THE INFLUENCE OF HABITAT QUALITY UPON DENSITY OF COTTON RAT POPULATIONS

By

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1957

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1959

Submitted to the Faculty of the Graduate School
of the Oklahoma State University
in partial fulfillment of the requirements
for the degree of
DOCTOR OF PHILOSOPHY
August, 1962

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OF COTTON RAT POPULATIONS

Thesis Approved:

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ACKNOWLEDGEMENTS

This investigation was supported by means of the combined facilities made available by the Oklahoma Cooperative Wildlife Research Unit.* In addition, aid was received from the National Wildlife Federation. The final two years of this investigation were supported by the U. S. Department of Health, Education and Welfare through the Division of General Medical Sciences (Fellowship GF-9904).

The project was carried out under the direction of Dr. A. M. Stebler, my major adviser, and Leader of the Unit and the other members of my graduate advisory committee, namely: Drs. F. M. Baumgartner, B. P. Glass, J. R. Harlan, D. E. Howell and R. W. Jones.

Many other persons have been of direct assistance: Dr. D. D. Dwyer offered helpful suggestions for sampling vegetation and along with Dr. H. I. Featherly and Mr. R. E. Jones assisted in the identification of certain plants.

I wish to thank the members of the staff of Oklahoma State University library for their assistance in finding literature, especially Mr. Cecil Howland, Biological Science Librarian, and members of the Special Services Department for obtaining manuscripts from other libraries.

Lorna B. Edwards Goertz, my wife, was especially helpful in the compilation of data for this manuscript.

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*Oklahoma Department of Wildlife Conservation, Oklahoma State University, United States Fish and Wildlife Service and the Wildlife Management Institute cooperating.

The scientific names of plants and animals were in accordance with: The American Ornithologists' Union Checklist of North American Birds (1957, 5th ed.), for birds; Hall and Kelson (1959), for mammals; and Waterfall (1960), for plants. In matters of style, The American Institute of Biological Science's Style Manual for Biological Journals (1960), generally was followed.

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CHAPTER I

INTRODUCTION

The major objective of this investigation was to study population ecology of the hispid cotton rat, Sigmodon hispidus texianus, under conditions of superior and marginal habitat. Data were collected in the following manner: by comparing the vegetation found at livetrap and along snaptrap transects to the numbers of cotton rat captures at these locations; by livetrapping, marking and releasing rats on grids of 16 and 20 acres; and by snaptrapping on transects. The habitat preferences, area of homesteads, greatest distances traveled, disappearance rates, and population fluctuations of the cotton rat were considered.

All of the data were gathered in western Payne County, Oklahoma, in the vicinity of Lake Carl Blackwell. Field work was accomplished between September 15, 1959 and September 30, 1961. During this time, 3,453 individual rodents were trapped in a total of 74,206 trap nights. A total of 10,016 rodents, including recaptures, were taken in livetraps and snaptraps. Of this number, 1,009 cotton rats were captured 4,734 times in livetraps while another 425 were taken in snaptraps.

The population of Sigmodon was dense on the 20-acre grid for the first five months of trapping. In late February and March of 1960, the population fell to zero from previous highs ranging from 20 to 30 animals per acre. The decline coincided with a period of severe winter weather, after which cotton rats were only found in areas of dense grassy cover.

The information obtained suggests that Sigmodon is limited to those areas in northern Oklahoma where grassy cover, and at times, associated forbs and low-growing woody species, provide a dense overhead cover. Rats were found also in areas where ground cover was sparse, which was considered marginal habitat, when the population was dense.

CHAPTER II

METHODS

This project was pursued mainly as a field investigation employing conventional methods, such as: Livetrapping on established grids, marking and releasing, and snaptrapping on transects to sample differing habitat types.

Livetrapping

Two livetrap grids were established with a trap interval of one chain. One grid of 20 acres (Grid 1) was established thirteen miles west of Stillwater in October 1959. The second grid, one of 16 acres (Grid 2), was established six miles west of Stillwater in July 1960.

On Grid 1, traps were first opened on October 16, 1959. Traps were checked almost daily until December 17, 1959, after which they were in operation 3 to 6 days a month until July 2, 1960. From July 3, 1960 to September 30, 1960, all of the traps were open 73 days. After September, the livetraps were opened for two 5-day periods each month. The second grid was laid out over a period of three months. Thirty-five traps were opened July 22, 1960 and thereafter additional traps were added as follows: 42 by July 25, 50 by July 30, 56 by August 11, 90 by August 22, and 140 by October 1, 1960. Traps were checked irregularly during July, Ausust, and September of 1960. Thereafter, from October 1960 through September 1961, traps were opened for two 5-day periods each month except for January 1961.

All rodents were marked by toe clipping and released. Each animal was examined for the following: 1) sex, 2) weight, 3) sexual condition and 4) toe mark.

On the two grids of livetraps, a total of 2,011 rodents were captured 8,563 times in 59,156 trap nights. A total of 1,009 cotton rats were captured 4,734 times. All livetrap data were compiled from these captures.

Snaptrapping

Transects of Victor snaptraps were placed in operation beginning April 2, 1960. Each transect consisted of 25 traps set at a 5-pace interval in as straight a line as possible. The total length of each transect was about 600 feet. Each trap was provided with an extended trigger. Transects were run, generally, at the rate of 12 lines per month from April to June, 1960-61. Traps were set for three nights on each transect. A total of 1,411 rodents, of which 425 were *Sigmodon*, were captured in 14,850 trap nights from the 198 transects laid out.

Vegetation Sampling Methods

Grass along snaptrap transects and at livetrap sites was sampled by the line intercept method of Canfield (1941). The edge of a meter stick was used as the point of intercept. The method of determining height of cover, frequency of forbs, frequency of shrubs and per cent of tree canopy follow:

1. Height of grass cover was measured in cm at the foliar crown.
2. Forbs were tallied from a 25 cm belt transect of one meter.

3. Woody shrubs and vines were counted from square meter plots, on either side of the meter stick.

4. Coverage by tree canopy was estimated in per cent.

Each 600-foot snaptrap transect was measured with 20 one-meter line intercepts. The first 30 transects were sampled as near as possible to the time that the line was in operation, while the other 153 transects were sampled when the line was in operation. Three snaptrap lines were run during the same general time period, each in a different specific location, but in the same vicinity. This was done in order to compare different plant associations during the same time period.

Measurements were also taken at each end of the long axis of livetraps. This was done as near the trap as possible, where the vegetation was not disturbed by the investigator's trampling. Vegetation was sampled twice at livetrap sites, once during February and March of 1961 and once during August and September of 1961. These periods were assumed to correspond roughly to the low and high points of the growing season.

In all, a total of 4,904 one-meter transects and corresponding measurements were taken. This included 1,244 samples at livetrap sites and 3,660 measurements taken along snaptrap lines.

Vegetation data were analyzed statistically with the aid of an I. B. M. 650 computer for correlation with per cent capture. In this correlation, all captures made during October-November-December 1959 were used for determining per cent capture for 1959 on Grid 2, and compared to the variables measured during the summer of 1961, except for certain traps located in mowed areas. Traps were assigned a grass height and density average as measured from identical areas mowed during 1961. The rate of capture for the January and February captures were compared to the variables measured during the winter of 1961, except for those traps in the mowed areas. For all other periods, the rate of capture was correlated with captures taken during 25 trap nights per trap centered closest to the time at which the actual measurements of vegetation were taken. Rates of capture for 25 trap nights per trap on each grid during the summer of 1960, were compared to vegetation analysis taken during the same period in 1961. Capture rates from snap-trap transects were calculated and correlated with 12 variables measured at the same time that the transects were in operation.

CHAPTER III

DESCRIPTION OF THE TRAPPING AREAS

Grid 1

Grid 1 was located about 13 miles from the west edge of Stillwater in T 19 N-R 1 W- Sec. 3, Payne County, Oklahoma. The eastern edge of the grid was about 200 feet from state Highway 86. The long axis of the grid ran north and south parallel to the highway.

A mixture of grasses occurred on the area. Japanese brome (*Bromus japonicus*) was scattered over the entire grid. It occurred sparsely where mixed with perennial grasses, but at times formed dense stands especially at the edge of a drainage way and in areas infested by forbs. Little bluestem (*Andropogon scoparius*) covered more area than any other grass species, and formed several almost pure stands. Johnsongrass (*Sorghum halepense*) big bluestem (*Andropogon gerardi*), silver bluestem (*Andropogon saccharoides*), silver beardgrass (*Andropogon ternarius*), purpletop (*Triodia pilosa*), switchgrass (*Panicum virgatum*), Indiangrass (*Sorghastrum nutans*), Chase fall witchgrass (*Leptoloma cognatum*) and smaller amounts of other grasses were found in small patches or in mixed stands with the other grasses. Little bluestem, Indiangrass, switchgrass, big bluestem, purpletop and Johnsongrass were the components of the densest stands that occurred on the grid.

Of the numerous forbs that occurred, everlasting (*Gnaphalium obtusifolium*), western ragweed (*Ambrosia psilostachya*), Louisiana sage

(Artemisia ludoviciana), horseweed (Conyza canadensis), annual sunflower (Helianthus annuus), giant ragweed (Ambrosia trifida), bundle flower (Desmanthus illinoensis), showy partridge pea (Cassia fasiciulata) and others were most abundant on the area.

Elm (Ulmus americana) was the most prevalent tree on the area. It shaded the entire drainage way, in season, where it was mixed with a small number of honey locust (Gleditsia triacanthos), willow (Salix sp.) and hackberry (Celtis sp.). A few elm trees of small size along with a few hackberry were scattered savanna-like over the entire area. Dogwood (Cornus drummondii) false indigo (Amorpha fruticosa) and coral berry (Symphoricarpos orbiculatus) formed several small clumps mostly along the drainage way.

Grid 2

Grid 2 was located six miles from the western most edge of Stillwater in T 19 N- R 1 E, of the NW quarter of Sec. 15, Payne County, Oklahoma. The north edge of the grid was about 300 feet south of the Lake Carl Blackwell spillway. As far as it is known, this area has not been farmed or grazed in recent years.

The vegetation on this area was much less complicated than that found on Grid 1. Little bluestem was by far the most abundant grass. It was mixed at intervals with Indiangrass, big bluestem, silver bluestem, silver beardgrass, three awn (Aristida spp.), and other grasses with less frequency.

Forbs never formed dense stands but were found scattered amidst the grass. The most common forbs, in season, were daisy fleabane (Erigeron annuus), horseweed, Indian hemp (Apocynum cannabinum), golden hairy aster

(Chrysopsis sp.), gayfeather (Liatris sp.), rough buttonweed (Diodia teres), purple prairie flower (Dalea sp.), and wild alfalfa (Psoralea sp.).

A stand of blackjack oak (Qercus marilandica) occupies the northern one to three chains of the grid. This area was very sharply delineated from a zone of grass and sumac which ran diagonally across the grid from the northeast corner to a point half way down the south side. The rest of the area, namely the southeast corner, was predominantly grass. A few hackberry and red bud (Cercis canadensis) were intermingled among the oaks. Winged sumac (Rhus copallina), smooth sumac (Rhus glabra), dogwood and coral berry were the main components of the shrub flora.

Snaptrapping Areas

Transects of snaptraps were placed in operation in a variety of areas. Bottomlands, sidehills, uplands, flatlands and intergrading areas together with their vegetation types were sampled with snaptrap transects.

CHAPTER IV

RESULTS

General Trapping Results

It is well known that small mammal populations may vary considerably from month to month and season to season. The trapping results showed that this was true of the _Sigmodon_ populations studied during the term of this investigation (Table 1).

The cotton rat population was dense during the first five months of trapping on Grid 1. A "crash" decline occurred during the latter part of February and early March of 1960. No rats were trapped on the area for a period of four months after the decline. A small number of animals were taken in July and thereafter, until the end of the study, the population increased slowly except for a downward trend in May and June of 1961.

On Grid 2, the population was relatively stable in comparison to Grid 1. Numbers of rats known to have been on the area did not vary sharply from month to month (Table 1).

Habitat of the Cotton Rat

Assuming that rate or degree of trap response is a reliable indicator of _Sigmodon_ density, a comparison of certain aspects of vegetation at traps should indicate cotton rat habitat preferences. It is seen, for example, in Figure 1, that with few exceptions a large or small number

TABLE 1. Monthly summary of Sigmodon population fluctuations on Grids 1 and 2 between October 16, 1959 and September 27, 1961, Payne County, Oklahoma. Per cent of capture per trap per month is in relation to trap nights.

Mo.	Grid 1						Grid 2					
	Trap Nights	New Captures	Re-captures	Total Captures	No. of Individuals	Per Cent Capture per trap	Trap Nights	New Captures	Re-cap tures	Total Captures	No. of Individuals	Per Cent Capture per trap
Oct.	735	307	257	564	307	41.8						
Nov.	1,107	208	564	754	385	34.8						
Dec.	749	53	603	656	290	38.7						
Jan.	437	63	139	202	153	35.0						
Feb.	1,026	30	229	259	146	14.2						
Mar.	826	0	0	0	0							
Apr.	684	0	0	0	0							
May.	684	0	0	0	0							
June	855	0	0	0	0							
July	4,959	6	29	35	6	0.1	431	12	18	30	12	2.8
Aug.	5,301	2	16	18	5	0.1	979	15	101	116	24	2.5
Sept	2,223	0	1	1	1	0.1	980	1	45	46	12	1.2
Oct.	1,710	4	2	6	4	0.3	1,400	7	19	26	17	1.2
Nov.	1,710	8	15	23	10	0.6	1,400	7	54	61	14	1.0
Dec.	1,710	6	15	21	12	0.7	1,400	4	64	68	15	1.1
Jan.	1,710	5	22	27	13	0.8	1,260	2	27	29	9	0.7
Feb.	1,710	10	51	61	21	1.2	1,400	10	52	62	18	1.3
Mar.	1,710	10	79	89	26	1.5	1,400	6	79	85	22	1.6
Apr.	1,710	7	57	64	20	1.2	1,400	2	77	79	19	1.4
May	1,710	4	40	44	13	0.8	1,400	9	63	72	21	1.5
June	1,710	8	26	36	14	0.8	1,400	11	67	78	24	1.7
July	1,710	40	194	177	48	2.8	1,400	17	97	114	34	2.4
Aug.	1,710	27	187	214	61	3.6	1,400	5	74	79	20	1.4
Sept	1,710	77	339	416	101	6.9	1,400	26	96	122	31	2.2

(A)

Vertical Rows (columns) × Horizontal Rows (rows)

Horizontal Rows	J	I	H	G	F	E	D	C	B
2	5 11	10 21	9 18	5 18	6 12	7 14	9 14	9 17	11 21
3	7 21	10 14	7 18	6 10	8 10	5 9	10 22	9 13	7 16
4	9 25	11 18	8 13	4 12	8 17	10 16	10 22	12 23	13 19
5	9 15	7 17	1 1	7 14	11 15	6 9	8 12	13 18	9 16
6	3 9	1 1	9 14	19 33	13 21	11 20	7 18	7 20	11 19
7			7 14	2 3	7 8	3 3	11 14	10 12	10 15
8		3 3	8 22		8 19	7 17	4 15	8 10	10 17
9		1 1	2 2	2 4	3 4	6 10	5 5	10 16	10 16
10	1 1		5 8	5 7	6 11	3 3	11 16	14 23	13 17
11	4 6	4 8	7 15	4 10	4 14	1 1	14 24	10 14	9 18
12	5 7	1 1	11 33	8 20	3 6	5 9	8 15	9 15	9 15
13	2 3	3 3	8 12	11 21	4 6	11 17	4 6	12 19	7 12
14	8 16	12 21	8 20	6 23	10 17	9 18	8 16	8 22	7 19
15	9 13	9 13	9 14	7 14	11 17	8 13	7 19	4 7	7 13
16	6 16	14 17	7 15	4 11	12 21	10 18	10 21	9 18	8 23
17	4 5	11 18	6 9	5 14	9 13	11 20	9 15	9 17	7 12
18	9 15	9 22	3 8	6 17	8 16	14 22	9 17	9 22	9 19
19	8 19	12 19	12 18	9 18	10 15	4 6	12 20	11 14	7 19
20	8 20	14 20	9 21	11 23	10 17	10 14	9 19	10 17	16 36

(B)

Horizontal Rows	J	I	H	G	F	E	D	C	B
2	8 16	2 2	5 6	7 8	1 1	5 5	4 6	4 7	10 12
3	1 1	8 12	11 15	8 10	7 9	4 5		12 14	1 1
4	8 10	6 6	1 1	5 5	10 11	4 5	13 18	12 14	5 6
5	12 16		5 6		6 7	4 4		7 8	6 6
6	4 5	7 9	3 4	5 6	26 42	3 3	2 2	10 11	3 4
7	29 52	26 55	9 12	8 10	16 26	33 65	32 49	16 22	14 15
8	1 1	8 9	14 15	4 4	3 3	3 4	17 25	10 10	6 6
9	26 50	3 3	7 7	3 4	1 1		3 4	6 6	11 12
10	11 15	5 6	11 15					3 3	3 3
11	6 9	4 4	12 22		1 1		1 1	2 2	4 6
12			6 6	10 23				2 3	1 1
13			3 4	1 1	1 1			2 2	
14	5 6	8 10	3 3	5 6	2 5	2 2	1 1	1 1	3 4
15	14 16	2 3	6 6	3 4		2 2	1 1	3 3	4 4
16	3 3	3 4		3 3	4 7	3 3	1 1		1 1
17		2 2	2 2	4 4	9 14	7 10	2 2	1 1	
18	4 5	8 14				4 5	5 7		1 1
19		12 18	1 1	1 1				7 10	9 16
20	7 7	3 3	9 15	5 7	5 7		1 1	7 11	11 19

(C)

Horizontal Rows	H	G	F	E	D	C	B	A	I	J
14						1 1	3 4	14 21	2 3	15 41
13								6 8	16 17	17 31
12				1 1			1 1	3 3	1 2	4 4
11				2 2	3 3	7 11	8 10	2 3	3 5	6 12
10				2 2	2 2	23 48	22 41	18 51	20 64	4 5
9				1 1	12 34	15 28	15 31	9 10	8 23	9 15
8				5 11	12 24	2 2	9 13	8 9	16 55	2 2
7			2 2	10 12	15 36	7 9	15 27	13 25	11 24	
6		1 1	2 2	1 1	13 20		10 18	6 6	10 22	1 1
5			1 1	13 24	8 14	1 1	1 1	6 10	14 29	1 1
4	2 4	3 3		5 5	8 11	2 2		6 15	2 4	1 1
3	2 3			2 2	6 10	9 13	8 15			
2	2 2	1 1			4 6	3 3	5 8		2 2	
1		2 2						2 2	1 1	

FIG. 1. Individual and total captures of Sigmodon per trap on (A) Grid 1 from October 16, 1959 to February 27, 1960, (B) Grid 1 from July 4, 1960 to September 27, 1961 and (C) Grid 2 from July 22, 1960 to September 22, 1961. Top numeral within each block denotes individual captures, while bottom numeral denotes total captures, at each trap location.

of captures at a particular trap had an equally large or small number of individual captures. This means that individual rats were not greatly influencing results at particular traps.

Results of vegetation analysis suggest that grass height and density are important components of cotton rat habitat. The per cent of capture increased in relation to an increase in both height and density of grassy cover (Figures 2 to 8). When the population was low, this relationship, in per cent, varied from 0 to 92, 0 to 75, 0 to 52 and 0 to 53 (Figures 2, 4, 5, and 7, in that order) on Grids 1 and 2 and snaptrap transects. During periods of high population density, the variation was from 0 to 72 and 34 to 118 per cent (Figures 3 and 6). A summary of all the captures of Sigmodon (4,734) is represented by Figure 8. In all cases the per cent of catch increased with increase in height and density of grassy cover, regardless of the density of the population or the time of the year. However, at low population densities rats were captured more frequently at a high level of grass height and density. Whereas, during high population densities, captures were spread out from the lower levels to the upper limits with less variation.

It appears that areas of sparse cover were not used to any great extent by Sigmodon. This was evident on Grid 1 during the fall and winter of 1959-60. The numeral 34 (Figure 6, 50-75 cm at 30-35 %) represents the per cent of capture at 41 traps that were in the mowed areas. Capture results from all of the traps in the mowed areas were lumped, since all were in cover of essentially the same height and density from an average obtained by running 41 transects on similar mowed areas during 1961. Of the 41 traps located in mowed areas, 25 were 10 feet or more from unmowed cover, while 16 were near the edge of unmowed

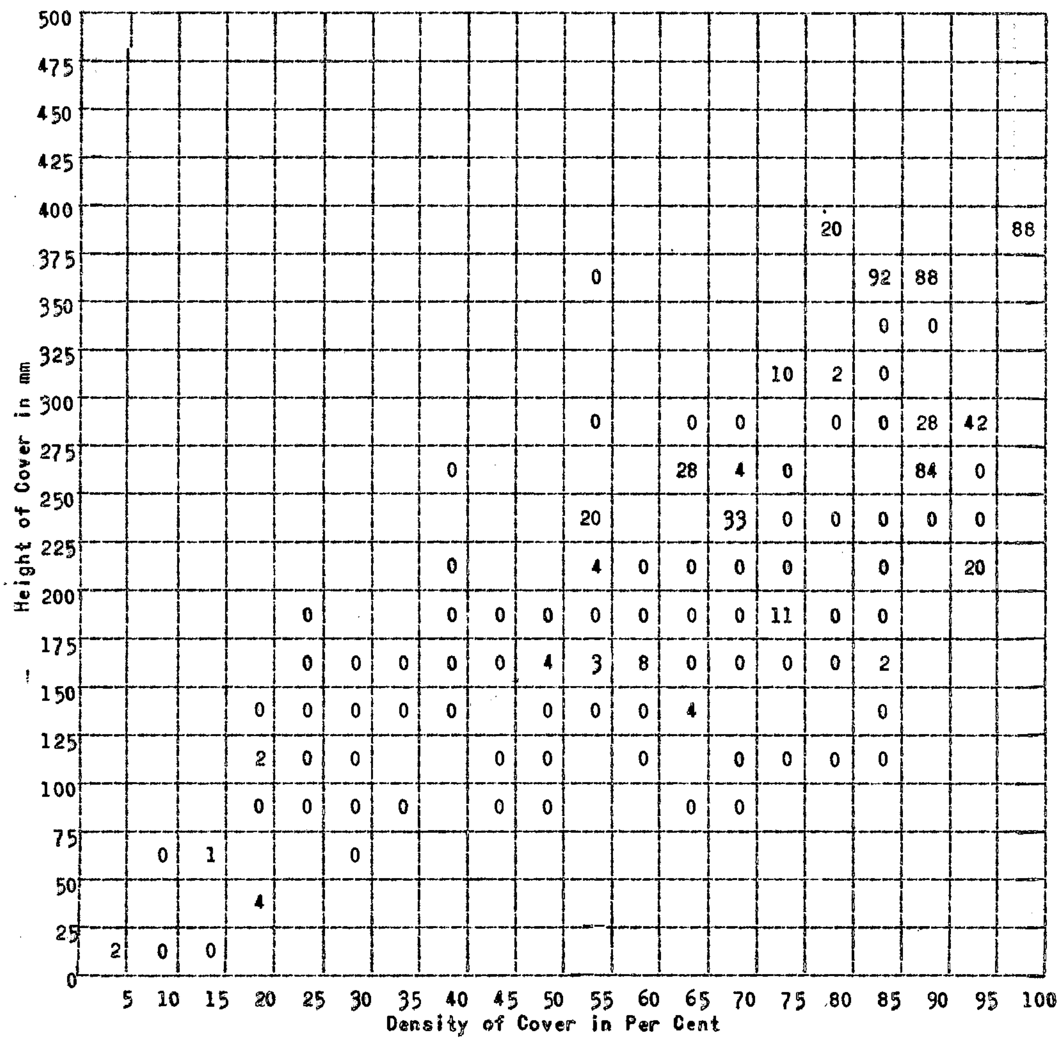

FIG. 2. Rate of capture, expressed in per cent, of Sigmodon per trap night in relation to height and density of grassy cover. Each entry represents per cent capture at one or more traps each set for 25 trap nights during the winter of 1961 on Grid 1. 200 captures are represented in a total of 4,275 trap nights.

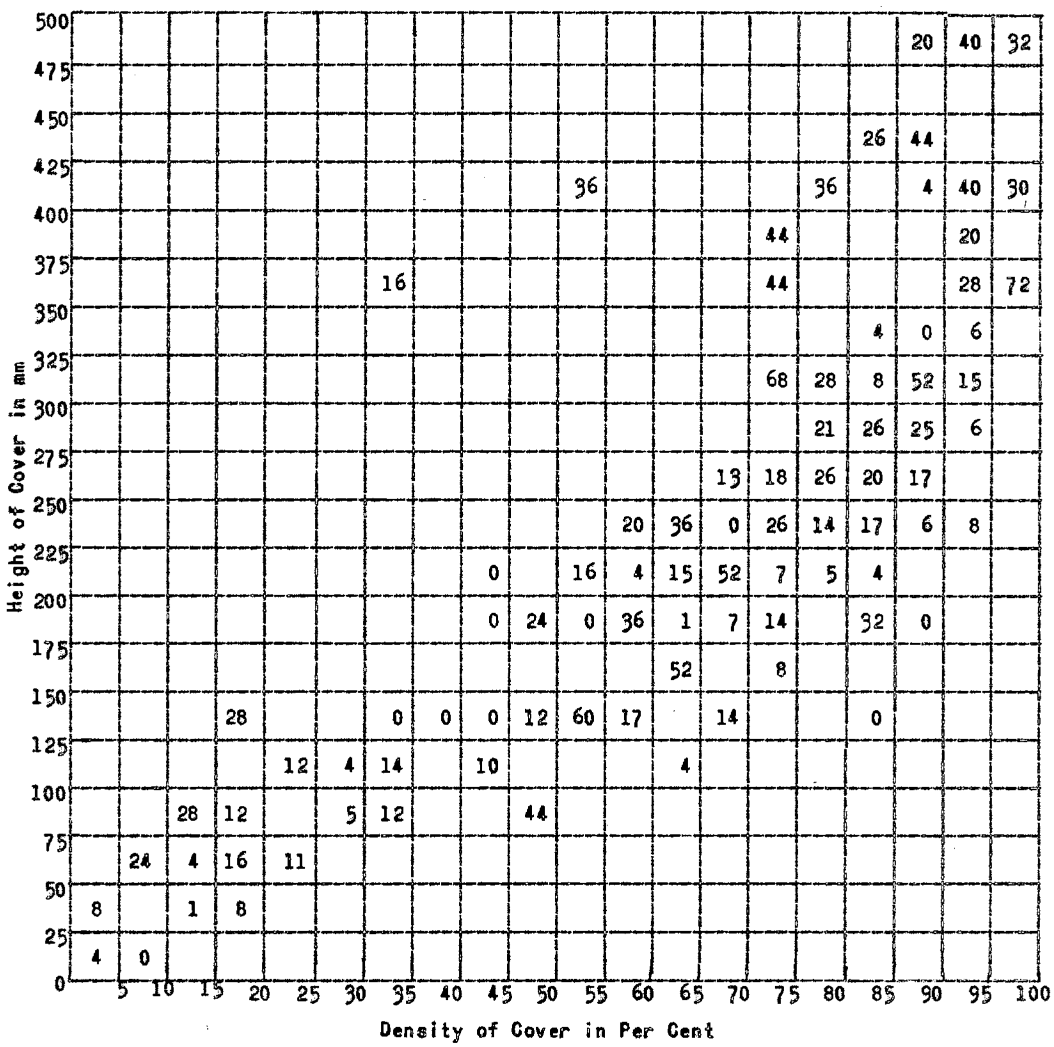

FIG. 3. Rate of capture, expressed in per cent, of Sigmodon per trap night in relation to height and density of grassy cover. Each entry represents per cent capture at one or more traps each set for 25 trap nights during the summer of 1961 on Grid 1. 748 captures are represented in a total of 4,275 trap nights.

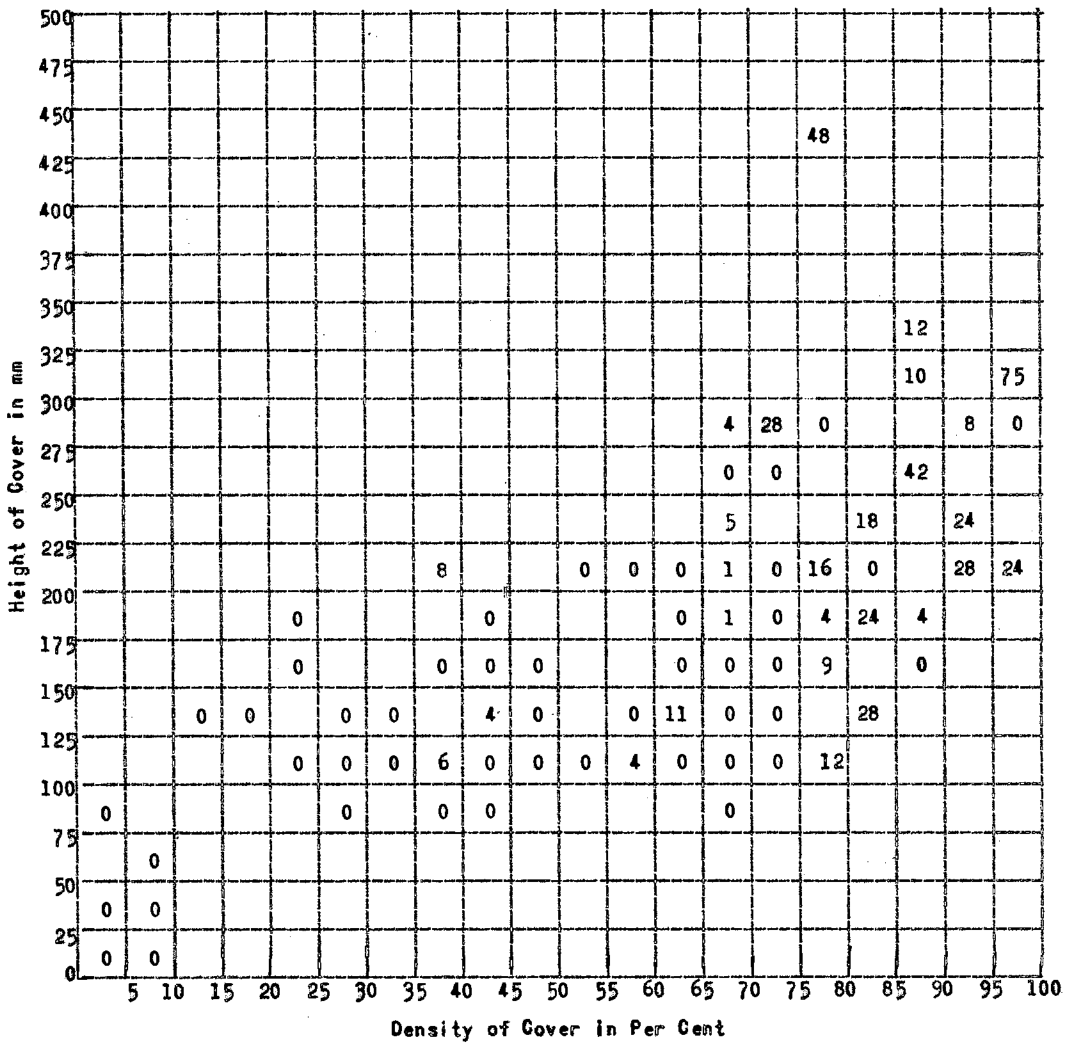

FIG. 4. Rate of capture, expressed in per cent, of <u>Sigmodon</u> per trap night in relation to height and density of grassy cover. Each entry represents per cent capture at one or more traps each set for 25 trap nights during the winter of 1961 on Grid 2. 159 captures are represented in a total of 3,500 trap nights.

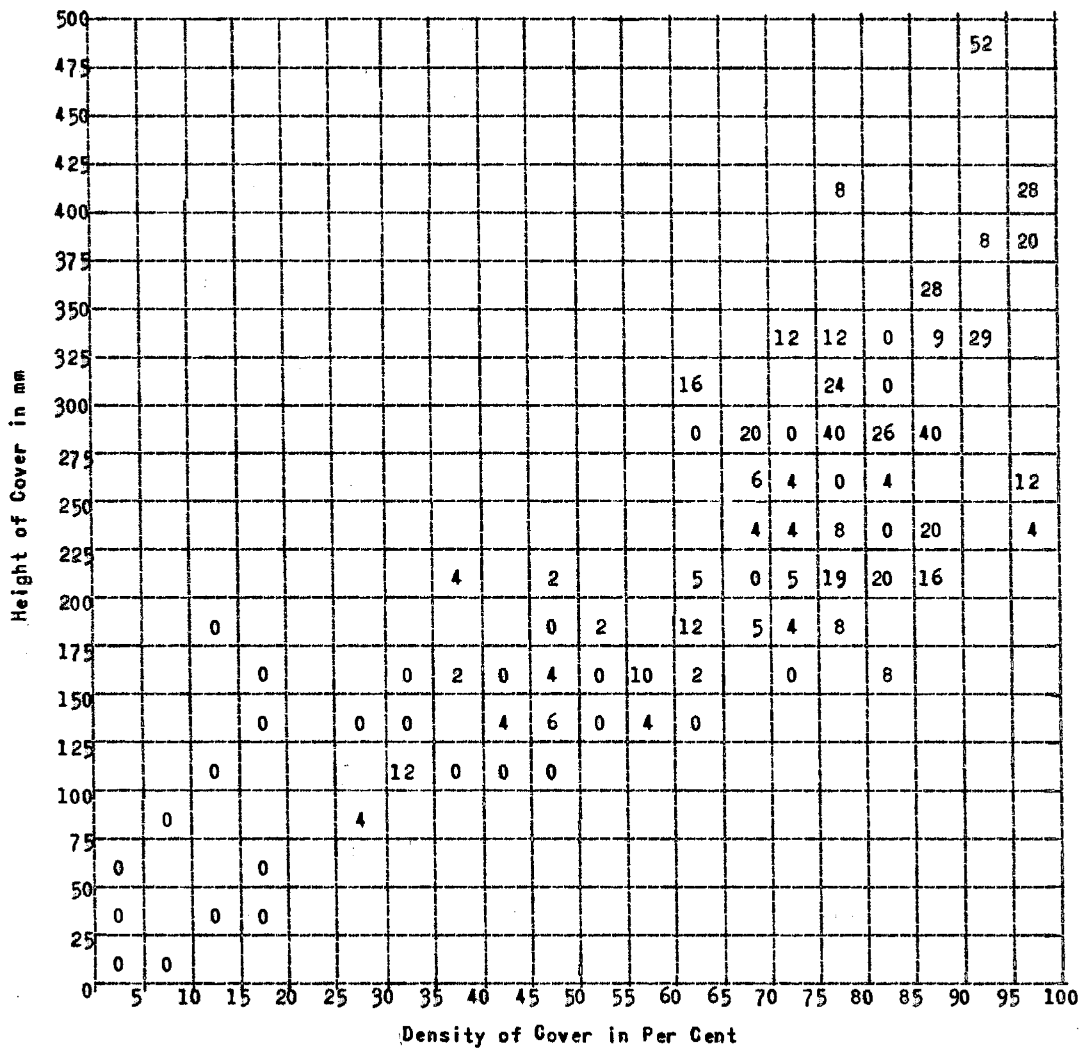

FIG. 5. Rate of capture, expressed in per cent, of Sigmodon per trap night in relation to height and density of grassy cover. Each entry represents per cent capture at one or more traps each set for 25 trap nights during the summer of 1961 on Grid 2. 289 captures are represented in a total of 3,500 trap nights.

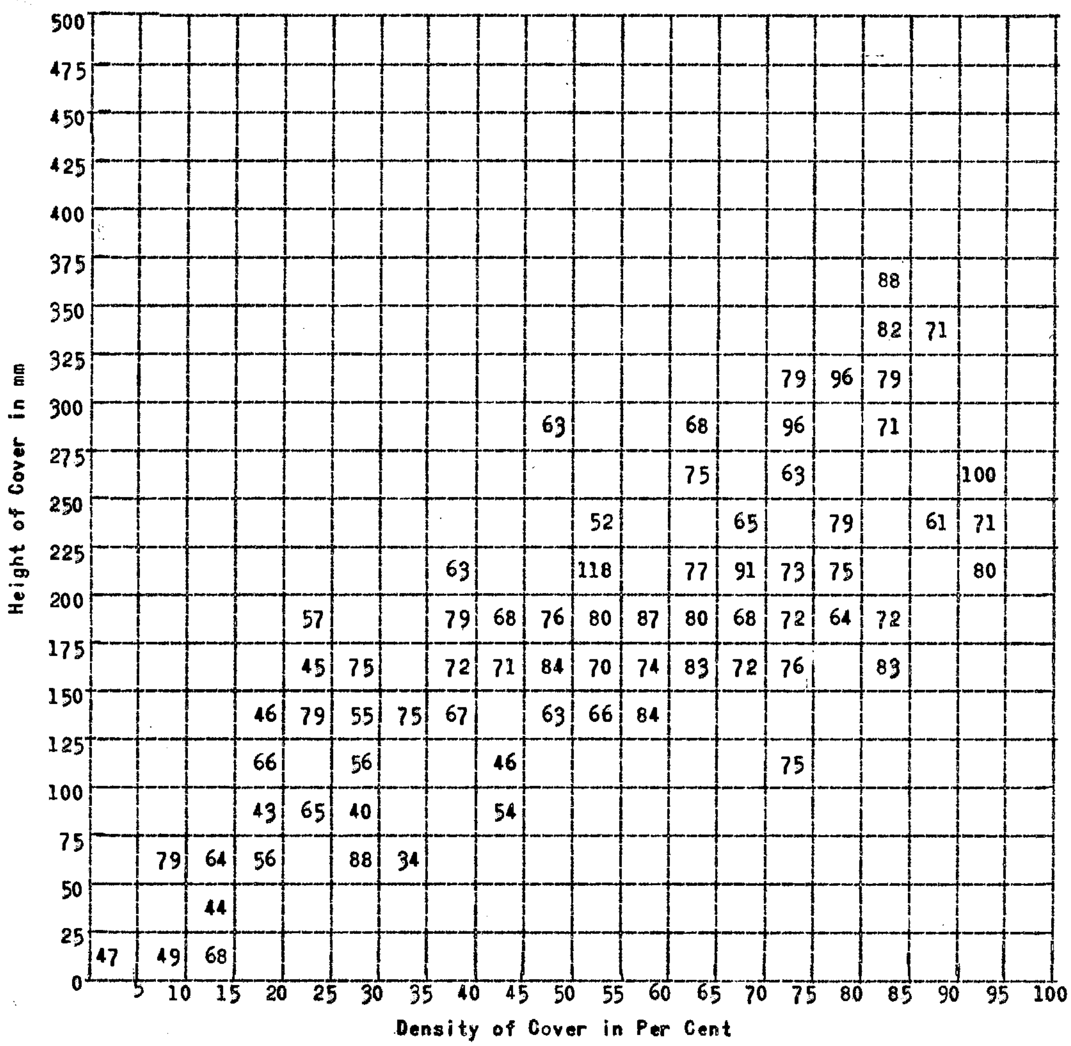

FIG. 6. Rate of capture, expressed in per cent, of Sigmodon per trap night in relation to height and density of grassy cover. Each entry represents per cent capture at one or more traps each set for 19 to 28 trap nights each from October 16, 1959 to February 27, 1960 on Grid 1. 2,435 captures are represented in a total of 4,054 trap nights.

Height of Cover in mm \ Density of Cover in Per Cent	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100
500															0	53			3	19
475																				
450																				9
425													11							
400																		19	12	
375																				
350																		10	17	10
325																	17			19
300														0		1	8	9	10	
275														1	4	15	3	5	6	
250								0				0		0	1	7	6	7	3	1
225									4				1	2	2	2	1			
200								0				5	1	1	2	4				
175							0		0		0	0	1	1	0		0			5
150						0		0		0	0	0	0	0						
125							3	0		0	0	0	0		0					
100		0	0	0		0	0	0	0			0								
75		0	0	0	0			0												
50	0	0		0																
25	0	0																		

FIG. 7. Rate of capture, expressed in per cent, of *Sigmodon* per trap night in relation to height and density of grassy cover. Each entry represents per cent capture along one or more snaptrap transects each set for 75 trap nights from May to July of 1960-61. 425 individuals are represented in a total of 13,725 trap nights.

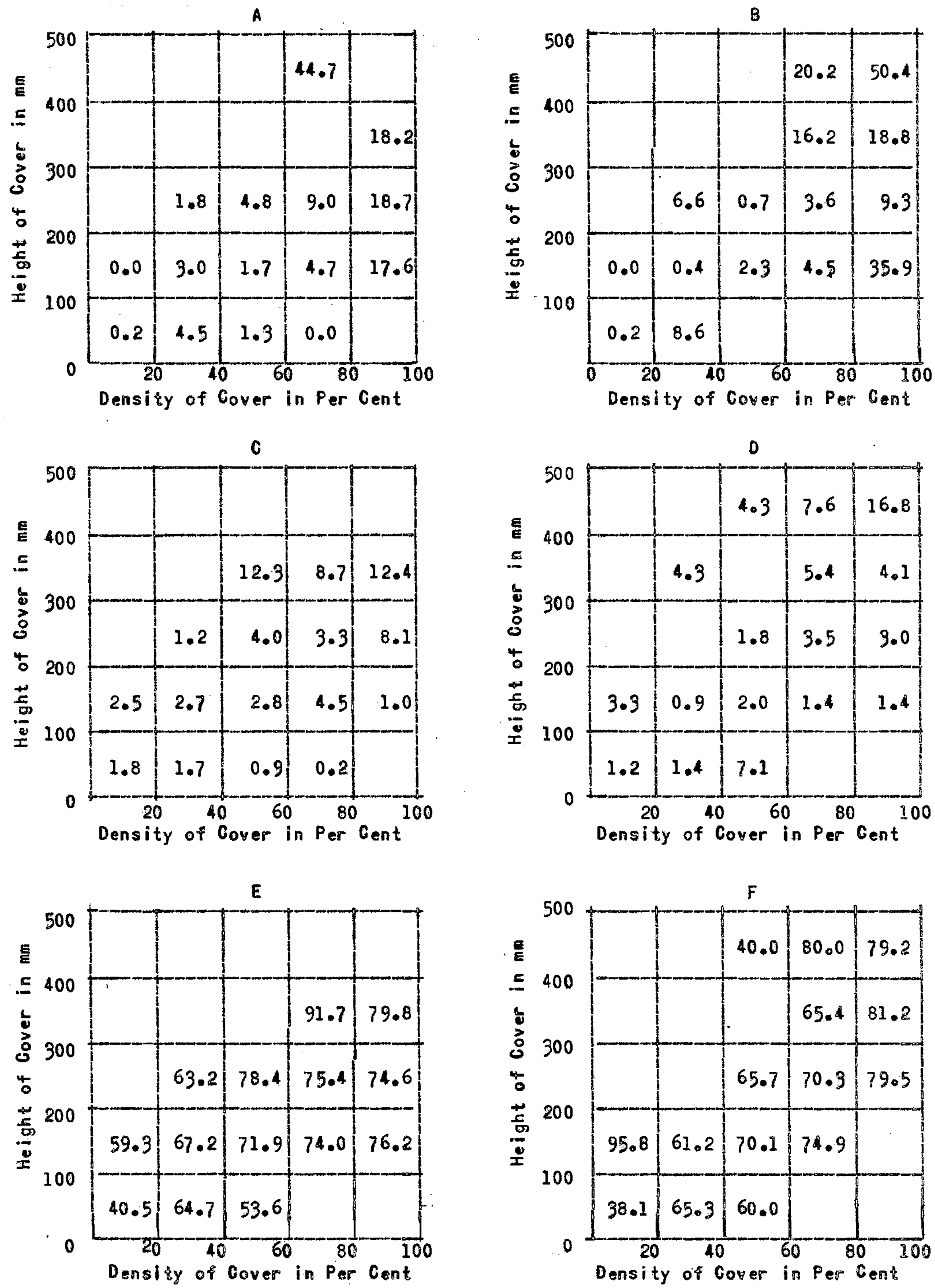

FIG. 8. Rate of capture, expressed in per cent, of Sigmodon per trap night in relation to density and height of grassy cover. A and B represent the captures of 134 rats captured 1,067 times on Grid 2 between July 22, 1960 and September 22, 1961, when the population was low. C and D represent the captures of 214 rats captured 1,232 times on Grid1 between July 4, 1960 and September 27, 1961, when the population was low. E and F represent captures of 661 rats captured 2,435 times on Grid 1 between October 16, 1959 and February 27, 1960, when the population was high. A, C, E represent the entire catch in comparison to cover measured in August and September while B, D, F represents the entire catch in comparison to cover measured in February and March.

areas. The 25 traps 10 feet or more away from unmowed cover represented 64 per cent of the 41 traps, but only 22 per cent of the captures were made in them or 74 of 336. The centers of these areas, with only a few exceptions, are represented in Figure 1-A by those traps with captures of four or less individuals. The others, or 36 per cent of the 41 traps set at the mowed-unmowed edges captured 78 per cent of the 336 captures. A great contrast in numbers of captures on Line 7 during 1959-60 as compared to 1960-61 is shown in Figure 1, A and B. This was apparently due to the fact that the area was mowed during September of 1959. The low growth form due to the mowing seemed to reduce the catch considerably. This line was not mowed thereafter. By the end of the next summer after mowing this line had about the heaviest cover of any line and the greatest rate of capture.

Areas of sparse ground cover were used infrequently by cotton rats on Grid 2. In 3,511 trap nights, only three rats were captured in 31 traps located beneath blackjack oak where the ground cover was sparse. The remaining 109 traps had made 1,064 captures in 15,539 trap nights. This was an average of .001 per cent capture beneath tree cover as compared to 6.847 on the open grassy areas. The wooded area is represented in Figure 1-C by the large area without any captures. The areas of grass are represented by the traps with many captures.

Correlation coefficients of per cent catch (Y) at different locations in comparison to 12 vegetation variables (X's) were used to estimate overall habitat preferences for cotton rats (Table 2). In most instances, these variables were based on plant life-form rather than taxa. The per cent of catch was correlated positively with the height and density of grass. The correlation coefficient ranged respectively

TABLE 2. Correlation coefficients of per cent capture of <u>Sigmodon</u> in comparison to 12 vegetation variables.

Per Cent of Catch, Location and Time	Grass Height	Grass Density	Perennial Grass Density	Annual Grass Density	Forbs, Total Count	Cover Value Forbs	Sumac and Plum	Coral Berry	Shrubs, Total Count	Tree Canopy	Litter Depth, Grass	Litter Depth, Grass
Grid 1 Summer, 1961	.41	.29	.27	-.00	-.05	.08	.11	.04	.06	-.13	--	--
Grid 1 Summer, 1960	.28	.16	.15	-.01	-.09	-.01	-.03	.08	.04	-.03	--	--
Grid 1 Summer, 1959	.51	.39	--	--	--	--	.08	.05	.07	-.28	--	--
Grid 1 Winter, 1961	.36	.19	.28	-.04	-.04	.03	-.02	-.02	-.05	-.06	--	--
Grid 1 Winter, 1960	.45	.23	--	--	--	--	.00	.11	.11	-.17	--	--
Grid 2 Summer, 1961	.34	.27	.28	-.04	-.14	.18	.30	--	.13	-.01	--	--
Grid 2 Summer, 1960	.36	.35	.35	-.01	-.18	.02	.27	--	.06	-.17	--	--
Grid 2 Winter, 1961	.42	.40	.41	-.11	-.06	.06	.12	--	-.06	-.17	--	--
Snaptraps All Seasons	.57	.42	.40	.11	.09	.30	.06	.00	-.02	-.23	.57	-.23

from .28 to .57, and from .16 to .42. Other positive correlations were observed for the density of perennial grass, in which the correlation ranged from .15 to .41; and for the depth of grass litter, which was .57. Conversely, tree canopy and leaf litter were the most negatively correlated variables at -.03 to -.23 and -.23 respectively. Most other groups were not well correlated. This was true of annual grass, made up almost entirely of Japanese brome. Forbs were somewhat negatively correlated. Three species of perennial forbs were considered as "cover value forbs," namely: Louisiana sage, everlasting and aromatic aster, because of their persistance as standing cover through much of the winter. However, a positive correlation was expressed only along snaptrap lines. The association of Louisiana sage with stands of mid and tall grasses may account in part for this one high value. Sumac and plum (*Prunus americana*) show correlation coefficients ranging from -.02 to .30. Sumac was most strongly correlated with per cent catch on Grid 2. On this area, the sumac was associated with the densest stands of perennial grasses, which together formed the best capture sites. Neither coral berry nor brushy species taken together were correlated with captures. The results indicate that taxa are not satisfactory units of measure for correlation, since they may be replaced by other similar units at another location. As expressed in the results, plant life-form is a more valuable criterion of habitat.

The single most important component of the habitat of *Sigmodon*, as far as plant life-form type was concerned, appeared to be moderate to dense stands of mid to high perennial grasses. The greatest number of cotton rats taken along any one snaptrap line (No. 108) was 40 individuals. These were taken in a stand of undisturbed tall Johnsongrass, where litter had accumulated to a depth of 10 to 30 cm. In each case, where 10 or more rats were taken per transect, the area was primarily of mid to high perennial grasses (Table 3).

Table 3. Vegetation measurements in comparison to transects of snap-traps where 10 or more Sigmodon were captured per transect, Payne Co., Oklahoma, between April 2, 1960 and June 1961.

		Average per 20 samples per transect						
Trans. No.	No. of Rats	Month	Grass Height cm	Per cent Density of grass	Per cent tree canopy	No. of Forbs	No. of Shrubs	Litter Depth cm
31	21	5-60	28.7	92.	0.	3.5	3.5	5.0
63	13	7-60	33.9	99.	0.	9.4	0.5	5.8
97	14	10-60	50.0	99.	0.	1.9	1.1	9.5
107	21	11-60	32.9	93	0.	5.4	0.3	4.4
108	40	11-60	50.0	79.	3.	22.0	7.5	10.9
150	22	3-61	32.4	95.	0.	4.7	1.5	4.5
174	10	5-61	26.6	93.	0.	7.6	2.3	3.1
175	11	5-61	25.9	79.	0.	25.2	2.2	1.5
178	19	5-61	30.7	84.	1.	21.9	0.0	0.0
185	11	6-61	29.4	83.	0.	13.4	0.5	0.5
192	14	6-61	38.0	89.	1.	1.8	6.8	6.8
200	12	7-61	33.3	89.	0.	8.2	2.2	2.2

The foregoing data indicate that variation in habitat quality has a great influence on cotton rats. As depicted, areas of scant cover, such as mowed areas and locations under a dense tree canopy, were of poor habitat quality for cotton rats and thus considered marginal habitat. Conversely, areas of dense and high ground cover, especially perennial grasses, was considered the superior habitat of cotton rats. That is, assuming that trap response is a reliable indicator of Sigmodon density and habitat preference.

Variation in Area of Cotton Rat Homestead

The area of cotton rat homesteads varied considerably from grid to grid at different times, and in a variety of ways. The major differences occurred between high and low population densities.

Homestead areas were small during the high population of 1959-60 on Grid 1 (Table 4). A total of 96 males and 104 females captured only once were assumed to have had a homestead of at least .10 acres each, with each trap representing .10 acre. One female captured nine times in a single trap was also assumed to have had a homestead area of at least .10 acres. A male captured 10 times had the largest homestead, 1.70 acres, for the trapping period indicated. Only six animals were known to have had homesteads of 1.00 acres or greater. The majority were less than .50 acres regardless of the number of captures. The most frequently recaptured animal during this period, a male captured 21 times, had a comparatively small homestead of .30 acres. The homestead areas of males and females were similar.

After July, 1960, homestead area was considerably greater, on the average, than for the previous period (Table 5). The variation ranged from .10 acres for animals caught once to 9.90 acres for a male captured 25 times. Another male captured 35 times had a homestead of 3.9 acres. One female, captured 15 times, had a homestead area of 3.30 acres. There was a tendency for the homestead areas of males and females to increase with an increase in the number of captures. On Grid 2, during the same period, the results were similar (Table 6). Homesteads ranged from .10 acres to 3.90 acres for a male captured 58 times and 1.80 acres for a female captured 23 times.

Examples of the homesteads of individual Sigmodon are depicted in Figures 9 to 14. Each figure depicts the area used by an individual as well as the number of times each individual was captured in various traps.

TABLE 4. Homesteads of 661 male and female *Sigmodon* in relation to captures in livetraps on Grid 1 between October 16, 1959 and February 27, 1960. Underscored numerals represent females.

Acres	Captures of Males and Females																																									
	1		2		3		4		5		6		7		8		9		10		11		12		13		14		15		16		17		18		19		20		21	
	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F
.1	96	104	31	31	11	10	1	1	2	6		4	1	1				1																								
.2			22	17	18	12	7	13	6	12	6	6	4	1	4	3		2		1	1																					
.3			3	14	13	11	8	6	10	7	2	10	1	5	2	3	1	3	1		1	1		1				1									1				1	
.4			5	3	3	6	3	2	4	3	3	2	1	3		3		1	1	3	3		2										1		1							
.5			1		1	1	3	4	2	3	2	1	2				1		1	2	1				2	2	2	1				1							1			
.6					1	1		1		2						1		1		1		1				1	1		1		2											
.7									1			1						1	1				1		1			1														
.8					1							1			1												1		1													
.9																																		1								
1.0							1			1																																
1.1														2																												
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1.3																														1												
1.4																																										
1.5																																										
1.6																																										
1.7																			1																							
1.8																																										
1.9																																										
2.0																																										

TABLE 5. Homesteads of 214 male and female *Sigmodon* in relation to captures in livetraps on Grid 1 between July 4, 1960 and September 27, 1961. Underscored numerals represent females.

Captures of Males and Females

Acres	1		2		3		4		5		6		7		8		9		10		11		12		13		14		15		16	
	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F
.1	31	19	1	3	1	1	1																									
.2			6	2	3	2		1		1						1												1				
.3			6	2	3		1			1					1																	
.4			2				2	1	2	5		3																				
.5			1		1	1	2	1			1	1				2																
.6				1	1		2		1	1	1			1																		
.7			1					1	2			1		1																		
.8			2		2		1				2		1		1								1			1						
.9					1	1					1					1	1		1												1	
1.0											1	1	1						1													
1.1			1				2	1														1										
1.2							1	1																		1						1
1.3					1				1					1	1													1				
1.4											1														1							
1.5									1				2						1													
1.6									1						1																	
1.7																					1											
1.8							1		1		1				1		1		2				1		1							
1.9															2											1						
2.0													1														1					
2.1					1										1				1													
2.2										1																						
2.3													1																			
2.6																1																
2.8																							1									
3.2								1																					1			
3.3																														1		
3.4																									1							
3.5																			1												1	
3.9																																
4.0																																
4.3																																
4.6																																
6.0																	1															
6.1																			1													
9.9																																

Acres	17		18		19		20		21		22		23		24		25		26		27		28		29		30		32		35	
	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F
.1																																
.2																																
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1.8																																
1.9						1																										
2.0																																
2.1																																
2.2												1																				
2.3																																
2.6			1																													
2.8																																
3.2																																
3.3																																
3.4																																
3.5																													1			
3.9																															1	
4.0			1		1																											
4.3													1																			
4.6	1								1																							
6.0																																
6.1																																
9.9																	1															

TABLE 6. Homesteads of 134 male and female *Sigmodon* in relation to captures in livetraps on Grid 2 between July 22, 1960 and September 22, 1961. Underscored numerals represent females.

Captures of Males and Females

Acres	1		2		3		4		5		6		7		8		9		10		11	
	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F
.1	22	13	1					1														
.2			4	3	1		1				1				1							
.3			1	1	2	2	3		2				1							1		
.4					1	1	1	1		2		1	1		1			1				
.5				1		1		1	1				1		1		1					
.6			1				2						1		1		1					1
.7			1		1										1							
.8					1	1					2									1		
.9							1	1												1		
1.0							1					1			1							
1.1																						
1.2																						
1.3									1									1				
1.4																			1			
1.5																					1	
1.6																						
1.7																						
1.8											1								1		1	
1.9																						
2.0																						
2.1											1											
2.3																						
2.5																						
2.6																						
2.8																						
3.9																						

Acres	12		13		14		15		16		17		18		19		20		21		22	
	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F
.1																						
.2																						
.3																						
.4																						
.5																						
.6																						
.7																		1				
.8		1						1		1										1		1
.9																						
1.0									1							1						
1.1																						
1.2	1																					
1.3			1																			
1.4				1																		
1.5					1							1										
1.6																						
1.7			1											1								
1.8																						
1.9																						
2.0																						
2.1																						
2.3											1											
2.5									1													
2.6									1													
2.8																						
3.9																						

Acres	23		24		25		26		27		33		38		40		44		55		58
	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M
.1																					
.2																					
.3																					
.4																					
.5																					
.6																					
.7																					
.8											1										
.9																					
1.0										1											
1.1																		1			
1.2			1																		
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1.5				1										1							
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1.8		1																			
1.9																					
2.0																					
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2.6																			1		
2.8													1								
3.9																					1

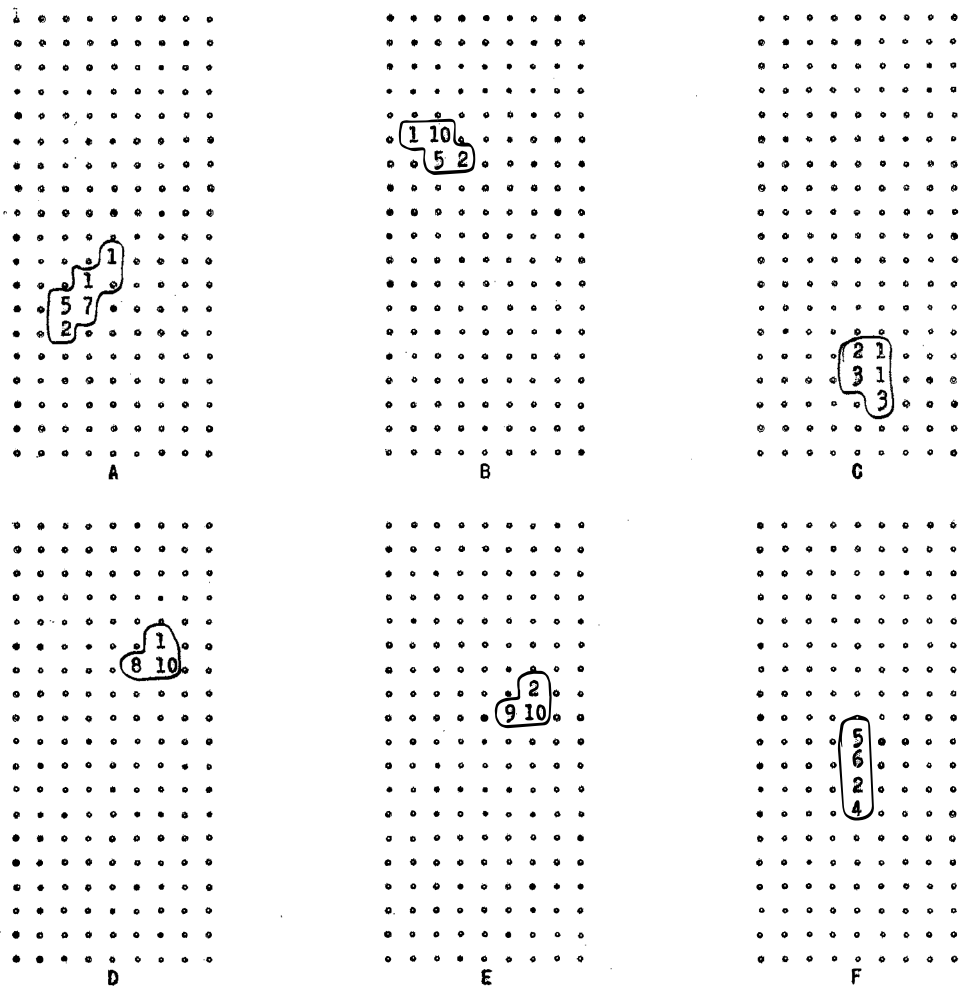

FIG. 9. Homesteads of the six most frequently captured male <u>Sigmodon</u> live-trapped on Grid 1 between October 16, 1959 and February 27, 1960. Interval between each of 171 traps (dot or numeral) is 66 ft. Numerals represent the number of captures at each trap.

	No. of Captures	Homestead In Acres	Date First Captured	Date Last Captured	Greatest Distance Traveled in ft
A. Male 54	16	.6	10-16-59	12-13-59	238
B. Male 86	18	.4	10-17-59	12-16-59	148
C. Male 119	20	.5	10-17-59	12-17-59	148
D. Male 196	19	.3	10-22-59	12-16-59	93
E. Male 242	21	.3	10-26-59	2-13-60	93
F. Male 286	17	.4	10-29-59	12-17-59	198

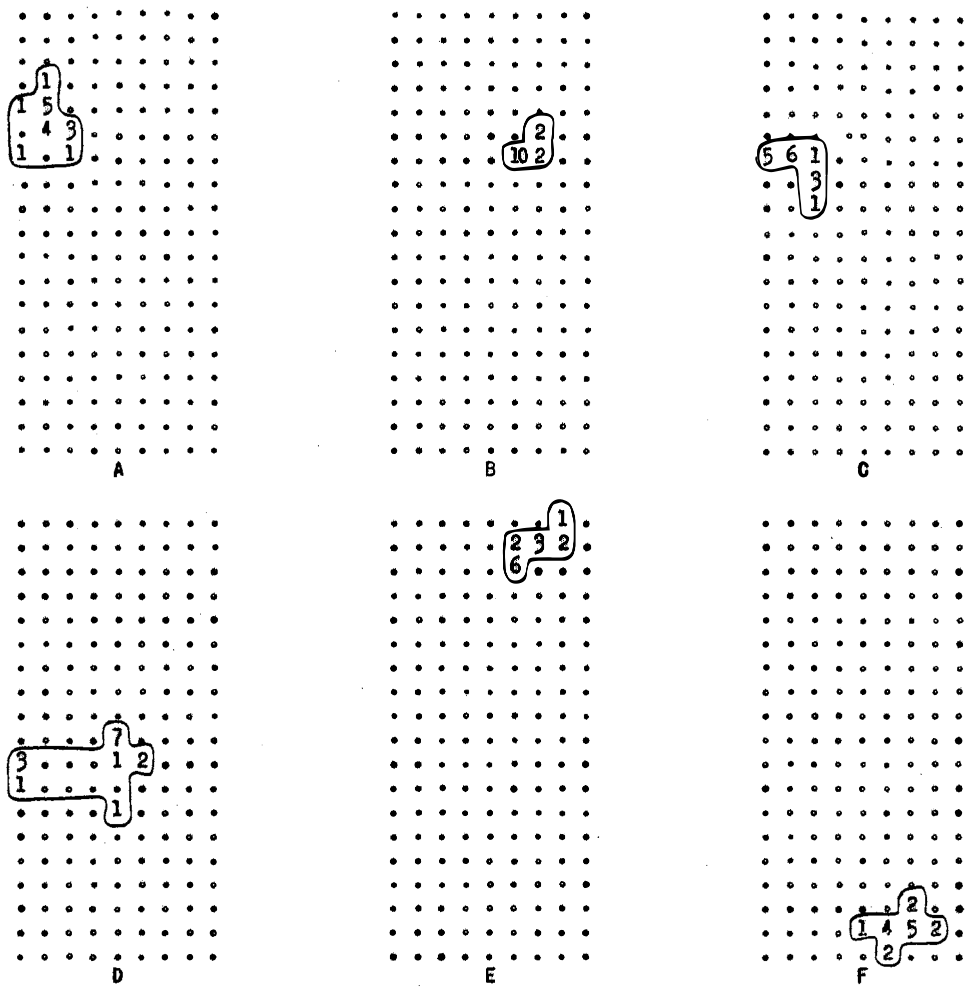

FIG. 10. Homesteads of the six most frequently captured female Sigmodon livetrapped on Grid 1 between October 16, 1959 and February 27, 1960. Interval between each of 171 traps (dot or numeral) is 66 ft. Numerals represent the number of captures at each trap.

	No. of Captures	Homestead In Acres	Date First Captured	Date Last Captured	Greatest Distance Traveled in ft
A. Female 126	17	.9	10-16-59	2-14-60	209
B. Female 173	14	.3	10-21-59	12-17-59	93
C. Female 219	16	.5	10-24-59	12-13-59	187
D. Female 298	15	1.3	10-30-59	2- 2-60	337
E. Female 306	14	.5	11- 2-59	2- 3-60	187
F. Female 348	16	.6	11- 6-59	12-17-59	198

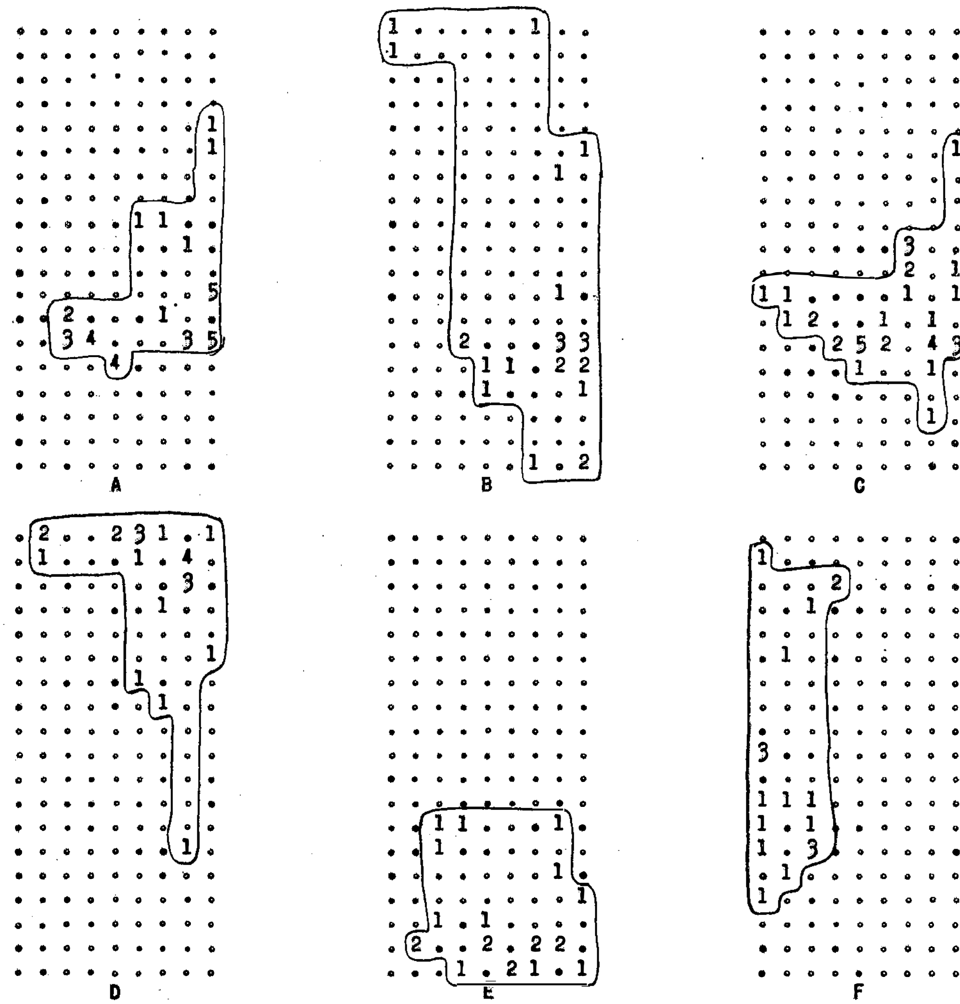

FIG. 11. Homesteads of the six most frequently captured male *Sigmodon* livetrapped on Grid 1 between July 4, 1960 and September 27, 1961. Interval between each of 171 traps (dot or numeral) is 66 ft. Numerals represent the number of captures at each trap.

	No. of Captures	Homestead in Acres	Date First Captured	Date Last Captured	Greatest Distance Traveled in ft
A. Male 668	32	3.5	2-11-61	8- 9-61	714
B. Male 684	25	9.9	3-12-61	9-27-61	1,300
C. Male 698	35	3.9	4-28-61	9-27-61	729
D. Male 711	23	4.3	6-24-61	9-27-61	945
E. Male 723	21	4.6	7- 5-61	9-26-61	560
F. Male 737	19	4.0	7-16-61	9-27-61	924

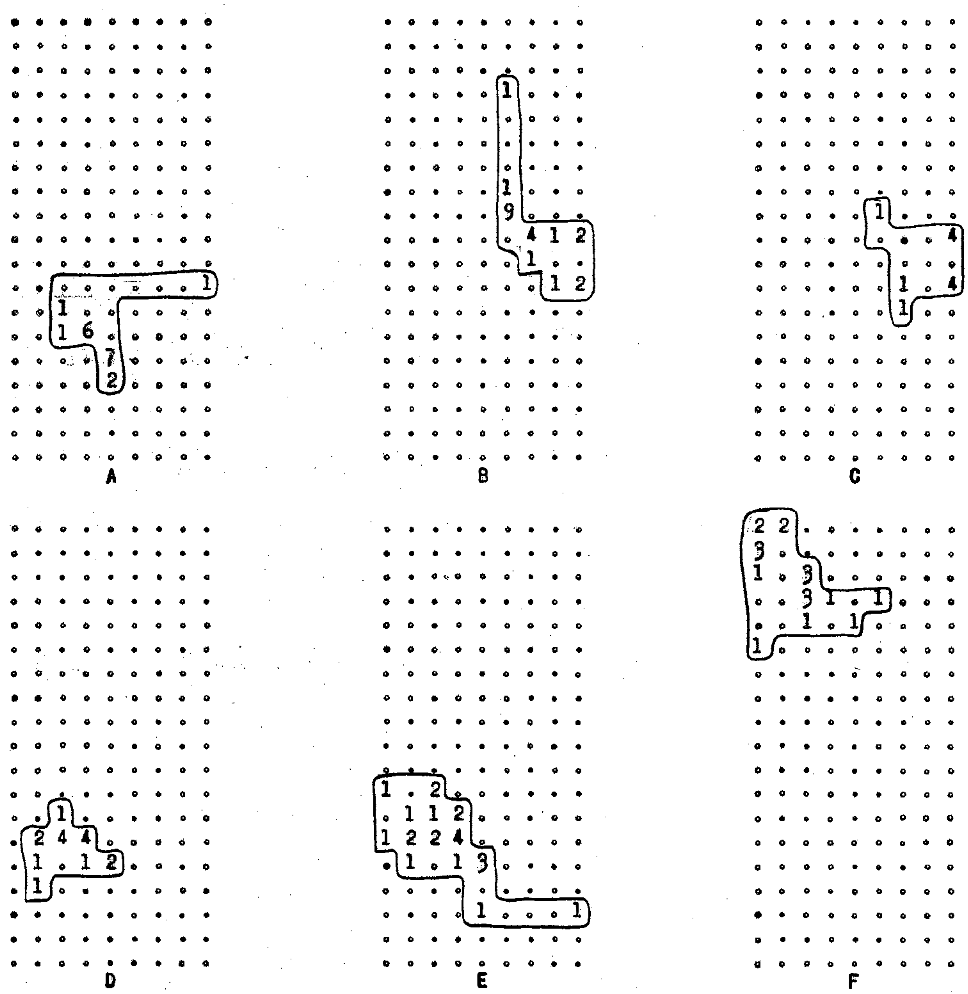

FIG. 12. Homesteads of the six most frequently captured female *Sigmodon* livetrapped on Grid 1 between July 4, 1960 and September 27, 1961. Interval between each of 171 traps (dot or numeral) is 66 ft. Numerals represent the number of captures at each trap.

	No. of Captures	Homestead In Acres	Date First Captured	Date Last Captured	Greatest Distance Traveled in ft
A. Female 667	18	1.5	12-19-60	3-31-61	417
B. Female 669	22	1.5	2-11-61	3-28-61	564
C. Female 680	16	1.2	2-25-61	5-11-61	280
D. Female 692	16	.9	3-30-61	5-27-61	209
E. Female 713	23	2.2	7- 4-61	9-27-61	623
F. Female 733	19	1.9	7- 7-61	9-27-61	385

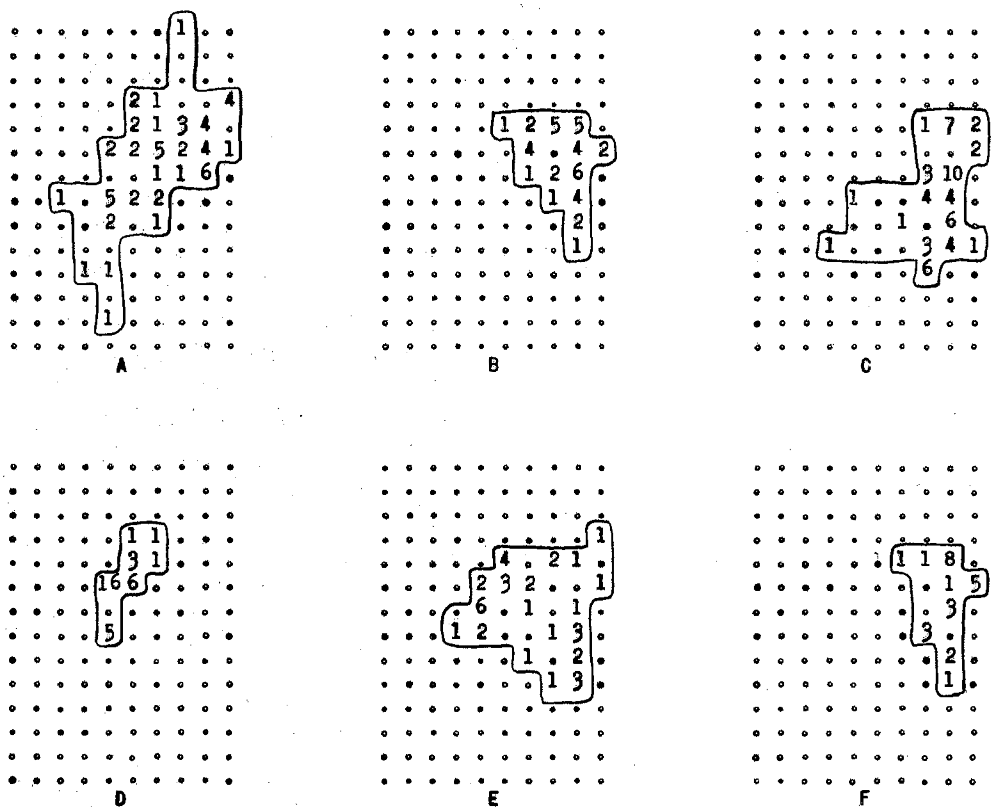

FIG. 13. Homesteads of the six most frequently captured male *Sigmodon* live-trapped on Grid 2 between July 22, 1960 and September 22, 1961. Interval between each of 140 traps (dot or numeral) is 66 ft. Numerals represent the number of captures at each trap.

	No. of Captures	Homestead In Acres	Date First Captured	Date Last Captured	Greatest Distance Traveled in ft
A. Male 13	58	3.9	8- 1-60	7-15-61	816
B. Male 35	40	1.5	11- 3-60	3-24-61	385
C. Male 38	55	2.6	11- 2-60	6- 4-61	515
D. Male 40	33	.8	11- 1-60	2-21-61	295
E. Male 53	38	2.8	2-18-61	8- 7-61	476
F. Male 54	23	1.2	2-18-61	5- 5-61	355

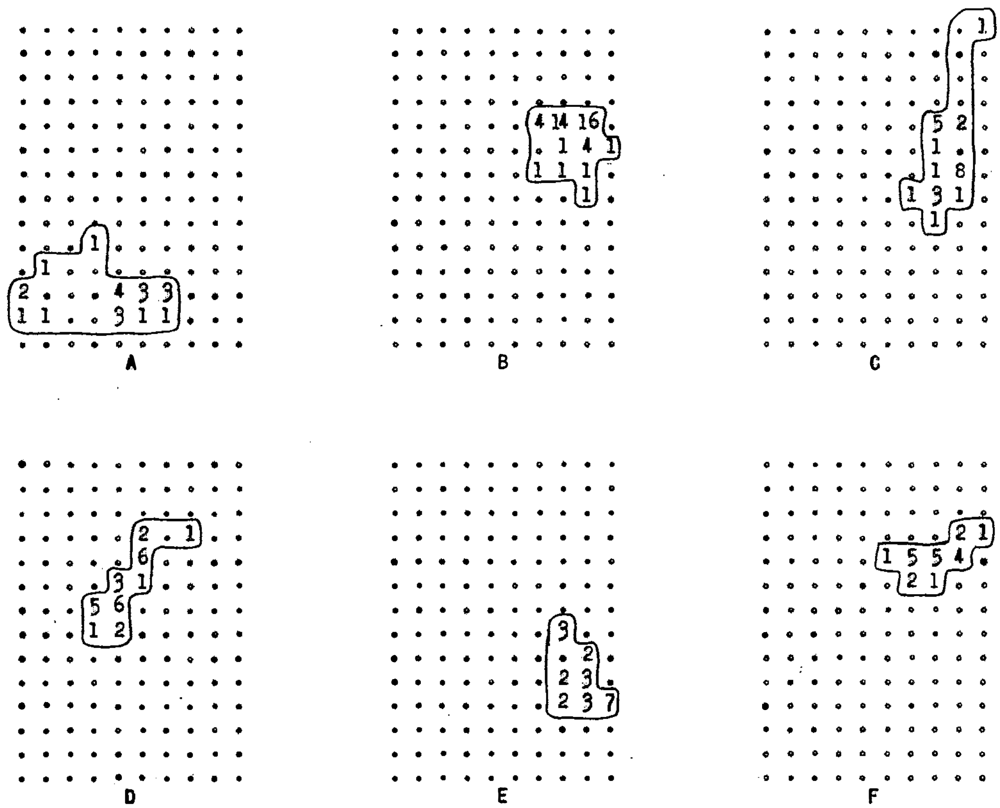

FIG. 14. Homesteads of the six most frequently captured female *Sigmodon* livetrapped on Grid 2 between July 22, 1960 and September 22, 1961. Interval between each of 140 traps (dot or numeral) is 66 ft. Numerals represent the number of captures at each trap.

	No. of Captures	Homestead In Acres	Date First Captured	Date Last Captured	Greatest Distance Traveled in ft
A. Female 5	23	1.8	7-27-60	9-22-60	402
B. Female 37	44	1.1	11- 1-60	7-14-61	238
C. Female 48	24	1.5	2-17-61	6-13-61	544
D. Female 68	27	1.0	5- 5-61	9-21-61	373
E. Female 84	22	.8	6-17-61	9-22-61	238
F. Female 95	21	.8	7-12-61	9-22-61	272

These examples are from the most frequently trapped animals captured on each grid. Since the examples used represent only 36 of 1,009 marked animals, the variation in pattern should not be considered representative of all the marked animals. However, in the first 12 (Figures 9 and 10), of the 36 examples given, the homesteads were considerably smaller than for those examples depicted by the remaining 24 examples (Figures 11 to 14). The examples from Figures 9 and 10 show that there is little difference between the homestead sizes of males and females. These represent individuals from a dense population. The results from Figures 11 to 14 show that the homesteads of males were larger than for those animals represented in Figures 9 and 10. In addition, males represented in Figures 11 to 14, have much larger homesteads than the females taken at the same time.

The variations in area of homesteads shown in Tables 4 to 6, and partially shown in Figures 9 to 14, are summarized in Table 7. The average area of homesteads, in acres, for numbers of males and of females increased with the number of times individuals were recaptured, when group averages were compared. Smallest increases from group to group were noted for animals taken during the fall and winter of 1959-60, where the variation was, on the average, .10 to .60 acres, from the least to greatest number of captures. Differences in homestead area between males and females were slight. This can be seen by comparing the columns of male and female averages to total averages and group averages.

For rats taken after July of 1960, there were striking increases in the area of homesteads with increase in recaptures. This is clearly shown again by group averages (Table 7). Averages for rats captured two to three and four to seven times are more nearly alike across the table than

TABLE 7. Area of homestead in acres for male and female *Sigmodon* in relation to number of captures from Grid 1 and 2.

No. of Captures	Average Sizes of Homesteads in Acres for Numbers of Males and Females																							
	Oct. 16, 1959 to Feb. 27, 1960 on Grid 1								July 4, 1960 to Sept. 27, 1961 on Grid 1								July 22, 1960 to Sept. 22, 1961 on Grid 2							
	No.	Male	No.	Fem.	Tot. No.	Tot. Ave.	Group Total	Group Ave.	No.	Male	No.	Fem.	Tot. No.	Tot. Ave.	Group Total	Group Ave.	No.	Male.	No.	Fem.	Tot. No.	Tot. Ave.	Group Total	Group Ave.
1	96	.10	104	.10	200	.10	200	.10	31	.10	19	.10	50	.10	50	.10	22	.10	13	.10	35	.10	50	.10
2	62	.18	65	.18	127	.18			20	.39	8	.24	28	.35			8	.31	5	.28	13	.30		
3	48	.24	41	.25	89	.25	216	.21	14	.61	5	.38	19	.55	47	.43	6	.45	5	.46	11	.45	24	.37
4	23	.33	27	.29	50	.31			13	.72	7	1.04	20	.84			9	.51	4	.48	13	.50		
5	25	.31	34	.29	59	.30			9	1.00	9	.59	18	.79			4	.60	2	.40	6	.53		
6	13	.31	25	.30	38	.30			8	.98	6	.57	14	.80			5	1.14	2	.70	7	1.01		
7	9	.29	12	.43	21	.37	168	.31	6	1.52	3	.87	9	1.30	61	.88	4	.45	0		4	.45	30	.62
8	7	.31	10	.33	17	.32			8	1.46	5	.94	13	1.26			6	.57	0		6	.57		
9	2	.40	9	.34	11	.35			3	2.90	0		3	2.90			2	.55	2	.85	4	.70		
10	5	.72	7	.43	12	.55			8	2.30	0		8	2.30			2	1.60	3	.67	5	1.04		
11	6	.37	2	.45	8	.39			1	1.70	1	1.10	2	1.40			2	1.65	1	.60	3	1.30		
12	3	.50	1	.30	4	.45			3	1.80	0		3	1.80			1	1.20	1	.80	2	1.00		
13	3	.57	3	.53	6	.55			3	2.20	3	1.30	6	1.75			2	1.50	1	1.40	3	1.47		
14	4	.60	3	.50	7	.56	65	.43	1	2.00	2	.75	3	1.17	38	1.24	1	1.50	0		1	1.50	24	.97
15	2	.70	1	1.20	3	.87			1	3.20	1	3.30	2	3.25			0		1	.80	1	.80		
16	2	.60	1	.50	3	.57			2	2.20	1	1.20	3	1.87			3	2.03	1	.80	4	1.73		
17	1	.40	1	.90	2	.65			1	4.60	0		1	4.60			1	2.30	1	1.50	2	1.90		
18	1	.40	0		1	.40			2	3.30	1	1.50	3	2.70			0		1	1.70	1	1.70		
19	1	.30	0		1	.30			1	4.00	1	1.90	2	2.95			0		1	1.00	1	1.00		
20	1	.50	0		1	.50							0				0		1	.70	1	.70		
21	1	.30	0		1	.30			1	4.60	0		1	4.60			0		1	.80	1	.80		
22					0				0		2	1.85	2	1.85			0		1	.80	1	.80		
23					0				1	4.30	0		1	4.30			0		1	1.80	1	1.80		
24					0								0				1	1.20	1	1.50	2	1.35		
25					0				1	9.90	0		1	9.90							0			
27					0								0				0		1	1.00	1	1.00		
28					0		12	.60					0		16	3.30					0		16	1.38
32					0				1	3.50	0		1	3.50							0			
33					0								0				1	.80	0		1	.80		
35					0				1	3.90	0		1	3.90							0			
38					0								0				1	2.80	0		1	2.80		
40					0								0				1	1.50	0		1	1.50		
44					0								0				0		1	1.10	1	1.10		
55					0								0				1	2.60	0		1	2.60		
58					0		0						0		2	3.70	1	3.90	0		1	3.90	6	2.12

for those animals captured more than eight times. Examination of the vertical columns for males and females taken after July of 1960 show that in the majority of cases the males had a homestead of greater area than the females. For males captured more than eight times on Grid 1, the range in area of homesteads was from 1.46 to 9.90 acres as compared to .94 to 3.30 for females. On Grid 2, homesteads ranged from .55 to 3.90 acres for males to .80 to 1.80 acres for females.

Greatest Distance Traveled

A total of 609 Sigmodon were captured two or more times in two or more traps during this study. From these rats some measure of distances traveled can be gained by comparing the greatest distances traveled between any two capture sites. Between October 16, 1959 and February 27, 1960, 354 cotton rats were captured on Grid 1 at a time when the population was dense. The greatest distances between any two capture sites for individual male and female Sigmodon is given in Figures 15 and 16 in relation to numbers of captures. It can be seen that regardless of the number of captures, the greatest measured distance traveled by any animal was nearly always less than 300 feet. Only four males and four females were known to have traveled more than 300 feet during this period. Little difference can be discerned between distances traveled by males and females during this period.

From July 4, 1960 through September 1961, a total of 157 individuals were captured two or more times in two or more traps. The distances traveled by these rats are depicted in Figures 17 and 18. Rats trapped during this period had a much greater travel distance than those rats shown in the first period. Animals taken in this period also had an

Distance in Feet

60 .100. . . .200. . . .300. . . .400. . . .500. . . .600. . . .700. . . .800. . . .900

Number of Times Captured											
2	21	3	1	4	1	1					
3	18	9	5	2	1			1	1		
4	7	4	5	2	2	1				1	
5	6	8	2	4	1			2			
6	6	2		2	2	1					
7	3	1		3							
8	4	2							1		
9		1			1						
10			1	2	1						1
11	1	3		1		1					
12		1		1				1			
13				2			1				
14				1		1	1				
15				1				1			
16							1				
17					1						
18				1							
19		1									
20				1							
21		1									

FIG. 15. Greatest distances traveled by 170 male *Sigmodon* in comparison to number of times livetrapped on Grid 1 between October 16, 1959 and February 27, 1960.

Distance in Feet

60 .100. . . .200. . . .300. . . .400. . . .500. . . .600. . . .700. . . .800. . . .900

Number of Times Captured												
2	15	11	3	4								
3	11	9	3	5	1			1				
4	13	5	2	1	1	3	1					
5	11	5	3	3	1	1	1	1		1		1
6	5	9	1	1		1		1				
7	1	4	1	2							1	
8	3	5		1			1					
9	2	1	2	2				2				
10	1		2	2	1		1					
11		1					1					
12		1										
13				2			1					
14		1			3							
15									1			
16					1	1						
17						1						
18												
19												
20												
21												

FIG. 16. Greatest distances traveled by 184 female *Sigmodon* in comparison to number of times livetrapped on Grid 1 between October 16, 1959 and February 27, 1960.

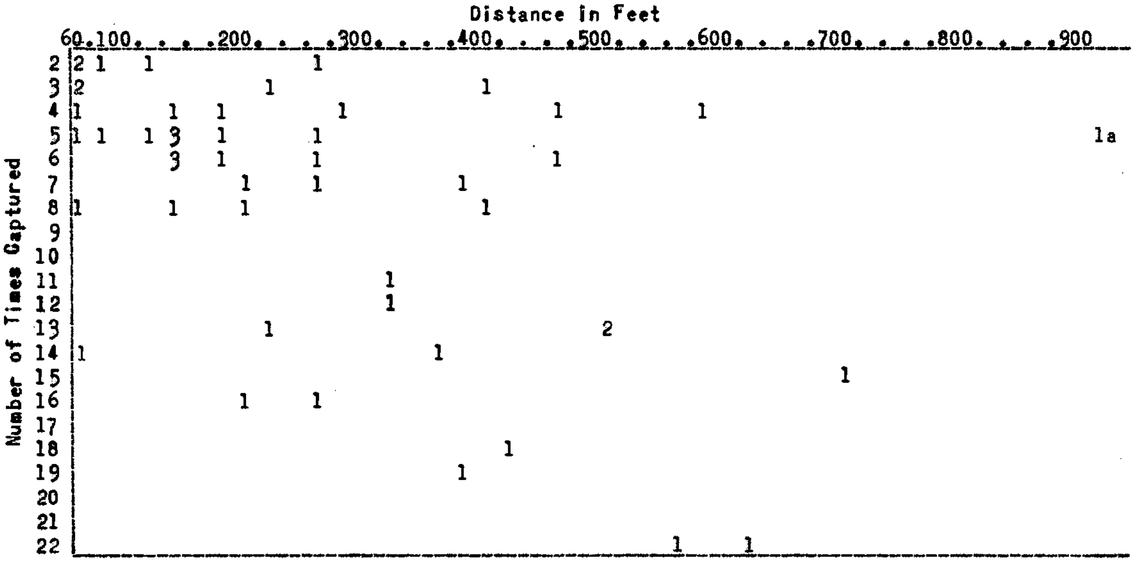

FIG. 17. Greatest distances traveled by 51 female *Sigmodon* in comparison to number of times livetrapped on Grid 1 between July 4, 1960 and September 27, 1961. The letter "a" represents 1,007 ft.

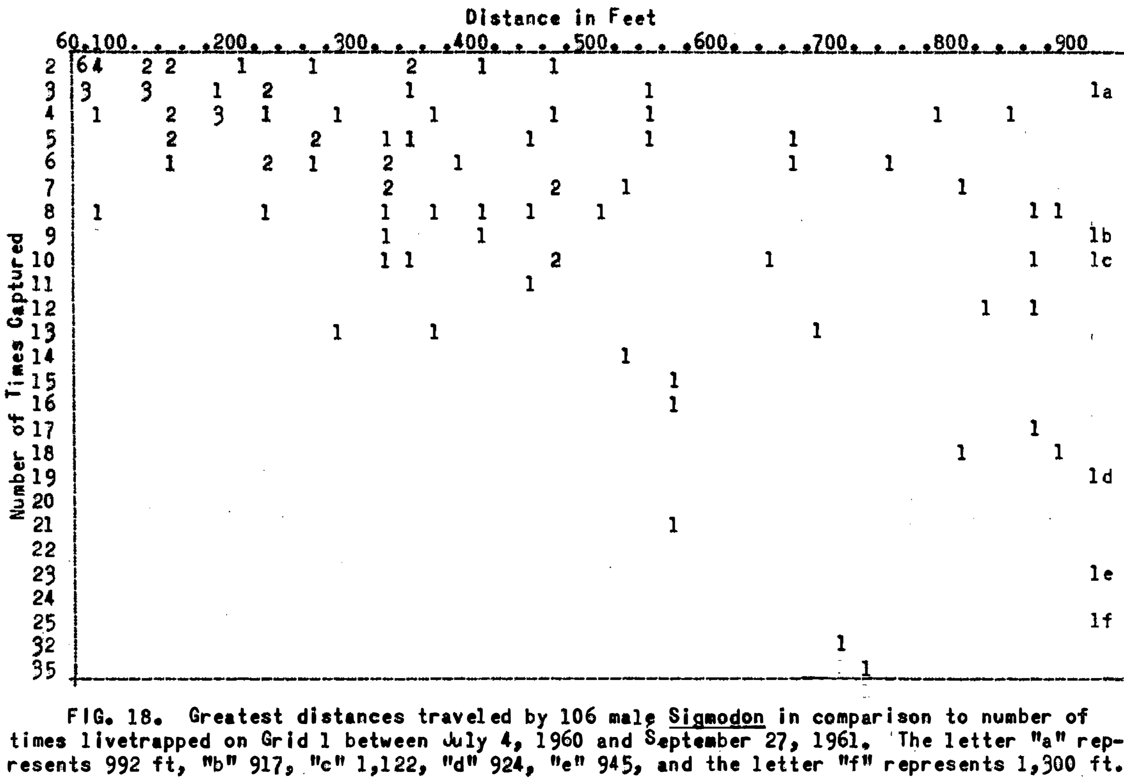

FIG. 18. Greatest distances traveled by 106 male *Sigmodon* in comparison to number of times livetrapped on Grid 1 between July 4, 1960 and September 27, 1961. The letter "a" represents 992 ft, "b" 917, "c" 1,122, "d" 924, "e" 945, and the letter "f" represents 1,300 ft.

increase in the distance traveled in relation to the number of captures. A large number of rats ranged more than 300 feet. In this group, one male was known to have traveled at least 1,300 feet, another, 1,122 feet and one female 1,007 feet. On the average the distances traveled by males were greater than those traveled by females.

A total of 98 Sigmodon were livetrapped two or more times in two or more traps on Grid 2. Livetraps were in operation from July 22, 1960 through September 1961. The greatest distances traveled by individuals trapped on this grid are given in Figure 19, for males, and in Figure 20, for females. Many of these rats ranged more than 300 feet, and the greatest distance traveled by any one of these rats, a male, was 816 feet.

Table 8 summarizes, in per cent, the greatest distances traveled between any two capture sites for the 609 males and females captured two or more times in two or more traps. The great majority of the 354 animals trapped on Grid 1 during the fall and winter of 1959-60 traveled less than 300 feet. This was when the population was dense. A total of 50.3 per cent of the rats captured after July of 1960, on the same grid, traveled more than 300 feet when the population was reduced. It is shown that 24 males, 22.7 per cent, traveled more than 600 feet while 3 females, 5.9 per cent, did so. The travel of 44 males, 41.5 per cent, was found to have been in the 0-300 foot range. This range was also traveled by 34 females, 66.6 per cent. On Grid 2, 36.4 per cent of the rats traveled more than 300 feet. Four males, 6.45 per cent, moved more than 600 feet, but no females ranged this far. The average distances traveled by males was greater than those traveled by females (Table 8, bottom two rows).

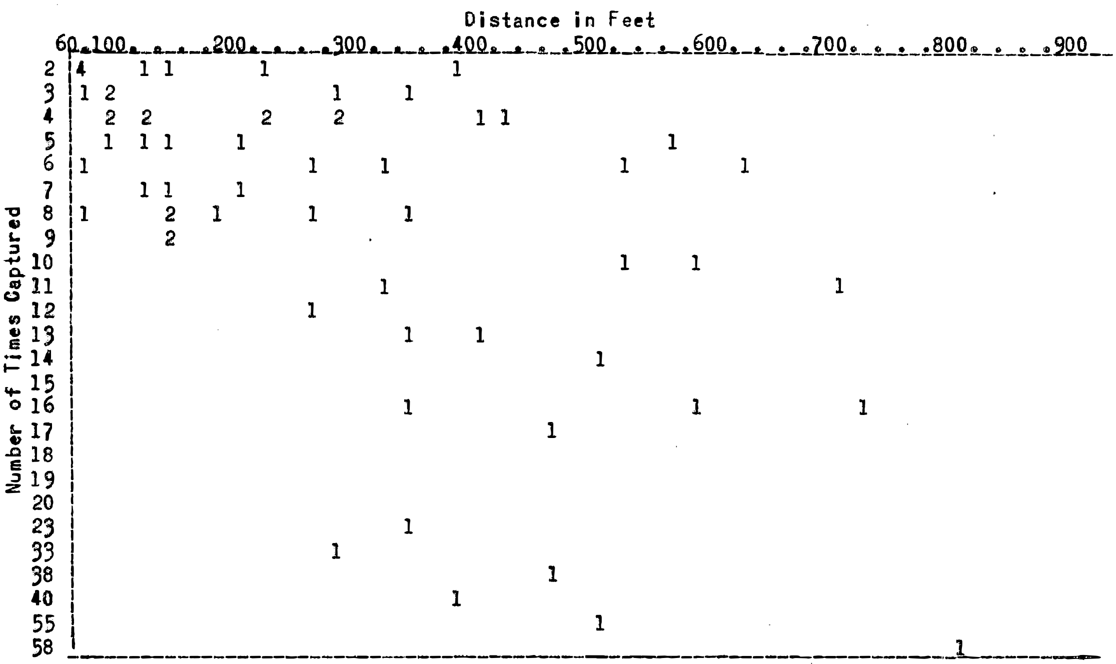

FIG. 19. Greatest distance traveled by 62 male <u>Sigmodon</u> in comparison to number of times livetrapped on Grid 2 between July 22, 1960 and September 22, 1961.

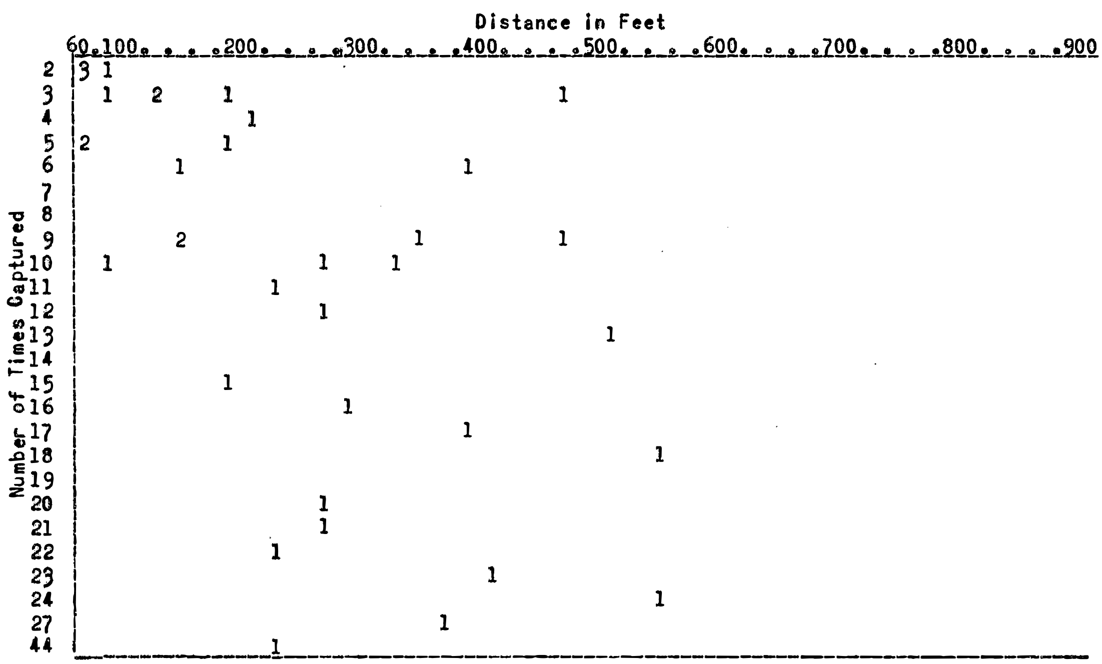

FIG. 20. Greatest distances traveled by 36 female <u>Sigmodon</u> in comparison to number of times livetrapped on Grid 2 between July 22, 1960 and September 22, 1961.

TABLE 8. Greatest distances traveled between any two capture sites by 609 male and female *Sigmodon* on Grid 1 and 2. Numerals represent the per cent of the total within 100 ft intervals.

	Distance in Feet													
	0	100	200	300	400	500	600	700	800	900	1000	1100	1200	1300
170 males Grid 1 High Population		60.00	30.00	7.65		1.76			.59					
184 females Grid 1 High Population		61.95	26.09	9.78	.54	1.09	.54							
106 males Grid 1 Low Population		14.15	15.09	12.26	16.04	11.32	8.49	3.78	3.78	9.43	3.78		.94	.94
51 females Grid 1 Low Population		19.61	25.49	21.57	9.80	9.80	7.85	1.96	1.96			1.96		
62 males Grid 2 Low Population		19.66	20.97	19.35	14.52	8.06	11.29	1.61	3.23	1.61				
36 females Grid 2 Low Population		22.22	22.22	25.00	13.89	8.33	8.33							
Average Distance Traveled by all males		38.17	23.67	11.24	7.69	5.92	4.73	1.48	2.07	3.25	1.18		.30	.30
Average Distance Traveled by all females		48.71	25.46	14.02	4.05	3.70	2.95	.37	.37			.37		

Trap Use

Directly related to determination of homestead area and distances traveled by rats is trap use. The number of captures of individual Sigmodon in relation to the number of different traps in which they were captured is shown in Figures 21 and 22. Animals captured on both Grid 1 and 2 from July 1960 through September 1961, when the population was low, are summarized together because of their similarity (Figure 21). There was an increase in the use of different traps with an increase in captures. Of 348 rats, 153 were taken in four or more traps, while 53 were taken in 8 or more traps. One male was captured 58 times in 26 traps. Figure 22 reveals that only 26 of 661 rats were captured in four or more traps. The majority were captured in one or two traps regardless of the number of times that they were captured. The greatest number of traps used by an individual during 1959-60 was eight traps. Fewer traps were used when the population was high and more were used when the population density was low.

Population Behavior

Disappearance, Known Survival and Population Turnover

Although mortality and longevity can rarely be completely measured in wild animal populations, the disappearance rates and known length of survival time can be used to give some measure of these factors. Figures 23 through 26 compares the known disappearance rates, and the length of time certain animals were known to have been alive. The first numeral of each horizontal series of numbers represents the number of rats marked each month. Each succeeding number represents the number of

Number of Livetraps

Number of Captures	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	19	20	26	Total
1	86																				86
2	5	38																			43
3	1	11	15																		27
4	2	3	10	16																	31
5		5	7	11	4																26
6		1	6	5	6	4															22
7					5	5	2														12
8		2	1	3	5	1	5	2													19
9			1	1	1	2	1	1													7
10			1		2		4	2	3												12
11					1		1	1	2												5
12					1	1	2			1											5
13						1	2	2	2	2											9
14		1					1		1	1											4
15							1		1				1								3
16				1	1		1	1		1				1	1						7
17										1	1			1							3
18						1		1					2								4
19										1	1			1							3
20						1															1
21								1								1					2
22							1			1											2
23									1		1			2							4
24										1											1
25																	1				1
27									1												1
32													1								1
33						1															1
35																			1		1
38																		1			1
40														1							1
44										1											1
55																1					1
58																				1	1
	94	61	40	36	26	16	22	11	11	10	3	0	4	6	1	2	1	1	1	1	348

FIG. 21. Number of captures of different Sigmodon in relation to the number of different traps in which they were captured. Animals captured on Grid 1 and 2 between July 4, 1960 and September 27, 1961 when the population was low.

Number of Livetraps

Number of Captures	1	2	3	4	5	6	7	8	Total
1	200								200
2	63	64							127
3	23	40	26						89
4	2	26	19	3					50
5	10	20	23	6					59
6	4	14	12	5	2	1			38
7	2	4	11	3	1				21
8		7	6	4					17
9	1	2	5	1		2			11
10	1	1	3	5	2				12
11		1	2	4	1				8
12		1		2			1		4
13				2	2	2			6
14			1	2	2		2		7
15						2		1	3
16					2	1			3
17				1			1		2
18				1					1
19			1						1
20					1				1
21			1						1
	305	180	110	39	13	8	4	1	661

FIG. 22. Number of captures of different Sigmodon in relation to the number of different traps in which they were captured. Animals captured on Grid 1 between October 16, 1959 and February 27, 1960 when the population was high.

Mo.	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
Oct.	134	78	59	20	14																				
Nov.		100	60	16	13																				
Dec.			31	7	6																				
Jan.				32	24																				
Feb.					17																				
Mar.						0																			
Apr.							0																		
May								0																	
June									0																
July										5	3														
Aug.											2	1													
Sep.												0													
Oct.													4	2	1										
Nov.														5	4	3	2	2							
Dec.															3	3	3	1	1						
Jan.																2	2	1							
Feb.																	4	3	1	1	1	1			Known alive into 8th mo.- 0
Mar.																		7	4	1	1	1	1		Known alive into 7th mo.- 2
Apr.																			4	1	1	1	1		Known alive into 6th mo.- 3
May																				3	2	1			Known alive into 5th mo.- 20
June																					7	4	2	1	Known alive into 4th mo.- 40
July																						28	20	9	Known alive into 3rd mo.- 104
Aug.																							16	5	Known alive into 2nd mo.- 223
Sep.																								48	Total marked first month- 458

FIG. 23. Population turnover, disappearance and survivorship of male *Sigmodon* from October 1959 to September 1961 on Grid 1.

Mo.	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
Oct.	173	99	64	21	19																				
Nov.		108	54	19	15																				
Dec.			22	7	5																				
Jan.				31	20																				
Feb.					13																				
Mar.						0																			
Apr.							0																		
May								0																	
June									0																
July										1															
Aug.											0														
Sep.												0													
Oct.													0												
Nov.														3	1										
Dec.															3	2	2	2	1	1					
Jan.																3	2	2	1						
Feb.																	6	5	3	2					
Mar.																		3	2	2					Known alive into 7th mo.- 0
Apr.																			3	1	1				Known alive into 6th mo.- 1
May																				1					Known alive into 5th mo.- 20
June																					1				Known alive into 4th mo.- 41
July																						12	9	4	Known alive into 3rd mo.- 102
Aug.																							11	3	Known alive into 2nd mo.- 205
Sep.																								29	Total marked first month- 423

FIG. 24. Population turnover, disappearance and survivorship of female Sigmodon from October 1959 to September 1961 on Grid 1

Mo.	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
July	6	5	3	2	1	1										
Aug.		10	4	4	2	1	1	1	1	1	1	1	1			
Sep.			1	1	1											Known alive into 13th mo.- 0
Oct.				3												Known alive into 12th mo.- 1
Nov.					6	6	4	3	2	1	1	1				Known alive into 11th mo.- 1
Dec.						3										Known alive into 10th mo.- 1
Jan.							1	1	1							Known alive into 9th mo.- 1
Feb.								6	5	3	2	1	1	1	1	Known alive into 8th mo.- 2
Mar.									5	5	1					Known alive into 7th mo.- 3
Apr.										1	1					Known alive into 6th mo.- 4
May											1					Known alive into 5th mo.- 5
June												8	6	3		Known alive into 4th mo.- 9
Jul.													11	4		Known alive into 3rd mo.- 20
Aug.														3	1	Known alive into 2nd mo.- 39
Sep.															19	Total marked first month - 84

FIG. 25. Population turnover, disappearance and survivorship of male Sigmodon from July 1960 to September 1961 on Grid 2.

Mo.	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
July	6	4	1													
Aug.		5	3	3	1	1										
Sep.			0													
Oct.				4	2	1										
Nov.					1	1	1	1	1	1	1	1	1			
Dec.						1	1	1	1	1						Known alive into 10th mo.- 0
Jan.							1	1	1	1	1	1	1			Known alive into 9th mo.- 1
Feb.								4	4	3	3	2				Known alive into 8th mo.- 1
Mar.									1	1						Known alive into 7th mo.- 2
Apr.										1	1	1	1			Known alive into 6th mo.- 2
May											8	5	5	3	1	Known alive into 5th mo.- 7
June												3	1	1	1	Known alive into 4th mo.- 12
Jul.													6	3	1	Known alive into 3rd mo.- 19
Aug.														2	1	Known alive into 2nd mo.- 28
Sep.															7	Total marked first month - 50

FIG. 26. Population turnover, disappearance and survivorship of female Sigmodon from July 1960 to September 1961 on Grid 2.

animals that were present during later periods.

Disappearance and known survival rates for males, Figure 23, and females, Figure 24, are shown for the time period extending from October through February of 1960-61. All of the males and females captured during this period disappeared by March regardless of when they were first captured, since a complete population decline had eliminated all rats. Males and females disappeared at about the same rate (Tables 23 and 24).

Male and female rats captured from July through September of 1960-61 (Figures 23 and 24) disappeared at a less rapid rate than those rats captured previous to this period. Two males were known to have survived into the eighth month while one female survived into the seventh month. Complete turnover can then be said to have occurred within about five months, for the first period, and within eight months for the second period.

Known survival was somewhat better on Grid 2 than on Grid 1 for the same period. The data do not reveal the reason for this. One male was known to have survived at least 12 months while one female survived at least nine months. Since Grid 2 is enclosed on three sides by dense woods, with little ground cover, rats might have used the grid area moreso than on Grid 1 where rats might have drifted off the area, although they may have still been alive. Except for five rats on Grid 2, the disappearance rates were about the same for both grids for the same time period.

Disappearance of animals is shown to be about equal for both high and low populations except for the second month for the low population where survival from the previous month was ten per cent less, and in the fifth month where the survival was ten per cent greater (Table 9). The

TABLE 9. Population turnover, disappearance and survivorship total of 1,009 *Sigmodon* from Grid 1 and 2.

Months From Time First Marked	Disappearance and Survivorship					
	Grid 1-Oct. 1959 to Feb. 1960 High Population			Grid 1 and 2-July 1960 to Sept. 1961 Low Population		
	No. Known Alive	Per Cent of Total Alive	Per Cent Alive From Previous Month	No. Known Alive	Per Cent of Total Alive	Per Cent Alive From Previous Month
Total Marked First Month	661	100.00		348	100.00	
No. Known Alive Second Month	349	52.80	52.80	147	42.24	42.24
No. Known Alive Third Month	169	25.57	48.42	76	21.84	51.70
No. Known Alive Fourth Month	69	10.44	40.83	33	9.48	43.42
No. Known Alive Fifth Month	33	4.99	47.83	19	5.45	57.58
No. Known Alive Sixth Month	0	.00	.00	8	2.30	42.11
No. Known Alive Seventh Month				5	1.44	62.50
No. Known Alive Eighth Month				3	.86	60.00
No. Known Alive Ninth Month				2	.57	66.67
No. Known Alive Tenth Month				1	.29	50.00
No. Known Alive Eleventh Month				1	.29	100.00
No. Known Alive Twelfth Month				1	.29	100.00
After Twelfth Month				0	.00	.00

complete disappearance of rats that occurred on Grid 1 disallowed measurements after the fifth month. Disappearance is seen to have occurred at the rate of 40 to 60 per cent of the previous monthly total. This was so until about the tenth month when only one animal remained.

Population Fluctuations

Population fluctuations were exceptionally irregular for *Sigmodon* during the term of this study (Figure 27). When trapping began during October of 1959, rat numbers were high on Grid 1. The rate of catch per trap night ranged from 60 to 114.6 per cent. Although daily catches varied from October through December, there had been no indication that the population either was increasing or decreasing. During February 1960, the numbers decreased sharply to zero, especially in the second one-half of the month (Table 1, Figure 27). No rats were captured on the grid after February 27, 1960, until a capture was made on July 4, 1960. From October 16, 1959 through February 27, 1960 a total of 661 *Sigmodon* had been marked and captured 2,435 times, yet not one was known to have been on the grid after February 27, 1960. On July 4, 1960, the first cotton rat since the previous February 27 was trapped there. Only eight rats were known to have been on the grid during July, August, and September of 1960 even though all 171 livetraps were in operation 73 of 92 days in the quarter. During the next six months the numbers of *Sigmodon* increased slowly. Through reproduction and immigration numbers of rats increased through March 1960, after which there was a slight decline. During the last four months of trapping the population density increased sharply.

The population on Grid 2 fluctuated less than on Grid 1, for the same period. *Sigmodon* known to have been on this grid ranged from nine to 31 individuals per month.

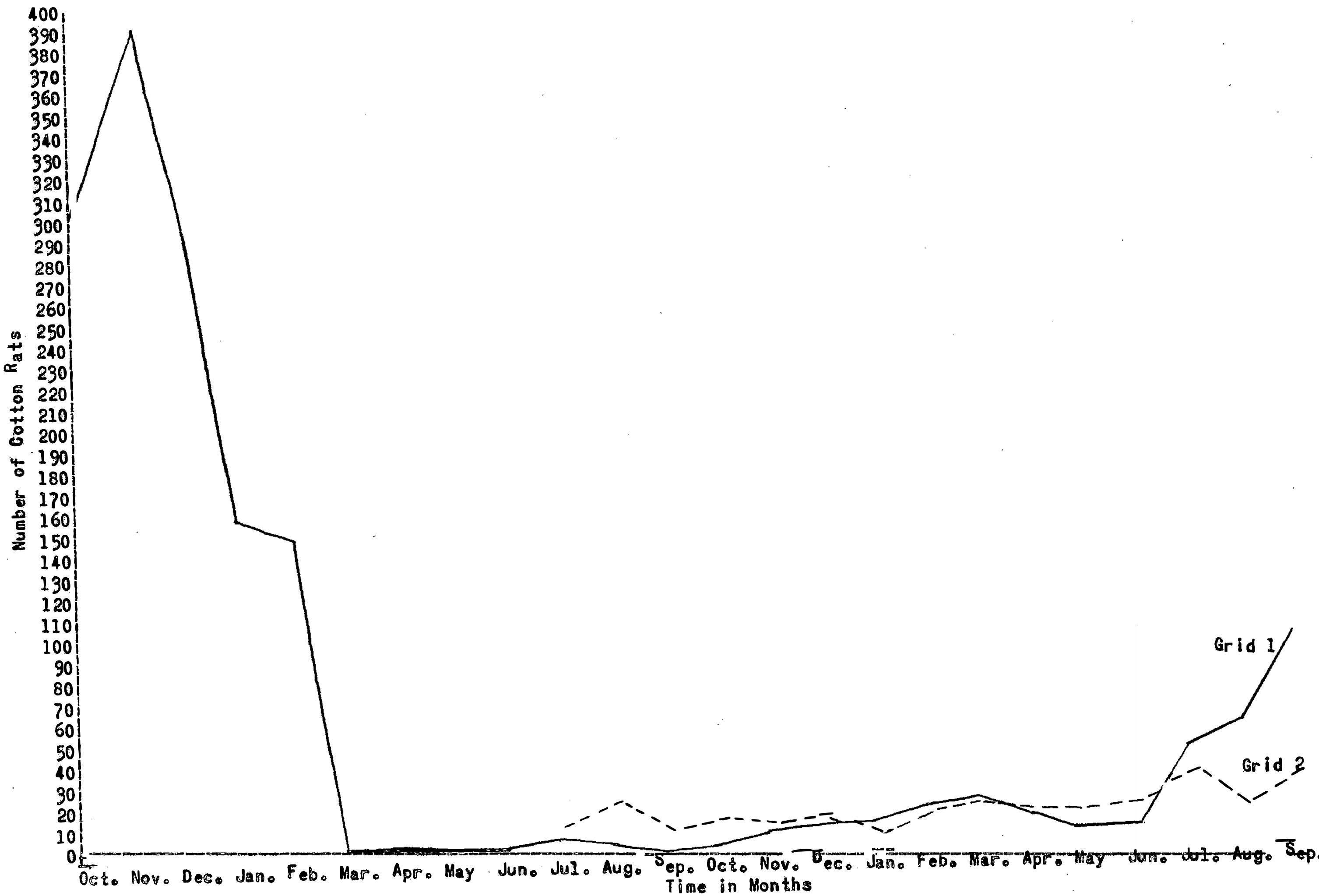

FIG. 27. Numbers of individual <u>Sigmodon</u> known to have been on Grid 1 and 2 October through September of 1959-1961.

CHAPTER V

DISCUSSION

The interpretation of these data can be considered in two contexts, namely: habitat and population behavior. Although habitat and population are thus separated, they are intimately interrelated. Habitat, of course, determines carrying capacity and this in turn is related to population density.

Habitat

The primary concern of the present study was with marginal and superior *Sigmodon* habitat. The cotton rat manifests an intense preference for dense mixtures of perennial grass and grass and forbs extending well "overhead" in height. These cover types, however, vary in species composition, density and height from locality to locality. For example, in the Stillwater, Oklahoma area, *Sigmodon* were found in a variety of grass-forb associations which provide dense cover. Elsewhere in Oklahoma cotton rats were found in sedge marsh associations (Blair, 1938), intermontane meadows (Glass and Halloran, 1961), tall grass along fence rows and terraces (Hayes, 1958), tall grass prairie (Frank, 1940); Phillips, 1936; and Smith, 1940), and mixed grass-forb associations (Schendel, 1940).

In Texas, cotton rats have been said to occupy tall grass and weeds (Bailey, 1905), high grass (Halloran, 1942), sedge meadow and drop-seed (Inglis, 1955) and tall grass prairie (Stickel and Stickel, 1949). In Kansas they have been found in sunflower-tall grass and riparian situations (Hill and Hibbard, 1943) and in Nebraska in dense stands of slough grass (Jones, 1960).

Elsewhere, in the south, Sigmodon have been reported in grassy fields and pastures (Howell, 1921), mixed broomsedge and Lespedeza in Missouri (Leopold and Hall, 1945), broomsedge associations in Virginia (Patton, 1941), sedge marsh and broomsedge associations in Georgia-Florida (Stoddard, 1931), beneath rank marsh vegetation (Svihla, 1930) and under tall thistle and grass (Svihla, 1931) in Louisiana, whereas in coastal Florida they have been reported to occur in sea oats (Sumner, 1926).

In dryer regions, for example, in the Imperial Valley of California (Dixon, 1922), the Colorado River Valley of California (Dice, 1923) and in southern Arizona (Burt, 1933), Sigmodon were reported to be restricted to those riparian associations where cover was dense. It is recognized that several sub-species of Sigmodon are referred to above and that cover preferences may differ somewhat between these sub-species from one geographical area to another.

According to Inglis (1959), cotton rats in the Texas Panhandle invaded only those upland sites with the most dense ground cover. Marginal areas were found to be occupied by cotton rats during certain years when rainfall was sufficient to enable grassy cover to become more dense in these areas than usual. He found that not only grass, but also that density of stand increasing to the extent that forbs met and shaded a large proportion of ground provided satisfactory, but emphemeral, cover for Sigmodon. Further, he states: . . . "dense ground vegetation is required for the animals to be found in any location." Inglis noted that dense stands of grass such as broomsedge and bluestem and other mid and tall grasses were preferred by cotton rats. Grasses such as silver beardgrass, however, which showed the same life-form physiognomy as broom-sedge and bluestem, were much poorer cover presumably due to their low growth form.

McCulloch (1959) has shown that cotton rat density varied with the intensity of grazing and that where grazing was least intense more Sigmodon were captured. Stoddard (1931) recommended that areas of dense vegetation be burned every few years to suppress Sigmodon numbers. Bailey (1905) had suggested the same thing for field edges. On the coastal prairie of Texas, both grazing and burning severely reduced the numbers of cotton rats (Baker, 1940). Stickel and Stickel (1949) found Sigmodon common in unburned tall grass prairie, but rare in burned prairie that was nearly identical except for the absence of the mat of dead grass.

From this review, it is apparent that "cotton rat habitat" varies from one locality to another in plant species composition. Nevertheless it usually includes tall and dense grass associated with various forbs and shrub species, which provide overhead cover, as well as food and nesting material. With the removal of cover, there is a decrease or total reduction of Sigmodon (Figures 2, 4, 5, 7, 8). A similar relationship seems to hold also with the lemming (Lemnus trimucronatus), where population declines occur every three to four years generally due, at least in part, to the destruction of food and cover (Pitelka, 1957; Ratcliffe, 1958; and Thompson, 1955).

The results of this study overwhelmingly support the observations reported in the literature that cotton rats prefer a dense ground cover (Figures 2 to 7). Where the population was low there was a tendency for this species to be captured only where the height and density of cover was high (Figures 2, 4, 5 and 7). Under these conditions, captures were relatively poor at trap sites with a cover density of less than 40 to 60 per cent and with a cover height of less than 10-20 cm. It appears that cover must be at least 10 to 20 cm in height to be attractive to Sigmodon. Even though the stand of grass may be dense, lawns, heavily grazed pastures and mowed areas do not provide habitat for Sigmodon. In the Lake Carl Blackwell area, cotton rats did not live in situations where the conditions of height and density of grass cover did not combine to provide a dense over-head cover for them.

During the fall and winter of 1959-60 on Grid 1, however, as well as during the summer of 1961 when the population was high, cotton rats occupied most trap sites (Figures 3 and 6) in considerable numbers. Trap sites that were not used when the population was of low density, which are here recognized as marginal situations, were used during the high population. Baumgartner (unpublished notes, as reported by Schendel, 1940), found as many rats in sparse growth as in dense growth during the high population of 1938. This was on the same general area as where this study was carried out, and comparable to the results presented in Figure 6.

Although Sigmodon were captured at all levels of height and density of cover, when the population was high, captures at lower levels of cover density were fewer than at higher levels of cover density (Figures 3 and 6). With about 25 rats or more per acre (Table 1), population pressure may be presumed to have "forced" cotton rats into what, under conditions of low population, would be considered inferior or marginal habitat. At high densities, captures might be expected of rats at almost every trap station regardless of the cover condition of the situation. McCulloch (1959), for example, found cotton rats in sparse cover only when the population was high. Stoddard (1931) found that, when abundant, Sigmodon fed out over adjoining fallow fields and lands of open cover for long distances. Cotton rats are known to use the heavy cover of field edges and to travel into the tilled areas some distances to forage (Bailey, 1905; Harper, 1929; Silver, 1924; Strecker, 1929; and Svihla, 1929). Lay and Baker (1935) reported that while cotton rats ranged into woods, they were trapped only one to ten yards inside the edge of the woodland from a grassy field. Schendel (1940) found that both upland and lowland timbered areas around Lake Carl Blackwell were not inhabited by cotton rats. Conversely, in southwestern New Mexico, as the vegetation became more sparse and more typical of disturbed areas, increasing percentages of S. hispidus were taken (Mohlhenrich, 1961). Mohlhenrich concluded that neither lack of suitable vegetation nor amount of rainfall directly affects the distribution of cotton rats in New Mexico. This observation is singular in this respect. Whether Mohlhenrich's study was conducted during high, moderate or low population was not pointed out. Results of this study show the cotton rat to be in sparse cover only during high population levels (Figures 3, 6, 8).

It has already been shown that Sigmodon did not use areas where a tree canopy shaded out ground cover nor where the cover was mowed. On the cover sampling of transects, rats were caught infrequently where tree canopy excluded ground cover. Of a total of 425 snaptrapped rats, 413 were captured where density of grass was 60 per cent or greater and where the tree canopy was less than 20 per cent of coverage. There was a negative correlation of per cent capture with tree canopy, and opposing this, a strong positive correlation of per cent catch to both density and height of cover (Table 2).

Where, and how many cotton rats are captured at any given place depends not only on the quality of the habitat but upon the numbers of animals present and probably the time of the year. Evans (1942) found that the extent of distribution of Clethrionomys appeared to be associated with its relative density and that population survival from a period of high density to one of low density appeared to be greatest in those habitats which had normally maintained a low population density, suggesting a density-dependent relation. He hints that habitats which maintain only low densities may be essential to the ultimate survival of a species. This was not the case with cotton rats captured during this study. After the total decline (Table 1, Figure 27), rats were found only in superior habitat (Figure 2). This agrees with the findings of Naumov (1936), who reported that when a population was at its lowest density, it occupied only the most favorable habitats; as density increased, individuals were forced into less favorable habitat situations until a maximum density was reached, when all possible habitat situations were occupied.

The first rats taken after the decline were trapped from 11 of the 45 snaptrap transects during April, May and June of 1960. Transect 31 accounted for 21 of the 51 Sigmodon trapped during this period. This transect was located in a dense stand of little bluestem and big bluestem mixed with a decadent stand of winged sumac. Similar areas acted as "reservoirs" where Sigmodon were able to survive. Both on Grid 1 (Figure 1-B, line 7) and on Grid 2 (Figure 1-C), a clump pattern of distribution of Sigmodon was evident. This clumping occurred in those areas where the height and density of grass and forbs was greatest.

Dice (1952) refers to habitat as the situation in which or on which any community, species, or individual lives with the habitat of a species including other species or organisms as well as the physical features of the habitat. Elton (1949) defined habitat as an area which seems to possess a certain uniformity with respect to physiography, vegetation, or some other quality which the student decides is important. Andrewartha and Birch (1954) use the phrase, "a place in which to live" instead of using "habitat." Stebler (1957) defines habitat as a place where the species satisfies its vital needs, including: food, shelter, living space and a place in which to reproduce. These ingredients are the niches. It seems appropriate to use the life-form classification system as an approach to the problem of habitat description (Pitelka, 1941; Stebler and Schemnitz, 1955). The life-form system of Du Reitz (1931) divides plants into three main life-forms: Woody plants, half shrubs, and herbaceous plants. Of these three categories, the herbaceous life-form seems most characteristic of Sigmodon habitat. This form can be categorized into the following:

High herbaceous grasses and forbs (more than 2 m)
Tall herbaceous grasses and forbs (0.8 to 2 m)
Mid herbaceous grasses and forbs (0.25 to 0.8 m)
Short herbaceous grasses and forbs (less than 0.25 m)

Of this group, it is evident that the short herbaceous category can be eliminated, since the growth form is short. Large expanses of short grass, for instance, are not known to support Sigmodon, or to sustain them for more than a short period (Figures 2, 4, 5, 7 and Table 2; Baker, 1940; Inglis, 1959; McCulloch, 1959; Phillips, 1936; Stickel and Stickel, 1949; and Stoddard, 1931). The remaining three categories fit well with the descriptions given of where Sigmodon lives throughout its entire range. Of the two herbaceous forms, grass seems the more important (Table 2). It would be difficult to dissociate forbs and certain shrub forms from the grass associations in which cotton rats are found, since they are an integral part of the association and in many cases are used as food and cover by Sigmodon. Of the two forms of grasses, perennial and annual, the perennials appear to be the more important (Table 2). Then, the single most important component of the habitat of Sigmodon, as far as plant life-form type is concerned, appears to be moderate to dense stands of mid to high perennial grasses. Such situations become more valuable, as a place for Sigmodon to live, as plant litter (Table 2) accumulates on the ground.

No clear-cut evidence was found to indicate that forbs and low-growing woody species were essential components of cotton rat habitat. "Cover value forbs" and sumac and plum appear to be positively correlated with per cent catch of cotton rats sometimes and at other times not correlated at all (Table 2). However, considerable use of certain forbs, sometimes, was known to have occurred. Almost all of the heads of sunflower and the stalks of lespedeza were cut and the seeds presumably eaten by cotton rats during the high population on Grid 1. Schendel (1940) found that as much as 97 per cent of the western ragweed stalks of a stand were cut by cotton rats on some pastures near Lake Carl Blackwell in 1939. This, however, took place also during a period of high population.

The evidence presented strongly suggests that Sigmodon are limited to those areas within their range where the density and the height of perennial grassy cover, and at times, associated forbs and low growing woody species, combine to provide dense over-head cover (Table 2). For example, during low populations cotton rats were found where perennial grasses and their plant associates reached a density of at least 60 per cent in combination with a height of at least 100 to 175 mm, in addition to the presence of grassy litter. It is presumed that an area of at least several acres in extent of such cover, which must be relatively undisturbed, is necessary to the welfare of Sigmodon. Areas like this provide a habitat for Sigmodon in which individuals are able to survive the usual regulatory forces affecting them. Because of its completeness relative to the cover needs of Sigmodon, vegetal growth like that described above is considered "superior habitat." "Marginal habitat," on the contrary, lacks one or more of the essential cover elements. For example, height or density or both may be deficient. In this light, it is suggested that through the removal of dense, overhead ground cover as by clearing field edges, grazing, mowing, plowing and burning that habitat situations favoring Sigmodon would be destroyed. This could be expected to be detrimental to this species. Before such cover is destroyed to achieve this aim, however, it is essential first to recognize what the effects might be on other, more generally desired wildlife forms.

Population Behavior

Affecting any animal population are a number of factors that serve to regulate its numbers. These factors are discussed in great detail by a number of major works (Allee et al., 1949; Andrewartha and Birch, 1954; Dice, 1952; Elton, 1942; Lack, 1954; and Slobodkin, 1962).

Sigmodon appear periodically subject to extreme fluctuations in numbers. During 1957-1958-1959 numbers of Sigmodon were found over broad areas in Oklahoma and Texas (Davis, 1958; McCulloch, 1959). High populations were also known to have occurred in Texas in 1854, 1886, 1889 (Allen, 1896; Anthony, 1917), in Oklahoma in 1936 and 1939 (Blair, 1938; Schendel, 1940), Arizona in 1923 or 1924 (Silver, 1924), Georgia in 1925-26 (Stoddard, 1931), Texas in 1928 (Strecker, 1929), Tennessee in 1933 (Komarek, 1937), south Georgia in 1946-48 and 1952 (Odum, 1955) and Missouri in 1949-50 (Schwartz and Schwartz, 1959). The majority of these highs were followed by low populations.

The cause of the Sigmodon "crash" that occurred on Grid 1 is not at all clear. Animals were known to have fleas, mites, lice, ticks, encysted cestodes, intestinal trematodes and cestodes and a variety of nematodes. Throughout the two years of the study, parasites were noted in decreasing, stable and increasing Sigmodon populations. Even if it could have been established that certain parasites had been more than ordinarily numerous in the "crashing" population it would still have been difficult to prove that the parasites in themselves caused the "crash," since they are found in stable as well as irrupting populations.

A reduction of food and cover on a given area is often cited as the cause of population decline. According to Pitelka (1957); "Winter cutting of vegetation and the resulting removal of food and cover exposed peak densities of lemmings to predation, which is the usual agent figuring in the inevitable decline of the population." During September of 1959, about one-third of Grid 1 was mowed for hay. The area mowed was not sufficient in quantity or quality of cover, presumably, to protect Sigmodon from either predation or weather. Baited traps may have acted as the main attraction in enticing rats into the mowed area, since only the basal part of the stems and leaves were left as cover and this usually did not exceed 100 mm in height from the soil. It has already been shown that few rats used these areas. Most of the rats caught in the mowed areas were presumably sub-adult dispersants. The effect of this mowing and subsequent removal of cover on the Sigmodon population is not completely known, but it is reasonable to assume that it probably was population limiting.

To what extent the physiology of the animal is impaired by physiological changes caused by shifts in population and crowding in wild populations is not entirely understood. Recurrent declines in the numbers of the vole, Microtus agrestis, seem to be associated with a pathological condition, which has yet to be diagnosed (Chitty, 1957). Crowding has been shown to decrease fecundity (Christian and Lemunyan, 1958; Crowcroft and Rowe, 1957), induce splenic hypertrophy (Chitty, 1957; Christian, 1950; Lauch, 1958) and decrease lactation (Christian, 1950). Chitty and Phipps (1960) reported that spleen weights increased in white rats, mice and voles subjected to dense flea infestation. Animals were not examined for either the "shock disease" of Green and Evans (1940), adrenopituitary exhaustion of Christian (1950), nor splenic hypertrophy of Chitty (1957). It must be recognized that any one of these conditions may or may not have been associated with the population decline on Grid 1 as induced by the animals themselves or by the habitat, but no evidence was brought forth in support of any of these.

One of the major extrinsic factors often thought of as working on wild animal populations is weather (Andrewartha and Birch, 1954). The year 1959 was marked by thirty-one inches of rain in excess of the long term average of approximately 30. This abnormal amount fell for the most part in July (17 inches), September (11 inches), and October (12 inches). Since traps had not been set previously to these periods of heavy rain, the effect, if any, that the rains may have had in relation to trap response was not measured. Flooding at lower levels could have forced additional numbers of Sigmodon onto Grid 1 during September and

October, in addition to those forced to better cover by mowing during the same period. Heavy rains that fell at various times while trapping operations were being conducted seemed to have little effect on population numbers even though traps were set continuously before, during, and after the rains. Rats were found to occupy areas previous to, and immediately after flooding. Some rats were trapped just before the area was flooded and were drowned in the traps, while other rats were known to have occupied traps within hours after flood waters had receded.

The fall and winter of 1959-60 was colder than usual (U. S. Dept. of Commerce, 1959-60). November had three periods, and January two periods when temperatures went below 15°F for a series of consecutive nights. December was somewhat warmer than usual. February began with warm temperatures. From February 10 to February 23, day time highs averaged from 30° to 60°F and night time lows ranged from 16° to 29°F, except for one day. An extremely cold period began the night of February 23 and lasted until March 5, during which time the nighttime lows ranged from 1° to 22°F, and daytime highs from 19° to 28°F. In addition to the abnormally cold weather, there was snow on the ground from February 22 to March 9, 1960. It had rained intermittently for two days, with the ground freezing, previous to the snowfall.

This long period of below-freezing weather, with snow on the ground and the ground frozen coincided with the *Sigmodon* population decline, and if not one of the primary factors involved, it appears at least to have been a contributory one. This decline actually seems to have begun before this abnormal period of weather (Figure 27). Although per cent capture per trap night dropped from 35 per cent at the first of February to only 14 per cent during the middle of February, the population may not have been as low as suggested by these data, because of low temperature (16° to 39°F) during the trapping period. On February 26, traps were opened during a sleet and snow storm. The next day only four rats were taken, a 2.4 per cent capture. Weather was so adverse, however, that the capture rate was assumed to have been lower than it would have been otherwise. No rats were taken thereafter until July. Rats were not observed to move about in the snow. Several observational trips were made to Grid 1, when snow was on the ground and rats were known to have been on the area. During these visits no tracks of rats were found in the snow. Long periods of severe winter weather of this type appear to "immobilize" rats to the point where they are not able to forage. If so, they would starve and die.

Whether this total reduction of the Sigmodon population would have occurred regardless of weather conditions is uncertain. The decline in population previous to this cold, snowy period may have been a rapid seasonal reduction, which would have declined to a "low," but likely not totally. Assuming that the severe winter weather was a contributing factor of major importance in the decline, then, the population can be said to have been limited by a density-independent factor, on Grid 1. However, it is known that rats did survive in certain presumably favorable situations, the more favorable ones. Thus, climate acted indirectly as a density-dependent factor through the preservation of those indivduals that occupied superior habitat. This is in concurrence with Dice (1952). That is, rats associated with dense and tall stands of grass and probably ground litter were able to survive, while areas without these elements were not able to support cotton rats. Andrewartha and Birch (1954) declared that density-independant factors do not exist, a view which tends to be supported by this investigation. Weather also may have served to catalyze some other action, the effect of which was to destroy the population, a view proposed by Nicholson (1954).

Chitty (1960) reviewed the views both of Andrewartha and Birch (1954) and of Nicholson (1954) in this regard: "Both theories already include enough qualifications to make such a synthesis possible. The vole work suggests that population densities are indeed governed or regulated, but that this is most commonly achieved by the action of the physical factors and since the action of any factor depends upon the properties of the individual, it seems a priori improbable that the effects of weather are independent of population density."

During the warming trend which followed the severe weather, a number of reconnaissance trips were made over the area in addition to the routine trapping. It was noticed at that time that predatory animals had dug out numbers of cotton rats, as evidenced by remains, in addition to cotton rat nests and small patches of ground litter. During March, the larger, fresh fecal remains found on the area contained cotton rat hair and bones. Since few, if any, cotton rats were presumed alive on the area, as indicated by trapping results, it was assumed that predatory animals were feeding on cotton rat remains that they had found or dug out after the snow and frozen ground had thawed. This suggests further that this period of abnormal weather did reduce the numbers of Sigmodon that were on the area at the time. During this same period near Oak Ridge Tennessee, Dunaway and Kaye (1961) experienced an almost total reduction of Sigmodon in their trapping results. Where rats were known to have been on their trapping areas February 24, 1960, they had disappeared by March 8, 1960. They made captures on April 6 and 14 in areas of dense cover, but none after that through July 1960. The reduction of the population was attributed to severe cold and snow.

A similar population decline was reported by Schendel (1940), also, as with this study, in the vicinity of Lake Carl Blackwell, Payne County, Oklahoma. The 1939-40 crash and the 1959-60 declines had these factors in common: 1) high summer and fall populations, 2) extensive periods of severe winter weather, 3) complete stoppage of cotton rat activity during the snow period followed by, 4) complete elimination of populations in some habitats with survival in only a few areas. It appears more than coincident that severe winter weather will decimate Sigmodon that are not situated in the most ideal habitat situations.

Repopulation of marginal habitat is believed to take place from the "reservoirs" of rats that survive in the superior locations. This is done when conditions again become suitable, that is, with spring and summer vegetative growth and rat reproduction. The animals that appeared on Grid 1, in the summer of 1960, after the "crash" are believed to have originated from one or more areas of dense ground cover which were considered superior habitat. All of these animals were young of the year. Some of these rats seemed to have been wandering, since their measured homesteads were large and in many cases they were caught only once in certain areas, after which they wandered elsewhere.

Sigmodon is generally considered to be a southern animal. It may very well be that the cotton rat is subject to great fluctuations in numbers at the northern periphery of its geographic range. In the central part of the United States, S. hispidus recently has extended its geographic range northward in Kansas approximately 100 miles in the fourteen years from 1933 to 1947 (Cockrum, 1948). In eastern Kansas, the winter of 1948-49 was much more severe than several of those immediately preceding it. Ice, snow and sleet covered the ground for about a month. After this period cotton rats were scarce. The following winter was mild, and by the summer of 1950 cotton rats were again numerous (Cockrum, 1952). Cockrum suggests that the northern expansion of the cotton rat may be inhibited or set back during severe winters, while mild winters may permit a northward expansion. The first record of a cotton rat in Missouri, according to Schwartz and Schwartz (1959) was in 1945. Jones (1960) found cotton rats in Nebraska for the first time in 1958.

To what extent the geographic range of Sigmodon has varied in the past is not entirely known. The presence of Sigmodon in the upper Pliocene Rexroad fauna of southwestern Kansas indicates that the winters then were no colder than at present (Hibbard, 1941). Hibbard (1958) also found Sigmodon in the Aftonian faunas of various states and the Yarmouth local faunas of Kansas. These periods were also mild. Certain of the faunas, the Cudahy fauna, for example, of southwest Kansas were boreal in nature with species such as Microtus and Synaptomys being abundant (Hibbard, 1944). Sigmodon is apparently absent from these cool climate faunas.

It can be assumed that Sigmodon range may vary then, historically, with the species advancing northward during mild periods and receding during extended cold periods. Extensive cold and snowy periods during a single winter may cause severe reductions or a "crash" decline in local populations while extended periods of cold may eliminate the species over large peripheral areas of its range. The data presented and found in the literature serves to emphasize the vulnerability of Sigmodon to severe wintry weather.

What may be recognized as superior habitat is used by Sigmodon during population lows and marginal areas are used more extensively during highs. From a review of the literature and experimentation Stickel (1960) concluded that homerange, that is the homestead area, of a species may vary widely in response to many different factors including habitat, breeding conditions, population density, and food supply. She found that, for another species, Peromyscus leucopus, larger home ranges were associated with smaller populations, and that males ranged further when populations were small.

According to the present investigation, Sigmodon homesteads were smaller when the population was dense (Figures 9 and 10, Table 7) and larger when the population was sparce (Figures 11 through 14; Table 7). The same relationship is shown by the greatest distance traveled between any two trapsites (Figures 15 through 20; Table 8). In low populations, males (Figures 12 and 13; Table 7) are shown to have had larger homesteads and to have had traveled greater distances between traps than females (Figures 11 and 14; Table 7).

At times it is possible that males and females wander about (Figures 11 and 12), and do not have what is normally thought of as a definite homestead area. Harrison (1958) stated that he had abandoned the idea of home range in favor of the idea that an individual has a center of activity surrounded by a series of concentric probability zones within which the rat (Rattus spp.) spends varying proportions of its time. This, of course, is a rather statistical concept. In the present study, males moved the greater distance (Figures 18 and 19). When wandering, cotton rats must traverse many marginal areas and this may account for some captures where the vegetation is of low height and density.

It is conceivable that Sigmadon can quickly reinvade marginal areas from whence others of its kind had disappeared. This appears to be what had happened after the winter of 1959-60. At this time, Sigmodon survived only in some areas of dense grassy cover. Upon moving onto the grid during July of 1960, male No. 644 was known to have traveled the following distances: 66 feet in one day, 355 feet in 8 days, 608 feet in 4 days, and then 272 feet in 25 more days. This rat then apparently settled down some 880 feet from where it had entered the grid. Female No. 642 was known to have traveled 795 feet in one night during the same period.

It is also conceivable that cotton rats actually occupy marginal habitats and survive there along with their progeny as long as conditions are not rigorous. Stickel (1946) found that most animals taken in previously trapped out areas were those from adjacent areas. It is assumed that cotton rats spread out from "reservoir" situations to reoccupy unused marginal habitat in the same way.

Homesteads as well as movements of Sigmodon have been reported by a number of authors. Howell (1954), for example, gave 1.06 to 1.27 acres as homestead for males captured 11 to 16 times, and .51 acres for a female captured 13 times in Alabama. Fitch (1958) gives 2.03 acres for a male and 1.11 acres for a female as the largest homesteads for cotton rats he studied in Kansas. He found that the average homestead was .65 acres for males and .45 acres for females, with homesteads increasing in area with the number of captures. Hayne (1950) stated that an animal's home range, as revealed by trapping, tends to increase with the first few captures and then to increase less rapidly or apparently to reach a maximum area not altered by further captures. Blair

(1942) reports that homesteads based on less than ten captures are likely to be incomplete. Stickle (1946) found that four captures were sufficient to show the maximum movements of Peromyscus within a week.

In this study, homestead area was associated with number of captures (Table 7). When populations were dense, there was less correlation between homestead area and the number of captures (Table 4, Figure 22) than when populations were sparse (Tables 5 and 6, Figure 21). It appears that the number of captures properly should be considered when comparing the homestead area and distance traveled by Sigmodon. During the high population, the average homestead area for rats captured 15 to 28 times was .60 acres. In the sparse population, the average was 3.30 acres on Grid 1 and 1.38 acres on Grid 2 (Table 7). Also, when the population was sparse, males used a homestead greater in area than that used by females (Table 7). Homestead areas during dense populations were of about the same size for both males and females (Table 7).

A number of authors list travel distances of cotton rats. Hays (1958), in Oklahoma, found that the average distance that 16 males traveled was 292.5 feet, while 15 females traveled an average of 302.9 feet. Erickson (1949) showed that some males traveled at least 200 feet and females 130 feet on the Savannah River Refuge in South Carolina. In Texas, Stickel and Stickel (1949) reported 279 feet as the greatest distance traveled by males and 94 feet as the greatest distance traveled by a female. The greatest distance traveled by a male during this study was 1,300 feet, and by a female was 1,007 feet (Figures 17 and 18). About 55 rats were known to have traveled a distance of at least 500 feet (Figures 17 and 20) when the population was scant, while only 2 ranged this far when the population was high (Figures 15 and 16). Distances traveled were much smaller when the population was high than when it was low (Table 8). This shows that there were significant differences in travel and homestead areas that were dependent upon the size of the population. These results, therefore, are in agreement with the findings of Dice (1952). This behavior allows rats to rapidly invade areas not already occupied. For control or suppression, this has important implications, since, if there is a desire to reduce a rat population, rats should be controlled in the "reservoir" areas before they emigrate to other areas.

There are few references in the literature, which cite probable age and disappearance rates for Sigmodon. Odum (1955) reported one female that was known to have lived at least 159 days, and he assumed complete population turnover to take place in about six months. Hays (1958) mentioned one cotton rat as having lived at least five months and one day, and McCulloch (1959) reported that one female lived at least seven months. Of 1,009 Sigmodon livetrapped during this study, about 50 per cent disappeared by the second month, 76 per cent by the third month, 90 per cent by the fourth month, 95 per cent by the fifth month and 98 per cent by the sixth month (Table 9). On Grid 1, the 661 rats marked between October 16, 1959 and February 27, 1960 had disappeared by March (Figures 23 and 24). During the low population, eight cotton rats were known to have lived into the sixth month, five into the seventh month, three into the eighth month, two into the ninth month, and one male, captured 58 times, was known to have lived as long as twelve months. About 50 per cent of the population can be said to turnover by the second month, with complete turnover varying from 5 to 7 months to as long as 12 to 15 months.

CHAPTER VI

SUMMARY AND CONCLUSIONS

Objectives of this investigation were to study population ecology of the hispid cotton rat, Sigmodon hispidus texianus, under conditions of superior and marginal habitat. Data were collected in the following manner: by comparing the vegetation found at livetrap and along snaptrap transects, to the numbers of cotton rat captures at these locations; by livetrapping, marking and releasing rats on grids of 16 and 20 acres; and by snaptrapping on transects.

The habitat preferences, area of homesteads, greatest distances traveled, disappearance rates, and populations fluctuations of the cotton rat were considered.

Field work was carried out between September 15, 1959 and September 27, 1962 within the vicinity of Lake Carl Blackwell, Payne County, Oklahoma.

During 24 months, some 3,453 individual rodents were trapped in a total of 74,206 trap nights, and including recaptures, these animals were trapped 10,016 times. Of this number, 1,009 cotton rats were captured 4,734 times in livetraps while 425 were taken in snaptraps.

A total of 4,904 one-meter transects and corresponding vegetation measurements were analysed statistically with the result that the per cent of catch of Sigmodon correlated positively with the density and height of grassy cover. In addition dense tree canopy was correlated negatively with per cent catch of Sigmodon.

The evidence presented strongly suggests that cotton rats are limited to those areas within their total range where density and height of grassy cover, and at times, associated forbs and low-growing woody species, provide dense cover.

Cotton rats did not use areas where the canopy shaded out ground cover or where the cover was mowed or heavily grazed.

Sigmodon were restricted to superior habitat when the population was low, but were found in marginal habitat as well when the population was high.

After the population decline in February and March of 1960, rats were found only in superior habitat.

The single most important component of the habitat of *Sigmodon*, as far as plant life-form is concerned, appears to be moderate to dense stands of mid to high perennial grasses.

The average area in acres of homesteads for numbers of males and of females increased with the number of times individuals were captured on the average. At least to the level of 25 to 58 captures per individual.

Differences in homestead area between males and females were slight when the population was dense. When populations were low males had larger homesteads than females.

For males captured more than eight times on Grid 1, the range in area of homesteads was from 1.46 to 9.90 acres as compared to .94 to 3.30 for females. On Grid 2, homesteads ranged from .55 to 3.90 acres for males to .80 to 1.80 acres for females. These animals were taken from July through September of 1960-61 when the population was low. Males taken during the fall and winter of 1959-60 had homesteads ranging from .31 to .72 acres. During the same period, females had homesteads of .30 to 1.20 acres, for those animals taken more than eight times.

A *Sigmodon* population decline occurred in February and March of 1960. A long period of below-freezing weather coupled with snow and frozen ground coincided with the population reduction.

Population turnover varied from five or six to as many as thirteen or more months for cotton rats. About 50 per cent of marked *Sigmodon* disappeared by the second month, 75 per cent by the third month and 90 per cent by the fourth month. One male was known to have lived at least 12 months.

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