COTTONTAIL RABBIT
RANGES AND MOVEMENTS
IN EASTERN KANSAS

A Thesis

Submitted to

the Division of Biological Sciences

Emporia Kansas State College, Emporia, Kansas

In Partial Fulfillment

of the Requirements for the Degree

Master of Science

---

by

Randall J. Clark

August, 1976

Dwight L. Spencer
Approved for Major Department

Harold E Durst
Approved for Graduate Council

ACKNOWLEDGEMENTS

I would like to thank Rhonda Baker and Robert Gress. Much of the data herein reported could not have been collected without their assistance. This study was financed by the Kansas Forestry, Fish, and Game Commission and Kansas Pittman-Robertson Project W-42-R; their support was sincerely appreciated. I am indebted to Dr. Robert Clarke and Dr. John Ransom, members of my graduate committee. William Peabody provided advice throughout the study which was appreciated.

Dr. Dwight Spencer, my major advisor, is extended special thanks. His aid and advice throughout both my undergraduate and graduate studies were greatly appreciated.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

INTRODUCTION

In August, 1974, a cottontail rabbit study was initiated on Ross Natural History Reservation (RNHR), in west-central Lyon County, Kansas. This study was undertaken because of concern among Kansas Forestry, Fish, and Game personnel, as well as among some Kansas sportsmen, that an apparent decline of the cottontail population had occurred during the fall and winter months of recent years (Peabody, pers. comm.; Watt, 1975).

Information on mortality, home range areas, movements, and population levels was gathered in an attempt to establish if the decline was due to: (1) increased mortality (from excessive predation or disease); (2) a change in cottontail behavior or habitat usage which would make the animals less observable during fall and winter; (3) a combination of these factors or some other factors. This study was the second year of a proposed five-year study on cottontail rabbits at RNHR.

The cottontail rabbit, Sylvilagus floridanus (J. A. Allen), has been the subject of many movement studies. Hanson (1959), Schwartz (1941), Dalke and Sime (1938), Hendrickson (1936), and Allen (1939) estimated cottontail home ranges using live trap capture points. Janes (1959) used trap capture points in conjunction with trailing and observation of color coded animals to estimate cottontail home ranges. Haugen (1942) utilized a "trapping square" technique, which connected points halfway between the actual point of capture and the next outermost trap in the "square". Connel (1954) defined cottontail home ranges as the average distance traveled from a computed center of activity. These varied pro-

cedures have yielded equally varying estimates of home range sizes from 0.1 acres to 100 acres.

Trent and Rongstad (1974), Watt (1975), and this study employed radio telemetry equipment to determine daily resting locations which, along with capture points, were used to estimate home range size. The use of radio telemetry techniques made it possible to: (1) record locational data points without capturing the animal a large number of times; (2) record movements and locations of rabbits during periods of activity occuring at night; and (3) accomplish these two functions with a minimum of researcher interference on the study population.

Radio telemetry has been used in wildlife investigations since 1960. Studies employing radio telemetry have gathered information on movements and home ranges (Storm, 1965; Ellis, 1964), mortality (Stoddart, 1970; Cook et al., 1971), habitat usage (Nicholls and Warner, 1972), activity periods (Kjos and Cochran, 1970), behavior (Kuck et al., 1970) and physiology (McGinnis et al., 1970).

Although telemetry has been in use since 1960 to extend the range of man's observational powers (Craighead and Craighead, 1965), each system must be evaluated for accuracy and performance before any conclusions from recorded data can be made. The system used in this study was tested during the first year of the project, and reported by Hutton (1975).

The objective of this portion of the five-year study was to determine cottontail rabbit ranges and movements on the study area. A knowledge of home range areas and movement patterns allows the problems of

predator and disease control, habitat manipulation, and censusing to be more intelligently approached (Doebel and McGinnes, 1974). Hopefully, the data gathered on ranges and movements during 1975-76, coupled with data collected in the first year (Watt, 1975) and years to come, will aid in the understanding of cottontail rabbit population dynamics in Kansas. All data reported in this paper were collected from 1 June 1975 to 1 May 1976.

Watt (1975) reported on rabbit ranges, movements, and mortality from data gathered in the first segment of this study (August 1974-June 1975) on the RNHR study area. Gress (1976) collected mortality data during the second segment (June 1975-May 1976).

DESCRIPTION OF STUDY AREA

This study was conducted on approximately 100 acres of RNHR. RNHR has been maintained by the Division of Biological Sciences, Emporia Kansas State College, as a natural history area since 1960. Hartman (1960) provided a detailed description of the location of the study area, and described its geological, physical, and historical aspects. Figure 1 (after Watt, 1975) is a map of the study area showing the major vegetational types. This map was used in conjunction with the home range map shown in Figure 2. In general, the study area is being invaded by woody vegetation except in certain areas which are maintained as grasslands by mowing or burning. Plants comprising the major vegetational types are listed in Table 1. Wilson (1963) provided a detailed account of the flowering plants of RNHR.

Watt (1975) stated that the cover was sufficiently dense and tall across the study area to serve as good rabbit habitat. When the criteria listed by Schwartz and Schwartz (1959) was applied to the cover on the study area, only in areas E-3,4 and D,E,F-1 was cover sparse. Cover in areas D,E,F-5 and D-7,8 did not appear to be particularly good rabbit cover.

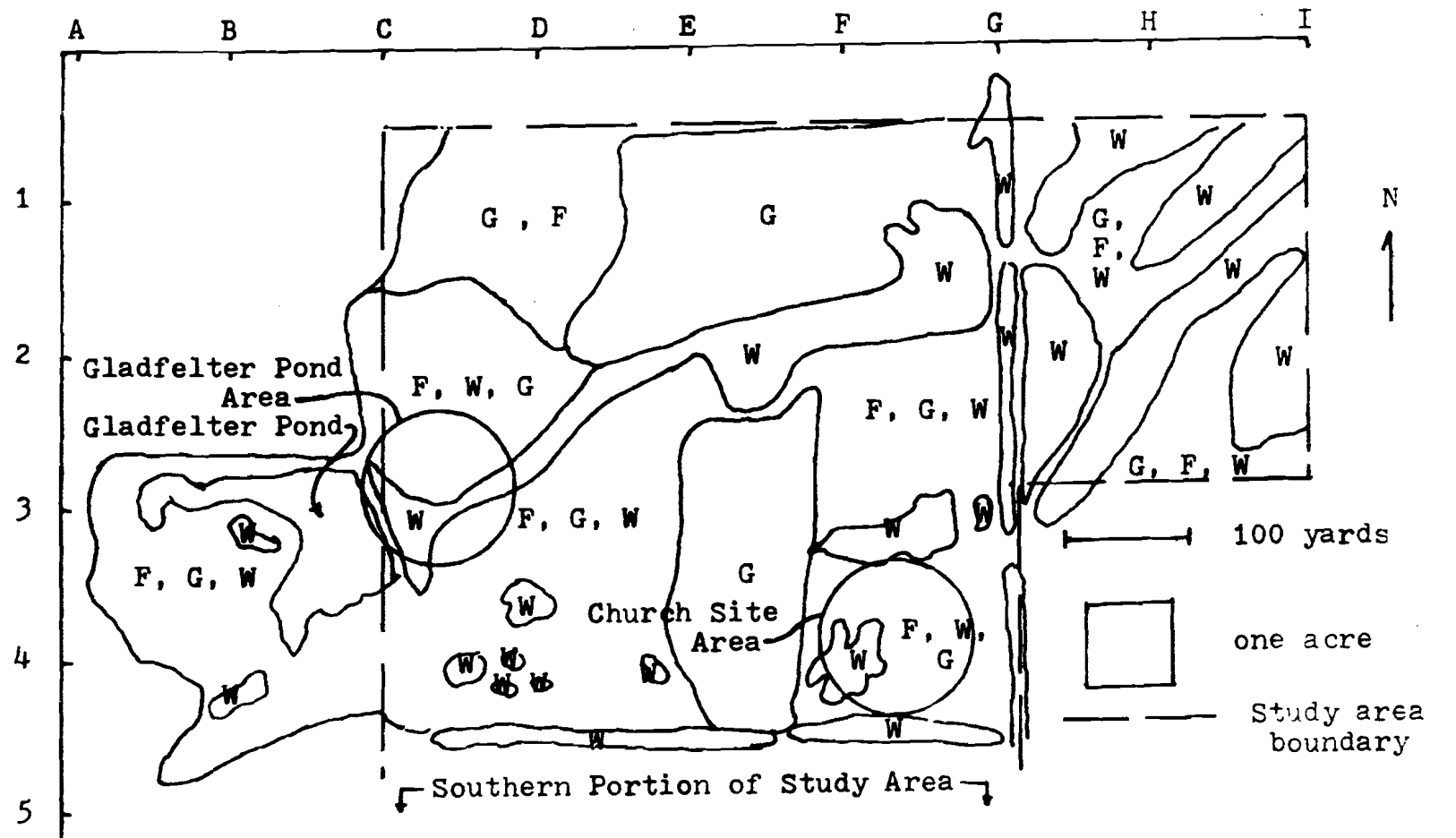

Fig. 1. Major cover types on the study area. W = woody vegetation, Int. W = intermittent woody, F = forbs and G = grasses (after Watt, 1975).

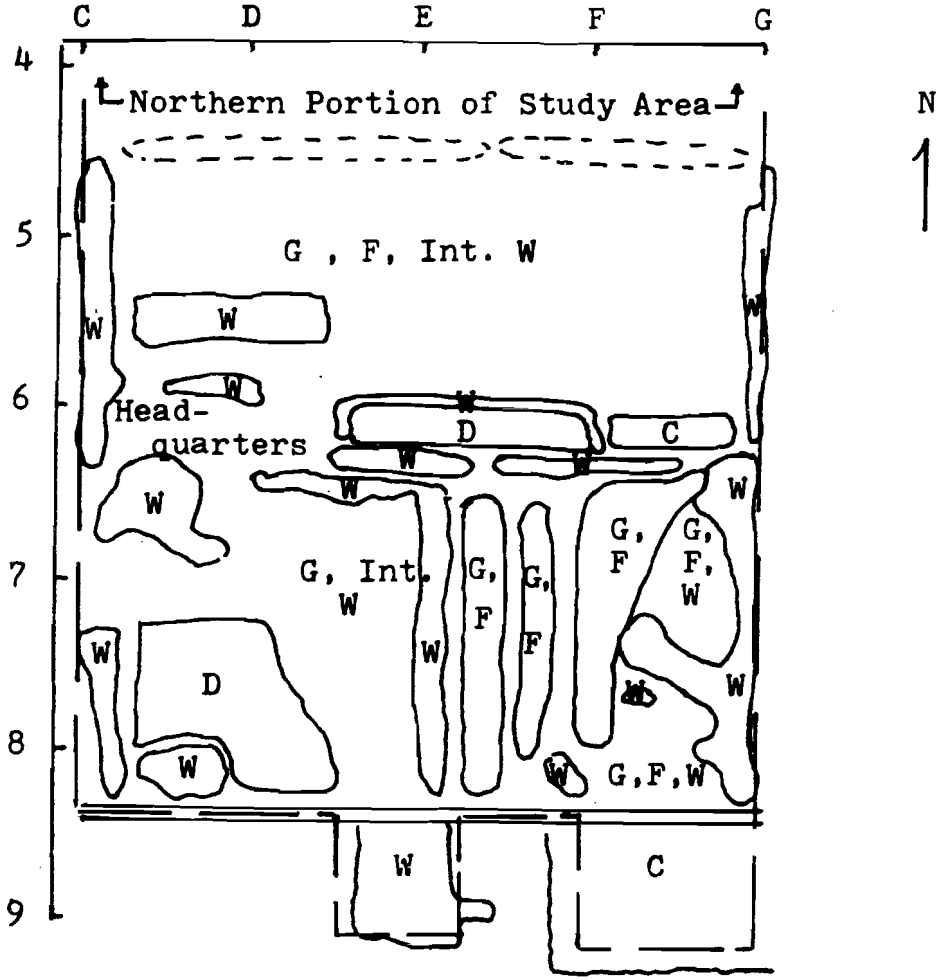
C
D
E
F
G
4
5
6
7
8
9
Northern Portion of Study Area
N
G , F, Int. W
W
Head-
quarters
D
C
G, Int.
W
G,
F
G,
F
G,
F
G,
F,
W
G,F,W
W
D
C

Fig. 1. Con't.

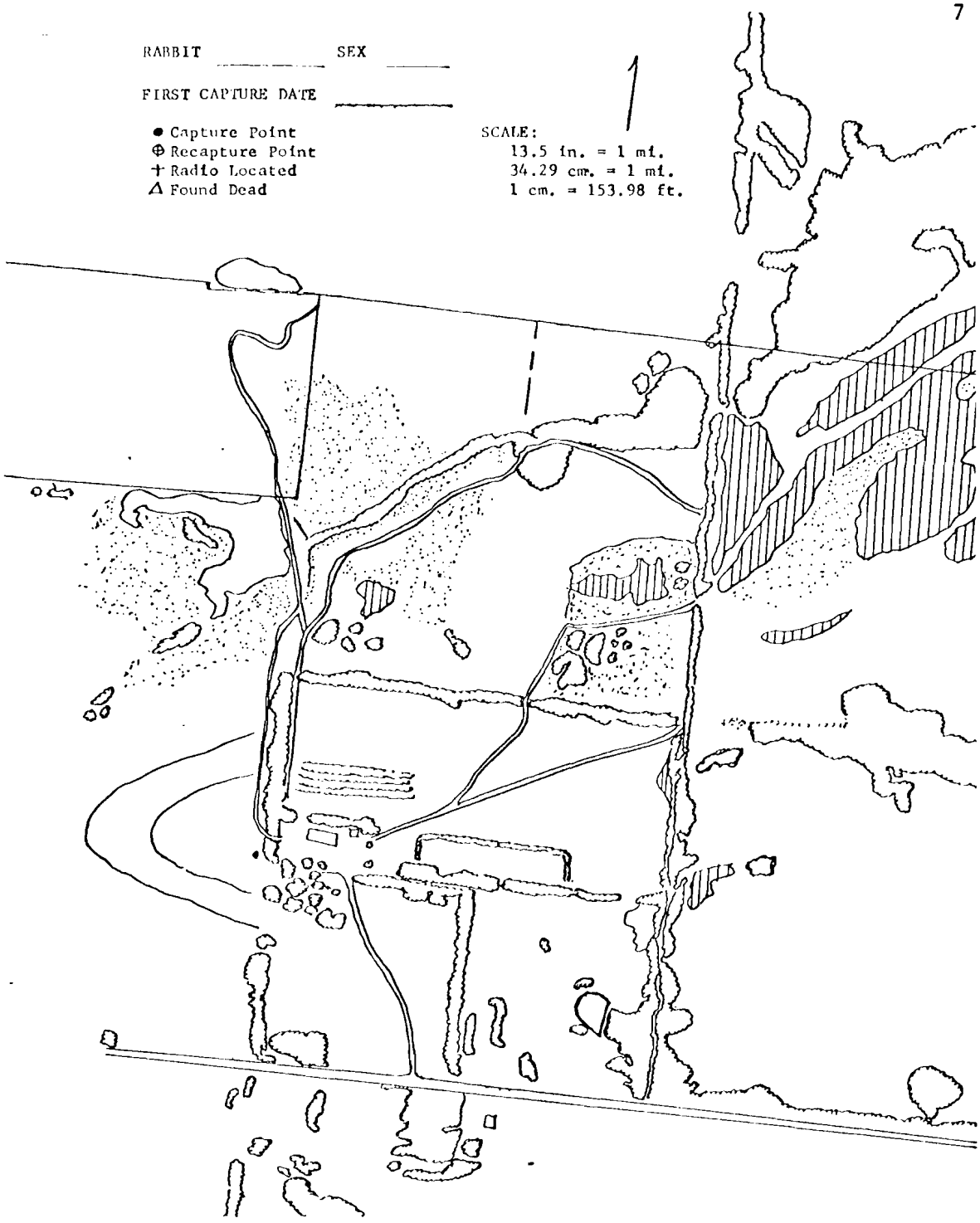

Figure 2. Home range map of the RNHR study area.

Table I. Genera of major plants found on the study area. * = common on study area. (after Watt, 1975)

Grasses *

- Andropogon
- Aristida
- Bouteloua
- Bromus
- Elymus
- Panicum
- Setaria
- Sorghastrum
- Sporobolus

Forbs

- * Ambrosia
- * Asclepias
- * Aster
- * Baptisia
- Cassia
- Cirsium
- Desmanthus
- * Erigeron
- Euphorbia
- * Eupatorium
- Gutierrezia
- * Helianthus
- Hibiscus
- * Lespedeza
- Liatrus
- Mirabilis
- Monarda
- * Oenothera
- * Opuntia
- * Salvia
- * Solidago
- Verbena
- Verbascum

Woody Vegetation

- Acer
- Celastrus
- Celtis
- * Cornus
- Fraxinus
- Gleditsia
- Juglans
- * Juniperus
- * Maclura
- Morus
- Populus
- * Prunus
- * Ross
- * Rhus
- Salix
- * Symphoricarpos
- Ulmus

METHODS AND MATERIALS

Rabbits were collected on Ross Natural History Reservation using two types of live traps. Conventional wooden box traps (Forsythe, 1974) were placed in what appeared to be good rabbit habitat. Tomahawk wire live-traps were placed in "runs". Approximately 100 traps were used (80 box and 20 wire) and both types of traps were unbaited. Trapping was conducted daily between June, 1975, and May, 1976 (except for two days in October, five days at Christmas, and two days in March).

Traps were checked each day between 0700 and 1100 hours. Captured animals were returned to the laboratory where sex, general physical condition, reproductive status, and presence of ectoparasites were determined and recorded.

Rabbits were marked with ear tags and collars. Ear tags were #898 Tab End, Size 3 National Wing Bands. Some adult rabbits which were not instrumented with radio collars were marked using numbered plastic collars. It was recommended by Hutton (1975) that all adult rabbits which were not radio instrumented be marked with plastic collars, since collars are not ingested when a predator eats a rabbit and they are easier to find than ear tags.

Depending on the availability of collars and the number of rabbits on the air, captured rabbits weighing over 600 grams were fitted with radio-transmitters. Radio-transmitters were obtained from Sidney L. Markusen, Cloquet, Minnesota. Each transmitter had a distinct frequency between 150.815 and 151.20 MHz and an estimated life span of 120 days.

It was soon noted that waterproofing applied to the battery terminals and transmitter leads at the factory was inadequate. Transmitter leads and battery terminals were covered (potted) with Luxe-cure #60 Superfine Quick Repair self-hardening resin to compensate for the inadequate waterproofing.

When a rabbit was instrumented the following methods were employed: (1) the battery lead was soldered to the transmitter lead, activating the collar; (2) the transmitter was tested to determine if it was functioning properly; (3) the battery-transmitter connection and battery terminals were potted; (4) the potted connection and battery poles were taped with yellow electrical tape; (5) the collar was fitted to the animal's neck and tightened; (6) the antenna was then taped in a loop along the collar. Step 6 was later altered from a loop antenna to a whip antenna to increase the range of the transmitter. Whip antennas were employed by potting a small spring (slightly larger in diameter than a ball point pen spring and about 1¼ inches longer) to the collar after Hutton (1975). By running the antenna through the spring it could then be extended posteriorly along the animal's body, and was thus protected from gnawing.

After an animal was instrumented it was returned to the capture point and released. Channel number, transmitter number, and capture or recapture points were recorded on a map of the study area (Figure 2).

Daily resting locations were determined by using a portable Markusen 24-channel VHF tracking receiver and a hand held, two element, directional,

yagi antenna. Rabbit daily resting locations were recorded on a map of the study area (Figure 2).

Approximately once a week instrumented rabbits were monitored hourly during the night. Readings were taken from a stationary tower and a mobile unit. Both units were equipped with an eight element, hy-gain, yagi antenna and a 24-channel VHF receiver. The mobile unit was oriented in the manner described by Hutton (1975). Readings taken from the two stations were recorded and later programmed into a Hewellet-Packard calculator, which calculated and plotted locational points, and the time readings were taken on a map of the study area (Figure 2).

Home ranges were determined using the Minimum Area Method (MAM) (Mohr, 1947), the Modified Minimum Area Method (MMAM) (Harvey and Barbour, 1965), night time location estimate, and beagle chases. To determine home ranges by the MAM and the MMAM, locational points were connected as indicated in the literature. When beagle chases were employed, an instrumented rabbit was flushed and the beagle released on the trail; researchers then followed the beagle and marked on a map of the study area the route of the escaping rabbit. A composite of all night time locational points was made, using a Hewellet-Packard programable calculator. In all four cases the enclosed home range area was measured using a compensating polar planimeter.

Home ranges were determined as adequately sampled by the method described by Odum and Kuenzler (1955). The area, in acres, of the home range was plotted on a X-Y coordinate, after each five locational data points. If the observation area curve indicated that the addition of

further locational points would not cause a marked increase in range area, the range was considered adequately sampled.

Mean daily travel distance was defined as a straight line between consecutive locational data points. Mean daily travel distance for the first five days of instrumentation was compared to the mean daily travel distance for the total period as a measure of the effect of handling and presence of the collar on animal movement.

Percentage of range overlap was used as a measure of territoriality (Haugen, 1974).

Statistical analyses were run on a Monroe 1785 programable calculator. Student's *t*-test at $p=.05$ was used to test for significant differences.

The Kansas Forestry, Fish, and Game Commission and Kansas Pittman-Robertson project W-42-R provided transportation, operating expenses, equipment, and stipends to support this study. Emporia Kansas State College, Division of Biological Sciences, provided maps of the study area and the use of facilities at RNHR.

RESULTS AND DISCUSSION

Effects of Handling and Transmitter Collar on Movements

Watt (1975) observed cottontail rabbits in pens after they were instrumented. He found that it appeared animals attempted to remove the collar by using their forepaws and hindfeet. However, it was not determined how long the animals spent trying to remove the collar or to what degree this activity modifies the animal's behavior. No attemps was made in this study to quantify the effects of instrumentation by observing penned cottontails.

Watt (1975) suggested that by assuming cottontails eventually become accustomed to the transmitter collar, one possible measure of the effect of the collar may be derived from a comparison of the animal's movements for a few days after release with movements over the total observational period. Mean Minimum Daily Travel Distance (MMDTD) for the first five days after release was compared, using the Student's t-test, with the MMDTD for the total period.

Thirty two animals were tested in this manner, and there was no significant difference between the MMDTD for the first five days and that for the total period. This suggests that handling and collar attachment have little effect on cottontail movements. However, it should be noted that there is no evidence supporting the assumption that cottontails eventually become accustomed to the collar. Also, MMDTD may not reflect the true extent of an animal's movements. Since MMDTD only compares the distance between daily resting locations or trapping locations, nothing is known about the actions of the animal between those two locational points.

Cottontail Home Ranges

Burt (1943) defined home range as "that area transversed by the animal in the normal activities of food gathering, mating and caring for young. Occasional sallies outside that area, perhaps exploratory in nature, should not be considered as part of the home range". If Burt's definition is applied, it would not include an area used primarily for escape from predators. Since the cottontail rabbit is a prey species of many predators, escape cover would be an important element within an animal's home range. Janes (1959) took escape routes into consideration when he defined home range as "an area in which an animal carries out the normal activities of eating, resting, mating, caring for young, and escaping from predators". This definition seems more plausible for a prey species such as the cottontail, since it is believed that a home range is established by a rabbit to enhance familiarity with food sources, hiding places, and escape routes (Davis et. al. 1948).

Brown (1956) cited many methods which have been devised to measure home range areas. In this study, four methods wereemployed to estimate the home range areas of cottontails of RNHR: (1) the Minimum Area Method (Mohr, 1947); (2) the Modified Minimum Area Method (Harvey and Barbour, 1965); (3) night time location estimate; and (4) beagle chase estimate (Toll et al., 1960).

Ranges as determined by the Minimum Area Method (Mohr, 1947)

The Minimum Area Method (MAM) is one of the most commonly used techniques due to its simplicity. When using this technique, one connects

all peripheral locational points for a given rabbit to form a polygon, the area of which represents the area of the animal's home range. However, Burt (1943) stated that many home ranges are probably ameboid in shape, and to connect the outlying points could give a false impression of the actual area covered, and may indicate a larger home range than really exists.

Burt (1943), in his definition of home range, stated that movements of an exploratory nature, or investigatory sallies, should not be included in estimates of home range areas. Due to the difficulty in determining excursions, two authors, Harvey and Barbour (1965) and Quadagno (1968), devised methods to determine which points represent investigatory sallies. Quadagno (1968) suggested that any point located two times farther than the calculated average distance from the center of activity should be considered a sally. If an animal was found twice at a location it would be considered as part of the home range. I agree with Watt (1975) that this rule is generally applicable but should be used in conjunction with a subjective appraisal of the situation.

Table II summarizes home range areas as determined by the MAM for 32 rabbits. Using the technique described by Odum and Kuenzler (1955), 23 of the 32 rabbits monitored were determined as adequately sampled. Mean home range size for all rabbits having adequately sampled ranges was 4.74 acres (N=23). Mean home range size for adequately sampled males was 5.67 acres (N=9); females with adequately sampled home ranges had a mean range size of 4.15 acres (N=14). Differences between sexes were not significant.

In most cottontail home range studies the MAM was used to estimate home range size. Table III summarizes the home range areas reported in the literature for adult cottontails.

Mean home range areas calculated for rabbits in the current study were somewhat larger than the mean home ranges reported by Watt (1975) for rabbits on the same study area. Watt stated that in most cases the home range areas he calculated were smaller than those reported in the literature. This was not the case in the current study. Janes (1959) indicated that a major factor contributing to variation in reported ranges is the variety of methods that have been used to measure them.

Table II. Home range areas as determined by the Minimum Area Method for 32 radio-tracked rabbits. N = number of locational data points.

Rabbit Number	Sex	N	Range in Acres
R-212	F	80	2.45
R-214	M	142	11.92
R-246	F	70	6.69
R-247	F	130	1.90
R-301	M	52	12.48
R-306	F	51	1.09
R-317	M	32	1.36
R-321	F	93	9.52
R-327	M	35	2.01
R-329*	M	24	1.90

Table II.Con't

Rabbit Number	Sex	N	Range in Acres
R-335	F	142	2.01
R-337	F	36	.36
R-338	F	126	6.91
R-342	F	75	8.16
R-344*	M	18	2.18
R-345*	F	17	1.14
R-346	F	93	1.79
R-347	M	46	2.83
R-349*	M	17	1.36
R-351*	M	19	1.25
R-355	F	40	3.75
R-359	M	93	4.90
R-377*	M	20	1.52
R-381	F	61	4.73
R-398	F	53	.98
R-402	M	33	5.93
R-407*	F	22	2.07
R-417*	F	21	2.23
R-419	M	35	8.43
R-446*	F	24	2.67
R-456	M	87	1.14
R-475	F	46	7.07

*Rabbits that were not determined to have adequately sampled home ranges.

While this probably was a contributing factor to the variation reported in the literature, it does not apply to the variation between Watt (1975) and the current study. Since collection of data and method of analysis were nearly identical in both cases, some other factor must be responsible for this variation. Abundance of food, cover, and density may affect the home range area of animals (Trent and Rongstad, 1974); it is possible that a change in one or more of these factors could have caused this variation.

Table III. Adult cottontail home range areas as reported in the literature. All home ranges are annual unless otherwise noted.

References	Method	Mean Home Range Areas (Acres) Males	Females
Dalke*	Trapping	8.3	2.9
Allen*	Trapping	3.6	2.2**
Schwartz (1941)	Trapping	1.4	1.2
Haugen (1942)	Trapping	---	14.0**
Atzenhoefer and Martin*	Trapping	16.4	13.3
Bruna*	Trapping	13.3	4.3
Janes (1959)	Trapping, Tracking	8.9	7.8
Lord (1963)	Trapping	2.3	2.3
Trent and Rongstad (1974)	Radio-Tracking	8.6	3.4
Watt (1975)	Radio-Tracking	4.1	2.4
Current Study	Radio-Tracking	5.67	4.15

*Cited in Trent and Rongstad (1974).
**Winter ranges.

Ranges as determined by the Modified Minimum Area Method

Harvey and Barbour (1965) stated that their Modified Minimum Area Method (MMAM) was an improvement over the MAM because: (1) in all probability the MAM was estimating home range areas too large, and included areas for which no indications of the animal's presence had been recorded; (2) all points are included within the MMAM estimation; and (3) the MMAM gives an objective tool for the determination of which points are investigatory sallies.

Some authors (Harvey and Barbour, 1965; Quadagno, 1968) have indicated that, in many cases, the estimate obtained using the MAM may yield the equivalent of an animal's maximum range or total range. Harvey and Barbour (1965) and Quadagno (1968) felt the MMAM yielded a better estimate of an animal's area of utilization. Watt (1975) believed that before concrete conclusions about the effectiveness of the MMAM could be made, comparisons between estimates obtained by MMAM and radio-tracking information for animals during their activity periods (night time location estimate) must be made. This comparison will be made in a later section of this report dealing with comparisons of all four techniques employed in this study.

Table IV summarizes the home range areas as determined by the MMAM. The mean home range size for the 23 cottontails with adequately sampled home ranges was 1.56 acres. Mean home ranges for adequately sampled males was 1.52 acres (N=9); females with adequately sampled home ranges had a mean home range size of 1.72 acres (N=14).

As was the case with the MAM, home range areas reported by Watt (1975)

using the MMAM on nine cottontails from the same study area, were in disagreement with those in the current study. Watt reported a mean range size of 2.86 acres (N=2) for males and .98 acres (N=7) for females as compared to 1.52 acres for males and 1.72 acres for females in the current study. Also, Watt found that male home ranges were significantly larger than female home ranges. This was not the case in the current study.

Table IV. Home ranges of 32 radio-tracked cottontails determined by the Modified Minimum Area Method. N = number of locational data points.

Rabbit Number	Sex	N	Range (acres)	Qualifications
R-212	F	80	.77	2 areas of activity
R-214	M	142	2.72	2 areas of activity
R-246	F	70	2.67	2 areas of activity
R-247	F	130	1.25	----------
R-301	M	52	3.16	3 areas of activity
R-306	F	51	.22	----------
R-317	M	32	.76	----------
R-321	F	93	3.59	2 areas of activity
R-327	M	35	1.09	----------
R-329*	M	24	.67	----------
R-335	F	142	.87	----------
R-337	F	36	.33	2 areas of activity
R-338	F	126	5.11	----------

Table IV. Con't.

Rabbit Number	Sex	N	Range (acres)	Qualifications
R-342	F	75	2.01	----------
R-344*	M	18	1.20	----------
R-345*	F	17	.27	----------
R-346	F	93	.60	----------
R-347	M	46	.92	2 areas of activity
R-349*	M	17	.16	----------
R-351*	M	19	.70	2 areas of activity
R-355	F	40	1.25	----------
R-359	M	93	3.06	----------
R-377*	M	20	.05	----------
R-381	F	61	1.25	----------
R-398	F	53	.16	----------
R-402	M	33	.81	2 areas of activity
R-407*	F	22	.22	----------
R-417*	F	21	1.36	----------
R-419	M	35	1.09	----------
R-446*	F	24	.60	----------
R-456	M	87	.11	----------
R-475	F	46	4.03	----------

*Rabbits that were not determined to have adequately sampled home ranges.

Ranges determined by night time location estimate

Use of night time locations has been thought to be more appropriate

than methods using daily resting locations and capture points in the estimation of home ranges of nocturnal animals. However, due to the difficulty of locating animals during their activity periods, primarily because of the poor range of the transmitters used, only 10 cottontails were monitored in this manner. Table V summarizes the home ranges of the 10 animals for which adequate data were collected.

Table V. Home ranges as calculated employing night time location points.

Rabbit Number	Sex	Area (acres)
R-212	F	6.20
R-335	F	4.82
R-346	F	1.41
R-359	M	6.47
R-381	F	1.74
R-402	M	2.83
R-407	F	3.81
R-446	F	1.96
R-456	M	4.73
R-475	F	5.17

The mean range area for all 10 rabbits was 3.92 acres using the night time location estimate. Males had a mean home range area of 4.68 acres (N=3), and females 3.59 acres (N=7). Difference between sexes was not significant.

Ranges determined by use of beagle chase

Toll et. al. (1960) employed beagles to estimate the home range of swamp rabbits. They felt that beagle chases had much promise for range determination for the following reasons: (1) ranges determined by this method agreed closely with those determined by capture-recapture methods; and (2) successive chases of the animal encompassed similar areas.

Table VI summarizes the home range areas determined by beagle chases. Mean range area for six rabbits was 5.33 acres. Mean home range size for females was 4.77 acres (N=5). Since only one male was subjected to this technique, a mean home range value for males, and a comparison between sexes was not possible.

Table VI. Home ranges as determined by beagle chases.

Rabbit Number	Sex	Range (acres)
R-321	F	7.45
R-338	F	5.38
R-359	M	8.11
R-417	F	2.50
R-446	F	4.35
R-475	F	4.19

Comparison and Discussion of Home Range Estimators

Table VII shows the mean home range values obtained using the four different methods. Table VIII summarizes the home range areas for all rabbits as determined when using the different estimators.

When subjected to statistical analysis there was no significant differences between MAM, night time location estimate, and beagle chases. The MMAM was significantly smaller than all other methods employed.

Table VII. Mean home range values obtained using the four different methods for rabbits on the RNHR study area.

Method	All Rabbits	Males	Females
MAM	4.74	5.67	4.15
MMAM	1.56	1.52	1.72
Night time location	3.92	4.68	3.59
Beagle chase	5.33	8.11*	4.77

*only one animal

Table VIII. Home range areas as calculated by four methods.

Rabbit Number	Sex	MAM	MMAM	Night time Location est.	Beagle Chase
R-212	F	2.45	.77	6.20	----
R-214	M	11.92	2.72	----	----
R-246	F	6.69	2.67	----	----
R-247	F	1.90	1.25	----	----
R-301	M	12.48	3.16	----	----
R-306	F	1.09	.22	----	----
R-317	M	1.36	.76	----	----
R-321	F	9.52	3.59	----	7.45

Table VIII. Con't.

Rabbit Number	Sex	MAM	MMAM	Night time Location est.	Beagle Chase
R-327	M	2.01	1.09	----	----
R-329*	M	1.90	.67	----	----
R-335	F	2.01	.87	4.84	----
R-337	F	.65	.33	----	----
R-338	F	6.91	5.11	----	5.28
R-342	F	8.16	2.01	----	----
R-344*	M	2.18	1.20	----	----
R-345	F	1.14	.27	----	----
R-346	F	1.79	.60	1.41	----
R-347	M	2.83	.92	----	----
R-349*	M	1.36	.16	----	----
R-351*	M	1.25	.70	----	----
R-355	F	3.75	1.25	----	----
R-359	M	4.90	3.06	6.47	8.11
R-377*	M	1.52	.05	----	----
R-381	F	4.73	1.25	1.74	----
R-398	F	.98	.16	----	----
R-402	M	5.93	.81	2.83	----
R-407	F	2.07	.22	3.81	----
R-417*	F	2.23	1.36	----	2.50
R-419	M	8.43	1.09	----	----
R-446*	F	2.67	.60	1.96	4.35

Table VIII. Con't.

Rabbit Number	Sex	MAM	MMAM	Night time Location est.	Beagle Chase
R-456	M	1.14	.11	4.73	----
R-475	F	7.07	4.03	5.17	4.19

*Rabbits that were determined not to have adequately sampled home ranges, as determined by the MAM.

Even with a small sample size (N=10), I believe that the night time location estimate was, in all probability, the best measure of a rabbit's home range, since the locational data points were taken during activity periods. Therefore, this estimator yielded a value which was compared to the other methods.

Although previous authors (Harvey and Barbour, 1965; Quadagno, 1968) felt that the MMAM yielded a better estimate of the area of utilization, when it was compared to the night time location estimate the MMAM significantly under-estimated the area of utilization for cottontails. It appears that the objective tool for determining investigatory sallies (any point separated by a distance greater than one-quarter the distance of farthest detection was considered a sally) was too large to be adequate for cottontails. In all probability a "blanket rule" to determine excursions for all species is impractical. While the MMAM may have yielded a better estimate of the area of utilization for Harvey and Barbour while working with Microtus, the application of this method, which reduces the size of the home range estimate, should be done in conjunction with other methods.

Harvey and Barbour (1965) and Burt (1943) cautioned against the use of the MAM. They felt the MAM yielded an estimate of an animal's "total range", and in some cases estimated home ranges were too large.

However, during this study, the MAM yielded a home range estimate which was not significantly different from the results obtained using the night time location estimate. For this reason, it appears that the MAM was an adequate technique.

Toll et. al. (1960) believed that beagle chases held much promise for estimating rabbit home range areas. Janes (1959) stated that it was not easy to drive a cottontail out of its home range. Watt (1975) determined a chase range on one rabbit, and felt that in all probability it was not a good estimator of an animal's home range. In Watt's chase range the animal was jumped and pursued on foot with the aid of radio telemetry equipment. This made the chase a "jump and run affair", with the pursuer's approach path affecting the direction in which the rabbit moved. In a beagle chase, this was not the situation. From personal observations, I concluded that after the initial start the rabbit was usually 15 to 25 yards ahead of the beagle, and the rabbit, not the dog, set the direction and pace of the chase. The slow constant pressure of a beagle chase yielded a different home range estimate than the chase range conducted by Watt.

In this study, beagle chase results showed the same pattern as was observed by Toll et. al. (1960): (1) ranges determined by this method were not significantly different from ranges determined by the MAM and night time monitoring; (2) successive chases of the same animal encompassed

similar areas; (3) rabbits displayed familiarity with escape and hiding places on the periphery of the home range area. These three points were evidence of the validity of this method.

Much speculation has been afforded to the concept of a maximum range with a smaller portion of that maximum range being the area of utilization (Odum and Kuenzler, 1955; Quadagno, 1968; Harvey and Barbour, 1965; Watt, 1975). When one applies these discussions to the beagle ranges, it appears that beagle chase ranges would fall under the category of maximum range. Watt (1975) stated that from an ecological-management standpoint, the area of utilization is probably more important than the maximum range. While there was no significant difference between the three methods, beagle chases did yield a slightly larger mean area and were more ameboid, including more escape cover than the other methods. It was apparent that areas on the periphery of the home range were used by rabbits for escape or hiding, and were important components of the home range. Therefore, it seems questionable to exclude these areas from the area of utilization. This author questions the importance of an area of utilization to a wildlife manager, if escape cover on the periphery of a rabbit's home range is excluded.

Seasonal Variations in Home Range Areas

Janes (1959) stated that cottontails increase their home ranges areas five to fifteen percent in the summer. If home range areas are larger during the summer months than in the winter months, this could possibly make cottontails more observable in the summer. To determine

if there was a seasonal variation in cottontail home range areas on the RNHR study area the MAM was employed to estimate home ranges for each season. Locational data points which were recorded between the traditional calendar seasons (spring 20 March - 20 June; summer 21 June - 21 September; fall 22 September - 20 December; winter 21 December - 19 March) were used to estimate the seasonal home range areas.

Tables IX and X summarize data on seasonal home range areas. Mean home range sizes for both males and females were 3.92 acres (N=7) in the spring, 4.62 acres (N=7) in summer, 3.98 acres (N=11) in fall and 2.71 acres (N=9) in winter. An increase in home range size in the summer reported by Janes (1959) was evident in this study. Home ranges were smallest in the winter, which may make rabbits less observable during this portion of the year, particularly if their winter cover is more dense than summer cover. It should be noted that the calendar seasons may not be appropriate time intervals for comparing seasonal differences in home range size for cottontails. Also, although seasonal changes of the magnitude reported by Janes were observed, when subjected to the Student's t-test at $p=.05$ level of significance the differences were not significant.

Home range sizes varied with sex and season. Males ranges varied from largest to smallest as follows: summer, 6.94 acres (N=3); spring, 4.82 acres (N=3); fall, 4.08 acres (N=4); and winter, 1.63 acres (N=3). Female ranges varied from largest to smallest as follows: fall, 3.93 acres (N=7); spring, 3.27 acres (N=4); winter, 3.21 acres (N=6); and summer, 1.52 acres (N=3). Seasonal variations for both male and female were not significantly different.

Table IX. Home ranges determined for spring and summer using the MAM.

SPRING 3/20-6/20			SUMMER 6/21-9/21		
Rabbit Number	Sex	Home Range Area	Rabbit Number	Sex	Home Range Area
R-306	F	1.09	R-214	M	11.92
R-359	M	4.90	R-247	F	1.90
R-417	F	2.23	R-301	M	12.48
R-419	M	8.43	R-317	M	1.36
R-446	F	2.67	R-327	M	2.01
R-456	M	1.14	R-337	F	.65
R-475	F	7.07	R-338	F	2.00

Table X. Home ranges determined for fall and winter using the MAM.

FALL 9/22-12/20			WINTER 12/21-3/19		
Rabbit Number	Sex	Home Range Area	Rabbit Number	Sex	Home Range Area
R-214	M	5.66	R-212	F	2.45
R-246	F	6.69	R-214	M	1.04
R-329	M	1.90	R-246	F	2.18
R-335	F	2.01	R-321	F	9.52
R-338	F	5.82	R-335	F	2.01
R-342	F	2.72	R-338	F	2.23
R-346	F	1.79	R-359	M	2.72
R-347	M	2.83	R-398	F	.98

Table X. Con't.

FALL 9/22-12/20			WINTER 12/21-3/19		
Rabbit Number	Sex	Home Range Area	Rabbit Number	Sex	Home Range Area
R-355	F	3.75	R-456	M	1.14
R-381	F	4.73			
R-402	M	5.93			

The small summer home range areas for females may be a result of females nursing young, and therefore staying close to the nest during the reproductive period.

Cottontail Movements

Three measures of cottontail movements were applied to the data recorded in the present study: (1) mean minimum daily travel distance; (2) degree of form reuse; and (3) movements from an established home range area.

Mean minimum daily travel distance (MMDTD) for 29 radio-tracked rabbits is shown in Table XI. Mean MMDTD for all rabbits was 42.4 yards. Mean MMDTD for males was 52.9 yards (N=12) and for females was 34.9 yards (N=17). Differences between MMDTD for males and females were not significant.

MMDTD was used as an indicator of seasonal variations in cottontail movements, and in all probability was not a valid indicator. Nonetheless, MMDTD's were calculated seasonally using the traditional calendar seasons. Tables XII and XIII summarize the MMDTD for each season.

Table XI. Mean minimum daily travel distance (MMDTD) in yards for 29 radio-tracked rabbits.

Rabbit Number	Sex	MMDTD
R-212	F	26.3
R-214	M	67.9
R-246	F	49.8
R-247	F	31.3
R-301	M	95.7
R-306	F	16.1
R-317	M	41.1
R-321	F	49.4
R-327	M	48.1
R-335	F	23.9
R-337	F	42.1
R-338	F	39.2
R-342	F	39.8
R-344	M	54.5
R-345	F	58.2
R-346	F	8.2
R-347	M	25.1
R-349	M	40.8
R-351	M	33.9
R-355	F	30.2
R-359	M	73.7
R-377	M	35.4

Table XI. Con't.

Rabbit Number	Sex	MMDTD
R-381	F	29.4
R-402	M	115.2
R-407	F	28.4
R-417	F	19.2
R-446	F	30.0
R-456	M	3.9
R-475	F	72.4

Table XII. MMDTD's calculated for spring and summer.

SPRING 3/20-6/20			SUMMER 6/31-9/21		
Rabbit Number	Sex	MMDTD	Rabbit Number	Sex	MMDTD
R-306	F	16.1	R-214	M	144.4
R-359	M	97.3	R-247	F	31.3
R-417	F	19.2	R-301	M	95.7
R-446	F	30.0	R-317	M	41.1
R-475	F	72.4	R-327	M	48.1
			R-335	F	21.7
			R-337	F	42.1
			R-338	F	39.2

Table XIII. MMDTD's calculated for fall and winter.

FALL 9/22-12/20			SUMMER 12/21-3/19		
Rabbit Number	Sex	MMDTD	Rabbit Number	Sex	MMDTD
R-214	M	29.1	R-212	F	34.4
R-246	F	49.8	R-214	M	1.2
R-335	F	23.9	R-246	F	31.7
R-338	F	36.5	R-321	F	49.4
R-342	F	39.8	R-335	F	22.3
R-346	F	8.2	R-338	F	35.2
R-347	M	25.1	R-359	M	73.7
R-355	F	30.2	R-456	M	3.9
R-381	F	29.4			
R-402	M	115.2			

Mean MMDTD's for all rabbits varied seasonally from largest to smallest as follows: summer, 57.9 yards (N=8); spring, 47 yards (N=5); fall, 38.7 yards (N=10); and winter, 31.5 yards (N=8). The variations in seasonal MMDTD's were not significantly different.

Female mean MMDTD's did not show a reduction in the summer months corresponding to the reduction observed in seasonal home range areas. Mean MMDTD's for females were rather constant throughout the year, being 34.4 yards (N=4) in spring and 33.6 yards (N=5) during the winter months. Seasonal variation in female MMDTD's were not significantly different.

Male mean MMDTD's were more variable than mean female MMDTD's throughout the year, being 82.3 yards (N=4) in summer, 56.6 yards (N=3) in fall,

26.3 yards (N=3) in winter, and the only male observed during the spring had a MMDTD of 97.3 yards. Male mean MMDTD's showed a reduction in male movements during the winter months that corresponded to the reduction in home range size during the winter months. However, seasonal variations of male MMDTD's were not significantly different.

Degree of Form Reuse

Janes (1959) determined that, on the average, cottontails on his study area maintained 3.5 forms. This was considerably smaller than the average of 18.3 forms calculated by Watt (1975) on the RNHR study area. In the current study an average of 11.6 forms per cottontail was calculated (range 4 to 30).

Table XIV shows the degree to which animals reused their forms. As the reuse ratio approaches one, this would indicate the animal was in a different location nearly each day.

The mean reuse ratio for all animals was .303; .364 for males and .260 for females. Differences between sexes were not significant. Watt reported a reuse ratio of .549, and Jane's low number of forms per cottontail would mean that the reuse ratio, if it had been calculated, would have been much smaller than that calculated by Watt or for the current study.

The difference between Watt and the current study would indicate that on the same study area rabbits reused their forms 50.4 percent of the time in 1974-75 and only 30.3 percent of the time in 1975-76. The cause of this variation is unknown.

Table XIV. Form reuse ratios for 31 radio-tracked rabbits. N = number of days monitored.

Rabbit Number	N	Form Reuse Ratio Number of data points/ Number of days monitored
R-212	80	.167
R-214	139	.173
R-246	67	.313
R-247	127	.134
R-301	50	.420
R-306	51	.300
R-317	32	.355
R-321	93	.138
R-327	35	.441
R-335	142	.144
R-337	36	.267
R-338	126	.252
R-342	75	.243
R-344	18	.733
R-345	17	.438
R-346	93	.078
R-347	46	.256
R-349	17	.467
R-351	19	.444
R-355	40	.222
R-359	93	.310
R-377	20	.352

Table XIV. Con't.

Rabbit Number	N	Form Reuse Ratio Number of data points/ Number of days monitored
R-381	61	.220
R-398	53	.078
R-402	33	.333
R-407	22	.250
R-417	21	.706
R-419	35	.375
R-446	24	.318
R-456	87	.070
R-475	46	.400

Movements From an Established Home Range Area

Janes (1959) concluded that rabbits usually established their home ranges where they were born and remained in these areas until they died. He cited only one instance of home range change in his study. Watt (1975) found no indications of an animal moving from an established home range to another area.

Exceptions to the conclusions of Janes and Watt were found in the current study. Four animals moved from an established home range area. R-321 (female) was captured four times as a juvenile in one area, and was instrumented three months after her last capture as a juvenile. After instrumentation, R-321 was never located in the area she occupied as a juvenile. Her juvenile center of activity and her center of activity three months later were separated by a distance of 323.4 yards.

R-336 (female) was instrumented and located for five successive days and went "off the air". She was recaptured one month later and reinstrumented. The home range area she occupied during the second instrumentation was 657 yards from the area occupied during the first period.

R-338 (female) was monitored for five months (August - January). During this period R-338 moved her center of activity 282.3 yards. This movement was a gradual change, in a northward direction. However, once the movement ceased, the original area of occupation was not revisited.

R-402 (male) relocated in a brushpile 241.3 yards from his original home range area. This movement occurred during late fall-early winter and may have indicated this animal's preference for better escape cover or shelter.

Comments on an Introduced Rabbit

Watt (1975) discussed the movements of R-247 which was accidently introduced to the area on 10 October 1974. The exceptionally large movements observed after her escape were interpreted as an indication of difficulty in establishing a normal home range. Watt stated that this difficulty could account for the lack of success in restocking cottontails. While I agree with Watt's reasoning, it should be noted that R-247 finally did establish a normal home range area of 1.9 acres (MAM was used to estimate home range size). Also, R-247 was pregnant when recaptured 19 June 1975. These facts would seem to indicate that R-247 established herself within the area.

Territoriality

The question of whether territorial behavior is exhibited by eastern cottontails is still a matter of controversy. Getz (1961) defined the term territory as "that portion of the home range of an individual that is defended from instrusion by members of the same species of the same sex". It might involve the defense of the whole home range or just a portion of it.

The percentage of range overlap has been used as an indicator of territoriality (Haugen, 1942; Janes, 1959; Trent and Rongstad, 1974) and was used in this study.

Table XV summarizes the information gathered on percent of range overlap. There were no significant differences between any of the categories. This differed from the conclusions of Watt (1975) who found male ranges overlapped female ranges to a significantly greater extent than female ranges overlapped the male ranges; male ranges overlapped female ranges to a significantly greater extent than the ranges of males overlapped those of other males. Watt stated that whether these differences were artifacts of the small sample size or actual differences was not known.

Due to the small sample size of both Watt (1975) and the current study, the question of whether or not cottontails exhibit territorial behavior on the RNHR study area is a matter open to confirmation or refutation by more data.

Table XV. Percent of home range overlap by contemporary rabbits.

	N	Percent Overlap Mean	Range
Female-Female	8	34.0	4.7-100
Male-Male	2	32.6	21.4- 44.0
Male-Female	7	48.8	7.4-100
Female-Male	7	35.5	3.2-100

Trapping Success and Population Estimates

Trapping was conducted from 5 August 1974 to 1 June 1976 on RNHR. Watt (1975) and Gress (1976) reported on trapping success during this time period. Also, both authors made population estimates from the capture-recapture data recorded during these time intervals.

Equipment Performance

Generally, transmitters used in this study were adequate. Most of the recovered malfunctioning transmitters had "bad" batteries. Since battery failure was the major source of malfunction, future studies should attempt to obtain "fresh" batteries, store replacement batteries in a refrigerator, and explore the possibility of using certified batteries (which may be cheaper and more efficient in the long run).

Although the transmitters were adequate for determination of daily resting locations and use in the mortality aspects of this study, they were inadequate for night time monitoring. Transmitters did not have the range of one-quarter mile in typical rabbit habitat reported by Hutton (1975). The poor range exhibited by these transmitters made it impossible

to use the two permanent receiver sites. Limited success was obtained in a 50-acre plot (Figure 1, all areas in the southern portion of the study area plus F-4,5 and G-4,5), when using one permanent receiver site and the mobile unit.

SUMMARY

1. A study of cottontail home range areas and movements was conducted on Emporia Kansas State College's Ross Natural History Reservation in west-central Lyon County, Kansas, from 1 June 1975 to 1 April 1976. Trapping and radio telemetry equipment were used to collect data.

2. Rabbit home ranges were calculated using four methods: (1) Minimum Area Method; (2) Modified Minimum Area Method; (3) night time location estimate; and (4) beagle chases.

3. Mean home range size for adequately sampled males was 5.67 acres and 4.14 acres for females, using the Minimum Area Method.

4. Mean home range size using the Modified Minimum Area Method was 1.52 acres for males and 1.72 acres for females.

5. When employing the night time location estimate, a mean home range area of 4.68 acres was obtained for males and 3.59 acres for females.

6. Beagle chases yielded a mean home range size of 4.77 acres for females. Only one male was subjected to this technique, and an estimated home range area of 8.11 acres was obtained.

7. The differences between male and female home range areas were not significantly different.

8. When comparing the four different estimators, the author believed that the Modified Minimum Area Method under-estimated home range size, and that the other three methods were adequate for the estimation of cottontail home range areas.

9. Home range areas were calculated seasonally using the Minimum Area Method. Mean home range size for all rabbits was 3.92 acres in the

spring, largest in summer at 4.62 acres, 3.98 acres in fall, and smallest in the winter at 2.71 acres.

10. Three measures of cottontail movements were applied to the data: (1) mean minimum daily travel distance (MMDTD); (2) degree of form reuse; and (3) movements from an established home range area.

11. Mean MMDTD for all rabbits was 42.4 yards. Mean MMDTD for males was 52.9 yards and for females was 34.9 yards. Differences between MMDTD for males and females were not significant.

12. When calculated seasonally MMDTD for all rabbits were largest in the summer at 57.9 yards, 38.7 yards in fall, smallest in winter at 31.5 yards, and 47 yards in spring.

13. The mean form reuse ratio for all animals was .303. This would indicate that rabbits were found, on the average, 30 percent of the time resting in a location that they had previously used.

14. An average of 11.6 daily resting locations was found for rabbits with adequately sampled home ranges.

15. Four animals moved from an established home range to another area.

16. An introduced rabbit moved over a large area indicating that it had difficulty establishing a home range, but finally established herself within the study area.

17. Conclusive evidence of territoriality in cottontails was not found.

18. I believe that the reduction observed in the MMDTD's and home range size make cottontails less observable during the winter months. When this factor is coupled with the population estimates and mortality

rates reported by Gress (1976), for this period, an explanation for the reported "disappearance" of cottontails in the fall and winter months may be found.

LITERATURE CITED

LITERATURE CITED

Allen, D. L. 1939. Michigan cottontails in winter. J. Wildl. Mgmt. 3(4): 307-332.

Brown, L. E. 1956. Movements of some British small mammals. J. Animal Ecol. 25: 54-71

Burt, W. H. 1943. Territoriality and home range concepts as applied to mammals. J. Mamm. 24: 346-352.

Connel, J. H. 1954. Home range and mobility of brush rabbits in California Chaparral. J.Mamm. 35(3): 392-405.

Cook, R. S., M. White, D. O. Trainer, and W. C. Glazener. 1971. Mortality of young white-tailed deer fawns in south Texas. J. Wildl. Mgmt. 35(1): 46-56.

Craighead, F. D., and J. J. Craighead. 1965. Tracking grizzly bears. BioScience 15(2): 88-92.

Dalke, P. D. and P.R. Sime. 1938. Home and seasonal ranges of the eastern cottontail in Connecticut. Tran. Third North Amer. Wildl. Conf.: 659-669.

Davis, D. E., J. T. Emlen, Jr., and A. W. Stokes. 1948. Studies on home range in the brown rat. J. Mamm. 29(3): 207-225.

Doebel, J. H. and B. S. McGinnes. 1974. Home range and activity of a grey squirrel population. J. Wildl. Mgmt. 28(2): 363-368.

Ellis, R. J. 1964. Tracking raccoon by radio. J. Wildl. Mgmt. 28(2): 363-368.

Forsythe, S. W. 1974. Parasites of cottontail rabbits in Lyon County, Kansas. Unpub. M. S. thesis, Emporia Kansas State College, Emporia, Ks. 29p.

Getz, L. L. 1961. Home ranges, territoriality and movement of the Meadow vole. J. Mamm. 42: 24-36.

Gress, R. J. 1976. Cottontail mortality in Lyon County, Kansas. Unpub. M. S. thesis, Emporia Kansas State College, Emporia, Ks. 80p.

Hanson, J. C. 1959. Activity and use of habitat by cottontails during winter. Trans. Ill. Acad. of Sci. 62(3): 294-302.

Hartman, E. L. 1960. The F. B. and Rena G. Ross Natural History Reservation. Emporia State Research Studies VIII(4): 1-40.

Harvey, M. J. and R. W. Barbour. 1965. Home range of Microtus ochrogaster as determined by a modified minimum area method. J. Mamm. 46(3): 398-402.

Haugen, A. O. 1942. Home range of the cottontail rabbit. Ecology 23(3): 1-18.

Hendrickson, G. O. 1936. Summer studies on the cottontail rabbit; Sylvilagus floridanus. Iowa State Coll. Jour. Sci. 10: 367-372.

Hutton, T. A. 1975. Establishment and testing of a radio telemetry system. Unpub. M. S. thesis, Emporia Kansas State College, Emporia, Ks. 37p.

Janes. B. W. 1959. Home ranges and movements of the eastern cottontail in Kansas. U. of Kansas Publ. Mus. Nat. History. 22: 227-237.

Kjos, C. G. and W. W. Cochran. 1970. Activity of migrant thrushes as determined by radio telemetry. Wilson Bull. 82(2): 225-226.

Kuck, T. L., R. B. Dahlgren, and D. R. Progulske. 1970. Movements and behavior of hen pheasants during the nesting season. J. Wildl. Mgmt. 34(3): 626-629.

Lord, R. D., Jr. 1963. The cottontail rabbit in Illinois. Illinois Dept. of Cons., Tech. Bull. No. 3: xi + 1-94.

McGinnis, S. M., V. A. Finch, and A. M. Hawthorn. 1970. A radio telemetry technique for monitoring temperatures from unrestrained ungulates. J. Wildl. Mgmt. 34(4): 921-925.

Mohr, C. O. 1947. Table of equivalent populations of North American small mammals. Am. Midl. Nat. 37: 223-249.

Nicholls, T. H. and D.W. Warner. 1972. Barred owl habitat use as determined by radio telemetry. J. Wildl. Mgmt. 36(2): 213-224.

Odum, E. P. and E. J. Juenzler. 1955. Measurement of territory and home range size in birds. Auk 72: 128-137.

Quadagno, D. M. 1968. Home range size in feral house mice. J. Mamm. 49(1): 149-151.

Schwartz, C. W. 1941. Home range of the cottontail in central Missouri. J. Mamm. 22(4): 386-392.

Schwartz, C. W. and E. R. Schwartz. 1959. The wild mammals of Missouri. The U. of Missouri Press and Missouri Cons. Comm. xvi + 1-341.

Stoddart, C. L. 1970. A telemetric method for detecting jack rabbit mortality. J. Wildl. Mgmt. 34(3): 501-508.

Storm, G. L. 1965. Movements and activities of foxes as determined by radio tracking. J. Wildl. Mgmt. 29(1): 1-13.

Toll, J. E., T. S. Baskett and C. H. Conaway. 1960. Home range, reproduction and foods of the swamp rabbit in Missouri. Am. Midl. Nat. 63(2): 398-412.

Trent, T. T. and O. J. Rongstad. 1974. Home range and survival of cottontail rabbits in southwestern Wisconsin. J. Wildl. Mgmt. 38(3): 459-472.

Watt, C. C. 1975. Cottontail rabbit ranges and mortality in eastern Kansas. Unpub. M. S. theses, Emporia Kansas State College, Emporia, Ks. 128p.

Wilson, J. S. 1963. Flowering plants of the Ross Natural History Reservation, Lyon and Chase Counties, Kansas. Emporia State Research Studies XI(4): 1-91.