Technical Report No. 301

SMALL-MAMMAL HABITAT MODIFICATION IN NORTHEASTERN COLORADO

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GRASSLAND BIOME

U.S. International Biological Program

May 1976

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ABSTRACT

This preliminary study was designed to determine which of two factors were influencing immigration and colonization of *Microtus ochrogaster* in a grassland ecosystem. In many previous studies the influence of food or cover has been obscured by the inability to separate these factors and by contradictory results.

Three experimental treatments (cover, food, and food plus cover) and a control were established on 1-ha study plots in the shortgrass prairie of northeastern Colorado. Population data were collected from February 1975 to October 1975 during a pre-habitat-modification period and a post-habitat-modification period.

M. ochrogaster did not immigrate and/or colonize the area. For other small-mammal species, population trends from premodification to postmodification were similar for all treatments and there were no statistically significant differences between periods within treatments. Results indicate that the added cover or food were not sufficient to trigger any detectable response or *Microtus* were not present nearby in numbers high enough to immigrate. For further research, modifications of present study techniques are recommended including a possibility of modifying habitat already occupied by *M. ochrogaster* to obtain an initial response.

INTRODUCTION

This research was of a preliminary nature, intended to discover whether food and/or cover was a major influence on the immigration, colonization, and subsequent population growth of the meadow vole (*Microtus ochrogaster*). Since there was no response from this target species, responses of other "incidental" species populations were observed and analysis and discussion of these results predominate.

In long-term research (Grant 1972, Abramsky 1975, personal communication) conducted in an "Environmental Stress Area" on the short-grass prairie in northeastern Colorado the investigators found a significantly larger population of *M. ochrogaster* in highly productive areas which were artificially fertilized and irrigated. In the first year of fertilization and irrigation *M. ochrogaster* rose from a population of zero to over 50/ha in less than 3 months. In subsequent years the *Microtus* population peaked at more than 140/ha. In adjacent areas without irrigation and fertilization the population of *M. ochrogaster* was essentially zero. The large amount of plant growth in treated areas modified ecological factors of major importance to *M. ochrogaster*. Two obvious factors altered were food and cover. One of these may have been controlling or both may have been regulating mechanisms. They may also have been time-dependent, one factor regulating the population at one season and other factors during other seasons.

Because of the results found in the studies of Grant and Abramsky, the failure to specifically define or test for differences in cover and food in vegetative studies, and some contradictions in other published results; this research was initiated. The study was

conducted in northeastern Colorado on the Pawnee Site, the field research facility of the Natural Resource Ecology Laboratory, Colorado State University, located on the USDA Agricultural Research Service Central Plains Experimental Range.

LITERATURE REVIEW

Much research has been done on food as limiting and regulating populations of small mammals. In research on dispersion Batzli (1968) indicated food rather than refuge as being a major factor controlling dispersion of grassland mice. Fordham (1971) stated that there was little doubt that excess artificial food induced population growth of *Peromyscus* populations in spring and summer. Bendell (1959) concluded that supply of food is an important factor controlling the abundance of *P. maniculatus* in nature. Gentry (1966) suggested that the quantity and quality of available food was a limiting factor for *P. polionotus*, and Smith (1971) concluded addition of food increased the density of this species. Flowerdew (1972) found that in populations of wood mice food supply was not the important population control in summer but did increase immigration and survival after winter. Meserve (1971) showed no evident correlation between the location of grasses important as food and the distribution of capture for voles, indicating food was not the major factor regulating their dispersal. Krebs and DeLong (1965) supplemented food to a low population of *M. californicus* and found that supplemental food was not sufficient to produce a rapidly expanding population or prevent a decline to low numbers. In the small-mammal study on the Pawnee Site (Grant 1972) there was a lack of correlation between food supply and density of

P. maniculatus, *Spermophilus tridecemlineatus*, or *Onychomys leucogastor*, suggesting that food may not be the limiting factor for these three species. Grant concluded that the supply of food was not an important factor controlling abundance of *P. maniculatus* in nature.

Cover has been suggested to be important in population regulation. In a burned area with abundant food, recovery of rodent populations was restricted chiefly due to deficiencies of cover and it appeared that the *Microtus* needed an accumulation of mulch to build runways (Cook 1959). Warnock (1965) found in the laboratory that in the absence of cover, crowding precipitated fights and increased mortality.

In other grasslands, Hoffmann and Birney (1972) found that *M. ochrogaster* population densities appeared to be highly correlated with standing dead-plant biomass. They also speculated on the high probability of smaller population sizes of *Microtus* in grids when there was not as much cover due to grazing pressure. Results of overgrazing (short vegetation, increases in seed producing forbs, and bare ground) favor *P. maniculatus*, while lack of grazing favors *M. ochrogaster* (Koford 1958).

There was therefore, much evidence that food and cover could be important population controls, but some of the results were contradictory within species. Many other studies made no separation between cover value and the food quantity or quality inherent in vegetative cover. LoBue and Darnell (1959) suggested in a study of farming disturbance that a lack of reinvasion of *Microtus* must have been related primarily to the absence of vegetative cover. They found a high correlation of *Microtus* to broomsedge. In a study of vegetation

in fence rows Ogilvie and Furnam (1959) found *Microtus* abundant in weedy type fence rows. Eadie (1953) also observed that *M. pennsylvanicus* was abundant in areas of heavy cover and noted a direct response of *Microtus* to measurable differences in the amount of vegetative cover. In other small-mammal studies (Pearson 1959, Rosensweig and Winakur 1969) vegetation has been the critical factor investigated relating to small-mammal abundance.

METHODS

Treatments were designed to separate effects of food from those of cover. The study area did not contain resident *Microtus*. The closest possible source of *Microtus* was a roadside ditch approximately 100 m from the study area (Fig. 1). The next closest source was 1 km away in the Environmental Stress Area described by Grant (1972). This study, then, hoped to modify the area sufficiently to promote immigration of *M. ochrogaster* and test if the species selected food, cover, both, or neither of the habitat treatments. A non-nutritional cover of straw and pine boughs was selected. The food treatment was whole oats and alfalfa pellets thought to appeal to *M. ochrogaster*.

The experimental design consisted of four treatments, each applied to a square 1 hectare. Areas were selected at random to receive the treatments. Treatments FC and C were given additional cover, and treatments FC and F were given additional food. Treatment CN was a control.

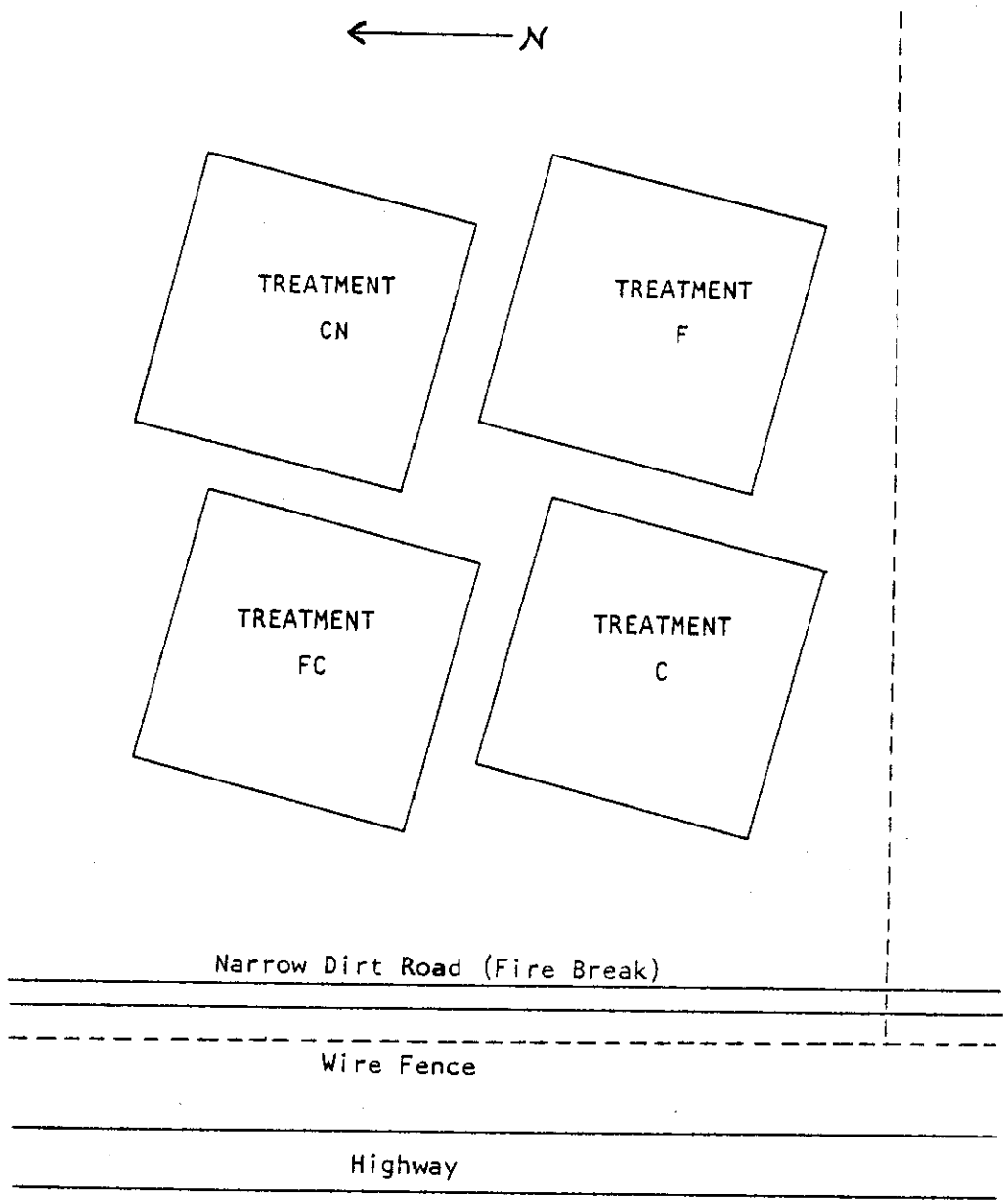

Fig. 1. Arrangement of treatments and their relation to highway and pastures. C = cover supplement, CF = cover and food supplement, F = food supplement, CN = control.

Description of Study Area

The study area was located 12 miles northeast of Nunn, Colorado, and 25 miles south of Cheyenne, Wyoming, on the Central Plains Experimental Range. The study area was approximately 225 by 225 m. Within this area were established four areas of 1 ha each, 100 by 100 m. Each treatment area was 10 m from an adjacent treatment area.

The study area was bounded 50 m on the west by a fire break, 10 m wide, running north-south, a roadside ditch 15 m wide, and then a major highway also running north-south. On the north, south, and east sides were open pastures used for buffalo grazing and extending at least 500 m. The study area was used as pasture until initiation of this study. Buffalo were then excluded from this area during the entire study, February to September 1975. The predominant soil type was a sandy loam with a gradual increase of gravelly soil in the northeast section of treatment CN.

Vegetation in this area has been classified (Klipple and Costello 1960) as shortgrass prairie, predominantly blue grama (*Bouteloua gracilis*). Other species found frequently are tumbling Russian thistle (*Salsola kali tenuifolia*), fringed sagewort (*Artemisia frigida*), scarlet globemallow (*Sphaeralcea coccinea*), and buffalo grass (*Buchloe dactyloides*). Each treatment area was analyzed in August using a canopy-coverage method (Daubenmire 1959) with a rectangular wooden frame 50 by 100 cm. Frame sides were marked to indicate coverages of 5, 25, 50, 75, and 95%. This frame was placed midway between all traps running east-west in each treatment to obtain a stratified random sample. Species found in the areas and percent coverage by each was recorded for each sample. Canopy coverages were

averaged for each treatment area (Table 1). Results indicate vegetation was similar in all treatments.

Habitat Modification

On the week of 7 April 1975 100 bales of straw, weighing approximately 36 kg each, were put on area FC and 100 bales were put on area C. This straw was fluffed up and put under 10 rows of wire mesh fence in each area. The fence rows were each 100 by 1 m and were laid flat on the straw. Fences and straw were held down with wooden stakes. On 24 May, and again on 31 May 1975, two loads of pine boughs weighing 675 kg each were brought from Roosevelt National Forest and put on areas FC and C. These pine boughs were laid in three equally spaced strips 2 m wide and 100 m long lying perpendicular to the strips of straw. During 22 to 25 July 1975, 36 more bales of straw weighing 22 kg each were put on each of areas FC and C. These bales were spread in large checkerboard patches through the middle of the two areas. The bales of straw covered a total area of approximately 1000 m^2 in each treatment (Fig. 2) and attained depths of 20 to 40 cm. The total biomass added to each cover treated area was approximately 574 g/m^2. This compares with an aboveground yield of approximately 200 g/m^2 in a control area and 570 g/m^2 in a water-nitrogen stressed area in 1971 (Lauenroth and Sims 1973), both 1 km from the cover treated areas in this study. The water-nitrogen stressed area is the area that had high immigration and population growth of *Microtus* in 1971 (Grant 1972).

Supplemental food consisted of whole oats and dehydrated alfalfa pellets. At the end of each bi-weekly trapping period, 11.5 kg of

Table 1. Plant species and their percent canopy coverages for each treatment-area.

Scientific name	Common name	Treatment-Area			
		FC	CN	C	F
Agropyron smithii	Western wheatgrass	-	-	-	-
Artemisia frigida	Fringed sagewort	*	*	-	*
Aristida longiseta	Red threeawn	-	*	-	-
Astragalus gracilis	Slender milk vetch	-	-	-	-
Bouteloua gracilis	Blue grama	***	**	***	***
Buchloe dactyloides	Buffalograss	*	*	*	*
Chenopodium leptophyllum	Slimleaf goosefoot	-	-	-	-
Chrysothamnus nauseosus	Rubber rabbitbrush	-	-	-	-
Chrysopsis villosa	Hairy goldaster	-	-	-	-
Cryptantha minima	Butte candle	-	-	-	-
Euphorbia glyptosperma	Ridgeseed euphorbia	-	-	-	-
Gaura coccinea	Scarlet gaura	-	-	-	-
Gutierrezia sarothrae	Broom snakeweed	*	-	-	*
Haplopappus spinulosus	Ironplant goldenweed	-	-	-	-
Helianthus petiolaris	Prairie sunflower	-	-	-	-
Mirabilis linearis	Four o'clock	-	-	-	-
Oenothera latifolia	Evening primrose	-	-	-	-
Opuntia polyacantha	Plains pricklypear	-	-	-	-
Orabanche fasiculata	Purple broomrape	-	-	-	-
Plantago purshii	Woolly Indian wheat	-	-	-	-
Salsola kali tenuifolia	Tumbling Russian thistle	*	-	*	*
Scirpus paludosus	Alkali bulrush	-	-	-	-
Sitanion hystrix	Bottlebrush squirreltail	-	-	-	-
Stipa comata	Needle-and-thread	*	*	*	*
Sporobolus cryptandrus	Sand dropseed	-	-	-	-

\- 0-1%
* 1-10%
** 10-50%
*** 50-95%

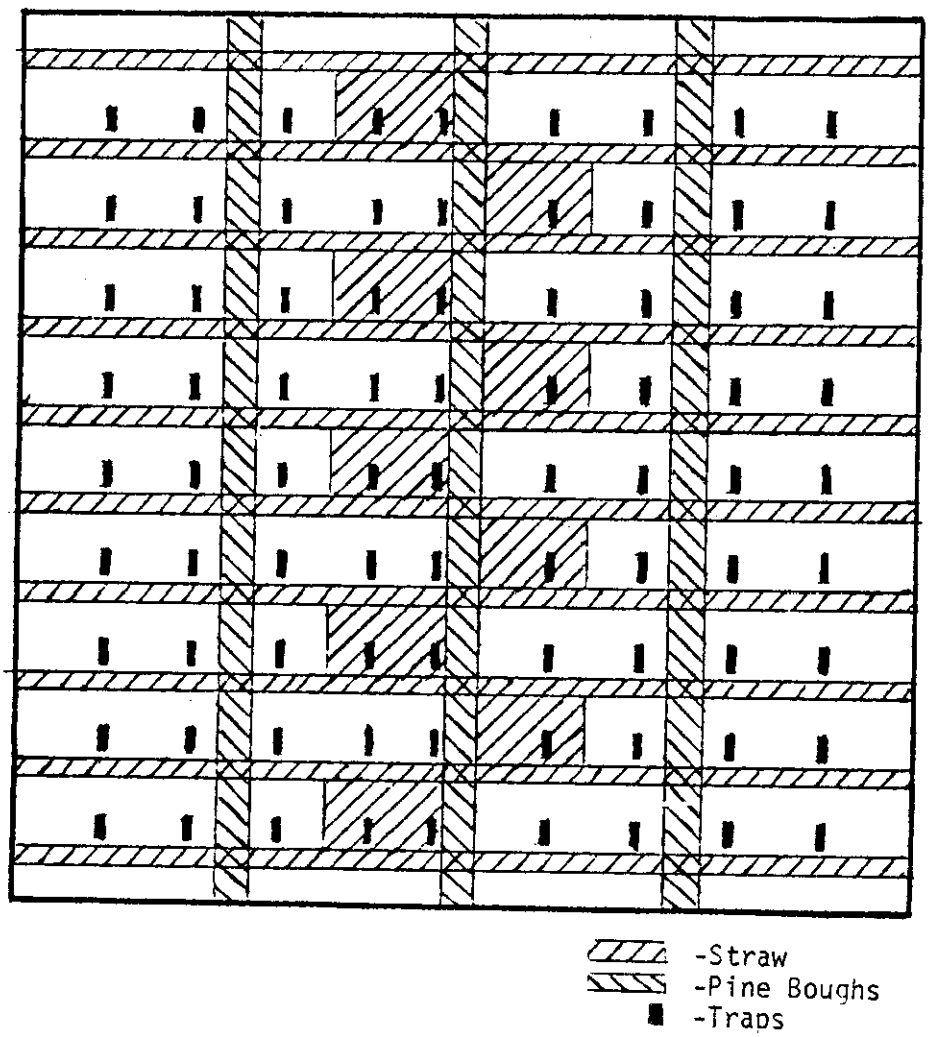

Fig. 2. Arrangement of supplemental cover and traps in treatments FC and C.

each kind of food was added in treatments FC and F. Food supplement began on 6 June and was spread by hand. The resulting modifications of the habitat are summarized in Table 2.

Trapping

Two types of Sherman live traps were used. Most traps were galvanized iron 7.5 by 7.5 by 30.5 cm. Other traps were aluminum with approximately the same dimensions. Aluminum traps were interspersed evenly among galvanized traps to lessen any bias due to differences between traps. In tests of three types of live traps Bendell (1959) did not find significant differences among traps.

Small mammals were marked by toe-clipping, with toes numbered from one through four on the front feet and one through five on the back feet. Up to one toe was removed from each foot. Each animal was recorded as a four-digit number from these marks. When possible, treatment, trap number, species, condition, sex, and weight were recorded for each capture.

Traps were baited with rolled oats at the beginning of each trapping period and replenished whenever a trap was found closed. Traps usually remained open all day during the trapping periods.

Trapping began on 24 February 1975 and terminated on 11 September 1975. Trapping periods ran for 4 days each and occurred on alternate weeks except when weather prohibited (Table 3). Traps were checked at each sunrise and later in the summer they were also checked in late afternoon. On extremely hot days traps were checked every 2 to 3 hours during daylight.

Table 2. Modifications performed in each treatment.

Treatment	Modification	Date of Modification (Julian Day)
1. Food + Cover (FC)	Food	June 6 (157)
	Cover	April 12-May 22 (102-142) July 23 (205)
2. Control (CN)	-	-
3. Cover (C)	Cover	April 12-May 22 (102-142) July 23 (205)
4. Food (F)	Food	June 6 (157)

Table 3. Trapping periods.

Trapping period	Julian days	Calendar days
	Pre-habitat Modification	
1	55-58	24 to 27 February
2	62-65	3 to 6 March
3	77-80	18 to 21 March
4	97-100	7 to 10 April
5	111-114	21 to 24 April
6	125-128	5 to 8 May
7	140-142	20 to 22 May
	Post-habitat Modification	
8	154-157	3 to 6 June
9	169	18 June
10	174-177	23 to 26 June
11	188-191	7 to 10 July
12	203-206	22 to 25 July
13	216-219	4 to 7 August
14	229-232	17 to 20 August
15	251-254	8 to 11 September

Trapping samples were taken through a pre-habitat-modification period and a postmodification period. This permitted comparing population trends before habitat modification with trends after modification. Since the addition of the initial straw coverage was completed at the end of May the seven trapping periods before this time were taken as the premodification period and the remaining eight periods as postmodification.

Since species may respond to habitat modification at different seasons and at different rates (Wecker 1963), the date selected as the boundary between premodification and postmodification was varied from one to three trapping periods before and after 1 June. The resulting six statistical analyses gave virtually the same results as when 1 June was used as the boundary between pre- and post-modification, and this latter analysis is presented.

A bird census was begun on 7 July 1975 and terminated on 11 September 1975. This consisted of counting all birds, by species, that were observed in each treatment while walking the traplines in the mornings. In this way an index of bird abundance for each treatment was obtained.

DATA ANALYSIS

Population Estimate

In this study direct enumeration of the population by species was used to estimate population sizes and supply indices to population fluctuations. In the direct enumeration method the number of individuals captured by species and treatment is counted for each trapping

period. This represents the minimum number of individuals that must be present. If an individual is caught in more than one treatment in a single trapping period it is only counted as being present in the first treatment. This was not very common. Chitty and Phipps (1966) needed a direct and simple method of examining population trends. They chose to use direct enumeration where the only error present would be error due to some animals being missed. Schroder and Rosensweig (1975) found excellent agreement between Lincoln index estimates and direct enumeration. Clough (1965) only trapped 2 days per trapping period and used relative estimates of animal abundance by enumerating the individuals caught. In 5-day trapping periods Krebs (1966) felt that he could enumerate 80 to 90% of the individuals in populations up to 250 to 300 per ha. Below this density more than this percentage could be accounted for by direct enumeration. Others (Cook 1959, Pearson 1959, Wirtz and Pearson 1960, Flowerdew 1972) used various methods of direct enumeration for indices and population estimates. In this research population levels were very low, which would increase the chances of catching all the trappable individuals present (Krebs 1966). In similar research on small mammals with similar population densities Packard (1972) found that the most useful density estimator was the Zippin (1956). Values of other methods were limited because the assumptions of the procedures could not be met by the small numbers of rodents taken (a situation very similar to this one). He also stated that no density estimator is wholly accurate.

The data collected in this study were analyzed using criteria for the Jolly stochastic model (Jolly 1965), the Zippin technique (Zippin

1956), and the minimum number (French and Grant 1974) which were used for studies of small mammals on the Pawnee Site. Results closely followed those found using the direct enumeration method. Only 13 population indices out of a total of 300 were different. The estimates differed by an average of 0.64 individuals. Most of the difference in the average was caused by a difference of 4.2 in one estimate which, according to the criteria by French and Grant (1974), was marginally acceptable. Because of this and the many problems and assumptions inherent in other estimates, the direct enumeration technique was chosen as a population estimator or index in this study.

Statistical Analysis

Data for population sizes represent a 3-way factorial experimental design with the three main factors of date, treatment, and species. These data were analyzed for premodification and postmodification periods using computer statistical packages BMD08V and STAT49V which are 3-way factorial analysis of variance programs. Tukey's "honestly significant difference" test, a multiple comparison technique, was performed at the 0.05 level of significance to test for differences among treatments within a period by species (Sokal and Rohlf 1969).

In order to perform a direct and fair test of premodification versus postmodification treatment means, the data were normalized to an initial population of one individual, and the populations on succeeding sample dates similarly adjusted. Then a 3-way analysis of variance was performed with treatment, period (premodification and postmodification), and date within period as the main effects. Then

any effects occurring would be due to factors within treatments without regard for different initial populations.

There may also have been weight gains or losses due to supplemental food. This was analyzed in much the same way as the population data except data from three successive trapping periods were grouped to supply enough data for statistical analysis.

The bird data were treated like the small-mammal population data. The number of birds counted was used as an index or population estimate for that period of trapping. They were then analyzed using the 3-way analysis of variance programs. Tukey's test was also performed at the 0.05 level to test for significant differences between treatments.

RESULTS AND DISCUSSION

Five species of small-mammals were caught during the study. They were *Spermophilus tridecemlineatus* (thirteen-lined ground squirrel), *Peromyscus maniculatus* (deer mouse), *Onychomys leucogaster* (northern grasshopper mouse), *Dipodomys ordii* (Ord's kangaroo rat), and *Perognathus* sp. (pocket mouse).

Microtus ochrogaster (prairie vole) was not captured on the experimental area. Two week trapping of the roadside ditch did not reveal any *Microtus*. There were old, unused runways in the ditch. Populations of *Microtus* were also low in the Environmental Stress Area at the Pawnee Site during the first part of the year (Abramsky, personal communication, 1975).

Different population trends occurred for the species observed (Figs. 3a to 3e). *Spermophilus* populations demonstrated a two

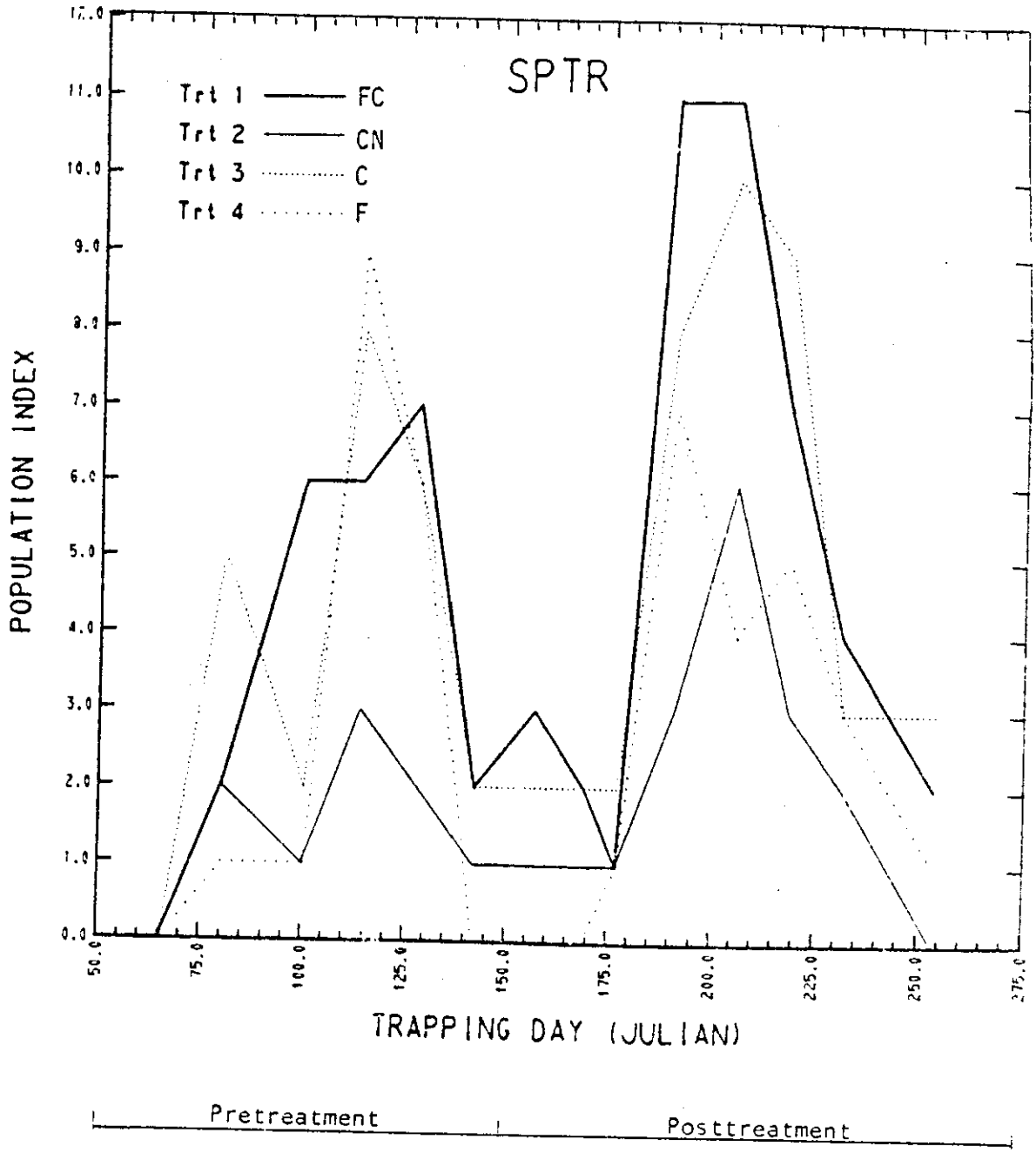

Fig. 3a. Minimum population estimates of *Spermophilus* for each trapping date by treatment. See Fig. 1 for treatment symbol explanation.

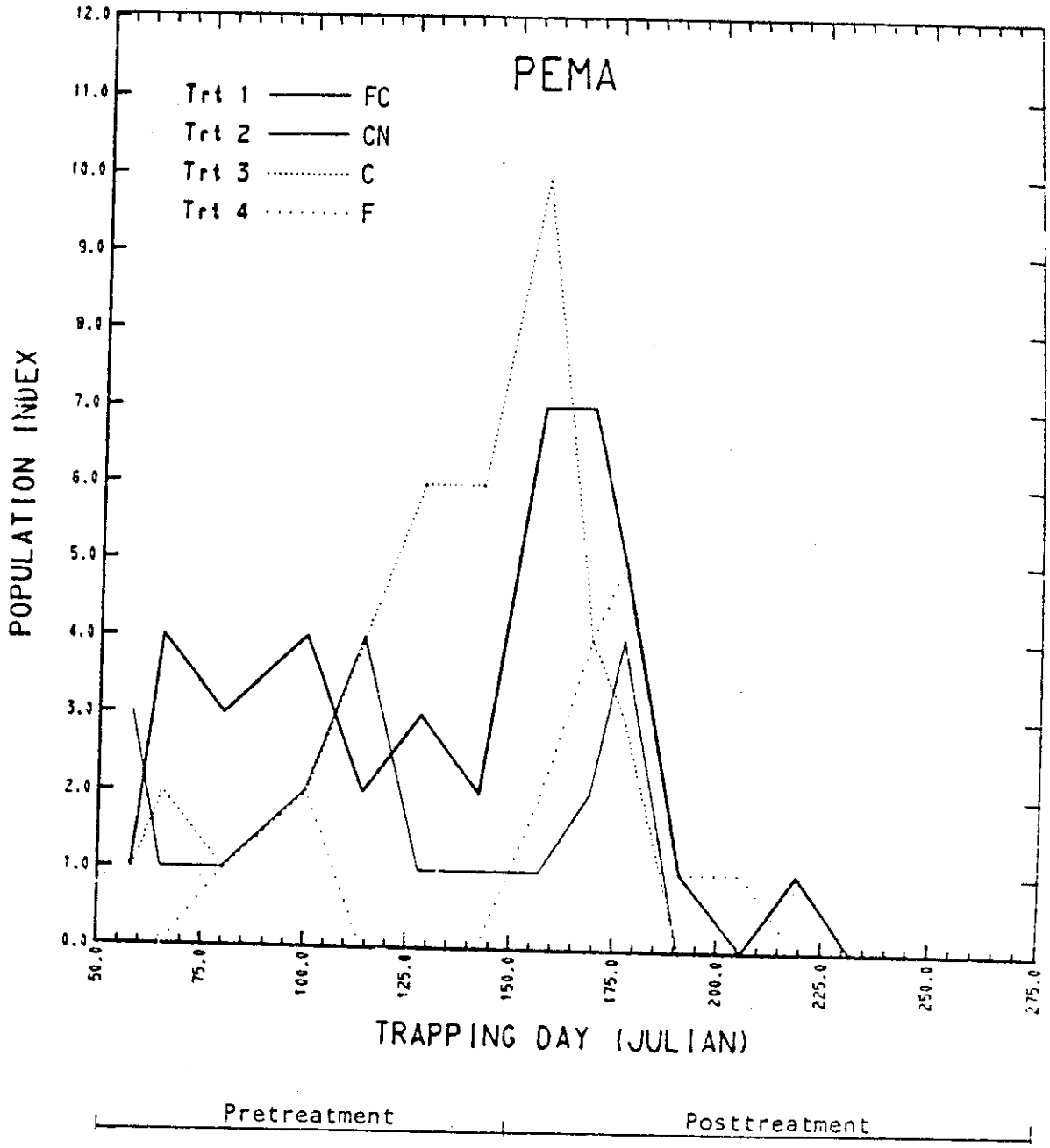

Fig. 3b. Minimum population estimates of *Peromyscus* for each trapping date by treatment. See Fig. 1 for treatment symbol explanation.

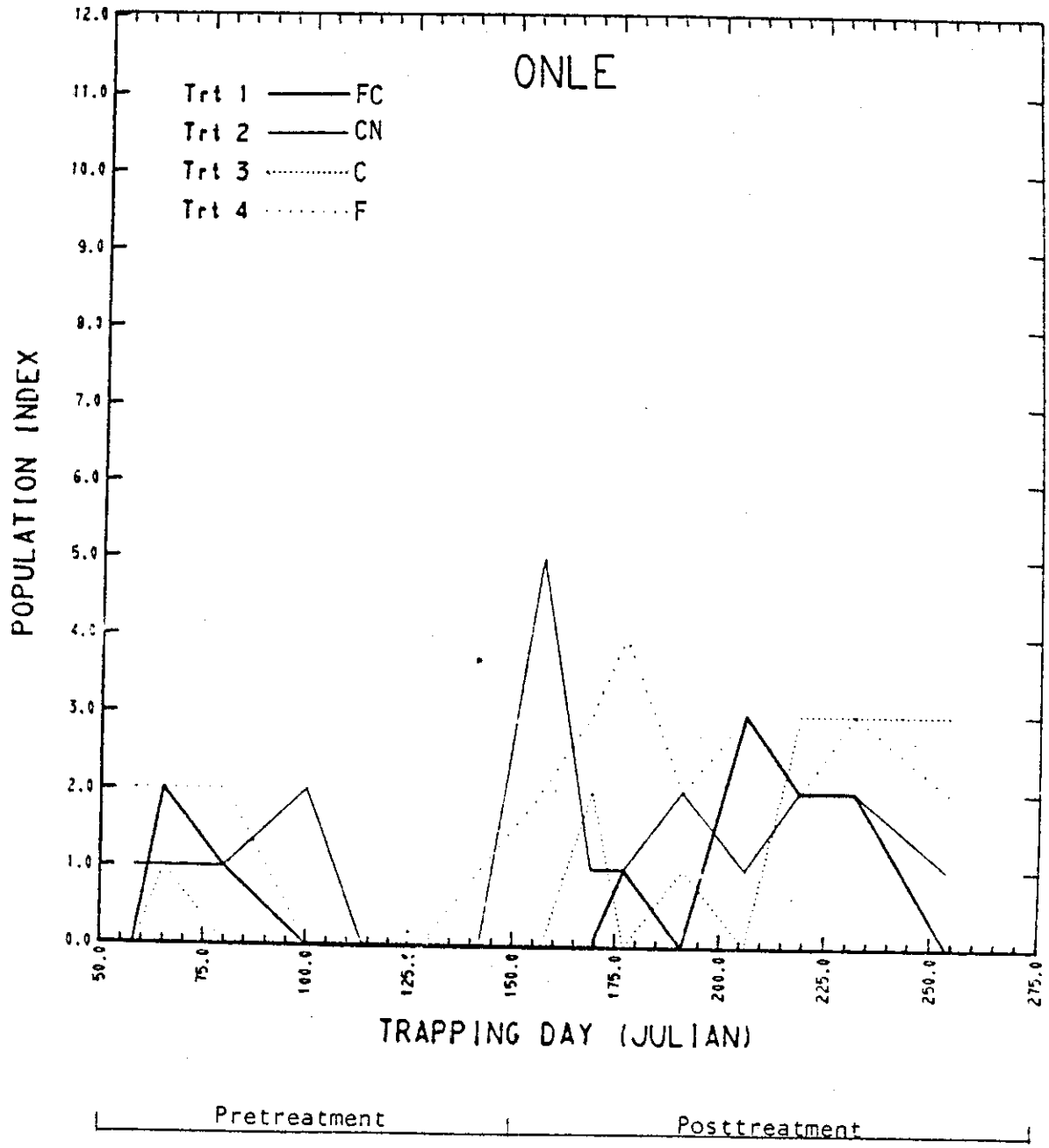

Fig. 3c. Minimum population estimates of *Onychomys* for each trapping date by treatment. See Fig. 1 for treatment symbol explanation.

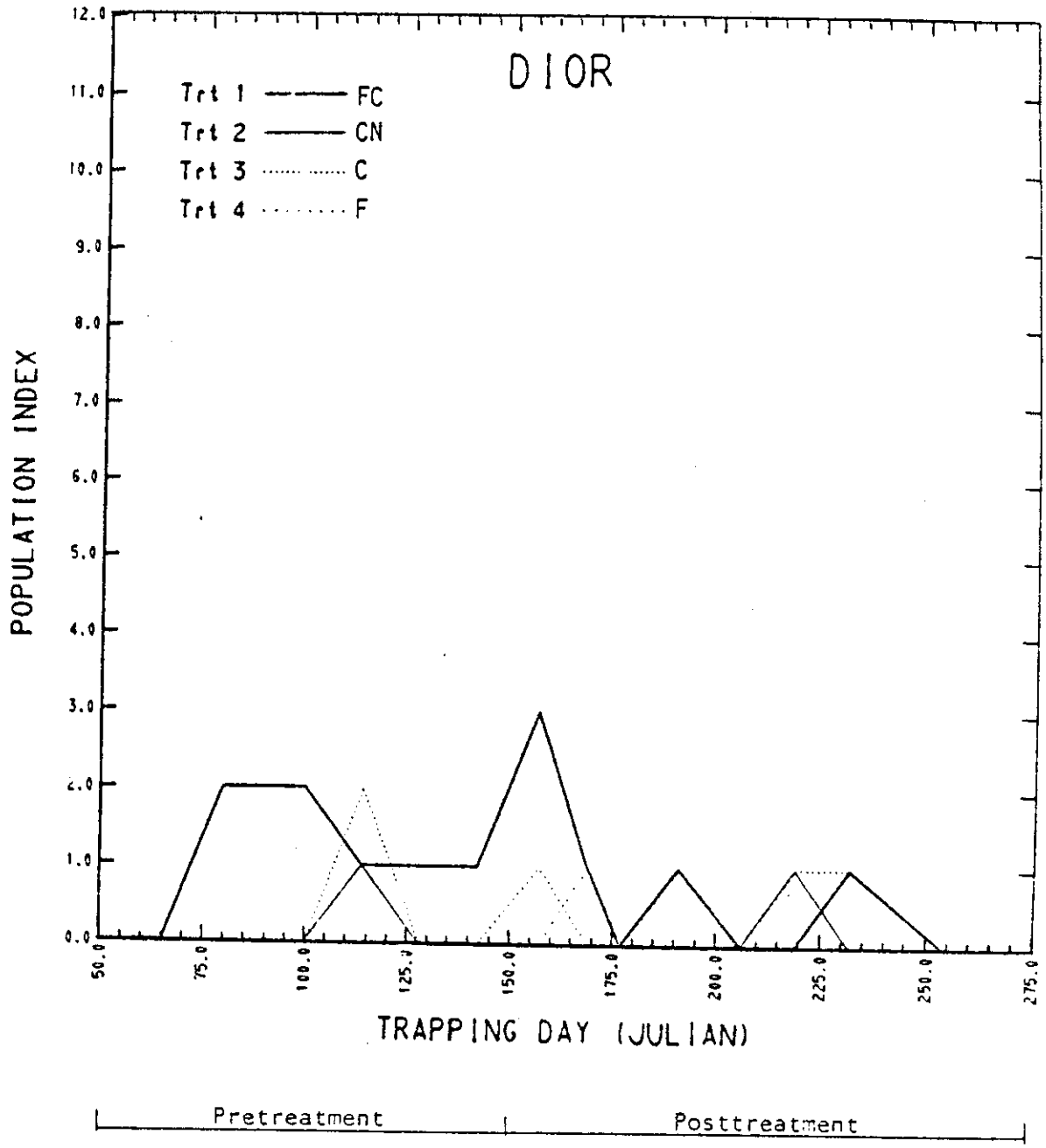

Fig. 3d. Minimum population estimates of *Dipodomys* for each trapping date by treatment. See Fig. 1 for treatment symbol explanation.

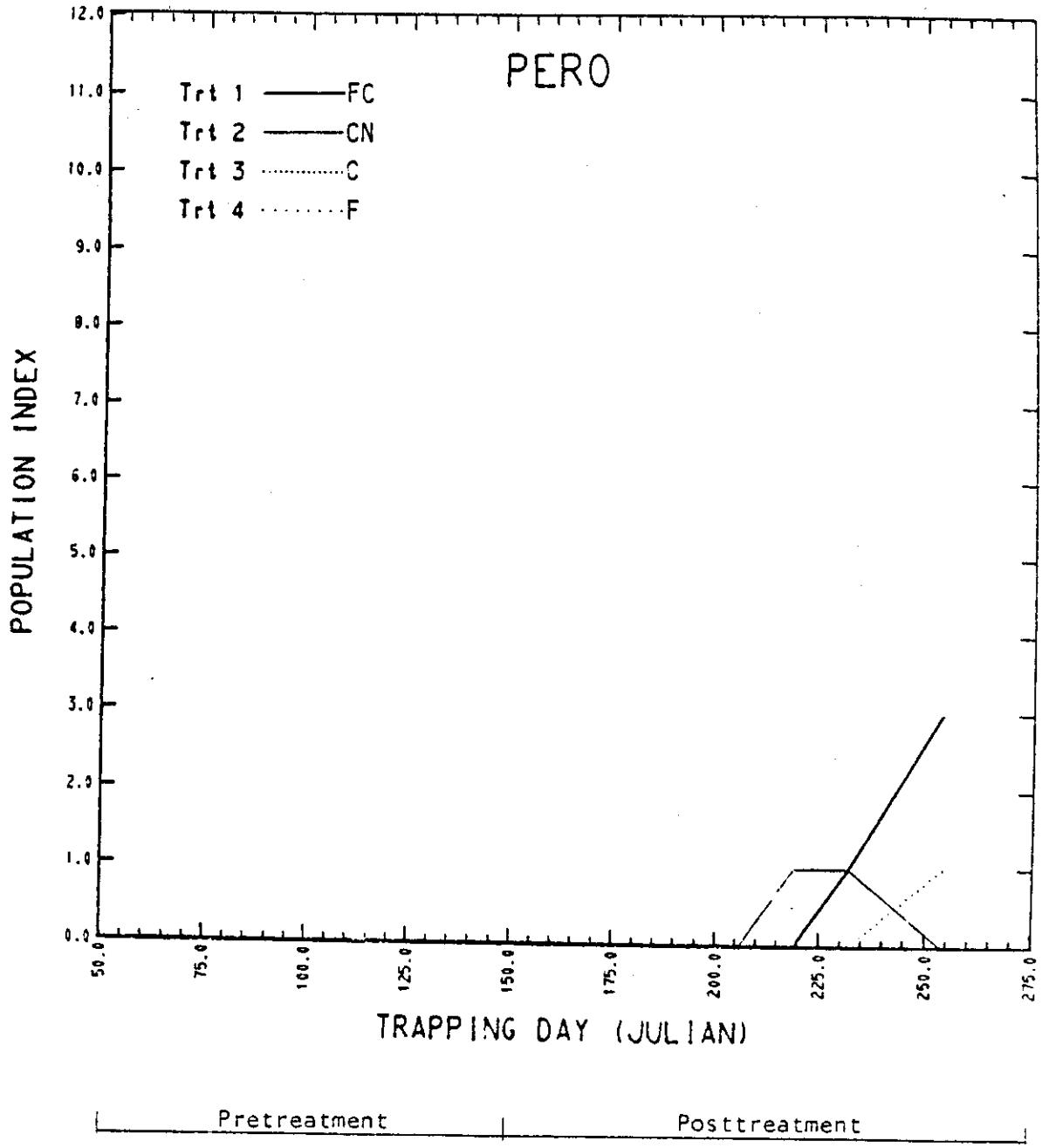

Fig. 3e. Minimum population estimates of *Perognathus* for each trapping date by treatment. See Fig. 1 for treatment symbol explanation.

oscillation population change through the trapping dates whereas *Peromyscus* populations rose to a peak and then decreased sharply. *Onychomys, Peromyscus,* and *Dipodomys* populations were very low and slight variations in size caused what appeared to be large density changes. Analysis of population data (Tables 4 and 5) indicates a significant interaction between treatments and species for the premodification period (Fig. 4) and the postmodification period (Fig. 5). Abundance of *Spermophilus, Peromyscus,* and *Dipodomys* showed the same pattern across treatments. *Onychomys* abundance showed opposite fluctuations across treatments giving significant interaction effects. This may indicate competitive effects occurring between *Onychomys* and the other species. This was also noted by Grant (1972).

In the premodification period *Spermophilus* populations were higher in the areas where cover was to be added (Fig. 6). Tukey's test demonstrated population sizes in treatment CN was significantly different from FC, F, and C. No other significant differences existed.

In the postmodification period *Spermophilus* populations were higher in the areas where cover was added (Fig. 7). Tukey's test for this period showed significant differences in population sizes between treatments FC and F, FC and CN, C and F, and C and CN. No significant differences were found between treatments FC and C, and F and CN. This period, therefore, showed a significant difference between treatment C and F which was not found in the premodification data. This can be due to a large change in population size caused by reproduction. The trends across treatments within periods remained the same from premodification to postmodification indicating food or cover did

Table 4. Analysis of variance for small-mammal populations in the seven premodification trapping dates.

Source	d.f.	M.S.	P	Q
Treatment	3	4.902	.0057	
Species	4	35.571	<.0001	
Date	6	6.174	.0001	
linear	1	11.491	.0017	
quadratic	1	17.350	.0001	
cubic	1	3.873	.0623	
quartic	1	.377	.5565	
residual	1	2.523	.1308	
Treatment × species	12	3.438	.0011	1.464
Treatment × date	18	1.225	.3394	
Species × date	24	5.430	<.0001	
Residual	72	1.080		

Table 5. Analysis of variance for small-mammal populations in the eight postmodification trapping dates.

Source	d.f.	M.S.	P	Q
Treatment	3	7.156	.0057	
Species	4	62.900	<.0001	
Date	7	3.356	.0521	
linear	1	6.373	.0490	
quadratic	1	8.535	.0232	
Cubic	1	3.111	.1665	
quartic	1	4.645	.0918	
quintic	1	0.134	.7727	
residual	2	0.348	.8046	
Treatment × species	12	5.146	.0008	1.662
Treatment × date	21	0.971	.9019	
Species × date	28	12.504	<.0001	
Residual	84	1.597		

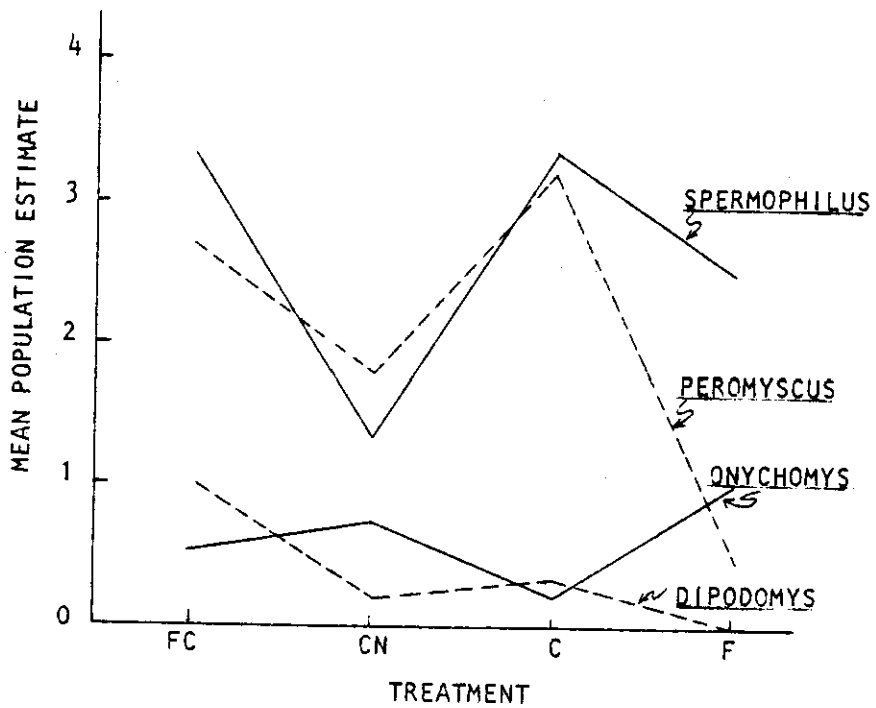

Fig. 4. Average populations of four small-mammal species on the four treatment-areas during the premodification period.

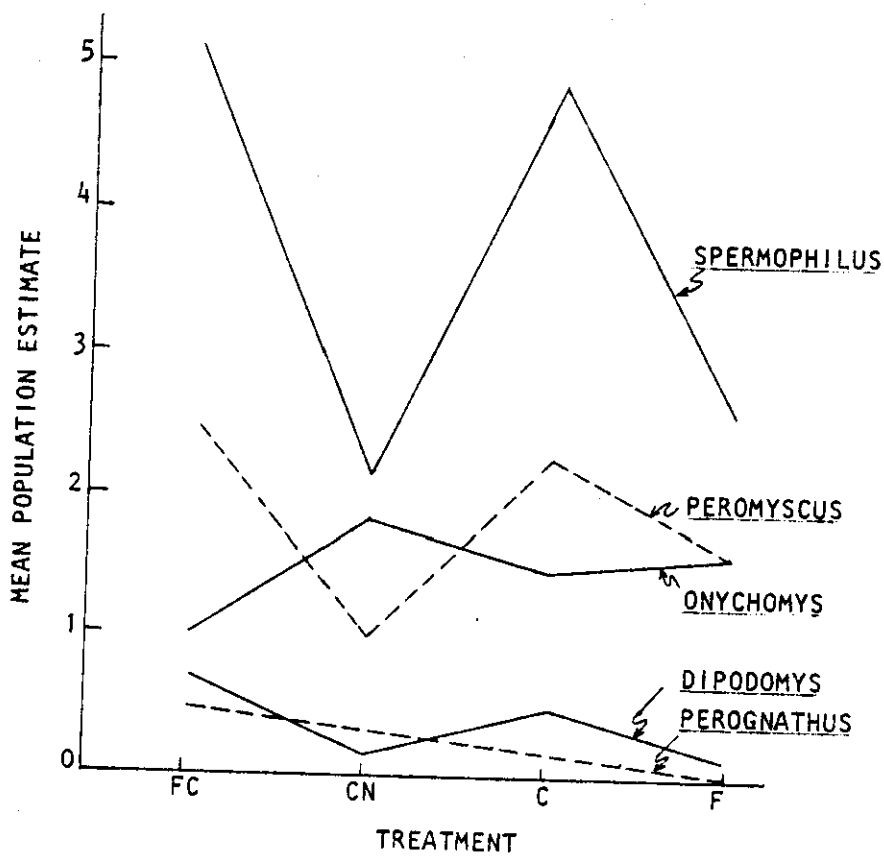

Fig. 5. Average populations of five small-mammal species on the four treatment-areas during the postmodification period.

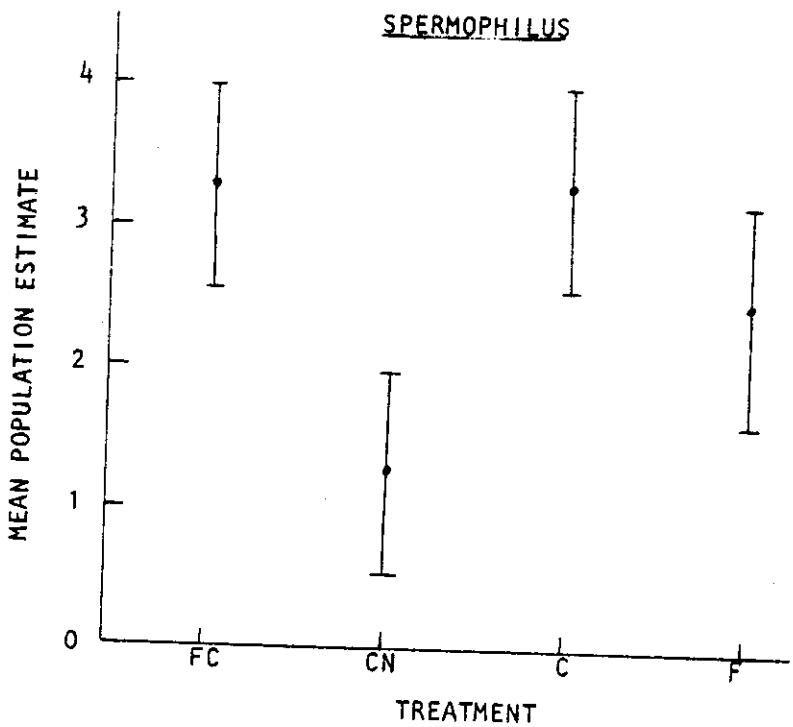

Fig. 6. Population estimates of *Spermophilus* on the four treatment-areas during the premodification period. Bars indicate Tukey's range of significance at the $\alpha = 0.05$ level. Any two lines having equal population estimates indicate there is no significant difference between the two treatments.

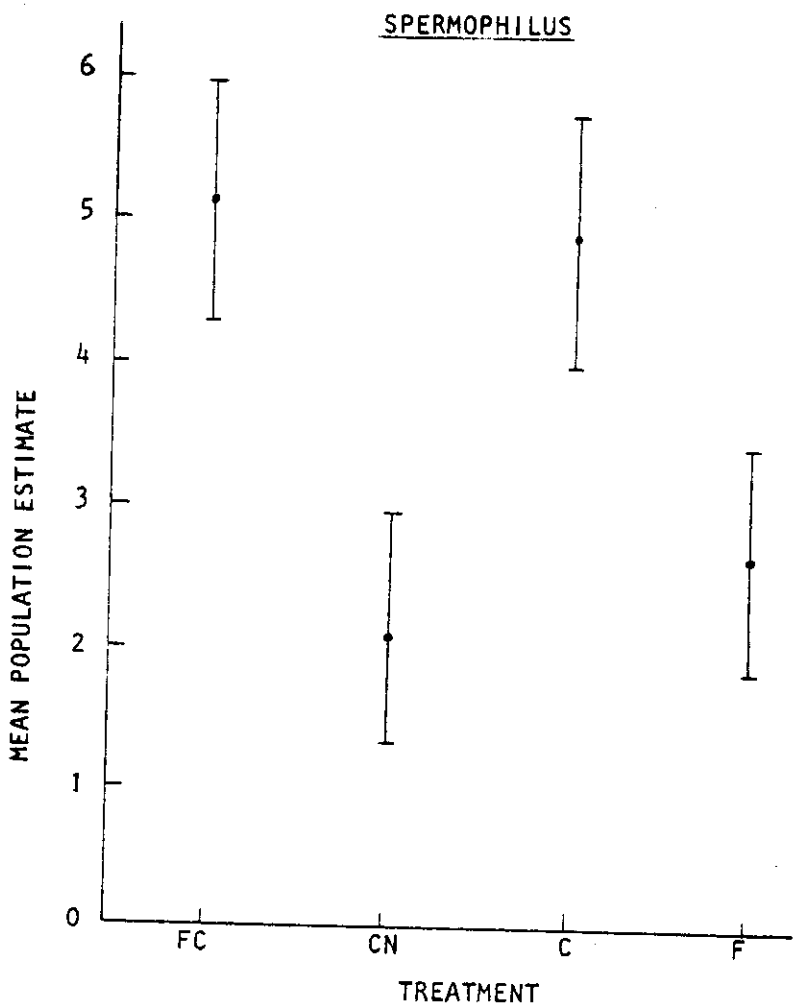

Fig. 7. Population estimates of *Spermophilus* on the four treatment-areas during the postmodification period. Bars indicate Tukey's range of significance at the $\alpha = 0.05$ level. Any two lines having equal population estimates indicate there is no significant difference between the two treatments.

not have a detectable effect on *Spermophilus* populations. Analysis of the normalized data indicated no significant population differences between periods within treatment (Table 6).

Peromyscus population analysis (Figs. 8 and 9) shows no difference in trends across treatments within periods from the premodification to postmodification period. The only significant difference between population sizes was found between treatment F and each other treatment in the premodification period. The postmodification analysis showed no significant differences between treatments. Normalized data analysis (Table 7) indicated no differences between periods within treatments demonstrating no advantage in cover or food.

Onychomys populations illustrated no significant differences between treatments within periods in premodification or postmodification periods (Figs. 10 and 11). Population trends across treatments remained similar indicating no effect of the food or cover. Analysis of the normalized data (Table 8) indicated no significant differences between periods within treatments, but did indicate a period difference ($P < .01$) for all treatments combined. This increase in *Onychomys* in all treatments was probably due to seasonal reproduction.

For *Dipodomys* and *Peromyscus* the populations were very low with high variance and analysis of pretreatment, posttreatment, and normalized data showed no significant differences between treatments or periods.

There is a significant species by date interaction. This is due to increases and decreases through time caused by mortality and natality which was species specific and did not occur simultaneously.

Table 6. Analysis of variance of normalized *Spermophilus* population data to test for differences between modification periods within treatments.

Source	d.f.	M.S.	P
Treatment	3	22.166	<.01
Period	1	18.601	--
Date (period)	13	28.060	<.01
Date (Premodification)	6	25.060	<.01
Date (Postmodification)	7	32.268	<.01
Treatment × period	3	2.077	--
Treatment × date (period)	39	2.315	

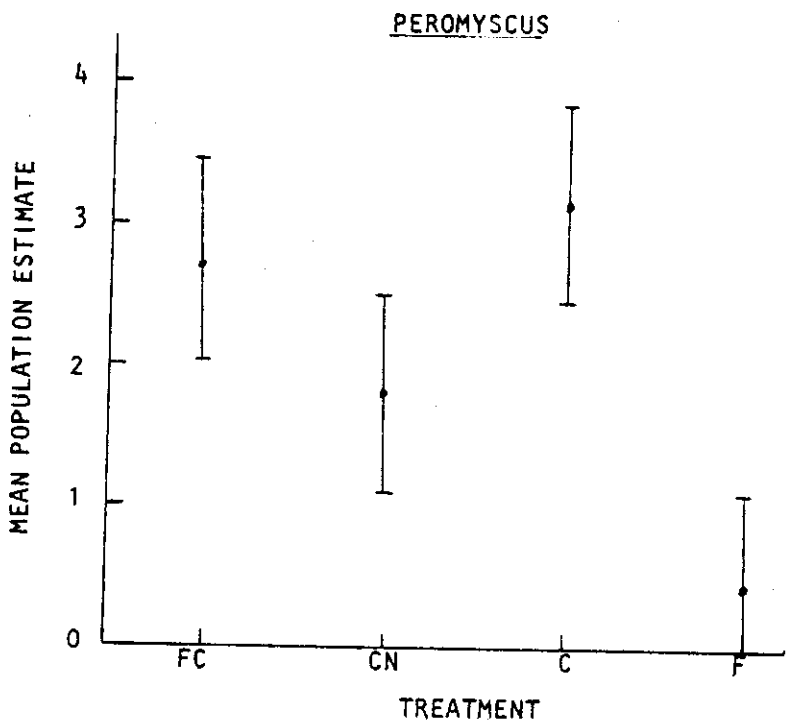

Fig. 8. Population estimates of *Peromyscus* on the four treatment-areas during the premodification period. Bars indicate Tukey's range of significance at the $\alpha = 0.05$ level. Any two lines having equal population estimates indicate there is no significant difference between the two treatments.

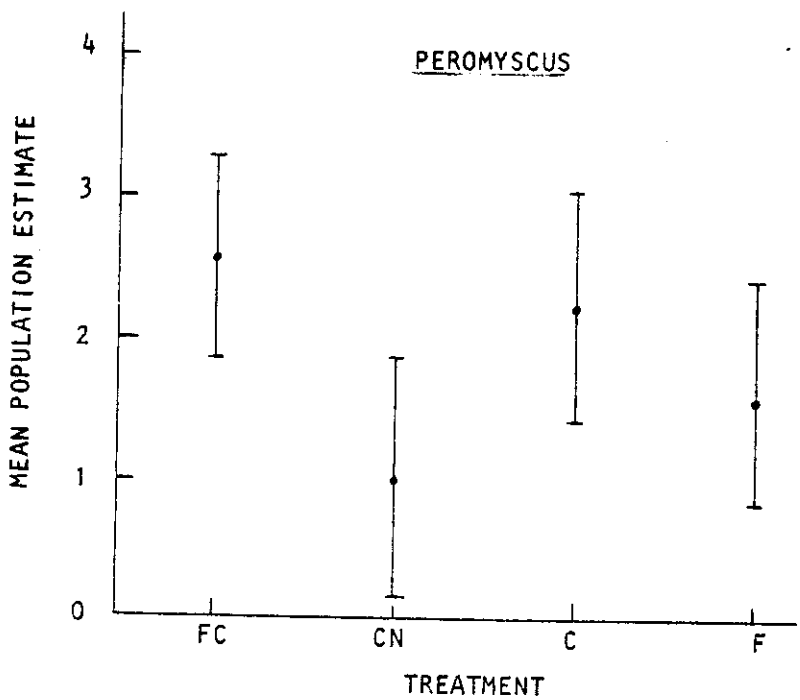

Fig. 9. Population estimates of *Peromyscus* on the four treatment-areas during the postmodification period. Bars indicate Tukey's range of significance at the $\alpha = 0.05$ level. Any two lines having equal population estimates indicate there is no significant difference between the two treatments.

Table 7. Analysis of variance of normalized *Peromyscus* population data to test for differences between modification periods within treatments.

Source	d.f.	M.S.	P
Treatment	3	19.345	<.01
Period	1	.005	--
Date (period)	13	9.438	--
Date (Premodification)	6	1.219	--
Date (Postmodification)	7	16.483	<.01
Treatment × period	3	2.883	--
Treatment × date (period)	39	2.592	

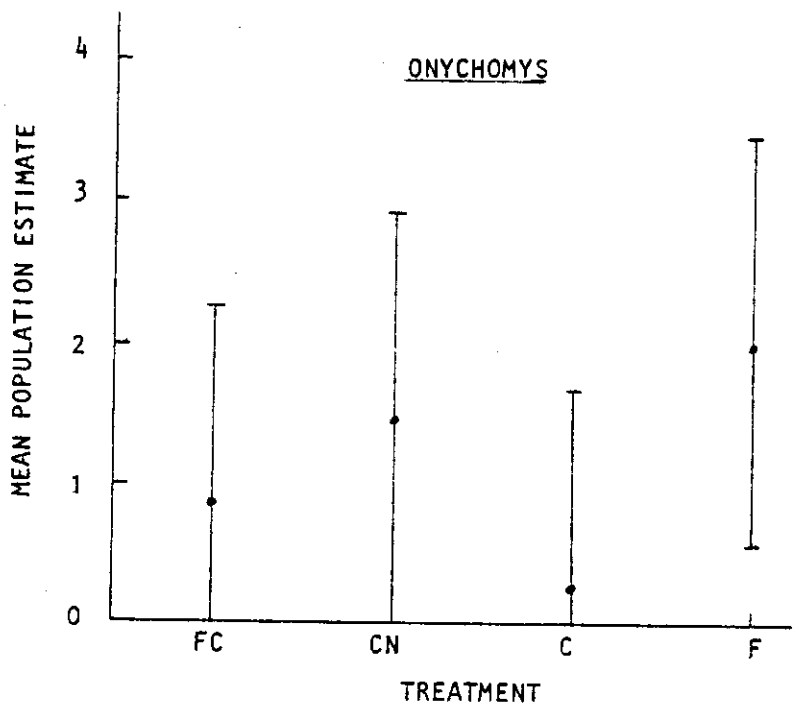

Fig. 10. Population estimates of *Onychomys* on the four treatment-areas during the premodification period. Bars indicate Tukey's range of significance at the $\alpha = 0.05$ level. Any two lines having equal population estimates indicate there is no significant difference between the two treatments.

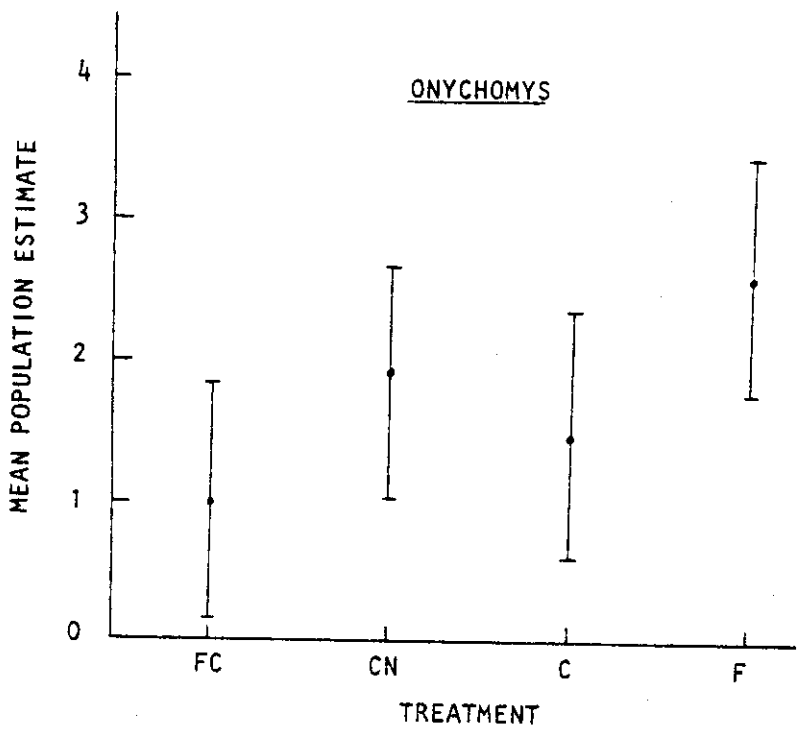

Fig. 11. Population estimates of *Onychomys* on the four treatment-areas during the postmodification period. Bars indicate Tukey's range of significance at the $\alpha = 0.05$ level. Any two lines having equal population estimates indicate there is no significant difference between the two treatments.

Table 8. Analysis of variance of normalized *Onychomys* population data to test for differences between modification periods within treatments.

Source	d.f.	M.S.	P
Treatment	3	.955	--
Period	1	14.209	<.01
Date (period)	13	.786	--
Date (Premodification)	6	.830	--
Date (Postmodification)	7	.749	--
Treatment × period	3	.460	--
Treatment × date (period)	39	.952	

Spermophilus, *Peromyscus*, and *Onychomys* all bear young at different times during the year causing this interaction.

Since there were premodification data for the small-mammal species this would show if there was any change in their activity or selection of habitat areas modified. The data show that the pattern of population size across treatments by species, after modification, was present before the modification. The normalized data analyses demonstrated no differences between period within treatment. Thus, there appeared to be some type of habitat selection occurring before modification, perhaps keying on some element of the habitat not discernable to the experimenter. This could be slight differences in cover, food, moisture, or some other microhabitat factor. The vegetation may have differed slightly in going from west to east. If so, this was not distinguishable using the vegetation analysis described. There are other factors which may be important, but other studies mentioned indicate food or cover is of major importance.

The significant species by treatment interaction (Table 9) in the analysis of small-mammal weights (Fig. 12) is due to differences in trends across treatments within periods between *Spermophilus* and *Peromyscus*. Tukey's test for *Spermophilus* (Fig. 13a) indicates a significant weight difference between treatment CN and the other treatments. The weight mean of *Spermophilus* for this treatment is much lower which may indicate better food resources in the areas with food or cover. For *Peromyscus* and *Onychomys* there are no significant differences in weights among treatments (Fig. 13b and 13c). Since these data were available only for the postmodification period, no

Table 9. Analysis of variance for adult individual small-mammal weights with every three trapping dates grouped into one to supply sufficient data points. Data taken during post-modification.

Source	d.f.	M.S.	P	Q
Treatment	3	199.606	<.0001	
Species	2	34552.440	.0141	
Date	4	334.585	.0001	
linear	1	33.641	.4339	
quadratic	1	166.504	.0830	
cubic	1	160.391	.0888	
quartic	1	977.805	.0000	
Treatment × species	6	131.462	.0304	
Treatment × date	8	344.238	<.0001	
Species × date	12	80.945	.1375	
Species × treatment × date	12	146.427	.0028	
Residual	141	54.632		

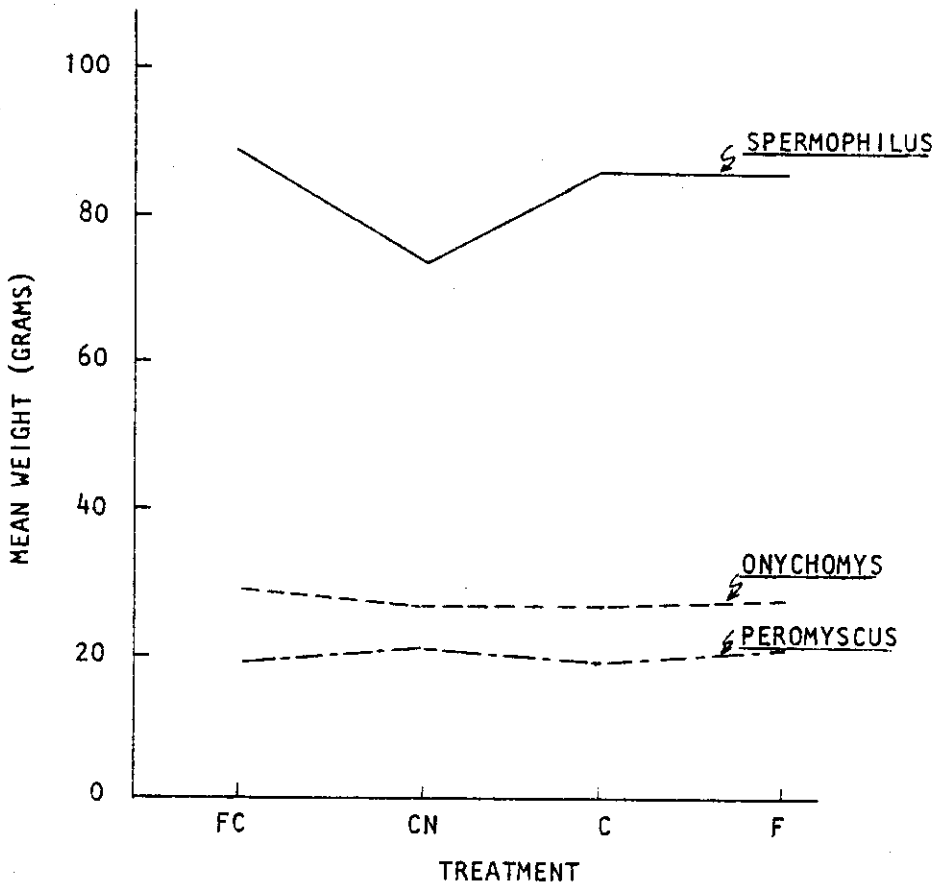

Fig. 12. Average weights of three adult small-mammal species on the four treatment-areas during the postmodification period.

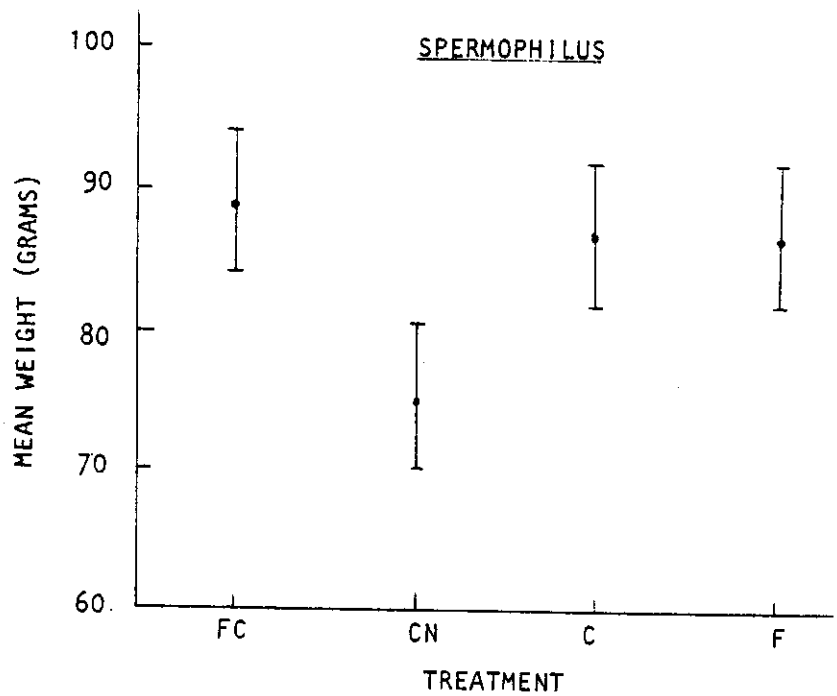

Fig. 13a. Average weights of *Spermophilus* adults on the four treatment-areas during the postmodification period. Bars indicate Tukey's range of significance at the $\alpha = 0.05$ level. Any two lines having equal population estimates indicate there is no significant difference between the two treatments.

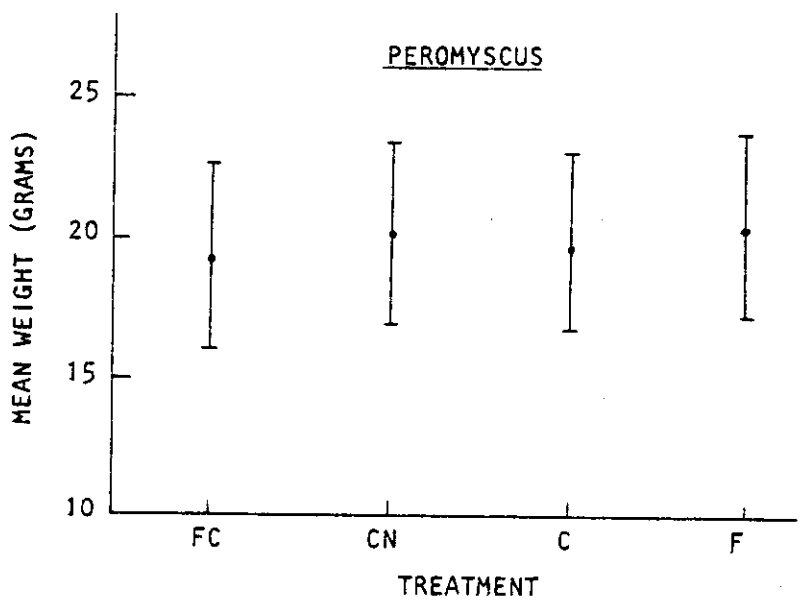

Fig. 13b. Average weights of *Peromyscus* adults on the four treatment-areas during the postmodification period. Bars indicate Tukey's range of significance at the $\alpha = 0.05$ level. Any two lines having equal population estimates indicate there is no significant difference between the two treatments.

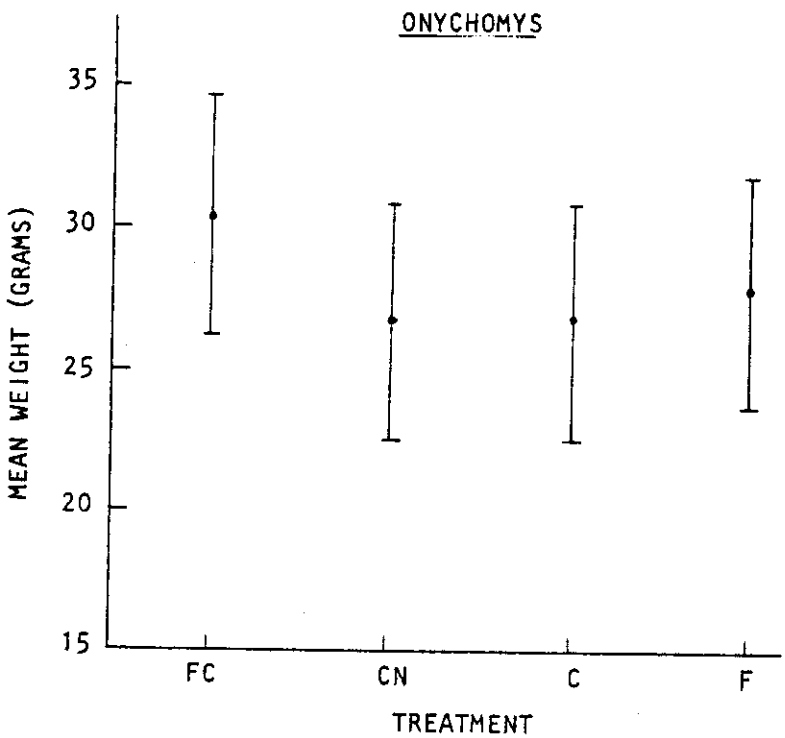

Fig. 13c. Average weights of *Onychomys* adults on the four treatment-areas during the postmodification period. Bars indicate Tukey's range of significance at the $\alpha = 0.05$ level. Any two lines having equal population estimates indicate there is no significant difference between the two treatments.

comparison with the premodification period can be made and one does not know if the trends across treatments were the same before this time.

Trap mortality followed the population curves as expected (Figs. 14a to 14d). Unfortunately, any trap mortality is serious and has an immediate effect on the population estimate. *Spermophilus* suffered most from this effect. Despite checking traps every 2 hours on the hottest days, there was trap mortality. This quickly added up with even one loss per day. This problem can serve as a warning that if the primary species, *Microtus*, will be captured it will be important to limit trap mortality and do all that is possible to prevent it. A loss of one new individual could, in this case, be disastrous to the experiment. This also points out an advantage of performing this preliminary research in areas where a high population of *Microtus* is present. Then a loss of one or two individuals would not be as potentially disastrous.

Two bird species, the Lark Bunting (*Calamospiza melanocorys*) and the Horned Lark (*Eremophila alpestris*), were present in numbers high enough to analyze statistically. All data were taken in the post-modification period. There were significant date and treatment differences (Table 10). Tukey's test for differences in bird population indices among dates (Fig. 15) indicates no significant differences. The pattern is erratic and probably due to the high mobility of the birds and changes in activity throughout late summer. Likewise, there were no significant differences among treatments (Fig. 16). Birds were most often seen in treatment FC which has food and cover supplement, followed by treatment F which has food supplement

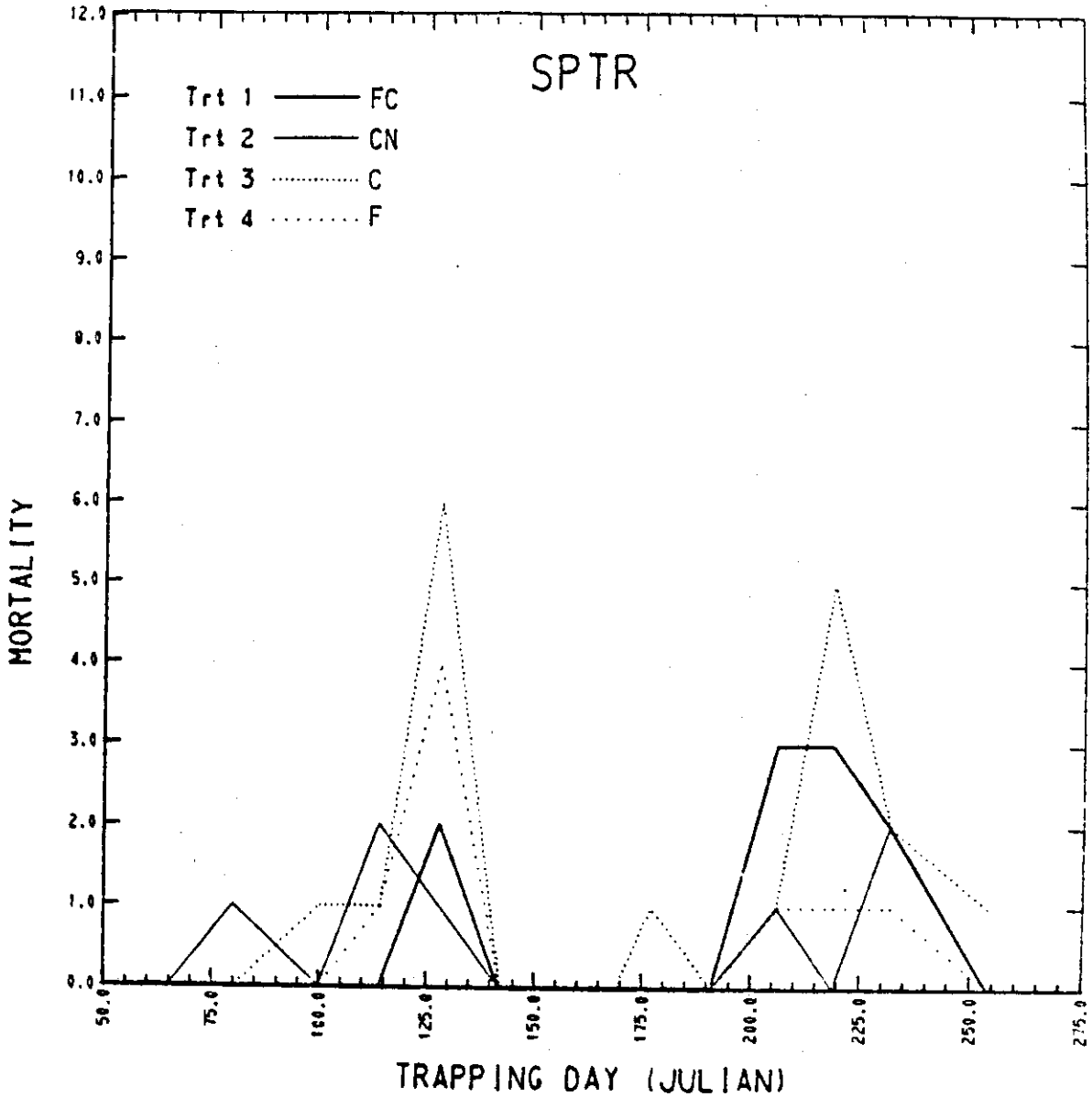

Fig. 14a. Trap mortality of *Spermophilus* for each trapping date by treatment. See Fig. 1 for treatment symbol explanation.

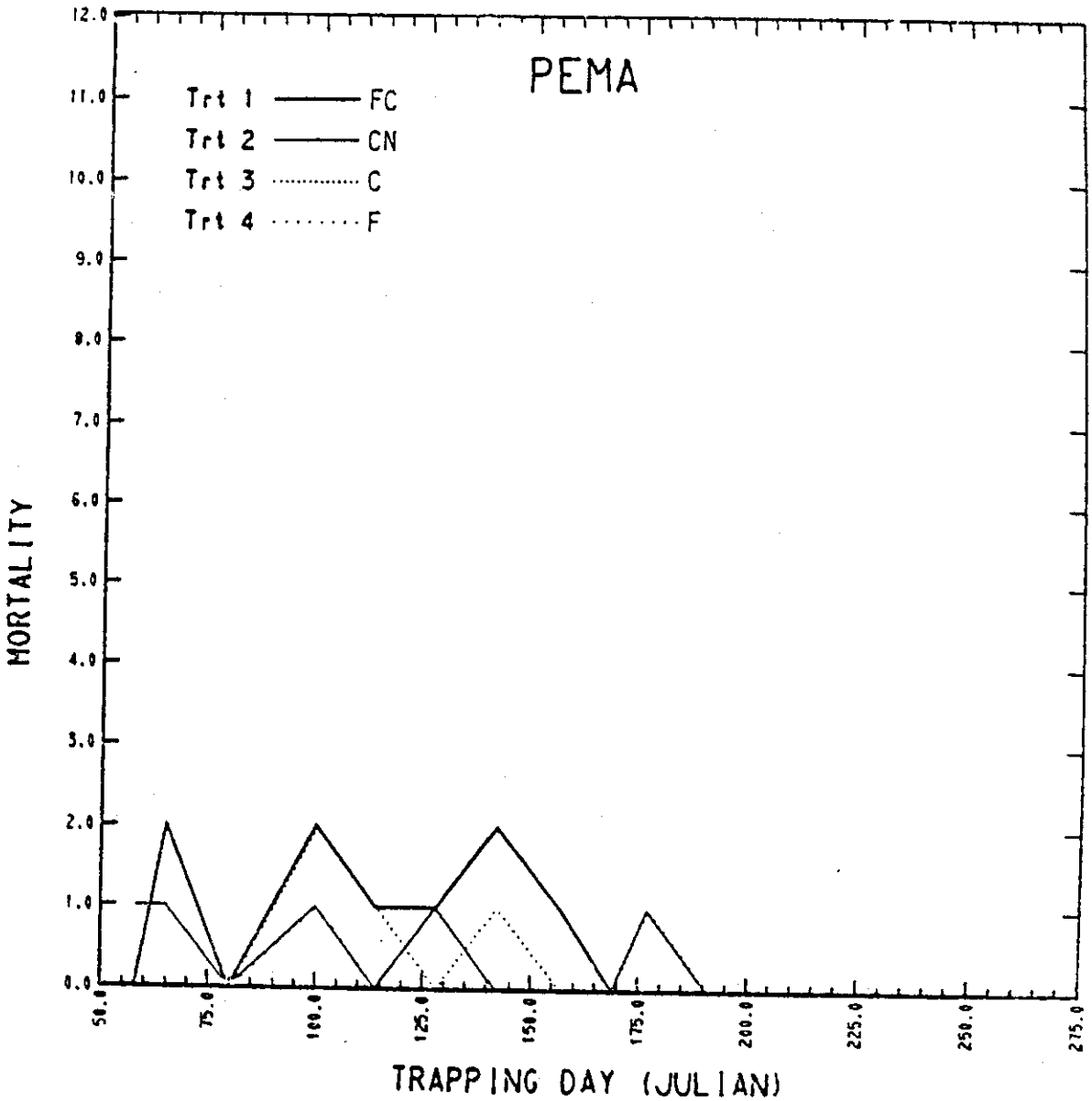

Fig. 14b. Trap mortality of *Peromyscus* for each trapping date by treatment. See Fig. 1 for treatment symbol explanation.

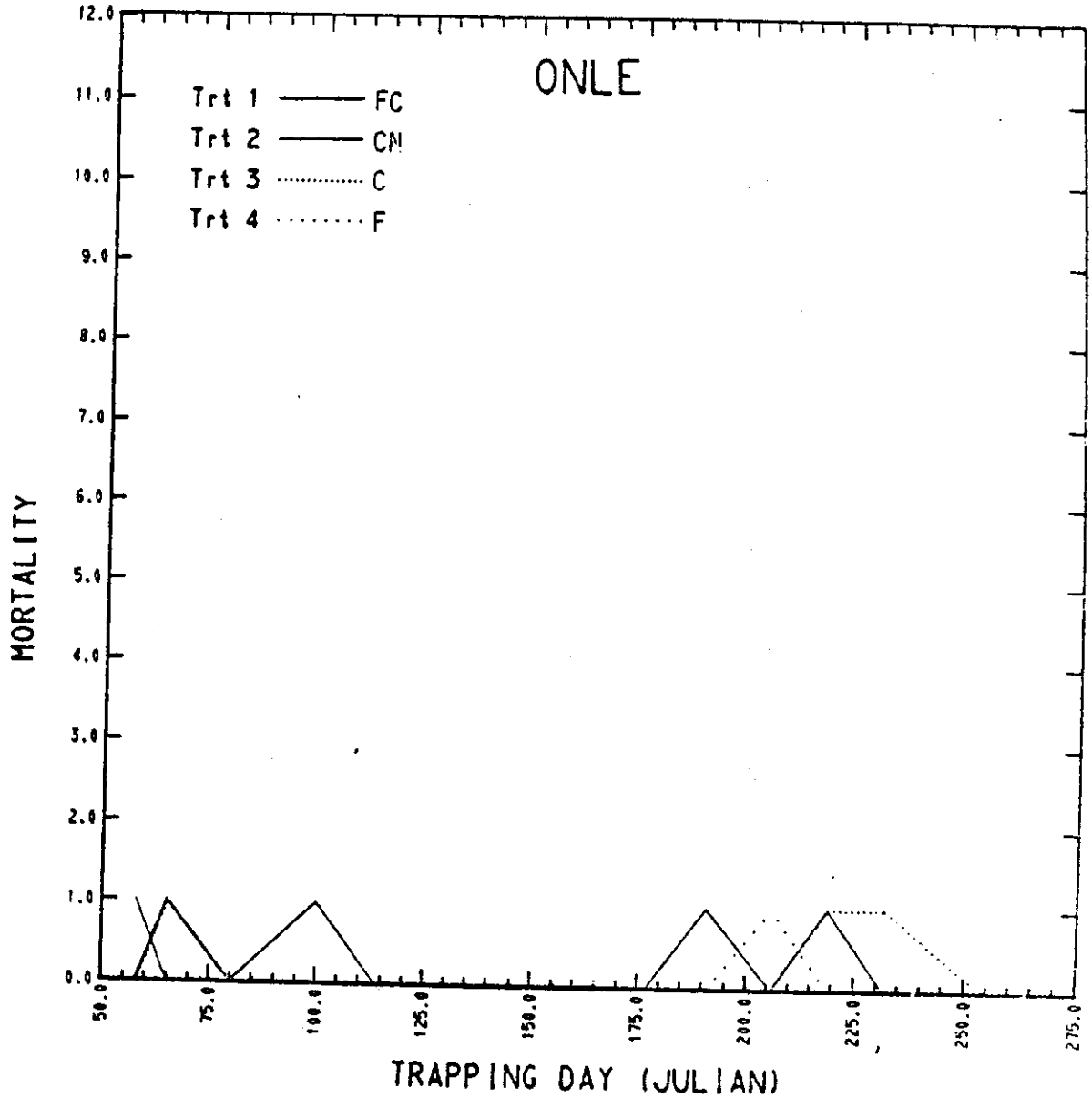

Fig. 14c. Trap mortality of *Onychomys* for each trapping date by treatment. See Fig. 1 for treatment symbol explanation.

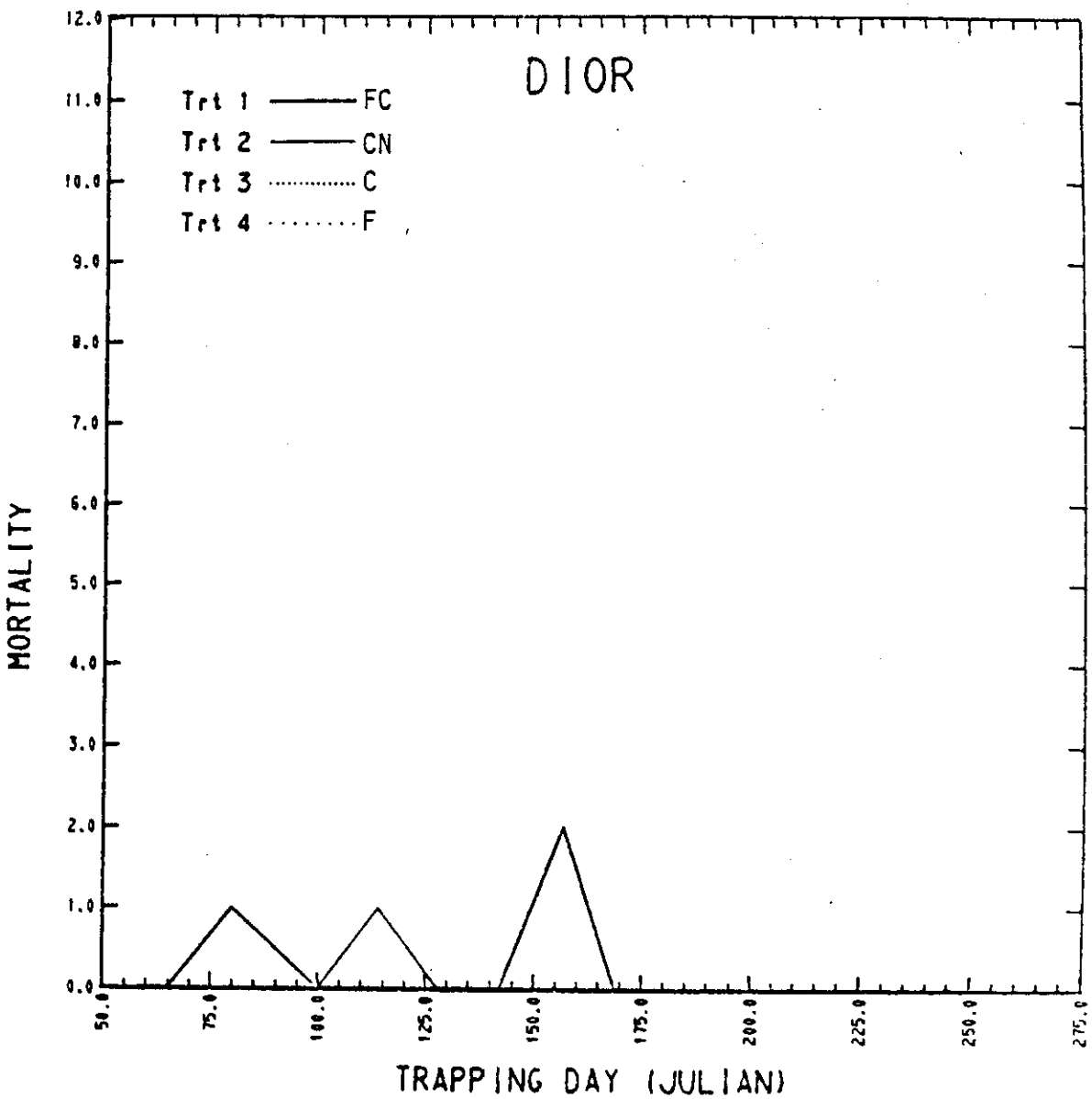

Fig. 14d. Trap mortality of *Dipodomys* for each trapping date by treatment. See Fig. 1 for treatment symbol explanation.

Table 10. Analysis of variance for the bird population indices on the four treatments. Data taken during postmodification.

Source	d.f.	M.S.	P	Q
Treatment	3	96.692	.0140	7.964
Birds	1	0.025	.9753	
Date	4	100.6	.0088	9.560
Treatment × date	12	25.733	.2721	
Date × bird	4	7.775	.7823	
Treatment × bird	3	11.225	.6124	
Bird × treatment × date	12	17.975		

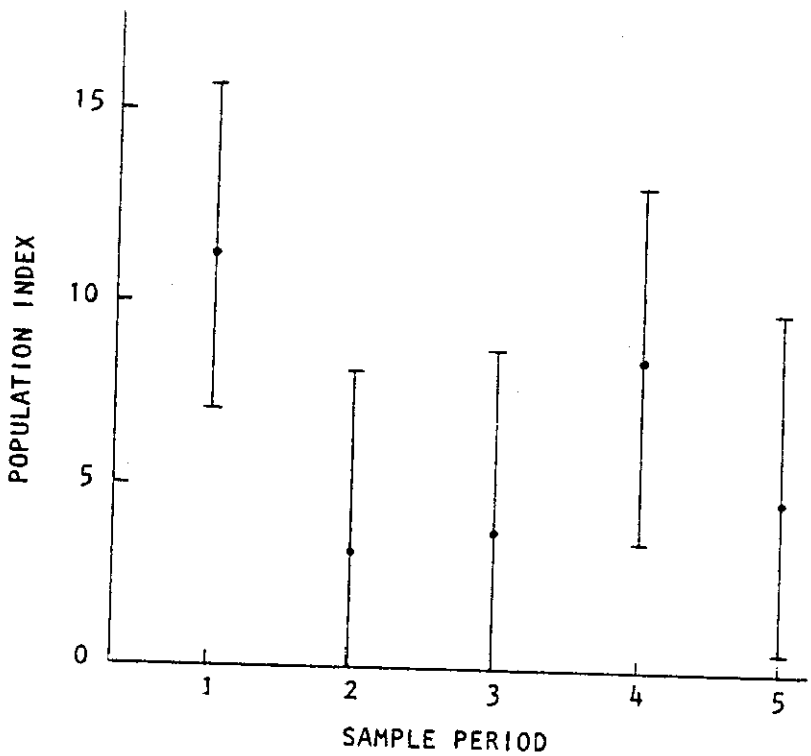

Fig. 15. Average population indices of bird species during the five sampling dates. Sampling dates coincide with the last five small-mammal trapping dates. Bars indicate Tukey's range of significance at the $\alpha = 0.05$ level. Any two lines having equal population indices indicate no significant difference between the two sampling periods.

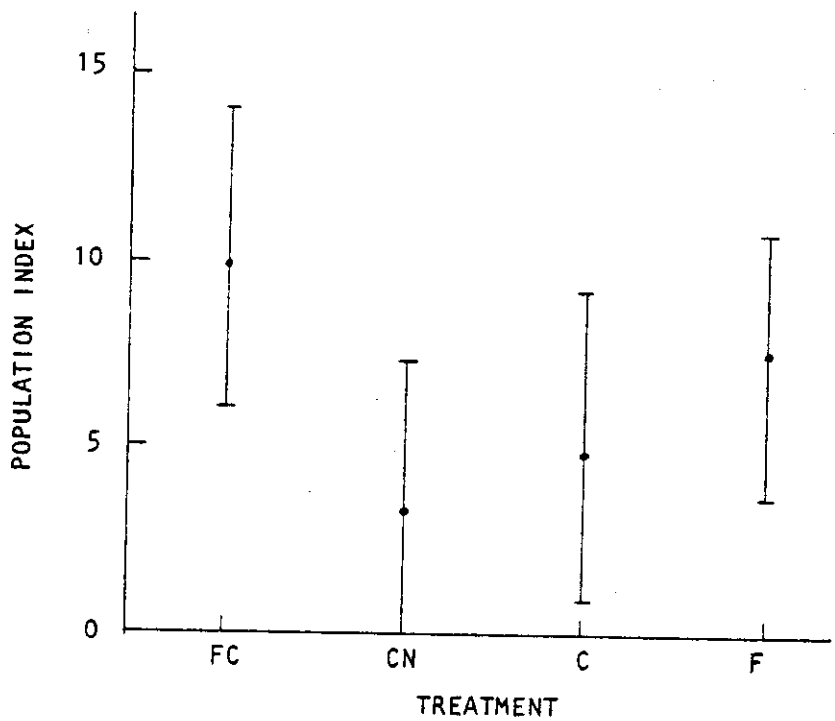

Fig. 16. Average population indices of bird species on the four treatment-areas averaged over all sampling dates. Bars indicate Tukey's range of significance at the $\alpha = 0.05$ level. Any two lines having equal population indices indicate no significant difference between the two treatment areas.

only, and then treatment C which has cover added. Treatment CN, the control, had the lowest population of birds.

Data indicate that the birds were responding to food as populations were higher in the food areas. Since no data were taken during premodification this hypothesis must be taken carefully. It seems logical that for these two bird species there was sufficient food added to attract them.

The target species, *Microtus*, was never captured in this study. Since *Microtus* inhabited the irrigated and fertilized areas in the Environmental Stress Area of the Pawnee Site soon after modification and from sources farther away than the sources for this study it may be assumed that the modifications done during this study were inadequate. It is also possible that *Microtus* never entered the area due to generally low populations in the surrounding areas.

Rosensweig (1973) showed that for some heteromyids the cover structure is the primary factor affecting habitat selection. He also has indicated that in grasslands this factor may differ among species; and since grasslands are fairly uniform in structure and height one of the important habitat factors for *Microtus* may be density of cover (Rosensweig, personal communication, 1975). *Microtus* may require high density cover for protection from predators since they are not as fast as other species present. Dense cover may also decrease conflicts and fighting (Warnock 1965). These studies indicate that high density cover may have advantages and may be necessary both behaviorally and physiologically for *Microtus*.

With additional cover and selection of experimental sites it will be possible to determine if cover or food is a major factor in

immigration and colonization of *Microtus* in grassland ecosystems. In a food-supplemented area on the Pawnee Site less than 200 m from the irrigated and fertilized areas of the Environmental Stress Areas which had high *Microtus* populations Abramsky (personal communication, 1976) has not found *Microtus* in trapping through March 1976. This casts doubt on whether food is important relative to cover at any time. The results found in the bird study indicated there was at least sufficient food in the treatments to cause a response of birds. The fact that there was no response from the small mammals may show that the food was not important to them at this time.

With the results found and problems faced in this study alternate methods and suggestions have been developed.

Modification of Present Study Technique

1. A very questionable practice is modification of the cover area with material not presently found in the grassland or with material that has inherent food qualities. Any results found with this material would be questionable since it would not be known whether the small mammals were reacting to the cover or the food value inherent in the cover, exactly the factors we are trying to seperate.

2. Modify the area more intensely with cover.

3. Pretrap the areas to find similar population sizes or find the trends present before modification. This is very important as shown by the results found in this study.

4. Replicate the treatments.

5. Simultaneously trap the surrounding areas for potential vole sources or migration.

6. Continue the research through the fall and winter of the year to see if there is a seasonal reaction to the food or cover.

SUMMARY AND CONCLUSIONS

Findings from this study are inconclusive. Premodification data illustrate the same trends across the treatments for individual species as the data after modification and no period differences within treatments was found. Mortality for each species censused was high which may have influenced reactions later in the study period. *Microtus* did not immigrate to the area under study. The question of why *Microtus* did not immigrate leads to many speculations. One of the most reasonable is the lack of sufficient populations of *Microtus* in the surrounding areas to supply immigrating individuals. Biomass of cover modification was equal to similar areas that had had large increases in vole populations within three months.

In a large open grassland area the problem is to obtain a reaction of the *Microtus*. This could be very difficult if the source of individuals is questionable. In experiments similar to Rosenzweig's (1973) on heteromyids, an area with a dense population of *Microtus* could be found with a large amount of cover and food. Then a number of small areas in this habitat could be cleared of all cover and food. Food could be added to some of these cleared areas and cover to others. There would then be a food area, food and cover area, and a cover area. Even more could be done in this type of area with structure of the cover itself, types of food, microhabitat data, etc. This research should continue throughout the winter to find response in the winter. This solves most of the problems inherent in the

previous research. After establishing the major factors for *Microtus* ir habitat already occupied it would be possible to modify an area without *Microtus* and see if their immigration requirements are the same as their colonization and living requirements.

Overall, the objectives of this study were partially satisfied. Further insight into the problems present in this study were obtained. Improvements or modifications have been suggested to make the next experiment more quantitative and rigorous.

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