed on factors which may affect population size such as maternal care and aggression between juveniles and adults. We will probably also get basic information on frequency of occurrence of some blood proteins using electrophoresis. The pens will be restocked at the same rate each year from the natural population on the INEL or in Curlew Valley. Changes in behavior and survival as a function of density of the natural population from which the stock is taken, as well as changes in frequency of blood proteins, will be noted. A graduate student will be starting on this project in fall 1975 and a detailed study plan will be developed at that time.

7. INEL Coyote Scent Posts

In spring 1975, 6 coyote scent post lines were established in the INEL study area. Three were located in the part of the area grazed by domestic livestock and 3 in the ungrazed portion (Fig. 14). A total of 11 coyote tracks were observed on the stations during the 5-day period of operation of each line, i.e. 1500 scent station nights. The result was a calculated mean coyote index per line of 8. This compares with the spring 1975 index in Curlew Valley of 9. A comparison with a complete coyote population cycle in Curlew Valley can be seen in Figure 1.

8. INEL Rodent Index

Twenty-five rodent snap-trap transects were located along each of the 6 15-mile coyote scent post lines (Fig. 14). In spring 1975 each transect was operated for 3 nights giving a total of 9000 snap-trap nights. A computer program was developed which will produce rodent density index estimates from the transect data, but the data has not been run as yet.

We had originally planned that each transect would be composed of 10 trap stations with a single trap at each station. However, this was modified; we are using 2 traps at each station. The reasoning behind this change is explained below.

Fig. 13. Plots showing inverse relationship of
coyote predation and rabbit density.

k_{32} = October-March coyote predation

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k_{42} = March-October coyote predation on adults

k_{21} = birth-October coyote predation on juveniles

Fig. 14. Location of 6 coyote scent post lines (numbered solid lines) on the INEL study area. Shading indicates portion of study area grazed by domestick livestock.

If we let N = number of operable traps at any time, t , and n = number of rodents having access to the N traps then:

$$\frac{dN}{dt} = -\lambda N$$

where $\lambda = cn$ and c is a rodent catchability constant.

then:

$$\int \frac{dn}{N} = -\lambda \int dt$$

or:

$$\log N/N_0 = -\lambda t$$

or:

$$N = N_0 e^{-\lambda t}$$

where N_0 is the original number of traps at $t = 0$

$$N/N_0 = \text{trap survival} = e^{-\lambda t} \dots \dots \dots (1)$$

let $t = 1$ = overnight time period

then overnight trap survival = e^{-cn}

and the number of rodents caught = $N_0 (1 - \text{survival})$

$$\text{or from (1) rodents caught} = N_0 (1 - e^{-cn}) \dots \dots \dots (2)$$

A plot of Equation (2) takes the following form:

It is apparent from the curve that after about 60 percent of the traps catch animals, the number of rodents caught becomes very insensitive to changes in rodent density and therefore is not a reliable index to density. Our experience in Curlew Valley with single trap stations would indicate a good probability of trap success of 60 percent or above with single trap stations on the INEL. Two trap stations will greatly reduce the likelihood of success rates in this range.

Six 12 x 12 live-trap grids were also operated for 5 days each on the INEL site. After 5 days of trapping, 3 snap-trap transects were located in and near the grids. The purpose was to get a conversion factor whereby we can relate transect results to absolute density. A computer program has been

developed in cooperation with the IBP Desert Biome which will compute absolute density estimates from the grid data. However, our grid data has not been run as yet.

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