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Some Movements of Black-Tailed Jackrabbits in Northern Utah

Donald H. Rusch

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SOME MOVEMENTS OF BLACK-TAILED JACKRABBITS

IN NORTHERN UTAH

by

Donald H. Rusch

A thesis submitted in partial fulfillment
of the requirements for the degree

of

MASTER OF SCIENCE

in

Wildlife Biology

Approved:

Major Professor

Head of Department

Dean of Graduate Studies

UTAH STATE UNIVERSITY
Logan, Utah

1965
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Donald H. Rusch
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INTRODUCTION

This work describes the extent and pattern of some black-tailed jackrabbit (*Lepus californicus*) movements and areas of activity in northern Utah and their relationship to sex and age, and season of the year.

Black-tailed jackrabbits are the most common lagomorphs in much of the western United States, particularly in that vegetational association described by McDougal (1908) as the sagebrush desert. Furthermore, Adams and Adams (1959) have suggested a correlation between sagebrush (*Artemisia tridentata*) incidence and jackrabbit density.

Farmers often regard this species as a liability because of its depredations on alfalfa (*Medicago sativa*), crested wheatgrass (*Agropyron cristatum*) and cultivated crops (Lewis, 1946). Ranchers claim that hares compete with grazing stock and Vorhies and Taylor (1933) found such competition in Arizona. On the other hand, jackrabbit hunting provides year-around sport in many western states.

If control or management of this species is necessary, movement information is essential, for Leopold (1933) stated: "Mobility of a species determines the minimum unit of management." Censuses and density indices are the yardsticks of success in game management. Movement is a determinant of density, and movement data provide insight into phenomena of population dynamics as well as management information.
THE STUDY AREA

Curlew Valley, Box Elder County, Utah was the site of this investigation. The valley occupies approximately 250 square miles, ranging in elevation from 5,100 feet in the foothills of the Raft River Mountains to 4,200 feet at the mud flats of the Great Salt Lake. Less than 10 per cent of the valley is farmed, mostly wheat and irrigated alfalfa. Stockmen utilize much of the valley as winter range for cattle and sheep. Fautin (1946) classifies Curlew Valley as part of the Northern Desert Shrub Biome. Although early settlers (Royal Morris, personal communication) recall that grass species were once predominant in this area, Costing (1948) states that the sagebrush association is climax for the northern Great Basin. Sagebrush occurs on those sites having highest available soil moisture (Fautin, 1946). Such sites in Curlew Valley are the bases of mountain ranges; the northern one-third of the valley, receiving more than 10 inches of annual precipitation; those areas with deep, permeable soils, usually adjacent to watercourses; and those soils with low mineral-salt content.

The greasewood (Sarcobatus vermiculatus) and shadscale (Atriplex spp.) communities occur on lower-lying soils having higher mineral-salt concentrations.

Within Curlew Valley, I conducted an intensive study of movements on two areas. The Wildcat Hills Study Area (WHSA) occupies 2 square miles of public (Bureau of Land Management) land on the north slope of the Wildcat Hills near the geographical center of the valley (Figure 1). Sagebrush is the most prevalent shrub (Figure 2), and is associated with
Figure 1. Location of the study areas in Curlew Valley, Box Elder County, Utah.
spiny hopsage (*Gravia spinosa*), gray horsebrush (*Tetradymia canescens*),
and broomweed (*Gutierrezia sarothrae*). Shadscale (*Atriplex confertifolia*)
and budsage (*Artemisia spinescens*) occur on those sites having pronounced
desert-pavement development. *Halogeton* (*Halogeton glomeratus*) is the
most common understory plant.

North-south roads at one-eighth-mile intervals facilitated travel.
Access, public ownership, relatively high hare densities and sagebrush
prevalence were factors influencing choice of the area.

The West Kelton Study Area (WKSA) encompasses 1 square mile of the
southwest corner of Curlew Valley (Figure 1). Greasewood is the most
common shrub (Figure 3), but sagebrush and rabbitbrush (*Crysothamnus
nauseosus*) occur frequently along the watercourse. East-west roads
traverse the area at one-eighth-mile intervals. I extended the investiga-
tion to this area because of its high hare densities in the winter of
Figure 3. Rabbit drive on the northeast corner of the West Kelton Study Area.
METHODS AND MATERIALS

Observational Approaches

Trapping and marking

Trapping and marking operations were conducted on the WHSA from May 1963 to February 1964, and on the WKSA during February 1964. They provided three sources of movement data: recapture of marked hares, observation of marked hares, and marker returns from hunters.

I captured 145 hares with single-door National "raccoon" traps and hand-made live traps of similar design (Figure 4). I baited 20-80 traps with apples and distributed them over the WHSA at the intersections of a one-fourth-mile grid. On May 17, 1963, I began checking and rebaiting traps daily during intermittent trapping periods of 5-15 days. By September 1, only one of 31 hares retrapped on Section 12 was taken in a trap other than that of original capture. This low recapture ratio might have resulted from having the traps spaced too widely (Stickel, 1946). I redistributed the traps at one-eighth-mile intervals on Section 7 of the WHSA and took 13 of the next 22 retrapped hares in traps other than those of original capture.

On February 22, 1964, 17 persons conducted a rabbit drive on the WHSA, capturing 20 hares in a corral at the apex of two one-fourth-mile wings.

I determined sex of the hares by genital inspection (Ingles, 1941). I judged hares as young or adult on the basis of weight, earlength and epiphysial closure as determined by external palpation (K. Wodzicki, personal communication). These age criteria permitted differentiation
Figure 4. Retrapped black-tailed jackrabbit in hand-made live trap. Well-used trails are visible in the upper right of the photo.
until sometime in November.

Each hare captured was individually marked before release, with lettered and numbered fluorescent, flexible, plastic earmarkers (Saflag material) (cf. Labisky and Lord, 1959). A National Band and Tag Company rabbit ear tag #441 held the marker to the ear. Another ear tag was used on the unmarked ear. I marked the right ear of the males and the left ear of the females (Figure 6). Marker attachment was satisfactory. Of the 38 recaptured hares, only one, recaptured 3 months after release, had lost its ear marker.

Approximately 2,650 hours were spent on the WHSA and WESA between May 15, 1962 and September 22, 1964. During this period I recorded 68 sightings of marked hares. Of these sightings, 29 different marked hares were identified on 48 occasions. Considerable travel and research activity were conducted in other portions of Curlew Valley, but I did not record any sightings of marked hares.

Of 31 hunters interviewed, none had sighted marked hares, but four hares were shot by hunters, and the markers were returned to me. The total kill by hunters is unknown. Most of the hunting pressure was applied to the southwest and northwest corners of the valley, including the WESA. I was unaware of any hunting on the WHSA.

Snow-tracking

Snow was unusually heavy during the winter of 1963-1964 and persisted from late November to mid-March. Several late-afternoon snowfalls in December and January provided ideal conditions for determining hare movements by tracking. I attempted to obtain complete track records (e.g. from evening form to flush) on 45 occasions, and succeeded on eight. In most cases, the track became indistinguishable from others,
Figure 5. Completed transmitter with batteries taped in position. Scratching by hare 001 caused the abrasions on this unit, resulting in disruption of the circuit.
Table 1. Results of trapping, observation and hunter recoveries of hares, Wildcat Hills Study Area, 1963-1964 and West Kelton Study Area, 1964

<table>
<thead>
<tr>
<th></th>
<th>WHSA Males</th>
<th>WHSA Females</th>
<th>WESA Males</th>
<th>WESA Females</th>
<th>Total</th>
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<td>77</td>
<td>18</td>
<td>20</td>
<td>145</td>
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<td>Trap mortality</td>
<td>5</td>
<td>2</td>
<td>0</td>
<td>0</td>
<td>7</td>
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<td>Retraps</td>
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<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total retraps</td>
<td>18</td>
<td>45</td>
<td>12</td>
<td>2</td>
<td>38</td>
</tr>
<tr>
<td>Individual hares</td>
<td>9</td>
<td>19</td>
<td>8</td>
<td>2</td>
<td>38</td>
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<tr>
<td>Sight observations</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Individual hares</td>
<td>4</td>
<td>16</td>
<td>4</td>
<td>5</td>
<td>29</td>
</tr>
<tr>
<td>Total sightings</td>
<td>6</td>
<td>21</td>
<td>13</td>
<td>9</td>
<td>48</td>
</tr>
<tr>
<td>Hunting kills</td>
<td>3</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>4</td>
</tr>
<tr>
<td>Individuals providing movement records</td>
<td>6</td>
<td>21</td>
<td>9</td>
<td>6</td>
<td>42</td>
</tr>
<tr>
<td>Total movement records</td>
<td>13</td>
<td>32</td>
<td>25</td>
<td>10</td>
<td>80</td>
</tr>
</tbody>
</table>

*a On the West Kelton study area (WESA), 20 hares were initially captured by a "drive" after the traps were removed, and hence were not available for recapture.

*b Totals for individuals are not additive, because some individual hares provided more than one type of movement record.

*c The number of movement records is not the sum of total retraps and total sightings, because some of the retraps occurred in the trap of original capture, and are not counted as movement records.
and I abandoned it for a new one. When I encountered a fresh, isolated track, I mapped the route until the track was lost or the hare was flushed. If flushed, I returned to my starting point, and backtracked the hare to its form of the previous evening. Thus the eight records obtained were those of one night's activities following a snowfall.

Radio-tracking

The radio equipment and techniques I used are similar to those described by Marshall (1963) and Cochran and Lord (1963) with some modifications. Mr. Patrick Buller of the Utah State University Engineering Department developed and assisted in the construction of the radio-tracking system from February 1 to August 14, 1964. The system was operated from August 15 to September 21, 1964.

The transmitting antenna was 11.0 inches in circumference constructed to fit the jackrabbit thorax. The size of the black-tailed jackrabbits with which we worked (1,800 to 2,200 grams) permitted use of the relatively large Eveready 401 and E3 Mercury batteries. The complete transmitters weighed from 40 to 100 grams, depending on battery size (Figure 5).

I tested several methods of transmitter attachment, and developed a satisfactory harness, similar to those used by Verts (1963) and Cochran and Lord (1963), out of five-eighths-inch diameter plastic electrical casing, stapled together. Harness loops encircled the thorax and neck of the hare. The transmitter antenna was taped to the thorax loop, with the transmitting package on the back of the hare (Figure 6).

I placed transmitters on live-trapped hares enclosed in burlap bags to facilitate handling. Hares to be rigged for radio were transported
from the capture site to the radio shack where the transmitter was mounted and tested. After this procedure, which took about an hour, I released the hares at the capture site.

The transmitter and harness did not noticeably impede hare locomotion. After hares were released, usually about noon, I attempted to observe initial movements, but most movement was obscured by dense sagebrush.

To locate moving animals accurately, two nearly simultaneous bearings are necessary (Verts, 1963). To accomplish this, I used a mobile receiving station (MRS) and a permanent receiving station (PRS) (Figure 7).

In order to simplify tracking from the Mobile Receiving Station (MRS), I placed numbered stakes along the roads at one-eighth-mile intervals and located them on aerial photos. They subsequently served as known locations. The MRS proceeded from one stake to another until the operator received a transmitter signal. When he obtained a signal bearing, he transmitted the bearing, MRS location and signal frequency to the PRS by two-way citizen's-band transceiver. The operator then repeated this procedure from another nearby location in order to obtain another signal bearing approximately 60 degrees from the first.

I used a similar procedure in obtaining a signal bearing from the PRS. The size of the triangle formed by the three signal bearings plotted on the map indicated the location of the animal and the magnitude of error (Marshall, 1963). If accuracy was not sufficient, e.g. a triangle having sides longer than 100 feet or badly skewed, I relocated the animal or simply discarded the inaccurate location.

I sampled daylight activity by 47 daytime radio fixes. I usually
Figure 7. Permanent receiving station, showing radio shack, rotatable antenna, Citizen's Band Communications antenna and generator shack. Truck housed the mobile receiving station.
began tracking at the onset of hare activity, about dusk, and attempted
to obtain an hourly fix on each hare throughout the night. Several
successive morning fixes on the same location indicated cessation of
nocturnal activities. I tried to sample nocturnal movements of three
hares hourly, but the sampling schedule varied slightly because of dis­
crepancies in available manpower, equipment performance, number of
tracked animals, and hare activity.

Equipment failures prevented continuous day-to-day tracking. Bat­
tery life varied from 3 days to more than 2 weeks, and I tracked as
often as possible during this period. A weak or intermittent signal in­
dicated battery power loss. I succeeded in retrapping two of four hares
bearing nonfunctional transmitters.

The FRS shack housed a Hammarlund HQ-140-X communications receiver,
converted from 5.7-32 to 46.7-73 megacycles. The receiver was equipped
with a 4-inch speaker and powered by a 3-kilowatt, 110-volt A.C. genera­
tor. A combination loop-yagi antenna mounted on a 50-foot mast received
the radio waves. The 16-inch diameter loop possessed better directional
sensitivity than the Channel 2 T.V. yagi, but the latter provided more
efficient signal reception at longer ranges (1.5 miles). A toggle
switch permitted antenna choice. A CDR antenna-rotor turned the antenna
complex. The radio shack also housed the rotor control and direction in­
dicator, in addition to other equipment.

An Army-surplus stationary communications-type receiver converted
for 50 megacycles reception served as a mobile receiver. It was equipped
with earphones and power by the 6-volt truck battery. A 16-inch di­
ameter loop antenna was attached to an 11-foot mast extending through the
truck roof and supported by a wooden base within the cab. This assembly
was designed after that described by Marshall (1963). The driver rotated
the loop from within the cabin, and read loop orientation from a pointer
and compass rose. A vehicle compass aided in aligning the latter.

A transmitter prototype, equipped with large Eveready E3 Mercury
batteries and a toggle circuit switch, was indispensable for checking and
standardizing equipment. The two-way radio communication, provided by
Heath citizen's band transceivers, was necessary for efficient tracking.

Analytical Problems and Approaches

With these sources of data, it was necessary to devise some quan-
titative scheme for describing the movements and areas of activity of the
animals so that comparisons could be made between sex and age classes,
areas, and times. The concept of home range has been used in the past
(cf. Haugen, 1942; Stickel, 1954; and others) but with varying shades of
meaning among different authors. The most frequent definition is simply
". . . that area traversed by the individual in its normal activities of
food gathering, mating and caring for young . . . " (Burt, 1943). How-
ever, related aspects often implicit in the use of this concept include
not only the total area of activity, but a geographic center of this area
(Hayne, 1949), and a distribution of activity around this center ana-
gous to a bivariate frequency distribution (Harrison, 1953; Calhoun,
1963).

Hayne (1949) suggested the mean radius from the center of activity
as a means of expressing area of activity quantitatively, and Harrison
(1953) and Sanderson and Sanderson (1964) proposed the analogous standard
diameter. Both of these methods assume an approximately circular home
range or area of activity.
Cursory examination of my data suggested a linear distribution of points, something previously noted by Harrison (1958) and Stumpf and Mohr (1962) in other species. These points are based either on the individual radio fixes derived from radio tracking, or on points occurring at arbitrary 100-foot intervals along the snow-tracking courses. The points for each animal were grouped into those accumulated within a 24-hour period, and those accumulated within a single season of the year.

In order to describe these linear groups of points in a more appropriate manner than the circular distribution assumed by Hayne's (1959) average radius, I assumed an elliptical distribution and fit regression lines to each set of data. The first line (Line BB, Figure 8) was the regression of \( X \) on \( Y \). The second line (Line AA) was perpendicular to the first, passing through the center of activity \((x, y)\). The perpendicular deviation from both lines was determined for each location. The average perpendicular deviations \((DB\) and \(DA)\) were calculated and these values were used as the major and minor axes of an ellipse circumscribed about the center of activity. I termed the area of the ellipse the average range, either daily (DAR) or intraseasonal (IAR), and utilized it as an index of the area of activity.

Mean DAR refers to the arithmetic mean of two or more DARs, either within or among hares. Mean IARs were calculated from IARs of two or more hares.

The ratio of average deviations \((DB\) and \(DA,\) Figure 8) is an index to the degree of elongation of the average range.
Perpendicular deviations of locations from:

<table>
<thead>
<tr>
<th>BB</th>
<th>AA</th>
</tr>
</thead>
<tbody>
<tr>
<td>2 of 60</td>
<td>2 of 100</td>
</tr>
<tr>
<td>2 of 40</td>
<td>2 of 60</td>
</tr>
<tr>
<td>2 of 20</td>
<td>2 of 40</td>
</tr>
<tr>
<td>2 of 40</td>
<td>2 of 100</td>
</tr>
<tr>
<td>2 of 40</td>
<td>2 of 60</td>
</tr>
</tbody>
</table>

Total = 400  Total = 800

Ave. deviation from BB = $\overline{DB} = \frac{400}{10} = 40$
Ave. deviation from AA = $\overline{DA} = \frac{800}{10} = 80$

Average range = area of ellipse = $\pi (\overline{DB})(\overline{DA})$
$= 3.14(40)(80) = 10048$

Linearity index = $\frac{\overline{DB}}{\overline{DA}}$
$= \frac{40}{80} = 0.50$

Slope of regression of X on Y = slope of line BB = 0.0

Figure 8. Calculation of regression slope, center of activity, average range and linearity index from a hypothetical set of 10 locations.
RESULTS

Daily Activity and Movement

Diurnal activity cycle

On 36 hare nights of radio-tracking during August and September, 1964, the seven hares tracked began movement between the hours of 6:00 and 9:00 p.m. Hourly radio fixes (261) throughout the nights showed that none of the hares ceased activity until 4:00 to 6:00 a.m.

Black-tailed jackrabbits are sometimes classed as crepuscular (Vorhies and Taylor, 1933; Lechleitner, 1958). Although hourly observations on seven animals were not adequate measurements of intensity of activity, they did indicate that the hares tracked were active, to some degree, in 7-9 of the 9 hours of darkness.

Hourly fixes on three hares over three 24-hour periods indicated that the hares remained in their forms during daylight hours. Of 92 forms examined in the summers of 1963 and 1964, 81 were beneath a sage-brush which provided shade between 9:00 a.m. and 3:00 p.m. I found 38 forms in the winter of 1964, but only 14 of these were shaded during midday. Hares evidently utilize shaded forms more during the summer months.

Magnitude of movement

The DARs for 14 hares on 42 hare nights ranged from 1.4 to 8.1 acres with a mean of 3.5 ± 4.4 (Table 2). The estimated maximum area of daily activity, based on the exclusive polygon enclosing all locations, varied from 55 acres to 1 acre. The mean was 3.4 ± 5.1 acres.
Table 2. Mean daily average ranges of radio-tracked and snow-tracked black-tailed jackrabbits, Wildcat Hills Study Area, 1963-1964

<table>
<thead>
<tr>
<th>Hare number&lt;sup&gt;a&lt;/sup&gt;</th>
<th>No. locations</th>
<th>No. days sampled</th>
<th>Mean DAR (acres)</th>
<th>$S^2_{DAR}$ (acres)</th>
<th>Coefficient of variation among days-%</th>
<th>Mean linearity index</th>
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<td>001</td>
<td>82</td>
<td>9</td>
<td>2.28</td>
<td>1.73</td>
<td>75</td>
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<td>002</td>
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<td>003</td>
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<td>017</td>
<td>91</td>
<td>1</td>
<td>8.08</td>
<td>-</td>
<td>-</td>
<td>.62</td>
</tr>
<tr>
<td>018</td>
<td>72</td>
<td>1</td>
<td>2.35</td>
<td>-</td>
<td>-</td>
<td>.17</td>
</tr>
<tr>
<td>Totals and means&lt;sup&gt;b&lt;/sup&gt;</td>
<td>1019</td>
<td>42</td>
<td>$\overline{3.483}$</td>
<td>$\overline{4.353}$</td>
<td>102</td>
<td>$\overline{.414}$</td>
</tr>
</tbody>
</table>

<sup>a</sup>DARs (daily average ranges) of hares numbered 00- were determined by radio-tracking, and the 01- by snow-tracking.

<sup>b</sup>Mean DAR are weighted and tabular mean is calculated from 42 DARs of each day for each hare.
I tracked hares 001, 006, and 009 for 6 consecutive days. A randomized-block-design analysis of variance indicated no significant difference ($s^2 = 23.27$, $F = 1.38$, $p > 0.10$) among the daily means of 9.6, 5.2, 1.4, 1.7, 1.7, and 2.4 acres, each computed from three DARs.

The mean DARs of adult males (2.3 acres), adult females (3.9 acres) and young females (3.7 acres) in the summer of 1964 were not significantly different ($s^2 = 25.91$, $F = 0.28$, $p > 0.10$). Similarly, the mean summer DAR of 3.4 acres was not significantly different ($s^2 = 5.1$ acres, $t = 1.09$, $p > 0.30$) from the winter mean of 3.9 acres.

Configuration of the daily activity area

A linearity index of 1.0 designates a circular range. The average linearity index of 42 DARs was $0.414 \pm 0.24$, indicating that the average DAR was about twice as long as it was wide. Also, 29 of the 42 indices were from 0.02 to 0.50; a higher number than expected in a random or even distribution ($X^2 = 6.10$, $p = 0.048$).

The long axes of 32 DARs examined appeared to be orientated randomly, not in any particular compass quadrant ($X^2 = 1.25$, $p = 0.75$). None of the 32 DAR orientations within seven hares showed a distribution significantly different from random.

The DARs showed no overlap among hares, but only 15 hares were tracked, and I purposely had chosen hares in different areas to facilitate tracking.

I examined 32 DARs, based on all-night radio-tracking or snow-tracking, and divided them into equal thirds perpendicular to the main axis. In 28 of these, the evening form was located in a terminal third. If forms were not within the DAR, I nevertheless counted them in the nearest third. Of these 28, the morning form occurred in the same third.
as the evening form in 18. In one case, the same form was utilized in
evening and morning; in seven, the morning form was within 100 feet of
the evening form; and in three cases, it was within 100 to 400 feet. In
four of the 28 DARs, the forms were in adjacent thirds. In the remaining
six, the forms were in opposite thirds. This distribution was signifi-
cantly different from the expected or random distribution ($X^2 = 12.2,
p < 0.005$), and indicated a tendency among the tracked hares to return to
the same area. This was further illustrated in Figures 9 and 10.

**Intraseasonal Movement**

**Magnitude of movement**

The mean IAR of the 14 hares trapped and radio-tracked or snow-
tracked was $4.8 \pm 3.5$ acres (Table 3).

The IARs and DARs of the snow-tracked hares (Tables 4 and 5) were
identical because the snow-track records of one day for different ani-
mals provided more than 90 per cent of the intraseasonal locations. A
paired comparison of DARs and IARs of six radio-tracked hares indicated
no significant difference ($s_d^2 = 1.3$ acres, $t = 1.1$, $p = 0.09$) between
the respective means of 3.4 and 6.0 acres.

The mean IAR of those hares tracked 1-4 days was 3.6 acres and the
4-9 day mean was 7.0 acres. The difference was not significant at the
5 per cent probability level ($s_d^2 = 1.8$ acres) but the probability of ob-
taining a larger $t$-value than 1.90 by chance was only eight out of 100.

The relationship of DARs and IARs (Figures 11 and 12) suggests that
the IAR may increase over time. The IARs evidently consist of a group
of smaller DARs with different centers of activity and orientation.

I did not have enough locations (20) on trapped hares to warrant
Figure 9. Snow-track record of hare 012 on the night of December 7-December 8, 1963, Wildcat Hills Study Area.

Figure 10. Snow-track record of hare 013 on the night of December 7-December 8, 1963, Wildcat Hills Study Area.
Table 3. Intraseasonal average ranges (IARs) of radio-tracked and snow-tracked black-tailed jackrabbits, Wildcat Hills Study Area, 1963-1964

<table>
<thead>
<tr>
<th>Hare number</th>
<th>No. locations</th>
<th>No. days sampled</th>
<th>IAR (acres)</th>
<th>Linearity index</th>
<th>Regression slope</th>
</tr>
</thead>
<tbody>
<tr>
<td>001</td>
<td>85</td>
<td>9</td>
<td>4.04</td>
<td>.97</td>
<td>0.77</td>
</tr>
<tr>
<td>002</td>
<td>36</td>
<td>4</td>
<td>2.17</td>
<td>.36</td>
<td>-0.20</td>
</tr>
<tr>
<td>003</td>
<td>42</td>
<td>4</td>
<td>4.37</td>
<td>.94</td>
<td>1.31</td>
</tr>
<tr>
<td>004</td>
<td>27</td>
<td>3</td>
<td>4.66</td>
<td>.29</td>
<td>1.17</td>
</tr>
<tr>
<td>006</td>
<td>58</td>
<td>7</td>
<td>5.80</td>
<td>.67</td>
<td>0.90</td>
</tr>
<tr>
<td>009</td>
<td>59</td>
<td>7</td>
<td>15.13</td>
<td>.34</td>
<td>-2.07</td>
</tr>
<tr>
<td>011</td>
<td>57</td>
<td>3</td>
<td>1.84</td>
<td>.47</td>
<td>0.16</td>
</tr>
<tr>
<td>012</td>
<td>55</td>
<td>1</td>
<td>1.43</td>
<td>.32</td>
<td>0.64</td>
</tr>
<tr>
<td>013</td>
<td>68</td>
<td>1</td>
<td>1.80</td>
<td>.80</td>
<td>-0.16</td>
</tr>
<tr>
<td>014</td>
<td>112</td>
<td>6</td>
<td>4.41</td>
<td>.88</td>
<td>-0.12</td>
</tr>
<tr>
<td>015</td>
<td>143</td>
<td>7</td>
<td>5.84</td>
<td>.76</td>
<td>0.06</td>
</tr>
<tr>
<td>016</td>
<td>137</td>
<td>3</td>
<td>5.80</td>
<td>.67</td>
<td>0.11</td>
</tr>
<tr>
<td>017</td>
<td>91</td>
<td>1</td>
<td>8.08</td>
<td>.64</td>
<td>-0.17</td>
</tr>
<tr>
<td>018</td>
<td>72</td>
<td>1</td>
<td>2.35</td>
<td>.17</td>
<td>0.69</td>
</tr>
</tbody>
</table>

Totals and means | 1047 | 59 | 4.337 | .699 |

\(^a\)Some of the snow-tracked hares (01-series) were also trapped and observed on additional days. Snow-tracking records provided more than 90 per cent of the locations for the 01-series hares.

Table 4. Intraseasonal and interseasonal mean recovery radii of black-tailed jackrabbits, Curlew Valley, 1963-1965. All means underlined by the same line are not significantly different (.05 probability level) according to DUNCAN'S TEST.

<table>
<thead>
<tr>
<th>Seasons of first capture and subsequent recovery</th>
</tr>
</thead>
<tbody>
<tr>
<td>Summer-summer</td>
</tr>
<tr>
<td>---------------</td>
</tr>
<tr>
<td>35.3</td>
</tr>
<tr>
<td>43</td>
</tr>
<tr>
<td>19360.0</td>
</tr>
</tbody>
</table>
Table 5. Per cent distribution of number of hares seen on 1-mile foot transects, Curlew Valley, Utah

<table>
<thead>
<tr>
<th>Number of hares sighted</th>
<th>78 transects October 1963</th>
<th>46 transects February 1964</th>
<th>78 transects April 1964</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>50</td>
<td>79</td>
<td>76</td>
</tr>
<tr>
<td>1</td>
<td>29</td>
<td>6</td>
<td>18</td>
</tr>
<tr>
<td>2</td>
<td>8</td>
<td>2</td>
<td>6</td>
</tr>
<tr>
<td>3</td>
<td>12</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>4</td>
<td>1</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>5-13</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>14</td>
<td>0</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td>15-54</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>55</td>
<td>0</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td>56-150</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>151</td>
<td>0</td>
<td>2</td>
<td>0</td>
</tr>
</tbody>
</table>

*a Unpublished October and April transect data, courtesy of Jack E. Gross.

calculation of the IAR. For these animals, I pooled the recovery radii (the distance between initial capture site and recovery location including recaptures in the same trap). Of 105 intraseasonal recovery radii, 79 per cent were from 0 to 220 yards, 16 per cent were from 220 to 440 yards. Of the four recovery radii (4 per cent) exceeding 440 yards, two were less than 660 yards, one was 1 mile and the largest was 4.3 miles. The mean recovery radius is 165 ± 1275 yards. I arbitrarily classified the two movements exceeding three-eighths mile as long-range movements.

The mean IARs of two adult males, three young females, and six adult females (4.9, 7.7 and 5.8 acres) were not significantly different ($s^2 = 14.00, F = 0.62, p = 0.10$). Similarly, there was no significant difference ($s^2 = 157767, F = 1.30, p = 0.10$) among the mean recovery radii of young males (260 yards), adult males (369 yards), young females (47 yards) and adult females (78 yards).

The mean summer IAR of 6.0 acres was not significantly different
Figure 11. Approximate spatial relationship of daily average ranges and intraseasonal average range of hare 006, Wildcat Hills Study Area.

Figure 12. Approximate spatial relationship of some daily average ranges and the intraseasonal average range range of hare 001, Wildcat Hills Study Area.
(sd = 1.9 acres, t = 1.10, p = 0.28) from the winter mean of 3.9 acres. The differences between intraseasonal mean recovery radii were not significant at the 5 per cent probability level (Table 4) as shown by the results of DUNCAN'S TEST (Steel and Torrie, 1960).

Configuration of intraseasonal activity area

The mean linearity index of the IARs was 0.699 ± 0.264, not significantly larger than the mean DAR linearity index of 0.414 ± 0.248. A paired comparison of the linearity indices of six radio-tracked hares indicated the mean IAR linearity index of 0.595 was not significantly larger (sd = 11.8, t = 2.27, p = 0.075) than that for the IARs (0.327).

The mean linearity index of IARs based on 1-4 days of tracking was 0.518, and the mean for 5-9 days was 0.724. Although the difference was not significant (sd = 14.1, t = 1.46, p = 0.19), these means, and the spatial relationships of the DARs and IARs (Figures 9 and 10) suggested a trend, over time, to circular IARs.

All of the IARs were elliptical to some degree and the regression slopes indicated the orientation of the long axes. If the slopes were randomly orientated, about six would be expected in each 45-degree sector of the compass, from north to south. Of the 24 slopes, 11 orientated between west and southwest ($X^2 = 7.33, p = 0.07$).

Interseasonal Movements

Magnitude of movement

I did not radio-track any animals through more than one season except for three tracked from August to September 21. I did not feel they qualified as interseasonal. Consequently all interseasonal data were
derived from recaptures, sightings of marked hares, and hunter kills.

Of 21 interseasonal recovery radii, 13 were 0 to 220 yards, five were 220 to 330 yards, one was 6.0 miles, another 8.3 miles and the largest 11.0 miles. The three hares which moved the longest distances were shot by hunters during the winter of 1964-1965, more than a year after the two longest-moving hares had been marked.

The results of the analysis of variance of intraseasonal and inter-
seasonal recovery radii indicated a significant difference \( (s^2 = 52441, F = 16.48, p < 0.005) \) among means. DUNCAN'S TEST (Steel and Torrie, 1960) indicated that the significant differences were between the inter-
seasonal means based on the two longest radii (Table 4).

The hares which moved 8.3 and 11.0 miles were both adult males.
The small number of recovery radii and large differences render an
analysis of variance superfluous.

Winter concentrations

French, McBride and Detmer (1965) referred to areas of high jack-
rabbit density in Idaho, and speculated on their relationship to move-
ment. There was also evidence of high density areas within Curlew
Valley, perhaps related to immigration.

During April 1964, and October 1963, Jack E. Gross walked 78 1-mile
foot transects randomly located within the valley. I walked 46 of these
same transects in February of 1964 (Table 5).

There were some differences among seasons in the percentage of
transects showing 1-4 hares, but more important, the data indicated a
more clumped distribution of hares in February.

On three February transects I sighted 14, 55 and 151 hares respec-
tively. On these same transects, only three hares were sighted on each
in October. The April count was one, zero and one respectively. No more than four hares were counted on any one October or April transect. These data indicated large changes in hare densities on certain areas, occurring in late fall or early winter, and again in late winter or early spring.

It seems unlikely that mortality or natality could have accounted for the density differences indicated, particularly between fall and winter. The areas of high density were probably winter concentrations resulting from interseasonal movement.

I have records of two interseasonal movements which were seemingly related to winter concentrations. Hares 259 and 268 were marked in the fall of 1963 on the WESA. Both were killed by hunters near the WESA, within a winter concentration area. Hare 268 was shot in December, 1963; 259 in January, 1965 (Figure 13).

The WESA was located within the largest concentration area in the valley. Although I trapped and marked 38 hares on the WESA, and recovered 17 of these 36 times, all recoveries were intraseasonal (winter). I have no data on winter-spring movements of hares marked on the WESA.
Figure 13. Locations of hares killed by hunters and winter concentration areas, 1963-1965; Curlew Valley, Box Elder County, Utah.
DISCUSSION

Daily Movement

Black-tailed jackrabbits tracked on the WESA, an area of relatively homogeneous sagebrush habitat, had DARs that averaged 3.5 ± 4.4 with a range of 1-8 acres. The mean maximum estimated area utilized by a hare in a day was 3.4 ± 5.1 acres. Most areas for other days and hares were less than 30 acres, but one was 55 acres.

Area utilized may vary with habitat conditions. Vorhies and Taylor (1933) recorded movements of 1-2 miles between food and cover on the rangelands of Arizona. James Morgan (personal communication) has similarly observed more lengthy movement between food and cover in portions of Curlew Valley in which crop fields and range-grass seedings are situated near areas of sagebrush cover.

The DARs of marked hares are linear, and the observations of Vorhies and Taylor (1933) may also imply linear movement patterns. My own observations and those of French et al. (1965) indicate a strong tendency for jackrabbits to travel on trails. Trail travel and the proclivity for returning to the area of the evening form are factors probably contributing to linearity of DARs.

Size, center of activity, and orientation of DARs for individual jackrabbits shifted daily. I detected no relationship between these shifts and weather conditions. The mean winter DAR was slightly larger than the mean summer DAR. Mean DARs among age-sex classes differed also, but the samples were small, the variability great, and the differences therefore not statistically significant.
Intraseasonal Movement

The IAR of a hare appears to be somewhat larger than the mean DAR, even though the size difference is not significant. IARs are composed of incongruent DARs with slightly different activity centers. For samples of up to 9 days, the IAR increases in size as DARs are added. I do not know whether the area of activity within one season is relatively fixed and a point is reached at which the addition of more DARs increases the IAR no further, or whether the IAR is subject to variation within a season. Tester and Siniff (1965) radio-tracked a raccoon which "... moved over only a portion of his total area of use each day ..." and the animal covered most of his area in about 4 days. The average length of the radii from the activity center remained relatively constant after 150 radio-tracking locations had been accumulated in the 4-day period.

The mean IAR is near 5 acres and the range 2-15. The maximum area utilized within a season ranged from 2-32 with a mean of 15.0 ± 8.4 acres. In the same hare, one DAR was as large as the IAR. Evidently, hares sometimes cover as much area in a day, less thoroughly to be sure, as they do in a season. Lechleitner (1958) reports similar findings: "... it became evident that an animal may use all of its known range in a very short period of time, even under what appear to be quite ordinary circumstances."

Differences in DAR and IAR linearity indices were not significant, but in all six radio-tracked hares the IARs were less linear than the mean DAR. Although this suggests a possible trend, with time, to circular ranges, the IARs were still, on the average, half again as long as they were wide. Stumph and Mohr (1962) found the California vole
*(Microtus californicus)* had "... ranges or territories which were considerably longer than wide." The authors cited evidence for linearity of home range in other mammals. Errington (1963, p. 65) observed Iowa muskrats that were residents "... of a linear or elongated type of home range that usually permit greater freedom of movement without trespassing on the property rights of other muskrats."

Animals I tracked did not live in adjacent areas. Errington's hypothesis is deserving of consideration, but my data provide no insight into the matter of whether jackrabbit IARs serve to space out the population. Home ranges of California jackrabbits overlap considerably (Lechleitner, 1958), and I have caught as many as six animals at one trap location within a season.

A larger number of IARs than expected by chance are oriented in a west-southwest direction. Conceivably, hares feed into the wind, as do some ungulates and waterfowl. I can find no wind-direction records for Curlew Valley, but at Salt Lake City, Utah, about 100 miles southeast, the wind blows most often from the south-southeast (Conway, May and Armstrong, 1963). Orientation may be a sampling artifact. Contrary to what one would expect, DARs show no marked orientation. If IARs are oriented with the prevailing winds, one would expect similar orientation in the DARs from which the IARs are formed.

All animals tracked showed pronounced localization of activity. Homing, also indicative of a strong site attachment, was recorded in two hares. I transported three hares 1 mile from the site of capture, and on the following day, two were taken in the same traps.
**Interseasonal Movement**

Some hares apparently remain in the same area throughout the year. I sighted one marked hare 16 times, at least once a month, during a 12-month period. The hare was always sighted within 300 yards of the trap site.

Most interseasonal and intraseasonal recovery radii were comparable (less than three-eighths mile). Three long-range movements sometime between summer and winter resulted in a large mean recovery radius for this period. Because of the small interseasonal sample, the significance of the difference is questionable.

French et al. (1965) suggested that the opportunity for dispersal increases with time elapsed from release. My own data corroborate this, as no long-range movements were recorded within 5 weeks of the release date (106 recoveries); but after 6 weeks, 20 per cent (five) of the recorded recoveries were at distances exceeding three-eighths mile.

Interseasonal movement patterns, particularly fall-winter and winter-spring, may differ from intraseasonal patterns. In most, and possibly all, years, winter concentrations of hares occur, often in the same areas of Curlew Valley. In these areas, fall densities are comparable to other areas of the Valley until about December when a marked increase occurs. French et al. (1965) suggested concentrations may be the result of widespread short-range immigration from surrounding areas. Two hares from the WBBA moved to the Kelton winter concentration area, but I have no further information on the magnitude and frequency of immigration.

After the jackrabbits arrive at concentration areas, magnitudes of
movement are comparable to those in summer and site tenacity in individuals seems to be equally pronounced.

Although 38 hares were marked in the Kelton concentration area, I recorded no spring dispersals. Those animals marked on the WHSA which moved to the Kelton area were shot by hunters. I do not know whether animals returned to the area from whence they emigrated, but the high densities of the concentration areas evidently disappeared. Bronson and Tiemeier (1959) recorded concentrations of black-tailed jackrabbits near croplands, apparently a response to drought-induced food shortages in adjacent sandhills. With the advent of spring rains, the concentrations dispersed back to the sandhills.

Dispersion may have been responsible for the dissipation of winter concentrations in Curlew Valley, but mortality may also have played a role. The winter mortality rate of these concentrations was unknown, but it was probably large. The accessible concentration areas absorbed practically all of the hunting pressure in Curlew Valley, and I counted up to 15 hunting parties near Kelton in 1 day in January, 1964. It was not unusual for one hunter to kill in excess of 50 jackrabbits in 1 day. However, more remote concentrations probably experienced no hunting. Avian predators and scavengers were also conspicuous in these areas.

The popular local explanation of concentrations is hare migration from adjacent foothills of the Raft River Mountains in response to heavy snowfall. Some are so situated as to make this seem possible, but other concentrations form in parts of the valley quite remote from the mountain.

Long-range movements were difficult to detect, particularly so when recovery efforts were concentrated on small areas. Yet four of the five
long-range movement records were provided by hunting kills, and hunting pressure was mostly on winter concentrations. The small areas studied intensively and the concentration of light hunting pressure may have resulted in an undersampling of long-range movements. The role and full extent of long-range movement and their relation to interseasonal immigration and population phenomena are yet to be determined for the black-tailed jackrabbits of Curlew Valley.

Home Range and Average Range

In attempting to understand those aspects of animal behavior involving movement and spatial orientation, we need abstract, quantitative concepts which permit objective description and comparison. The concept of home range has frequently been used in this regard.

Use of this concept for comparative purposes is difficult, however, because of the variation in meaning attached to it by different authors. Usually implicit in the concept (cf. Hamilton, 1939) are a localization of an animal's activities and the size of the area which encompasses these activities. The former aspect is evident in Burt's (1943) definition of home range. The latter aspect is evident in attempts to establish the outer perimeter of an animal's activity area by connecting lines between the outermost recovery locations, sometimes including an additional boundary strip (Stickel, 1954).

As our knowledge of animal behavior has grown, we have developed new insights into the matter which add more complexity to the home-range concept. Animals do not distribute their activities randomly over the entire activity area, but tend to concentrate them around a geographic center. The home range thus takes on the analogy of a bivariate frequency
distribution wherein the probability of an animal's presence is inversely related to the distance from the activity center (Harrison, 1958; Calhoun, 1963).

A more informative index of the activity area thus becomes some statistic based on the activity center and expressing the centralization of activity. Harrison (1958) explains the impracticality of determining an area encompassing all possible locations of an animal. Normally, there are no absolute limits on an animal's movement except possibly for physical barriers. But one can determine the area about the center of activity wherein the probability of finding an animal is fixed at some level below 100 per cent. Suggested indices include the mean activity radii (Hayne, 1949; Calhoun, 1963; Tester and Siniff, 1965) and the standard diameter (Harrison, 1958).

The average range which I have used in this study is analogous to these latter indices in expressing concentration of activity around a center of activity, but adapted to fit the elliptical distribution of activity in Curlew Valley jackrabbits. Hence, the average range, like the mean activity radius and standard diameter, does not encompass the full range of movement. It is not, therefore, entirely comparable with home-range measures which describe the entire activity area.

In the latter sense, Lechleitner (1958) in California and French et al. (1964) in southern Idaho found home range of the black-tailed jackrabbit to be less than 50 acres. I estimate home range (based on intraseasonal movements) to be less than 35 acres in Curlew Valley, and as low as 2 acres in some individuals. Maximum estimates of home range vary from 2-10 times the IAR.

In the past, we have perhaps thought of the home range as a
concrete entity in the life of an animal. But as we study animals with increasing intensity, we find movement and activity areas changing with a variety of influences. Bourlière (1964, p. 101) states: "The published figures (of home range) indicate great variation among the species and, in the same species, between the sexes for different habitats and in different years." Myers and Poole (1961) indicate that the areas of activity of individual European rabbits (Oryctolagus cuniculus) vary with population density and season of the year.

Due to small sample size and individual variation, my own data do not definitely display all of these variations but they may be present. The location and activity area of individual hares in Curlew Valley do vary from day to day, and in the aggregate, within individual seasons. Pronounced changes occur to an unknown extent between seasons, and in a few cases, within seasons. Hence, any home-range concept implying some fixed entity would not be very descriptive of jackrabbit activity, and would only serve to mask the complex changes an animal goes through from day to day as the annual cycle of events in its life-history unfolds. As our measurements of movements become more refined, we may in the future find the home-range to describe only part of animal activity.

**Function of Activity Localization**

Localization of the bulk of an animal's activities likely has survival value, and perhaps many of the same functions of avian territory outlined by Welty (1962). Bourlière (1964, p. 107) states: "One of the main advantages of the home range is probably that it assures to the individual frequenting it not only its daily food but also increased protection against predators." Home range may function to distribute small
mammals optimally in relation to habitat resources and to reduce intra- and interspecific strife (Calhoun, 1963).

Long-range movements may also be beneficial under certain circumstances. Bronson and Tiiemeier (1959) have found jackrabbits to congregate near domestic food sources during drought periods. Lechleitner (1958) recorded shifts of home range when former ranges were flooded. Andrewartha and Birch (1954) suggest that all animals have an innate tendency toward dispersal (movement away from a population area) which may be accentuated by environmental conditions such as severe weather. Thus, dispersal movements also play a role in population distribution.
LITERATURE CITED


