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Home Range Analysis of the Montane Vole

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HOME RANGE ANALYSIS OF THE MONTANE VOLE

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by

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TABLE OF CONTENTS

CHAPTER		PAGE
I.	INTRODUCTION AND STATEMENT OF THE PROBLEM	1
	Introduction	1
	Statement of the Problem	4
II.	STUDY AREA	5
III.	NESTS, BURROWS, AND RUNWAYS	10
	Method of Study	10
	Results	11
IV.	HOME RANGE DETERMINATION BY LIVE TRAPPING	19
	Trapping Methods	19
	Home Range Analysis	20
V.	HOME RANGE DETERMINATION BY RADIO-ISOTOPE LABELING	27
	Labeling Procedure	27
	Tracing Analysis	28
VI.	DISCUSSION AND SUMMARY	33
	Discussion	33
	Summary	41
BIBLIOGRAPHY		43

LIST OF TABLES

TABLE		PAGE
I.	Mean Home Range Size in Square Meters for Adults and Subadults Based on the Number of Captures.	22
II.	Mean Home Range Size When Combining the Number of Captures.	22
III.	Home Range Size Computed by the Minimum Area Method. .	23
IV.	Home Ranges Computed by the Minimum Area Method When the Captures are Combined	23
V.	Comparison of Home Ranges of Border and Interior Individuals.	24
VI.	Home Range Variation of Individuals Living along the Irrigation Ditch (A) and Individuals Living on other Parts of the Study Area (B).	25
VII.	Comparison of Home Ranges of Males and Females	25
VIII.	The Number of Survivors Indicated by Recaptures. . . .	26
IX.	Summary of Several Home Range Studies.	36
X.	Home Range Computations for this Study	36

LIST OF FIGURES

FIGURE		PAGE
1.	Vegetation Density Pattern	7
2.	A Representative Burrow Pattern.	11
3.	Photograph of a Portion of a Runway System, with the Vegetation Clipped and the Runways Limed	16
4.	The Minimum Area Method (Dotted Line) and the Exclusive Boundary Strip Method (Solid Line)	21
5.	A Comparison of Home Range Size as Determined by Two Methods	30
6.	The Activity Pattern of an Adult Male as Indicated by Radio-Isotope Tracing	31
7.	The Activity Pattern of an Adult Female.	32

CHAPTER I

INTRODUCTION AND STATEMENT OF THE PROBLEM

I. INTRODUCTION

Microtus spp. are small cricetid rodents with short legs and muzzles. Their tails are usually shorter than their heads and bodies. They are members of the subfamily Microtinae, which is confined to the northern hemisphere (16:375). The montane vole (Microtus montanus) occurs throughout much of western North America from New Mexico to British Columbia, where it inhabits grassy meadows in the Upper Sonoran, Transition, and Canadian life zones (16:413-417; 21:249). In Washington it occurs East of the Cascade Mountains in the sagebrush, irrigated grass, and Ponderosa Pine communities.

Hall and Cockrum record the following measurements for the adult montane vole: total length, 140-192 mm.; tail length, 31-69 mm.; hind foot, 18-25 mm.; weight, 37.3-85.0 gms. They are brown with a mixture of black-tipped hairs above and are white to light grey below (16:413).

Green vegetation, particularly the tender young shoots of grasses, is their major food item. They also eat grain and green bark from small shrubs and trees (22:252). Cahalane reports that in addition to green vegetation, voles eat flowers, roots, tubers, bulbs, insects and insect larvae (5:517). In some areas population outbreaks have resulted in complete destruction of orchards and farm

crops (1:524; 24:190-199). Bailey reports that voles can eat one-half ton of hay per year (1:523).

There has been little descriptive analysis of Microtus nests, burrows, and runways with the exception of that pertaining to the effects on crops and vegetation, particularly during periods of peak Microtus densities.

Godfrey has studied nesting behavior of Microtus agrestis. He found seasonal variation in nest location; summer nests were on the surface, and winter nests were in burrow cavities (14:305). However, Cahalane reports that voles often "leave their summer underground homes and build above ground during the winter" (5:513).

Burrows are used for both nesting and storage in some geographic areas. Cahalane reports that Indians took advantage of voles by robbing their store houses. He states that, "they (Indians) were rewarded by finding as much as five or six quarts of edible roots, bulbs, and tubers in one store room" (5:516).

No one has explored the general runway patterns of the smaller microtine rodents or attempted a study of the ecological significance underlying such systems. Numerous reports indicate that voles seldom venture from their runways and usually cannot be induced to do so even with baited traps.

Seaton (1909) stated that, "no wild animal roams at random over the country: each has a home region even if not an actual home" (4:350). A home range has been defined by Burt (1943) as being, "the area usually around a home site, over which an animal

normally travels in search of food." He excludes, "occasional sallies, perhaps exploratory in nature," from the home range (4:351). Hayne states that, "The significance of the home range concept in the life history of mammals must include some knowledge of the intensity of use by the animal" (19:1). Stickle states that the home range "boundaries may shift from time to time and must be considered diffuse and general rather than sharply or definitely defined" (26:1).

Several authors have indicated that voles increase their home range area during the breeding period. However, Brown found no correlation between the breeding season and home range size for Microtus agrestis (From Getz, 13:35).

Blair found that male meadow voles had smaller home ranges in moist than in dry grassland (2:149-161). Kalabukhov stated that "the more food available in a given territory, the smaller the radius of movement" (11:144-177, 221-245). Krebs reported that the occurrence of superabundant food did not decrease movement distances in Microtus californicus (23:571). Getz also reported that food supply was not a factor in determining home range size of Microtus agrestis (13:32).

The traditional home range analysis for small mammals has employed the live trapping - recapture method, and there are several problems in using this method. The most common are trap placement and spacing, human disturbance, and trap deaths.

Hayne found that trap spacing has an effect on movement patterns, thus affecting home range analysis. When traps were too

closely spaced, the animals were caught before reaching the distant portions of their home range. When those traps near the center of activity were removed, more frequent catches were made toward the periphery of the range (19:26-33).

The effect of disturbance is difficult to evaluate. Chitty states that "if natural conditions are to be maintained, individuals should be caught as infrequently as possible" (3:1-58). Burt modified the above to, "infrequently as practicable, for the end in view" (3:1-58).

Trap deaths are a constant problem when working with small mammals. Chitty found trap mortality to be as high as 20 per cent in Microtus agrestis, but the mortality dropped to 2 per cent among those recaptured (6:505-552).

Recently a new method, radio-isotope tracing, has been applied to home range analysis (15:5-10). Its application will hopefully minimize or eliminate several of the above problems.

II. STATEMENT OF THE PROBLEM

This study on Microtus montanus was divided into three major sections: 1) An examination of nests, burrows, and runways, 2) A comparison of two methods of home range analysis--live trapping and radio-isotope tracing, and 3) A comparison of the home range of Microtus montanus with other species of Microtus as published in the literature.

CHAPTER II

STUDY AREA

The study site, a .9 acre plot, is located in a pasture three miles northwest of Ellensburg (Section 22, Township 18 North, Range 18 East), Kittitas County, Washington.

Average annual precipitation is less than ten inches, most of which is received during the winter months. The average yearly snowfall is thirty inches; however, during both the year of the study and the preceding year, the Kittitas Valley received more than average snowfall. Irrigation supplements the normal moisture, providing water for production of hay and field crops. A thirty-nine year record indicates a temperature range of -31°F. to 110°F. at Ellensburg. Wind is a major factor in the valley, with an average yearly velocity of eleven mph. (7:1170-1181). It is strongest during the spring and summer months.

The western 2/3 of the study site lies on a 13 per cent east facing slope providing gravity-flow irrigation from a small ditch crossing the eastern edge of the field. There are numerous surface rocks measuring up to 12 inches in diameter scattered about. The area was over-grazed for years but was not grazed the year prior to the study. Although the flora consisted primarily of mixed grasses and clover, the vegetation was not uniform because of great variation in height and density. The distribution of plants, particularly the dominant species, seemed fairly uniform so that variation in height and density resulted from several environmental factors.

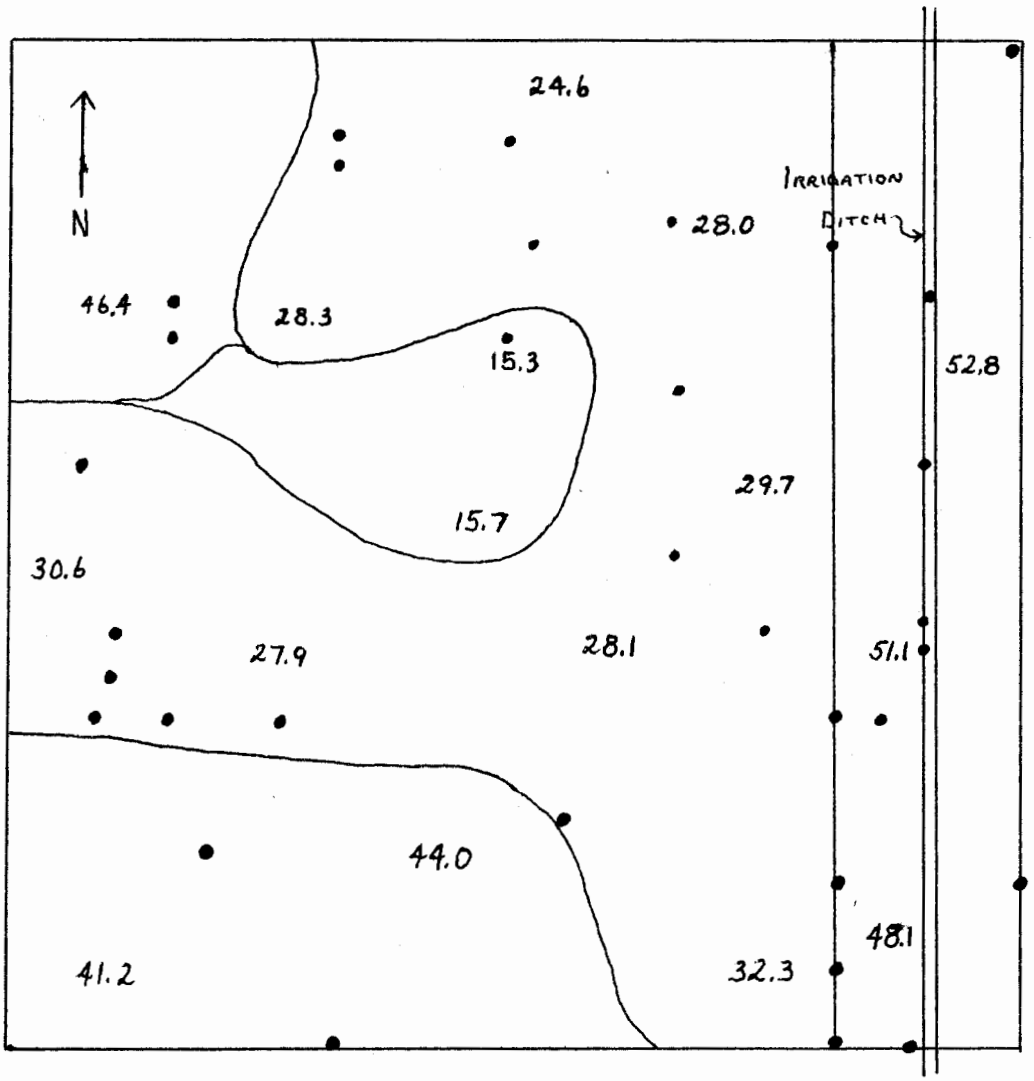
The dominant plants on the study area included the following: creeping bent grass (Agrostis stolonifera), Dudley's rush (Juncus dudleyi), timothy (Phleum pratense), and red clover (Trifolium pratense). Other species were Aster occidentalis, Juncus balticus, Juncus effusus, Plantago lanceolata, Rumex crispus, and Trifolium repens.

The major factor affecting plant growth was summer water supply which was received primarily from irrigation. Plants growing in areas receiving no irrigation water were noticeably stunted. Because of the uneven ground surface, water was not uniformly distributed, some areas remaining dry while others were temporarily flooded.

Another factor affecting vegetation was a prevailing northwest wind causing the vegetation to bend over and form a thick mat, particularly on the slope. Although vegetation was dense along the western edge of the study area, the mouse population there was very low (Figure 1).

The mice were active throughout the winter and did not have food caches to rely on. They were forced to depend upon their ability to forage during the entire winter. For a period of eight weeks when there was a deep snow cover, the matted grasses created a subnivean space for the mice to move about without burrowing through the snow. Since snow is an insulator, the temperature below the snow should have been higher than that above the snow. There is an obvious advantage in living in an area covered with snow during cold temperatures, particularly if a thick mat of vegetation provides a subnivean space

Figure 1. Vegetation Density Pattern. Figures indicate grams of vegetation (air-dried) taken from 16, 861.4 cm^2 samples. Dots indicate activity centers of Microtus.



for a freedom of movement. Middleton reports that the weather most liable to destroy voles is a period of hard frost without snow cover (25:156-166).

Perhaps the major effect on vegetation on the study plot resulted from the construction of runways, where the voles destroyed any plant growing in the runway. Summerhayes reports that voles reduce the luxuriance of the dominant grasses so that other plants, especially mosses, are enabled to exist more abundantly among the dominants. He also reports that "voles practically never eat moss" (27:47).

Voles are beneficial to plant growth in several ways. They are effective in recycling mineral nutrients, thereby enriching the soil. They aid in soil aeration by removing or disturbing leaf litter and by burrowing. Voles therefore tend to preserve a relatively open vegetation comparatively rich in species (27:47).

Several predators were found on the study area including: short-tailed weasel (Mustela ermina), prairie falcon (Falco mexicana), marsh hawk (Circus cyaneus), and short-eared owl (Asio flammeus). The owls were seen on numerous occasions when I arrived early in the morning to set the traps. I found 16 owl pellets, containing the remains of at least 35 Microtus (by skull count), in a small area 10 feet east of the trapping grid, where the owls were always seen.

There were also 12 vagrant shrews (Sorex vagrans) trapped on the grid. While it is questionable whether a Sorex vagrans would attack an adult vole, it is possible that they could prey on nestlings.

Eadie reports that the short-tailed shrew (Blarina brevicauda) prey on Microtus pennsylvanicus (10:263; 9:185-9). The short-tailed shrew, however, is larger than the vagrant shrew.

CHAPTER III

NESTS, BURROWS, AND RUNWAYS

I. METHODS OF STUDY

To prevent disturbing those individuals whose home ranges were being analyzed, thirty-three burrows were selected for examination off of the trapping grid (see below). The burrows of five individuals labeled with a radio-isotope tracer were examined after the trapping period. Burrows were opened with a small shovel and the contents removed from the central cavities. Each was then inspected, measured, and diagramed for comparison. Nests located in the above and six surface nests were checked for composition and shape.

The sample plot selected for study of runway patterns was located 30 meters south of the trapping grid and was chosen because of its habitat similarity with that of the grid. The irrigation ditch formed the eastern border of the sample plot. I might mention here that the vegetation on the sample plot appeared to be equivalent to the most luxurient type found on the trapping grid. Since the mouse density was high on the grid, it was expected to be high on the sample plot. This assumption was confirmed by the complexity of runway patterns found, which was consistent with that found on the grid.

The vegetation was removed with hand clippers as carefully as possible, to prevent disturbing effects. Lime was then applied to each runway surface. This permitted visual inspection of a sizeable

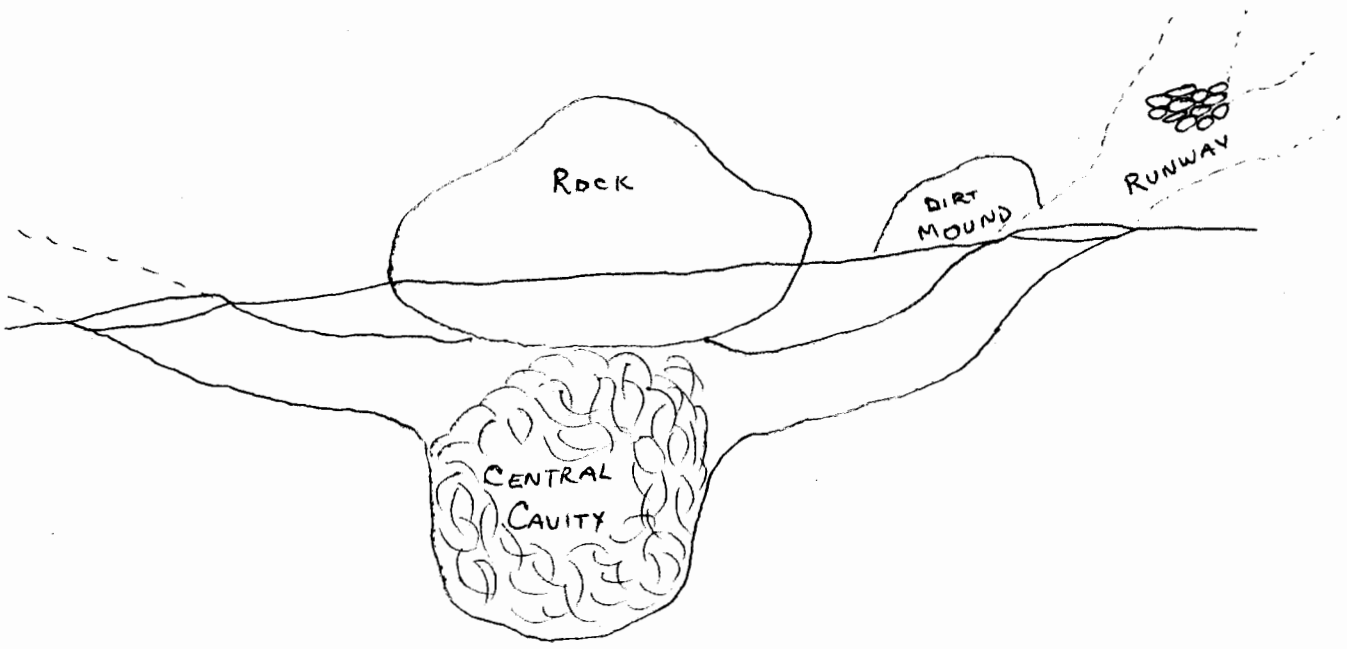
portion of the runway system, an appreciation if its complexity, and photographing of the runways.

II. RESULTS

Approximately one-third of the burrows were abandoned as a result of mortality or movement to a new burrow. Burrows were classified as abandoned if there was no fresh scat in the immediate area, there were spider webs in the entrance tunnels, or the nesting material within them was extremely wet.

The burrow cavity is spherical in shape, with a diameter of three to five inches, and lies two to three inches below the surface. Each cavity has two to three, or in one case as many as five, entrance tunnels which may vary in length from two to six inches (see Figure 2).

Figure 2. A Representative Burrow Pattern.



There appeared to be two major factors which influenced the selection of a burrow site. First, there were numerous rocks scattered about the study area, and burrows were concentrated among these rocks. The central cavities of 14 burrows were constructed under rocks, perhaps for added protection. In one area, I observed three adults emerge from separate burrows, each of which was located under rocks less than two feet apart. The vegetation close to the irrigation ditch is the second factor influencing burrow location. The burrow concentration in this region was extremely high in comparison with the rest of the area. This was a result of the high population of mice in this region of lush vegetation. Of three radio-isotope labeled individuals whose home ranges were crossed by the irrigation ditch, all had burrows on the east bank of the ditch on the uphill side. They were, of course, less likely to be flooded out.

During the summer and early fall, portions of the area were flooded as a result of irrigation. The snow melted quite rapidly during the first week of March, and again portions were flooded, forcing some individuals to evacuate to dry areas within their home range. Others were forced into new areas during the period of flooding.

Although voles are able to swim (one swam across the two-foot irrigation ditch), they are forced to concentrate in dry areas during these periods, imposing an increased grazing pressure on such dry areas where there was little vegetation to begin with. While concentrated in these areas, mortality may increase. The sparse

vegetation affords less protective cover, and predators might be attracted to these areas due to the concentration of activity. Mortality might also increase if the females are unable to move the nestlings in advance of the water.

Data gathered indicated that most survivors re-established their old home range after the water drained off. Several burrows that were examined after the flooding had stacks of wet nesting material piled outside an entrance tunnel, indicating that they were being reclaimed.

Two burrows examined in December, preceding the winter snowfall, contained leaf material which was much coarser than the fibers normally used in a nest cavity. Each was located in conjunction with a nest cavity, in a two-cavity burrow. In certain regions, Microtus is known to store grass, bulbs, and grain. It seems likely that these two leaf-filled cavities were food caches. Since more of these were not found and since most burrows had only one cavity, I conclude that Microtus living in this area are generally able to survive the winter without storing food, the extensive runway system under the snow permitting foraging during the winter.

Surface nests were examined during the winter and appeared to be abandoned. Before a surface nest is constructed, a shallow depression is prepared if not already present. Nests are then built in the depression and are made of fine root hairs which are soft and flexible. The consistent fiber size suggests that montane voles are selective in obtaining nesting material.

A surface nest containing several young was found on the area prior to this study. If there is a seasonal variation in the location of the nest, then it is possible that by late September all surface nesting had ceased.

Nests in burrows are much the same, the fibrous material filling the entire central cavity. The center of the nests, however, are hollow, and it is this cavity that the individual uses. This provides concealment, particularly for the young. I broke one nest open to examine its structure, unaware that there were two young inside. I retreated several feet to observe the response of the female when she returned. After her arrival she repaired the nest in about three minutes, working from the inside until it was completely remade. She was so attentive to her job that she appeared unaware of my presence.

The amount of time spent in the nest varies considerably. During cold, windy days, individuals marked with tracers spent most of their time in the nest, while during warmer days, they spent less time in the nest and traveled further from it.

Of five individuals whose home ranges were investigated by radio-isotope labeling, four nested near the border of their home range area. This suggests that nests are not located at random; there must be some compensating factor to displace the advantage of a centrally located nest. It would seem more efficient to nest near the center of activity, since the energy expenditure in getting to any peripheral point of the activity zone would decrease. Moreover, if the nest were centrally located, the individual would have the

advantage of remaining closer to its protective site. As previously mentioned, three of the above individuals nested in burrows at sites least likely to be flooded out. This could perhaps account for the peripheral position of their nests in their home ranges.

The runways vary in width from $1\frac{1}{2}$ to $2\frac{1}{2}$ inches. This may be a function of usage, the older or more frequently traversed runways being wider, with a more exposed surface. There appear to be some which are "major arterials", being used more frequently, as indicated by width, surface packing, and abundance of fecal deposits. Junctions are numerous, with side branches leading off a major runway approximately every 12 to 18 inches. The side branches either connect major runways or dead-end in shallow depressions which may serve as sites for sleeping. I occasionally found nesting material in these depressions. Fecal pellets are frequently voided at major junctions or near a nest site.

The degree of home range overlap indicated that several mice use the same runway system. During December, 1965, the number of different individuals caught at any given trap site varied from 0 to 8, with a mean of 2.8 per trap site. Microtus may also share their runway system with other species (24:176). Sorex vagrans were caught in traps set in Microtus runways during this study.

Measurements taken on the sample plot give some idea of the total amount of runway surface on an average home range of 145 square meters. If all sections of the runway were placed end to end, they would extend for approximately 615 meters (0.4 miles). If the

average home range were rectangular, 10 meters wide and 15 meters long, and the runways were straight, paralleling the length of the home range, there would be an estimated 4 runways per meter width. If, in reality, these runways are fairly uniform in distribution, an intense coverage of the home range is indicated. Since this study was undertaken when the population appeared to be very high, no comparisons can be made with runway patterns during population lows.

Figure 3. Photograph of a Portion of a Runway System, with the Vegetation Clipped and the Runways Limed.

There are several advantages to having a runway system, and selection should favor those individuals which establish and maintain such a system. The advantages may be divided into three categories: protection, social contact, and energy conservation.

The first category, protection, can be further divided into predator evasion and chill prevention. The former may be particularly true in relation to avian predators. Perhaps the greatest protection that the runway affords is to prevent the detection of the mice by the predator. An individual moving silently down a pathway does not reveal itself to the extent of one moving through clumps of vegetation. Of course avian predators have very good vision, so what appears to us as non-detectable movement may be quite evident to a bird. Evasive action may be necessary and is facilitated by a runway system. Two methods for evasion may be a random confusion route or a short decisive escape route leading to a safe site. They may depend on the knowledge of the runway system and the distance to a safe site, (i.e., a burrow). The mouse may simply dart along, turning at certain junctions, and eventually lose the predator--a random confusion route. The alternative is, of course, a knowledge of the runway system and escape routes which lead to the nearest burrow.

It was noted during this study that winter trap mortality was increased by mice becoming wet, and hence chilled. Even a slight degree of fur dampness was sufficient to create sluggishness in the mice. Most of the mice captured, however, were completely dry, even

on damp foggy days when the vegetation was extremely wet; and most, if not all, of those which were wet got so in the trap (i.e., urination and condensation). It is logical, then, that a runway prevents excessive contact with damp vegetation and allows the individual to remain dry. This can only add to the selective advantage of maintaining a runway system.

Although montane voles are not colonial, social contact is necessary, particularly in relation to reproduction. Post partum breeding is common, the females coming into heat soon after parturition and remaining so for only a few hours (Hamilton 1951, Hoffman 1958). It is then advantageous for them to quickly locate a mate, and this contact is certainly enhanced by overlapping home ranges having a common runway system. Having just given birth the female is obviously low in energy reserves; so the distance and ease of travel are important at this time. This leads to the final category, that of energy conservation.

Energy conservation can be achieved in two ways by restricting activity to a runway system. It is, first of all, less energy-consuming to move on a well-developed pathway than to force oneself through clumps of vegetation. Secondly, a knowledge of the runway system prevents random search, and leads to a more efficient mode of life.

It is evident from the above discussion that selection will favor the individual who does not venture from a runway because of the protection, social contact, and energy conservation it affords.

CHAPTER IV

HOME RANGE DETERMINATION BY LIVE TRAPPING

I. TRAPPING METHODS

Initially, homemade traps made from museum special snap traps and fruit juice cans were used. These were replaced by galvanized metal, No. 0 Havahart traps. Bait consisted of a mixture of peanut butter and rolled oats.

Upon capture, mice were aged, sexed, and toe-clipped for future identification. Age was based on size and appearance, and the mice were divided into three classes; young, subadult, and adult.

Forty-nine homemade traps were set on a five-meter grid from September 22 until October 3 and from November 1 until November 4, 1965. They were baited and checked at approximately 9:00 a.m., and 6:00 p.m., each day. No attempt was made to set the traps in runways at this time. These traps were discontinued because of questionable efficiency and high mortality. Some of these failed to close and the animals escaped. Others closed before the animals entered the trap. Mortality was higher than expected for two reasons. Several individuals were caught between the lid of the can and the door, which closed with great force. Others could have been thrown against the rear of the trap by the closing door with such force that they were killed.

Forty-nine Havahart traps were set on the ten-meter grid from December 4 until December 22, 1965 and from February 26 until March 4, 1966. The trap spacing was increased to ten meters, based on the

results published by Hayne, 1950 (20:26-39). The above increase quadrupled the trapping grid area. The former five-meter grid was located in the center of the east edge of the enlarged ten meter grid.

At this time traps were set in runways. No bait was used until December 14 when several trap deaths indicated that food might be necessary for trap survival in the increasingly colder weather, even though the traps were closed at night and checked every three hours during the day for the entire December, February, and March trapping periods. Rolled oats were supplied in liberal amounts, and this seemed to check trap mortality which remained low (.05 per cent) throughout the winter. Since Havahart traps are made of hardware cloth, open on three sides, each trap was wrapped with black polyethylene plastic and an additional plastic blanket was placed over each as an added precaution. This was particularly helpful in protecting the animal from wind and moisture. No nesting material was placed in these traps.

On December 7, sixteen traps were moved to different runway sites because they failed to capture any mice up to that date. Most were moved only a few feet and became "active traps" at that time.

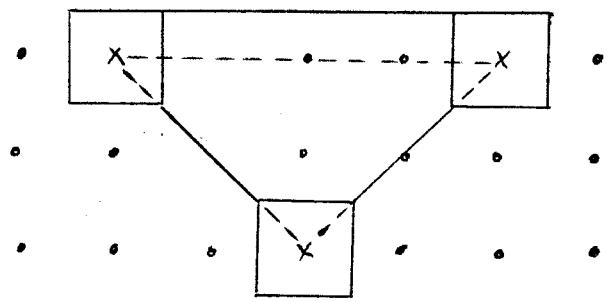
II. HOME RANGE ANALYSIS

There are several methods for measuring home ranges of small mammals based on recapture sites obtained from the trapping grid. The Minimum Area (8:106) and the Exclusive Boundary Strip (35:1-15)

methods were selected. The Minimum Area method is computed by connecting the outer points of capture with a straight line, and is therefore based on the area that the animal is known to be in. All animals which are captured in only two traps or in a straight row of traps are excluded. The estimates computed by this method (Tables C and D) are included only for comparison with those estimates obtained by the Exclusive Boundary Strip method. All further discussion refers only to this latter method.

The Exclusive Boundary Strip method is based on the assumption that animals, on the average, range halfway between a capture site and the next adjacent trap. Its measurement is computed by assuming each capture site to be the center of a rectangle extending halfway to the next trap site in each direction. The corners of the rectangles are then connected by a straight line to include the least possible area. The following diagram illustrates these methods.

Figure 4. The Minimum Area Method (Dotted Line) and The Exclusive Boundary Strip Method (Solid Line).



Several authors report that four to five captures are necessary to provide a good indication of home range size based on the Exclusive Boundary Strip method. My data are consistent with the above; after four captures the results are variable, some giving greater values, others smaller (Table I). This is more apparent when a number of captures are combined, as seen in Table II.

Table I. Mean Home Range Size in Square Meters for Adults and Subadults, Based on the Number of Captures.

Number of Captures	Number of Individuals	Mean Home Range Size
1	35	100
2	24	150
3	10	190
4	7	300
5	6	250
6	7	271.4
7	3	516.6*
8	3	250
9	1	400
10	1	300

*One vole had a home range of 700 m^2.

Table II. Mean Home Range Size When Combining the Number of Captures.

Number of Captures	Number of Individuals	Mean Home Range Size
3-10	38	273.7
4-10	28	300
5-10	21	305
6-10	15	326
7-10	8	375
8-10	5	290
9-10	2	350
10	1	300

During this study 144 individuals were captured, marked, and released; 47 of these were captured only during the initial trapping period, when a five-meter grid was used. They are therefore excluded from the home range analysis. Only 28 of the remaining 97 individuals were adults or subadults captured four or more times. Further discussion will relate only to this latter group.

Table III. Home Range Size Computed by the Minimum Area Method.

Number of Captures	Number of Individuals	Mean Home Range Size
3	3	53.3
4	4	97.4
5	3	96.9
6	4	111.4
7	2	119.0
8	1	75.0
9	1	100.0

Table IV. Home Ranges Computed by the Minimum Area Method when the Captures are Combined.

Number of Captures	Number of Individuals	Mean Home Range Size
3-9	18	78.8
4-9	15	86.0
5-9	11	87.2
6-9	8	95.0
7-9	4	96.2
8-9	2	75.0
9	1	100.0
Mean Average - 85.7		

For all individuals captured four or more times, those living along the border of the trapping grid had home ranges averaging 22 per cent larger than those living in the interior (see Table V).

Table V. Comparison of Home Ranges of Border and Interior Individuals.

Number of Captures	Mean for Interior Individuals	Mean for Border Individuals
4-10	(12) 266	(14) 329
5-10	(10) 260	(9) 344
6-10	(7) 251	(6) 400
7-10	(4) 325	(4) 425
8-10	(3) 283	(2) 300
9-10	(1) 400	-
10	-	(1) 300
Mean Average	(37) 273	(36) 353

The mean home range size for all individuals trapped four or more times can be computed as follows:

$$\bar{X} = \frac{1}{n} \sum_{e=i}^{h} (\bar{x}_i f_i) = 315.0 \text{ Square Meters}$$

where h is the total sample size, and $\bar{x}_i$ and f_i are the mean and frequency for each sample calculated in Table III.

Individual home ranges varied from 100 to 700 m^2. Those individuals living along the irrigation ditch had smaller home ranges than those living in other areas (Table VI).

The mice were breeding throughout the year so that no comparison of home range size could be made relative to breeding condition. Males, however, had home ranges averaging eight per cent larger than females (Table VII).

Table VI. Home Range Variation of Individuals Living along the Irrigation Ditch (A) and Individuals Living on Other Parts of the Study Area (B).

Number of Individuals	Total Variation	Mean Home Range Size
A. 15	100-450	242.2
B. 19	100-700	310.5

Table VII. Comparison of Home Ranges of Males and Females

Number of Captures	Mean Home Range Size for Males	Mean Home Range Size for Females
4-10	300	289
5-10	314.3	307
6-10	363.6	307
7-10	450	300
8-10	350	250
9-10	350	-
10	300	-
Mean Average	317	291.6

Some indication of the population density was obtained during the December trapping period. There were an estimated 75 individuals living on the trapping grid during December (computed by the Lincoln Index (8:143). This would indicate a population of 105 mice per acre. Of 66 mice captured during December (not

including 3 who died in traps), only 13 (19.7 per cent) were recaptured in February, indicating a very rapid population turnover (see Table VIII).

Table VIII. The Number of Survivors Indicated by Recaptures.

Sept.	Nov.	Dec.	Feb.
16 ----------		1	
16 ----------			2
	5 ----------	1	
	5 ----------		1
		61 ----------	10
			29*

*New individuals taken during five trapping days.

CHAPTER V

HOME RANGE DETERMINATION BY RADIO-ISOTOPE TRACING

I. LABELING PROCEDURE

Cobalt^{60} was selected for the tracer because of its strength and half life. Because cobalt^{60} has a half life of 5.2 years, the same material can be used for many studies. It takes 30 years for cobalt^{60} to decay to a non-detectable amount.

The available tracer was the chloride salt and had to be capsulated. Polyethylene surgical tubing (0.61 mm. diameter) was used for the capsule because it is not broken down by body fluids and is innert to the animal. The tubing was cut into 3/4-inch lengths, a hypodermic needle was inserted into one end, and the fluid was drawn into the capsule. Each capsule was then sealed with a soldering iron, and the seals were checked by compressing the sides of the capsule.

The capsules contained an estimated 100 millicuries of the tracer. This technique was designed for use of a liquid tracer; all previous studies have employed radio-active wire (15:5-10).

Mice were trapped on the study grid and labeled in the field. A small patch of hair was clipped from the mid-dorsum and the skin was cleansed with 70 per cent alcohol. A small incision was made with scissors, and the capsule, having been washed in alcohol, was inserted. The animals were released at their capture

site without sewing up the incision. This labeling process took approximately five minutes per mouse.

Subsequent tracing was done with a geiger counter, Model CD-V700, No. 4, with the geiger tube attached to the end of a ten-foot bamboo pole which facilitated rapid coverage of the study area. By sweeping the pole from side to side, a twenty-foot strip was covered. The detection range was approximately three feet, or slightly less if the mouse was in a burrow. When the mice moved too rapidly, I was unable to follow them. They had to be relocated by a searching process. Detection sites were marked with wooden stakes.

To recover the capsules, all labeled mice were caught and sacrificed after the study. Examinations at this time indicated that the wounds had completely healed, and there was no noted tissue damage.

II. TRACING ANALYSIS

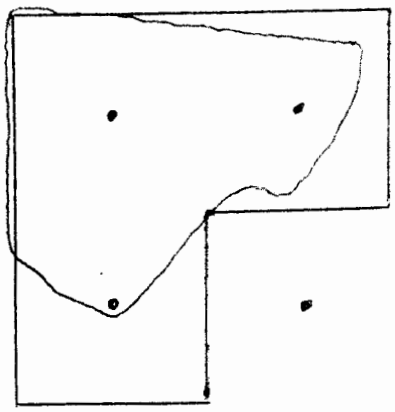
The movements of five adult mice were traced by the radio-isotope method. During warm weather, when the mice were most active, it took only two to three days to determine a home range.

Four of the labeled mice were also included in the trapping results, so that a comparison of the two methods is possible. The home ranges of all four mice, based on results of the tracer technique, were smaller than indicated by the trapping method (see Figure 4).

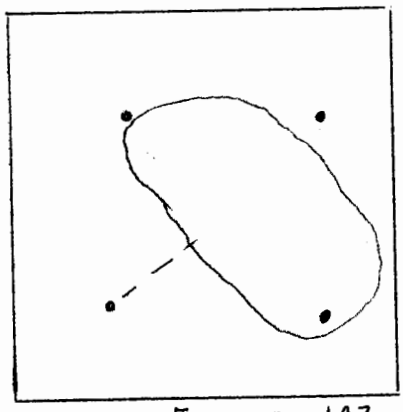
From the data obtained during the radio-isotope tracing, I conclude that the average home range size for Microtus montanus living on the study plot is approximately 145 square meters, which is considerably smaller than that indicated by the trapping data. Although the above is based on data obtained from only five individuals, two of the five indicated large home ranges when computed from trapping results.

Tracing data indicated a smaller area, within the home range, where the mice spent most of their time. Figures 6 and 7 show the zone of activity for a male and female mouse as determined by movement patterns.

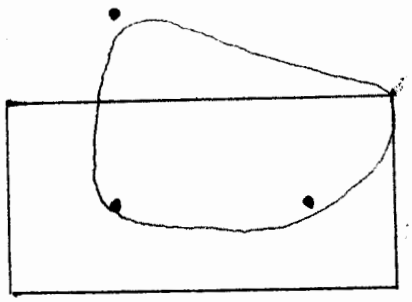
Figure 5. A Comparison of Home Range Size as Determined by Two Methods. Black lines enclose home ranges as determined by trapping. Red lines enclose home ranges as determined by radio-isotope tracing. Male-1a was not included in trapping data.



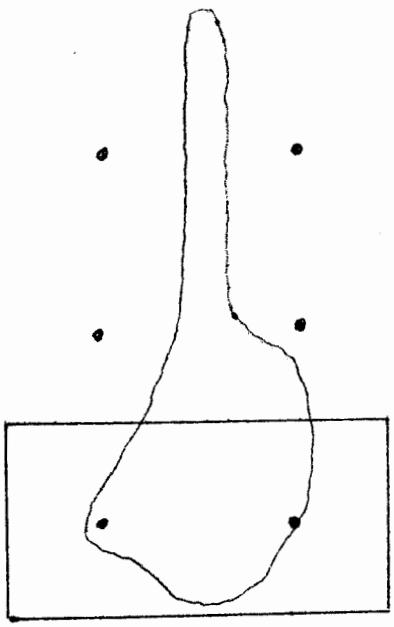
FEMALE - 303



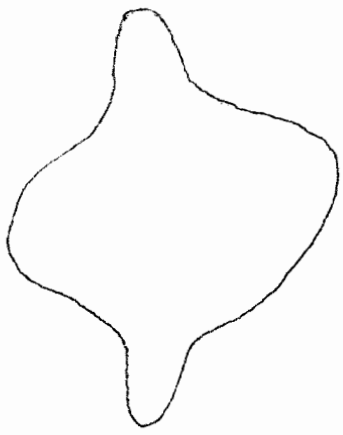
FEMALE - 143



FEMALE - 331



MALE - 322



MALE - 1A

Figure 6. The Activity Pattern of an Adult Male as Indicated by Radio-Isotope Tracing. The red lines enclose his home range; the black his activity zone. The numbers indicate the number of detections at a given site.

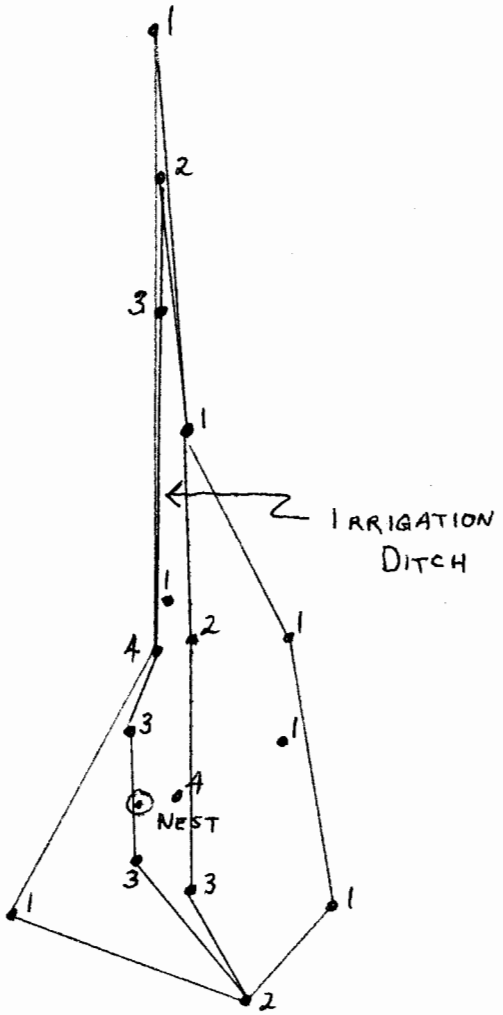
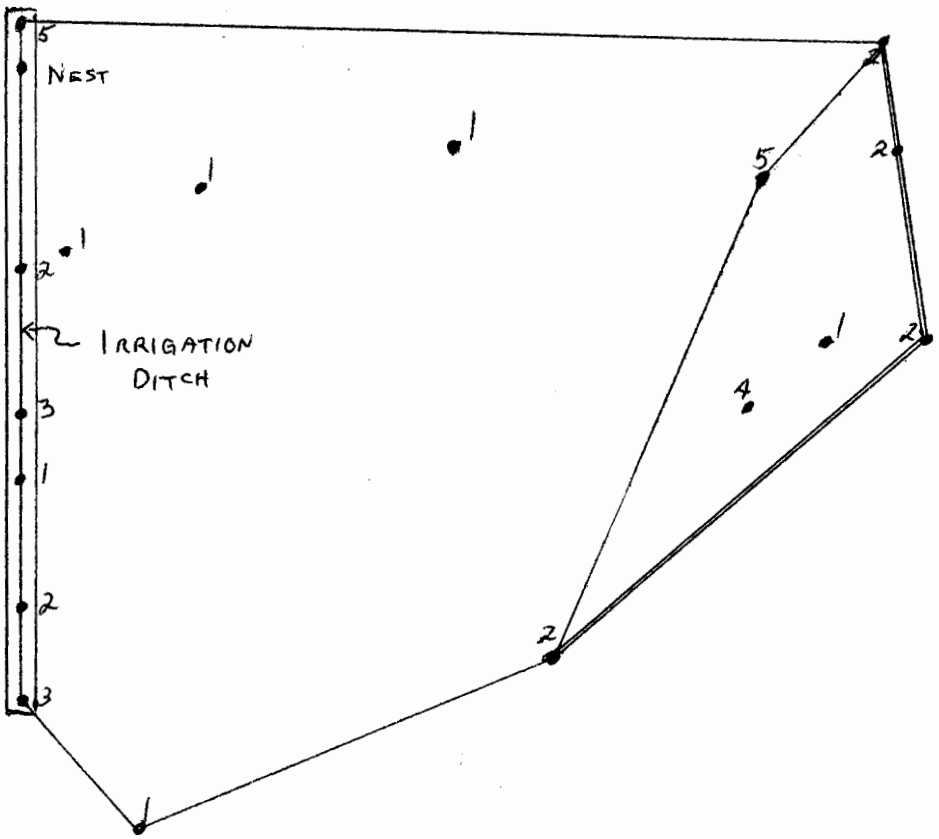


Figure 7. The Activity Pattern of an Adult Female.



CHAPTER VI

DISCUSSION AND SUMMARY

I. DISCUSSION

Numerous studies on the home ranges of various Microtus have indicated size variations. These variations are due to biological and mechanical factors. Biological factors represent the association between the animal and the environment. These often lead to local and geographic variations of home ranges for any given species (20:26-39).

Several authors have indicated local variations (26:1; 13:25; 3:351), and a relationship between food supply and area traveled (2:149-161; 11:144-177). It was noted above that those mice living along the irrigation ditch, where the vegetation was the most dense, had smaller home ranges than the mice living on other parts of the study area. Since the population density along the ditch was higher than elsewhere, the home range size may have been a result of density rather than food supply. This is supported by the fact that the home ranges were large along the west edge of the trapping grid where the vegetation was only slightly less dense than along the ditch (Figure 1), but where the mouse density was low. The factors affecting density were not determined.

It has been suggested that home range size may vary as a function of reproductive status, and that males have larger home ranges than females (Table VIII). Since the Microtus were

breeding throughout the study, no correlation can be made between range size and reproductive status. Males, however, had larger home ranges than females (Table VII). This may be due to the more aggressive nature of most males. Reproductive activity might affect home range size through two opposing forces, social contact and energy conservation. Those males with the largest home ranges should contact more females than those with smaller home ranges, and hence should leave more offspring. Females, who remain in heat for a period of several hours, would increase their chance for a mating by increasing their home range area during this time. During the reproductive season, much energy is undoubtedly expended by the males during copulation and by the females during pregnancy and while nursing the young. Those individuals traveling over a small area should conserve more energy than those traveling over a large area, so that more energy could be utilized for the above functions. The home range size might then be an adjustment between the effects of social contact on the one hand, and the effects of energy conservation on the other. (More research is needed in this area.)

Mechanical factors include experimental technique and data processing. These affect size estimates by biasing the results in favor of some individuals and sometimes affect the actual home range size by disturbing the individual (i.e., trap interference).

Trapping data were computed by both the Minimum Area and the Exclusive Boundary Strip methods. The Minimum Area method

has two disadvantages: 1) Individuals caught in only two traps or in a straight line of traps cannot be included, and 2) It does not account for any area beyond the capture sites that the animal might be utilizing. The results of this study indicate that trap spacing is very critical when using this method. As trap spacing is decreased, there is an increased chance of capture in peripheral traps. Ten meter spacings were used during this study, and proved to be too great. The results indicated by the Exclusive Boundary Strip method were much larger than those computed by the above method. This is due to the compensation achieved by adding an additional area to partially account for any area beyond the capture sites that the animal might be utilizing. Trap spacing also affects estimates obtained by the Exclusive Boundary Strip Method (see below).

Table IX is a summary of several home range studies on Microtus including the trap spacing (when traps were used), and the method of data analysis.

Table IX. Summary of Several Home Range Studies.

Year	Invest.	Species	Home Range Area in Acres M.	F.	Both	Trap Spacing	Method of Analysis	Habitat
1937	Hamilton	M. penn.	-	-	.06	16	M.A.M.*	-
1940	Blair	M. penn.	.31	.19	-	45-60	"	Moist Grass
			.50	.28	-	"	"	Dry Grass
1950	Hayne	M. penn.	.087	.023	-	21	"	Grassland
			.09	.031	-	30	"	"
			.48	.099	-	60	"	"
			-	.16	-	120	"	"
1953	Tanaka	M. monte.	-	-	.14	-	E.B.S.**	"
1961	Getz	M. orch.	.11-.19	.09-.19	-	39	"	Marsh
			.03-.2	.02-.12	-	"	"	Old Field
		Radio-isotope Tracing						
1954	Godfrey	M. agrestis			.084		M.A.M.	Grassland
1965	Harvey	M. orch.	.11	.02			"	-

*Minimum Area Method
**Exclusive Border Strip Method

Table X. Home Range Computations for this Study.

Live Trapping	85.7 sq. M. (.02 acres)	M.A.M.
	315 " " (.08 ")	E.B.S.
Radio-isotope	145 " " (.04 ")	M.A.M.

Table I indicates that a comparison of home range estimates is meaningless unless the data are standardized to compensate for various mechanical factors.

Several problems were encountered during this study in estimating home range size by the live trapping method. First, the border individuals normally excluded from home range computation, because part of their home range may extend off the trapping grid, had to be included. Secondly, the distance between traps was too great, thus distorting the home range estimates.

Trapping analysis indicates that there are certain individuals whose home ranges impinge upon or exceed the border of the trapping grid. One would expect the home range estimates for border individuals to be, on the average, smaller than those for interior individuals, because the estimate for border individuals is based only on that portion of their range extending into the grid area. It is common to include within the trapping grid a "buffer zone" as wide as the average length of the home ranges. Any individual whose range includes a portion of the buffer zone is excluded from home range analysis, unless the buffer zone is itself bounded by habitat unsuitable for the particular species. I was unable to include a buffer zone because of the size of the trapping grid, which was only 60 meters square--relatively small when several individuals had ranges at least 40 meters long. I included the border individuals in the analysis because:

1) Individuals with long home ranges have an increased chance of

"contacting" the grid border regardless of the center of their activity. To base a home range analysis only on the "interior" individuals, those whose home ranges do not touch the border would in effect eliminate many of those with long home ranges and thus bias the results in favor of those individuals with small home ranges (see Table III), 2) The probability of capture decreases as the distance from the center of activity increases. The number of captures required for inclusion in the analysis will select against those individuals whose main area of activity lies off the grid proper, and 3) The added boundary strip method of measurement will partially compensate for the remaining individuals, particularly those whose main activity areas are within the boundaries of the grid.

Hayne reports that trap spacing affects home range estimates by interfering with movement patterns (see Table VIII). Stickle, however, points out that trap spacing did not affect movement of transients but that it did influence home range estimates based on the boundary strip method of analysis. She states that if proper trap spacing for a given species is not indicated in the literature, one may have to run preliminary studies to determine it (26:1-15). She does not state how proper trap spacing is recognized, once achieved. Hayne indicated that the proper trap spacing for Microtus is between 30 and 60 feet (20:26-39). During this study traps were spaced approximately 39 feet apart.

A comparison of trap stations with home range borders, as seen in Figure 3, indicates the effect of this trap spacing which increased the boundary strip beyond an accurate estimate. With a closer trap spacing, the boundary estimate would have been more realistic.

As previously mentioned human disturbance may also affect home range analysis. Perhaps the major disturbance is that of interrupting the animal's normal routine during trap detention. This could result in delayed feeding by the individual, delayed nursing of young, or the prevention of a successful mating, particularly for females who may be in heat for a period of only several hours.

The field biologist is often faced with problems which await the development of new field techniques for their solution. For years, mammalian ecologists have determined home range size for small mammals by using a live trapping procedure. The accuracy of this method is subject to critical analysis in view of certain problems presented in this paper. More importantly, the above method gives very little indication of differential home range usage.

The use of radio-isotope tracers in the study of mammal activities minimizes some of the problems in home range analysis and, for the first time, provides a sophisticated technique for the determination of differential home range usage.

After the initial capture, an animal is free to travel about its area while the investigator records its movement patterns and notes the actual border of its home range. There are no periods of detention to upset the animal's daily routine; hence, rhythmic activities can continue uninterrupted. The home range area can be measured with great accuracy including only that area in which the animal is known to travel.

Table I indicates that the home range size as computed by radio-isotope labeling was between those values obtained by live trapping when computed by two common methods of analysis.

As is often the case, there are problems which were noticed during this study. Perhaps the most significant problem became apparent as the result of the radio-isotope tracing technique. Although there is an area which may be properly defined as a home range, the animals do not utilize all of the home range equally. There are certain parts which are used very extensively and could be termed the "activity zone". This activity zone is more significant to the animal than the total home range.

A knowledge of the activity zone could lead to more refined studies in determining food requirements, optimum population densities, the effects of habitat on movement, etc. In brief, the activity zone concept will become increasingly important to animal ecologists studying small mammals.

One major concern in using an incision for the insertion of the capsules is its effect on movement patterns. Although

the animals went immediately to their nests following the labeling process, they resumed their activity following a brief recuperation period. The labeling process should be of no more consequence than the commonly accepted toe clipping method for identification.

There are several problems which limit radio-isotope tracing to a well-planned program, where adequate facilities are available. The nature of the radio-isotope activity necessitates very cautious handling procedures. There is always the chance that the isotope may be transferred through a predator chain and carried out of the study area. Care must be taken to prevent domestic pets from picking up the isotope. One should try to recapture all labeled individuals in order to recover and properly dispose of the radio-isotope. When correctly used, there appears to be little or no effect on the activity of the animal.

II. SUMMARY

A study on the montane vole (Microtus montanus) was carried out in an irrigated grass field near Ellensburg, Kittitas County, Washington.

Nests were made of root fibers and were placed in shallow depressions on the surface, or in the central cavity of a burrow. All "active" winter nests found were located in the burrow cavity, indicating that surface nesting may occur only during the summer. The burrow system is quite simple, consisting of a central cavity and several entrance tunnels. Only two of the examined burrows

contained food caches; all others contained nesting material. Flooding was a major factor in causing mice to abandon burrows and may have influenced the selection of burrow sites. Due to home range overlaps, runways are shared and may be used by other species as well.

Home ranges were determined by two methods and results were compared. One method, radio-isotope labeling, is relatively new and probably provides reasonably accurate measurements of home range borders. The average home range size determined by the radio-isotope method was 145 square meters, about one-half the size indicated by a live-trapping technique based on the Exclusive Boundary Strip method. The large estimate based on this method was the result of spacing the traps too far apart, which increased the boundary estimate beyond a realistic value. Trapping data indicated that there were local variations in home range size and that males had slightly larger ranges than females.

Radio-isotope tracing indicated an extensively used area within the home range which may be termed the zone of activity.

A new technique is described which permits the use of a liquid tracer. $Cobalt^{60}$ was capsulated in polyethylene surgical tubing and inserted subcutaneously into the mid-dorsum of the mice. There were no noticeable adverse effects on the activity of the mice.

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