MASTERTECHNICAL PROGRESS REPORT--COO-1329-7

Project Title: Population dynamics, movement, and home range of black-tailed jackrabbits (Lepus californicus) in Curlew Valley, Northern Utah

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STATEMENT OF PROGRESS FOR THE PERIOD JULY 15, 1966, TO JULY 14, 1967

I. Introduction

Progress was made on all subprojects during the current reporting period. Our understanding of population dynamics has been further advanced. But more important, use of telemetry to detect mortality was advanced past the developmental stage and data which bear out the findings of our demographic calculations have now been accruing for about a year. Furthermore, we now have conclusive results on the effects of brain irradiation on the mobility and home-range phenomenon of jackrabbits. One paper was presented at a national meeting and a second has been submitted for publication.

II. Subproject (1): Population Dynamics

A. Population Measurement

Semi-annual population censuses were continued in October, 1967 and March 1968. As in the past, these were taken extensively over the valley as a whole, with 73 one-mile transects distributed at random and traversed on foot between the hours of 9 a.m. and 4 p.m. All flushed rabbits were counted, and the distance measured between the position of the observer at the time of flush and the point from which the rabbit flushed.

These transects provide the basis for measuring rates of population change (both from recruitment and mortality) between seasons and between years. Results of the October 1967 and spring 1968 counts (Figure 1) show continuation of the population decline that has been underway since the early stages of this study. The population increased between October 1962 and October 1963 and has declined every fall since then. The 10 percent decline from October 1966 to October 1967 and the ensuing overwinter decline of 48 percent to March 1968 reduced the population to the lowest point of the six-year study period.

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Figure 1. Seasonal and Annual Population Changes, 1962-68

With five to six years' data now at hand, some patterns are beginning to suggest themselves although previous experience points up the hazard of proposing very firm hypotheses on less than twice this amount of data. This tentative synthesis is deferred, however, until after consideration of the two components of population change, natality and mortality.

B. Reproduction Rates

1. Introduction. As in previous years, evidence on the reproductive activities of the population has been derived from the monthly collection of 50 to 150 animals from the valley populations. These are collected at random so as to reflect the sex and age structure of the population and the reproductive condition of a random cross-section of the females.

As discussed in previous reports, the reproductive performance of this population can be expressed in several different ways. Because of the extremely high breeding season mortality of adults, the actual reproductive output per female alive at the beginning of the breeding season is far below the potential implied by monthly litter sizes and pregnancy rates. Hence the latter do not provide accurate estimates of the reproductive rates. The more refined measure of reproductive output requires aging of fetuses and calculation of a monthly parturition rate of near-term litters rather than a monthly pregnancy rate based on litters of all ages.

Fetus aging is time consuming and requires a laboratory operation separate from the first autopsy when first judgments of visual pregnancy and crude litter size are made. Since only the first autopsies have been completed on material collected in spring and early summer of this year, the summaries here presented are based only on the preliminary estimates which, while inadequate as measures of the actual rates, do serve as indices of year-to-year reproductive rates.

2. Litter sizes. The monthly mean number of fetuses per pregnant female (Table 1), while not attaining the extremely high values of 1967, were slightly higher in 1968 in the three important breeding months of March, April, and May, and the seasonal average than the means for the period of study.

Table 1. Monthly mean litter size by years in adult females

Month	Mean No. Young in Litter							Average
	1962	1963	1964	1965	1966	1967	1968	
January	--	--	1.0	--	1.4	--	1.2	1.2
February	--	1.5	2.2	1.8	2.2	1.9	1.4	1.8
March	--	4.5	4.7	3.6	4.4	5.5	5.2	4.6
April	6.3	5.3	6.2	4.8	5.8	7.1	6.5	6.0
May	5.2	6.0	5.9	4.6	4.3	6.4	5.6	5.4
June	4.2	4.8	4.1	3.3	--	4.4	4.1	4.2
July	3.7	2.8	3.0	--	--	5.0	--	3.6
Avg. (Feb-June)	--	4.4	4.6	3.6	4.2	5.1	4.6	4.4

3. Monthly pregnancy rates. The monthly percentages of females pregnant (Table 2) in 1968 have all been above average except in the month of May, and in total from January through June about equal the 1967 values which were the largest so far recorded during the study. This array of values plus the slightly larger litter size make 1968 one of the most productive years in terms of reproductive rates so far observed.

Table 2. Monthly percentage of adult females pregnant by years

Month	Percentage of Females Pregnant							Average
	1962	1963	1964	1965	1966	1967	1968	
January	--	0	6	0	36	0	19	10
February	--	8	55	100	86	91	92	72
March	--	58	76	92	96	86	83	82
April	89	76	80	67	92	78	83	80
May	56	67	77	67	58	81	57	66
June	29	51	58	31	0	69	75	44
July	14	9	4	0	0	56	--	14
August	<u>3</u>	<u>0</u>	<u>0</u>	<u>0</u>	<u>0</u>	<u>0</u>	<u>--</u>	<u>1</u>
Total, Jan-July	--	269	356	357	368	461	409+	362

4. Products of monthly litter sizes and pregnancy rates. As stated above, it is possible to gain an index of reproductive effort by multiplying the monthly litter sizes and pregnancy rates, and summing the monthly values for each year (Table 3). These seasonal totals are not assumed to represent the actual production of young per female alive in January as they may overestimate the latter by as much as 100 percent. They do, however, serve as a relative base with which the years can be compared.

Three generalizations seem possible from these values on the basis of data so far accrued. The first is that substantial variation has occurred during the period of study. In the first three to four years of the study, little variation occurred and emphasis was placed in early reports on the constancy of reproductive output. In 1967 and 1968, however, the breeding effort has increased substantially. The 1967 index (22.52) was nearly double the lowest value (12.43) observed in 1965.

The second generalization is that these variations appear to be associated with density, a conclusion reached in the 1967 progress report. Reproductive rate thus appears to be negatively density dependent, an inverse correlation existing between adult densities in spring and reproductive output (Figure 2) This is a suggestion previously made by French et al. (1965).

The third generalization is that while reproductive rate is a function of density, changes in density have not been a function of reproductive rate. This point will be amplified below, but at this stage it can be pointed out that the population increased (Figure 1) in 1963 when the

Figure 2. Relationship Between Breeding Density and Reproductive Rate

reproductive rate was the second lowest observed. It declined in 1964 and 1967 when reproductive rates were above average.

Table 3. Monthly product of mean litter size and pregnancy rate by years

Month	Mean Litter Size X Percentage Pregnant							Average
	1962	1963	1964	1965	1966	1967	1968	
January	--	0	0.06	0	0.50	0	0.22	0.11
February	--	0.12	1.21	1.80	1.89	1.67	1.29	1.34
March	--	2.57	3.57	3.31	4.18	4.69	4.32	3.66
April	5.61	4.03	4.96	3.22	5.34	5.54	5.40	4.80
May	2.91	4.02	4.50	3.08	2.41	5.18	3.19	3.68
June	1.22	2.45	2.30	1.02	0	3.04	2.84	1.67
July	0.52	0.25	0.12	0	0	2.30	--	0.75
August	--	0	0	0	0	0	--	0
Total	10.36+	13.44	16.66	12.43	14.32	22.52	17.26+	16.01

C. Mortality Rates

Mortality rates have been measured, as in the past, by comparing the October and March censuses to reflect overwinter mortality of the entire population. Spring-fall adult mortality has been obtained by comparing the March census with the number of adults per mile of subsequent October census, the adult density index resulting from the product of total animals counted per mile in October and the percentage of adults in the October collection. Juvenile mortality from birth to October is calculated by (1) assuming a straight-line mortality pattern of adults between March and October, (2) multiplying the monthly number of females per transect mile thus derived by the monthly number of young produced per female, (3) summing these products, and (4) comparing the sum with the number of juveniles per mile of transect in October.

The results (Table 4) permit several tentative generalizations. First, some variation has occurred between years. No particular trend is evident for the October-March mortality, but the summer adult and juvenile loss were both comparatively low in the first year of study (1962-63) and have been comparatively high since. There thus appears to be some year-to-year correlation in these two warm-season parameters, but none with the overwinter loss. Since the warm-season loss of adults is so extremely high, it has a pre-eminent role in determining the magnitude of the total, annual mortality from October to October. Hence the annual rates measured between Octobers are also low in the first year of study and high each year thereafter.

Secondly, the high level of warm-season adult loss again bears emphasis although it has been pointed out in previous reports. Its magnitude is twice that of the preceding overwinter loss, and it is higher than the juvenile loss from birth to October. It is this loss which creates a

Table 4. Seasonal and annual mortality rates by years

Year	A: Total Pop., Oct-March	B: Adults, March-Oct	C: Cohort, Oct-Oct ¹	Juveniles, Birth-Oct
1962-63	35		79	
1963		67		18
1963-64	61		94	
1964		85		58
1964-65	33		95	
1965		93		77
1965-66	50		92	
1966		84		72
1966-67	47		93	
1967		86		75
1967-68	48		--	
1968		--		--
Means	46	83	91	60

¹This is the mortality of the entire population from October of one year to the following October.

rapid drain on the ranks of breeding females which start out the 7-month breeding season, and reduces the realized reproductive rate to half its potential.

Finally, there are some indications that population increase may be under way in 1968, although this will not be definitely ascertainable until the October census. One indication is subjective: simply that workers in the Curlew Valley area are seeing more animals during the summer than have been seen for several years.

A second indication comes from telemetry results to be reported on more completely in a subsequent section. These results show only 6 to 12 percent adult mortality from March to mid-July, the first half of the 7-month period during which an average loss of 83 percent has been occurring in prior years (Table 4).

A third indication lies in the numbers of young appearing in the collections in May and June. In prior years, the fractions of young in the May and June collection have averaged 10 and 45 percent, respectively. In 1968, the same two values have been 65 and 85. This large appearance of young probably implies either that adult survival has been high, as the telemetry results indicate, and that the realized reproductive output has been higher than usual; and/or that juvenile survival has been higher than usual. The reproductive effort, while somewhat higher than average (Table 3), has not been as high as in 1967 when the population declined. Hence a population increase in 1968, if it occurs, will probably result largely from high adult and/or juvenile survival for which there are indications.

D. Synthesis on Population Change

The density at which any population exists, and the changes in that density, depend on the continually opposed forces of reproduction and mortality. During the period in which the present population has been under study (1962-1968), reproductive effort per female alive in the population has varied by a factor of nearly two, although most of the values have varied from the mean for the period by less than 25 percent. The variation that has occurred has been significantly marked by variations in the very high mortality rates and, consequently, no correlation exists between reproductive rate and population trend.

Mortality rates, both juvenile and adult, have on the other hand been clearly correlated with annual rates of population increase from one October to the next (Figure 3). It appears as of this writing that 1968 may also follow this pattern, with some indication of below-average mortality and population increase.

The constraints on the population have thus operated through mortality. This is of course based on a small sample of years, but so far the evidence

Figure 3. Relationship Between Annual Rates of Population Change and Adult and Juvenile Mortality Rates

is fairly unequivocal. The actual causes of loss will be touched upon in a subsequent section.

We still have not observed the full range of fluctuation in the population, nor observed its behavior during prolonged periods of increase, attainment of high density, and subsequent decline. Hence we are not yet close to being able to generalize about the overall regulatory and fluctuation patterns of the population. Yet we are to the stage of forming some hypotheses and some general trends do appear to be emerging. It is important that we continue the studies in order to complete the picture and get full value received from the time and resources so far invested.

E. Calculation of Secondary Production

One aspect of the biology of this population which has not yet been touched upon during the course of the research is its secondary production. As the population fluctuates this parameter is obviously going to vary as is its role in energy flow in the desert ecosystem. The first need in any production estimate is an elucidation of the demographic pattern of the population. The present studies have provided most of the requisite data, the major remaining need being to determine the timing of the juvenile mortality. In fact, most of the production in a short-lived, fast-growing species like this takes place in the first few months of life. Whether or not the high rate of juvenile mortality evident in the species takes place largely in the early weeks of life or later in the summer will importantly alter the productivity value.

Work is underway in the summer of 1968 to determine telemetrically whether the mortality occurs early or late in the growth of the young. Once this is determined and animals of different ages are calorimetered, productivity calculations can be made.

III. Subproject (3): Movement and Home Range

All progress on this subproject during the report period was confined to the comparison of home range patterns in irradiated and control animals to be discussed next under Subproject (3): Influence of Gamma Radiation on Movement and Home Range.

IV. Subproject (3): Influence of Gamma Radiation on Movement and Home Range

A. Objective

The objective of this subproject has been to study the influence of massive, but sublethal, doses of X-irradiation on the movement and home-range patterns of jackrabbits. The rationale underlying this study has been that the movement and home-range patterns of an animal represent

a balance between its exploratory behavior and its site-attachment behavior or proclivity for inhabiting an area with which it is familiar. These behavioral characteristics vary between species, of course, and within species in different areas and times. Their origin in the individual is partly learned, partly inherent.

The present study has been one of damaging the cerebral tissue in order to alter the balance. Radiation has been used as a technique for damaging tissue which did not require the concomittant traumas of an operation: surface tissue damage, the need for penetrating the skull, infection risk, and blood loss.

B. Procedures

1. Irradiation procedures. The preliminary work on dosimetry and the equipment and facilities used have been described in previous reports. Field experiments were carried out between November 19 and January 6, inclusive. Rabbits were trapped on the study area by setting traps in the evening and checking them each morning.

When an animal was caught, it was sexed and taken immediately to the X-ray unit. Experimentals were subjected to 5,000 r exposure of the cerebral region administered in 25 minutes continuous dosage. They were then fitted with radio transmitters like those described in the 1967 report, returned immediately to the capture site, and released. Control animals were handled in identically the same manner, including 25 minutes restraint in the X-ray unit, but were not subjected to irradiation.

A total of 16 animals were handled with these procedures: seven controls and nine experimentals. All appeared in reasonably good health when released.

2. Field observational procedures. As soon as transmitter-equipped rabbits were released, nightly observations were begun on them, beginning at 5:00 p.m. and ending at 8:00 a.m. Two observers, one at each of the two receiving stations (described in the appended reports), made hourly, simultaneous azimuth readings on each animal. (Each animal was individually identifiable because its transmitter emitted a signal on a different frequency from the others.)

In order to coordinate efforts and promote simultaneity of readings, two-way radios were used during the observation periods. In addition, a transmitter was placed at a known location in approximately the center of the study area. Prior to each hourly series of observations, two readings were taken on this transmitter from each station, and two more were taken at the end of each hourly series. The objective here was to provide readings on a known location which would disclose the magnitude of mechanical errors inherent in the system produced by wind torque on

the antenna, temperature expansion and contraction, etc. These readings were later used to correct the hourly observations on animals.

A total of 2,188 triangulated locations were recorded on the 16 animals, with an average of 136 on each. These were distributed over 186 animal-nights observations with an average 12 per animal and 11 locations per animal per night.

3. Analytical procedures. At the end of the field observation period, all triangulated locations were corrected for the error detected with readings on the known-location transmitters. A computer program was then designed to transpose the corrected azimuth readings to an X-Y coordinate system. With the use of an X-Y plotter, each animal's nightly locations were plotted to scale and numbered sequentially starting at one. The result, then, was a point scatter for each of the 186 animal-night observations.

Three parameters are in the process of being, or have been, calculated from these data. The first is simply the distance between successive hourly points for each animal-night's observation. This provides an index of the animal's movement during the night. Obviously an animal can move a great deal in various directions during the course of an hour, so the distance between two locations measured at an hour's interval does not purport to be an accurate measure of his actual movement but only an index thereof.

A second parameter which we have calculated is the area enclosed by a polygon formed from connecting the outside points of the location scatters. Such home-range polygons can be formed for each animal-night's observations to form what Rusch (1965) called a "daily average range" or for the sum of observations for one animal to form what he called a "seasonal average range."

If an animal's locations over a period of time are viewed as a two-dimensional frequency distribution scattered about the geometric center of his locations, the daily or seasonal average range is only one of the expressions which can be used to describe the distribution. It is analogous to the range of variation in a single-variate population, and as such is no more satisfactory for completely describing the variation pattern of the home range than is the range for describing the distribution of the single-variate population. What is needed in addition is some measure of the scatter or central tendency of the points about the center analogous to the standard deviation of a distribution. Accordingly, probability bands about the geometric center of the rabbit locations are providing a third parameter of the animals' movement and home-range pattern.

C. Results

This is being written approximately 5 months after completion of field work. In this period the data have been tabulated, screened, and corrected

for error shown by known-location transmitters and faulty observation, a computer program designed, the data programmed and carded, and several preliminary analyses performed. In addition, a conference paper was written and presented (see attached). Additional analyses are still in progress, and hence the present report is only an incomplete and preliminary account of the results.

1. Analytical problems. Some screening of the data has been necessary in the interests of measurement accuracy. Ideally, the two azimuths taken to triangulate a single point location of an animal should be taken simultaneously. If any time lapse occurs between the readings by the two observers, the animal could move between first and second reading, and the result would be an inaccurate triangulation of his instantaneous location.

In practice, it is difficult to make the readings simultaneous even when the two observers are in two-way radio contact. Taking an azimuth requires a period of several seconds up to a minute or more to adjust the antenna under the best of conditions. Hence, even when two observers with radio contact agree immediately to take a reading, some time elapses before these are taken and this time will vary between observers. Under average observing conditions, wind will cause some variation in the position of the antenna. An observer may need to wait between gusts to take the reading and this will create further delay. Add to this malfunctions of the two-way radios, other equipment problems, and human failings and many of the paired readings are not simultaneous.

The poorer readings (those in which the time lapse was more than 6 minutes) were screened out and discarded. They constituted roughly one-third of the 2188 observations, and hence the data used for analysis constitute 1,478 point locations and 1,292 hourly movement values (Table 5).

Table 5. Screened sample sizes obtained in control and test animals

Control Animals				Test Animals			
Anim. No.	Sex	No. Anim.	No. Point	Anim. No.	Sex	No. Anim.	No. Point
		Nights	Locations			Nights	Locations
21	M	17	93	24	M	10	59
22	M	13	94	27	M	15	139
23	F	13	116	28	F	8	69
25	M	17	112	29	F	9	67
26	M	8	83	32	F	23	203
30	F	20	194	33	F	5	27
31	F	9	65	34	M	2	12
				35	F	8	54
				36	M	9	81
Totals (and Means)		97 (14)	767 (109)			89 (10)	711 (79)

A second analytical problem has arisen from the inherent bias present in fixed-receiver telemetry work. This problem is discussed in the attached conference paper, and has previously been reported on by Heezon and Tester (1967). It is based on the increasing distortion of measurement entailed by increasing proximity of observed animals to the line between the receiving stations (henceforth termed the "baseline.").

In consequence, home-range and movement patterns are measured with approximate accuracy only in the case of animals which are at right angles to the two receivers. Some degree of distortion is involved in all other individuals. While the results can probably be viewed as indices and used for comparative purposes, any comparisons between areas, times, sex or age classes, or experimental treatments as in this study, must be based on paired subjects located at the same relative distances from the base line.

The control and test animals used in this study are approximately, but not precisely paired. Hence, comparison of crude means, like those to be presented next, do not provide very sensitive tests. More refined analyses are currently in progress.

2. Mean hourly movement. The movement patterns of control and test animals are shown in Table 6. The animals are arranged in order of increasing distance from the baseline. The mean, hourly distance moved was calculated for each night of observation for each animal. These nightly means were then averaged for each animal to produce an average of the mean nightly movements. These values are shown in the table.

The crude, unweighted mean of these values for the test animals is slightly higher (ca 10 percent) than that for the controls. This is not a good comparison, however, because of the position bias described in the appended report. The test animals on the average were about 200 ft. farther from the baseline than the controls, and the difference between the two is therefore slightly underestimated. A paired comparison test of animals 21 and 24, 25 and 33, 22 and 36, etc. with 34 and 27 omitted produced a slightly greater difference but it was short of statistical difference. Animal 34 was excluded because of its small sample and 27 had no counterpart for pairing.

One problem with this test is that it reduces the degrees of freedom to only six, and using the means as they are gives as much weight to an animal which has been observed for only five nights as it does to one which has been observed for 20.

3. Daily average range. If the areas for each daily home range constituting the polygon enclosed by a line connecting the outer points of movement in one night of activity are calculated and averaged over the period of observation, the means provide an estimate of biome-range size between control and test animals. These are shown in Table 7, again in order of increasing distance from the baseline.

Table 6. Average of mean hourly distance moved per night of control and test animals

Control Animals				Test Animals			
Anim. No.	Ft. From Baseline	No. Hourly Moves ¹	Mean Dist. Moved in ft.	Anim. No.	Ft. From Baseline	No. Hourly Moves ¹	Mean Dist. Moved in ft.
21	911	76	1157.1	34	1021	10	591.0
25	1054	95	1294.2	24	1163	49	1435.7
22	1188	81	951.2	33	1256	22	1148.9
31	1526	56	1329.4	36	1465	72	1299.9
30	1770	174	879.5	32	1650	180	1024.3
26	2199	75	815.6	28	1811	61	579.4
23	2234	103	681.7	35	2323	46	953.8
				29	2412	58	1717.3
				27	2535	124	1400.4
Unwt'd Means 1555 - 1015.5				- 1736 - 1127.8			

¹ No. of hourly moves is always one less for each night of observation than the number of point locations shown in Table 5.

Table 7. Daily average ranges for control and test animals in acres

Control Animals			Test Animals		
Anim. No.	No. Nights Observed	Mean of Daily Home Ranges	Anim. No.	No. Nights Observed	Mean of Daily Home Ranges
21	17	22.80 acres	34	2	9.30 acres
25	17	40.88 "	24	10	53.34 "
22	13	25.63 "	33	5	41.76 "
31	9	84.69 "	36	9	100.10 "
30	20	30.75 "	32	23	50.80 "
26	8	31.64 "	28	8	14.84 "
23	13	26.62 "	35	8	45.94 "
			29	9	175.41 "
			27	15	65.68 "
Unwtd. Means 37.57			- - 61.91		

In these data again, the crude means suggest home ranges in the irradiated animals nearly twice the size of the controls. A paired-comparison test like that described for the mean hourly movement produced significance only at the 80 percent confidence level. Again the problem is beset by the small samples and tenuous comparisons of unweighted means. Reanalysis of the data is underway which will give proper weight to the sample sizes and in the process increase the number of degrees of freedom.

4. Conclusion. At this highly preliminary stage, both the mean hourly movement and daily average ranges suggest more mobility on the part of the irradiated animals. The data are being re-analyzed and calculations are being made of the degree of dispersion around the geometric mean. Furthermore, the geographic distribution of the daily centers of activity are being observed to learn whether the experimental animals are gradually shifting their ranges or undergoing daily movements within a fixed, if larger, seasonal range as do the controls.

V. Subproject (4): Mortality Factors

A. Objectives

The objectives of this subproject have been twofold. First, we have for some time been estimating mortality rates demographically. This assumes reliability and constancy of the census technique and randomness of sample in the case of the fall age structure. These assumptions have needed testing by independent estimates of the mortality rates.

The second objective has been to fulfill the need for determining causes of mortality. Mortality causes have seldom been quantitatively ascertainable in animal populations. In particular, the restraints on the Curlew Valley population apparently have operated through mortality, and hence a technique which permitted ascertainment of time and cause of mortality might well bring to light the major population restraints.

For these reasons, considerable emphasis has been placed on the development of transmitters which would enable us to detect the death of the animal. Hopefully, by going to the site with directional receivers, we could read the evidence and determine the cause of death.

B. Procedures

The circuitry which has been developed was described in some detail in the 1967 Progress Report. It is again described in the manuscript attached hereto along with field operating procedures.

In the summer of 1967, rabbits were first equipped with temperature-sensitive transmitters. Some difficulty was experienced in fixing the set firmly to the animal and this was quickly solved with the use of an acrylic spacer within the band around the animal's neck. By early fall, technical problems had been worked out and observations were underway.

C. Results

As this is written, 67 individual animals have been followed telemetrically while 23 adults and five juveniles are currently under observation. The results are summarized in Table 8.

Table 8. Monthly mortality as determined by telemetry

Month	No. Anim. Alive At Start	No. ¹ Dying	Percent ¹ Dying
September	8	2-2	25-25
October	14	7-4	50-29
November	8	0-0	0-0
December	15	2-0	13-0
January	14	3-1	21-7
February	13	4-1	31-8
March	15	4-3	27-20
April	17	2-1	12-6
May	16	1-0	6-0
June	20	0-0	0-0
July	23	0-0	0-0
Mid-Oct.-Mid-Apr. ²	--	-	76-43

¹ First value includes animals known to have died plus animals on which transmitter signals disappeared without being found. In every one of the latter cases, transmitter had been on animal a minimum of 4 months.

² Mid-October to mid-April is approximately the period between censuses. One-half the October and April losses are included in the calculations.

If all known dead animals plus those which were lost from observation are included, the mortality from mid-October to mid-April coinciding with the census period was 76 percent. This is undoubtedly high because in every case where transmitter signals disappeared the transmitters had been on the animals at least four months. Since some have used up their battery power in this period, it is likely that many or most of those which disappeared simply lost their power and stopped transmitting. If the mortality estimate is based only on animals known to have died, the loss becomes 43 percent, a very close correspondence to the 48 percent measured demographically for the same period (Table 4). If some animals were killed and carried beyond the range of the towers, or if transmitters were bitten into and destroyed, this value would be conservative. However, the towers now receive signals from animals at least within a 7-mile radius. This encompasses a major portion of the valley.

Causes of loss appear to have been primarily predation, and with the coyote apparently playing a significant role in this. The low, observed rate of mortality since fall coincides with a sharp drop in coyote numbers during the period (Figure 4) as determined in the course of separate studies underway on this species. While it is too early really to determine the role of this species in the overall mortality pattern of the jackrabbit population, the concurrent studies on the two species should eventually provide a clear insight into the interrelationships between the two. The coyote decline could be in response to the decline of rabbits, its staple food, and the coyote decline could conceivably release the rabbit population. The result would be a classical predator-prey oscillation. Time will shed light on the realism of this speculation.

VI. Miscellaneous Progress Related to Project

Jack Gross's dissertation has been deemed suitable for publication in Wildlife Monographs by Vincent Schultz to whom it was sent, and tentatively by Louis Krumholz, Monographs editor. It is currently in the hands of two more referees.

One paper, copies attached, was presented at the annual meeting of the American Society of Mammalogists in June. A manuscript, copy attached, has been sent to the editor of the Journal of Wildlife Management.

VII. References Cited

- French, N. R., R. McBride, and J. Detmer. 1965. Fertility and population density of the black-tailed jackrabbit. *J. Wildl. Mgt.*, 29:14-26.
- Heezon, K. L. and J. R. Tester. 1967. Evaluation of radio-tracking by triangulation with special reference to deer movements. *J. Wildl. Mgt.*, 31(1):124-141.
- Rusch, D. R. 1965. Some movements of black-tailed jackrabbits in northern Utah. Utah State Univ. M.S. thesis: V + 43 pp.

1. Jackrabbits flushed per mile of transect on 76 1-mile transects in Utah.
2. Coyote scats picked up on collection routes during the month of November.
3. Coyotes caught per 100 trap nights.
4. Coyote dens per hour of flying (only Milt Robinson flying in 1966 and 67).

Figure 4. Parallel Between Jackrabbit and Coyote Population Trends, 1966-68