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INTERACTIONS BETWEEN THE SHORT-TAILED SHREW, BLARINA BREVICAUDA, AND THE MEADOW VOLE, MICROTUS PENNSYLVANICUS

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by

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ABSTRACT

INTERACTIONS BETWEEN THE SHORT-TAILED SHREW, BLARINA BREVICAUDA AND THE MEADOW VOLE, MICROTUS PENNSYLVANICUS

by

DANIEL H. HUBBARD

A three-part study of the predator-prey relationship of *Blarina brevicauda* and *Microtus pennsylvanicus* was conducted from June, 1969 until November, 1971. (1.) Stomachs of *Blarina* were analysed to determine the prevalence of predation upon *Microtus* in the wild. (2.) The effect of *Blarina* on the population dynamics of *Microtus* was studied using a ½-acre field enclosure divided into two ¼-acre sections. *Microtus* was introduced into one section and both species into the other. (3.) Direct observation of *Blarina*-*Microtus* interactions was accomplished by using a laboratory enclosure.

Only 12 (5.7%) of 209 *Blarina* stomachs analysed contained meadow vole remains (hair only) indicating that short-tailed shrews do not prey upon *Microtus* to any great extent from April to November, the months studied.

A comparison of confined populations of *Microtus* showed similar patterns of rapid increase through the summer and fall months and drastic decline during the winter regard-

less of the presence or absence of Blarina. Numbers of Blarina and Microtus showed no linear relationship throughout the study. There were no differences in the monthly population levels of Microtus that could be attributed to Blarina predation.

Association between the two species in the enclosure as measured by joint use of trap stations did not depart from randomness. Microtus home range in experimental and control sections of the enclosure did not differ significantly. If Blarina predation did occur, it was not reflected in the sex and adult-juvenile ratios of Microtus.

Survival of Microtus was better than survival of Blarina. No difference in survival between experimental and control populations of Microtus occurred that could not be explained by differential habitat and cat predation.

Collection of shrew droppings in the spring revealed that Blarina did feed upon Microtus in the enclosure either as a predator or as a scavenger during the winter. In spite of the crash of the confined Microtus populations in both sections of the enclosure during the winter months providing many weakened or dead voles, Blarina did not survive either winter.

In the laboratory, Blarina was able to capture a Microtus occasionally in a restricted area. In 94 hours of observation, male Blarina were more active generally than females and interacted 52 times with Microtus in four food reduction test periods whereas females interacted only three times in two test periods. Hunger of Blarina was an important determinant of the level of interaction between the two species. Pursuit of _Microtus_ was not observed until food for the shrews was reduced to 3 grams or less of dog food per day. _Blarina_ initiated most of the interactions between the species but retreated from almost half of the encounters.

The survival of a vole, which had been the victim of a ten minute holding bite of _Blarina_, makes the value of the shrew's submaxillary, salivary gland toxin questionable. The limited predatory success which _Blarina_ displayed within the laboratory would probably have been diminished even more under natural conditions.

The successful defense of a _Microtus_ litter from a _Blarina_ provided with little food indicated that female _Microtus_ are capable of preventing predation on nestlings by the short-tailed shrew. The _Blarina_ involved died of starvation with two adults and five juveniles of its potential prey available.

It was concluded from all aspects of this study that the short-tailed shrew is an infrequent and fortuitous predator of the meadow vole. _Blarina_ and _Microtus_ co-occur due to preference for similar environments rather than to relationships to each other. Efficiency of predation in most laboratory studies does not reflect the situation in the field since vulnerability of voles is largely due to limitations of space in the laboratory.

INTRODUCTION

The ecological relationship between short-tailed shrews, *Blarina brevicauda*, and mice (chiefly the meadow vole, *Microtus pennsylvanicus*) has been studied for over one hundred years with the result that some researchers lend considerable importance to the predatory abilities of the shrew while others discredit its role as a predator of mice.

Observations of meadow voles and other species of mice being killed by *Blarina* in small cages in the laboratory have been recorded many times. Eadie (1944) cited several descriptions (published during the 19th century) of the destruction of mice by captive shrews. Shull (1907), after feeding four meadow voles to a shrew in six days, felt that *Blarina* preys heavily on voles and has the capacity to keep their population in check. Babcock (1914), however, after watching shrews kill voles in the laboratory, doubted the ability of a shrew to capture an uninjured vole in the wild because of its very limited vision. Evidence of the pursuit and capture of voles by short-tailed shrews under natural conditions was cited by Hamilton (1930) and Eadie (1944). Hamilton (1930) fed *Peromyscus*, *Mus* and a few *Microtus* to shrews, but found that after a heavy meal the shrews would pay little attention to live mice placed in their cages.

Shrews show a great deal of individuality in their encounters with *Peromyscus* and *Microtus* in the laboratory

(Rood, 1958). They either are afraid of the mice, make half-hearted attacks or attack viciously. The inability of a shrew to catch a *Peromyscus* in anything but a very small cage indicated to Rood (1958) that it was unlikely that it preys on them in the wild. From his observations, Martinsen (1969) felt that when a mouse was free to maneuver it was futile for the shrew to pursue it. However, because *Blarina* uses the surface runways of meadow voles, where the chances of interspecific encounters must be high, he thought that a shrew could undoubtedly capture a vole. His calculations of energy spent and gained showed that it would be worth the effort since a shrew, during 20 minutes subduing a 30 gram vole, would expend only 0.35 Kcal while gaining nearly 40 Kcal of potential energy. Fulk (1971) observed that the behavior of shrews toward voles in paired encounters does not represent specialized prey catching behavior since it corresponds closely with Olsen's (1969) description of intraspecific aggression.

Field observations which indicate shrew predation on meadow voles have been made by several researchers. Shull (1907) and Eadie (1944) give descriptions of *Blarina* nests surrounded by various vole remains. Eadie (1944, 1948, 1952) showed through the analysis of *Blarina* droppings that meadow voles formed a significant portion of the fall and winter diet of short-tailed shrews in every year studied for five years during the period 1942-1950. He found mouse remains in 56% of *Blarina* droppings during a period of high mouse abundance and in 14% in a low period. Eadie suggests that

Blarina numbers may have an important influence on the numbers of Microtus from year to year. Maurer (1970) observed a Blarina fighting with a juvenile Microtus under a hay bale in an uncut field. He also found several shrew-killed vole carcasses in other fields in the area.

Stomach analyses of Blarina may not indicate heavy predation on meadow voles. Hamilton (1930, 1941) found only 14 of 460 stomachs contained mouse remains, some of which probably represented trap victims. He therefore felt that "The short-tailed shrew has been credited with greater mouse destruction than it is capable of committing". Whitaker and Ferraro (1963) examined 220 stomachs taken in the summer and found no small mammals were eaten. Stomach analyses of 83 Blarina done on a seasonal and yearly basis by Lutz (1964) showed mammals in 9.7% of the stomachs.

For centuries, the bite of the shrew has been thought to be poisonous. The history of this supposition is reviewed by Pearson (1942) and Pournelle (1968). Pearson (1942) prepared a poisonous extract from the submaxillary, salivary glands of Blarina. This toxin, shown to be present in the saliva, might be introduced into wounds via the lower incisors. The assumption was made that the poison aids the shrew in overcoming prey such as mice. Lawrence (1945) believed that Blarina poison is a rapidly acting neurotoxin similar in some respects to that of elapine snakes. DeMeules (1954) demonstrated that the effect of Blarina venom may possibly be due to an anti-adrenalin action. The pharmacology of the toxin is described by Ellis and Krayer (1955). According to

Pucek (1968), if the toxin is not abundant enough to deliver a lethal dose, at least it is strong enough to immobilize the prey.

A study of the spatial and population relationships between *Microtus* and *Blarina* was made by Barbehenn (1958). His snap-trap census evidence suggested no causal relationship between the fluctuations of *Microtus* and *Blarina* populations and implied no ecological interaction. A bait station study of distribution and frequency of droppings showed that association between the two species was dependent upon monthly changes in habitat preference by *Microtus*. Unusually low survival of young *Microtus* in one study area coincidental with a change to positive association between *Microtus* and *Blarina* led Barbehenn (1958) to infer that the shrews were preying on nestlings. He hypothesized that the consequences of shrew predation on vole populations depend on the condition of the vole population and the timing of the predation. He presumed that shrews are capable of either precipitating a decline or prolonging a normal microtine cycle. Shapiro (1950), noting an abundance of *Blarina* and a low in the microtine population in his small mammal study, speculated that predation on *Microtus* by shrews might have been a factor contributing to the decline of the mice in the area. Getz (1961b), studying factors influencing distribution of shrews, concluded that *Microtus* abundance did not appear to be important.

Fulk (1971), through a field enclosure study and various laboratory studies, showed that voles tend to avoid places frequented by shrews and that this avoidance includes a negative response to shrew odor. He showed also that voles with less shrew experience avoided shrews and shrew droppings more than voles with more shrew experience. That the avoidance of shrew stimuli decreases with experience led Fulk (1971) to suggest that it prevents voles from sacrificing the use of space occupied by shrews. Fulk (personal communication) believes that Blarina is not an efficient predator of Microtus.

The foregoing review of the literature indicates much disagreement concerning the role of Blarina brevicauda as a predator of Microtus pennsylvanicus. I therefore attempted a comprehensive study to further clarify this complex relationship. A three-part investigation was conducted using different levels of control. First, stomach analyses were performed on wild-caught specimens of Blarina so that the effectiveness of Blarina as a predator on Microtus in the wild could be ascertained. Secondly, a field enclosure allowed study of population dynamics of the two species with a limited amount of control, and finally, a laboratory enclosure study permitted observation of shrew-vole interactions while providing a semi-natural environment.

Field enclosures have been employed by Caldwell and Gentry (1965), Gentry (1968), Grant (1969, 1970, 1971), Krebs, Keller and Tamarin (1969), Krebs (1970) and Fulk (1971). Fulk's study is the only one, however, that concerns a predator-prey relationship and his study is limited to the spatial distribution of Blarina and Microtus. My study is the first enclosure study of the population dynamics of this predator-prey system.

It was hoped that laboratory observations of the effectiveness of Blarina as a predator on Microtus and field observations of the effect of Blarina on the population dynamics of Microtus in conjunction with an index of Blarina predation on Microtus in the wild (stomach analyses), would lead to a better understanding of this predator-prey relationship.

METHODS AND MATERIALS

GENERAL

Specimens of Blarina brevicauda and Microtus pennsylvanicus were obtained during the snow-free months between May, 1969 and August, 1971 using Sherman live traps and Museum Special snap traps in old field habitats of Rockingham and Strafford Counties, New Hampshire. Generally, snap traps were used from the beginning of each month until at least ten Blarina had been trapped for stomach analysis. Live traps were used whenever experimental animals were needed. Trapping, using either or both types of trap, was done almost continuously during the snow-free months.

Traps, baited with peanut butter, were placed at about ten foot intervals in transects and checked in the morning and evening. Live animals were examined for weight, sex, and breeding condition, were marked by toe clipping and kept in the laboratory until needed for experimentation. Snap trapped animals were examined for sex, breeding condition and measurements. The stomachs of Blarina were removed and placed in vials containing 10% formalin.

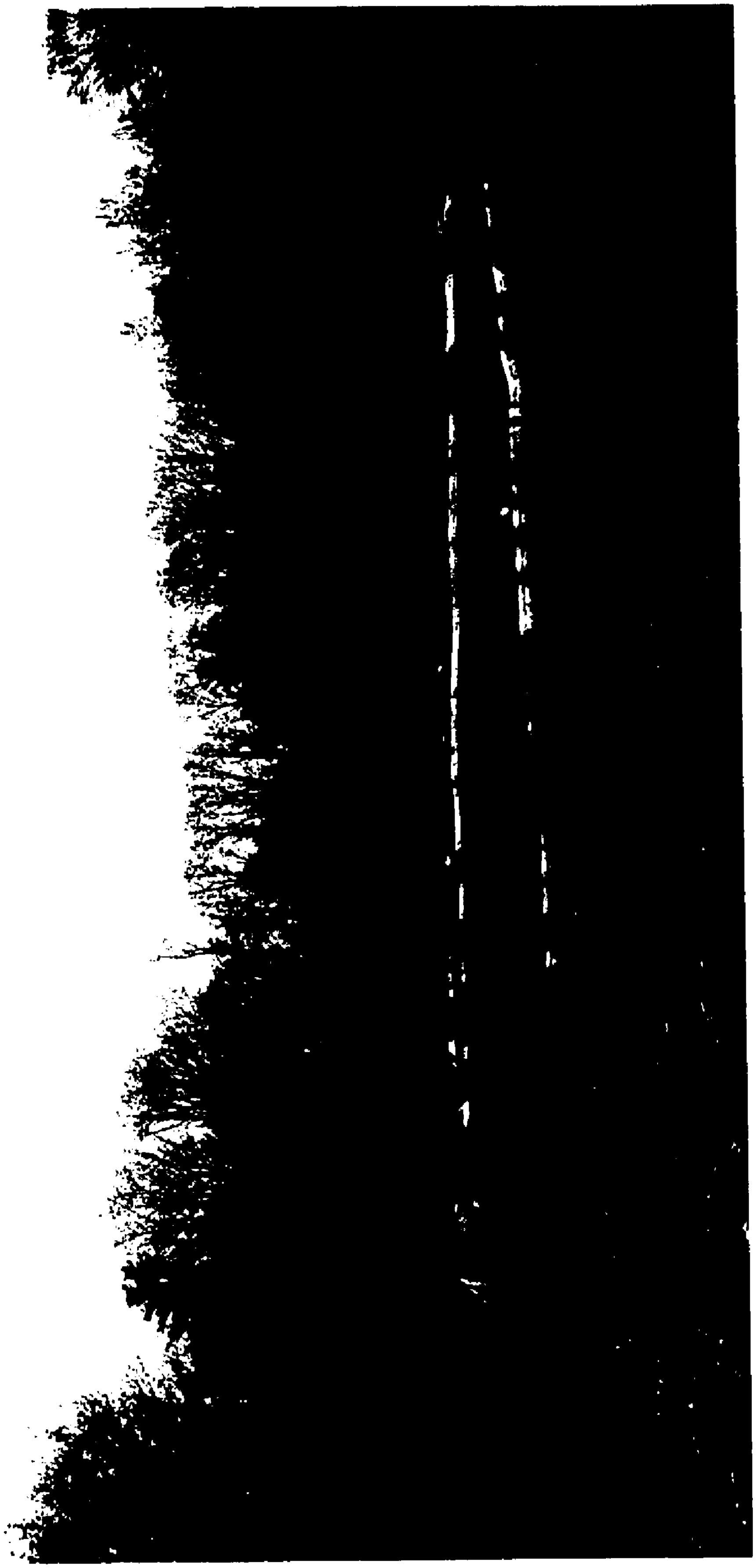
STOMACH ANALYSIS

To determine the prevalence of Blarina predation upon Microtus in the wild, analyses were done on the Blarina stomachs. The method used to examine the stomach contents is similar to that used by Hamilton (1930, 1941). The stomach contents were placed in a petri dish, teased apart with dissecting needles and examined under a dissecting microscope. Samples of the contents were mounted on slides and studied under a compound microscope and hairs found in these examinations were identified using criteria established by Mathiak (1938) and Williams (1938). The monthly, yearly and total percentage of stomachs containing the various food items of Blarina was determined with particular interest being given to the occurrence of Microtus remains.

FIELD ENCLOSURE STUDY

In order to study the effect of the presence of Blarina on the population dynamics of Microtus, an ellipsoidal field enclosure was constructed in the spring of 1969 that encompassed an area of ½-acre (major axis-200 ft.; minor axis-140 ft.) (Fig. 1). A partition spanned the minor axis creating two ¼-acre sections. Side B is the near side and side A the far side in Figure 1. The enclosure of ¼-inch mesh hardware cloth extended 1½-2 ft. into the ground and 2-2½ ft. above ground and was capped with ten inches of aluminum flashing. In November, 1969, the fence was extended to a height of about 4 ft. with four strands of wire in an attempt to exclude local domestic cats. This did not suffice and in June, 1970 the height of the enclosure was increased to 6-8 ft. with ½-inch mesh gill netting. The gill netting was supported by reinforcing rods bent outward creating an effective barrier to the cats.

Figure 1. Field enclosure: A, far side; B, near side
May, 1971.



The enclosure is located in an old field on the O'-Kane property next to the DeMeritt cemetery on land belonging to the University of New Hampshire. It is surrounded on three sides by mixed hardwoods and on one side by a grassy field which is mowed yearly. Small seedlings that tended to colonize the enclosure were removed as they appeared during the study. The vegetation is generally similar in both sections of the enclosure (Table 1). Timothy, Phleum pratense, and vetch, Vicia cracca, are the dominant plant species. The presence of Phalaris arundinacea, Carex spp. and Juncus spp. on side A indicates that more moisture is present in that area of the enclosure.

Prior to construction of the enclosure, live trapping of the area yielded four species of small mammals: Microtus pennsylvanicus; Blarina brevicauda; the masked shrew, Sorex cinereus; and the short-tailed weasel, Mustela erminea. After construction, the enclosure was live trapped for one week and then snap trapped for one week to remove all animals present.

To determine whether the presence of Blarina would have an effect upon the population dynamics of Microtus, an experimental treatment (Microtus and Blarina) was created on one side of the enclosure and a control (Microtus only) on the other. The investigation was initiated on June 25, 1969 with the introduction of two male and three female Microtus into each side of the enclosure. Six Blarina were introduced into side B on August 28, 1969. Sex of Blarina is difficult to determine because of the presence of a cloaca

Table 1. Vegetation of field enclosure. 5=abundant; 4=common; 3=frequent; 2=few; 1=rare.

Species	Side A	Side B
Phleum pratense	5	5
Vicia cracca	5	5
Agropyron repens	4	4
Dactylis glomerata	4	4
Poa pratensis	4	4
Bromus inermis	3	3
Calamagrostis canadensis	2	2
Alopecurus pratensis	1	1
Anthoxanthum odoratum	1	1
Phalaris arundinacea	2	
Juncus canadensis	2	
Juncus effusus	2	
Carex stipata	2	1
Carex scoparia	2	

rather than external sex organs and of the lack of secondary sex characters. The six Blarina introduced were sexed as three males and three females.

Enumeration of the populations by intensive live trapping commenced in August and was repeated monthly until discontinued in December due to snow. Three Blarina were introduced in October and one in November, 1969 to supplement the number of Blarina for over-winter survival. However, when live trapping was resumed in April, 1970, neither Blarina nor Microtus had survived the winter. This was possibly due to the lack of a protective snow cover before the middle of December, for part of February, and beyond the middle of March.

Introduction of animals was repeated on June 17, 1970. Two male and three female Microtus were introduced again into each side but, unlike the previous year, four Blarina (probably two males and two females) were introduced simultaneously. Experimental and control sides were switched in 1970, A receiving both species, B Microtus only. Cat predation shortly after introduction necessitated another introduction in July, 1970. Two male Microtus and four Blarina (two males and two females) were added to the three surviving female Microtus in side A. Due to a shortage of experimental animals, the control side B could not be stocked completely so that useful data was obtained for only the experimental side A in 1970. In 1970, snow caused the cessation of trapping in November. Trapping in April, 1971 revealed that Microtus had survived the winter while Blarina had not. Fourteen Blarina (5 males and 9 females) were introduced into side B between May 8 and August 15, 1971. Trapping continued monthly until November, 1971 when the study was terminated.

Sherman live traps baited with peanut butter or rolled oats were used in the trapping procedure. Eighty traps arranged in a grid pattern with about ten foot intervals were set in each side of the enclosure. Traps were opened in the morning, checked at approximately two hour intervals during the day, and closed in the evening. Frequent checking of traps and closing of traps during the night were employed to prevent death of animals in the traps. In spite of precautions, eight Microtus and one Blarina were trap casualties during the study due to the heat of summer months. Intervals between trap checks varied with temperature and number of animals captured. Trapping was done monthly for a period of four to seven days depending upon the population density. Trapping terminated when it was estimated that all animals were accounted for.

The Schnabel and Schumacher-Eschmeyer capture-recapture methods of population estimation (Mosby, 1963) were used but it was discovered that intensive live trapping provided almost complete enumeration of the population. Number of animals known to be present were used in analyses except when it was necessary to have a standard error. The Schumacher-Eschmeyer technique provides a standard error.

Microtus populations on experimental and control sides of the enclosure were compared using "Student's" t-tests. No control side data were obtained in 1970 that could be compared statistically with the experimental side. The experimental side was, however, compared with both the control and experimental sides of 1969.

To determine whether a linear relationship existed between the number of Blarina and the number of Microtus present each month during the study, a regression analysis was performed.

Monthly Schumacher-Eschmeyer population estimates of Microtus were compared using the ratio $\frac{N_1-N_2}{\sqrt{S.E._1{}^2+S.E._2{}^2}}$. A ratio greater than 2 indicates that the populations are "different" at the 95% confidence level.

Following the method described by Dice (1952), a test for association between Blarina and Microtus was performed for each trapping period by means of a 2X2 contingency table and chi-square test of significance. This measures whether the two species are taken at the same trap with greater or less frequency than would be expected by chance. Association coefficients were calculated to determine whether there was any monthly pattern of change in association between the two species. A coefficient of association of 1.0 would indicate that the two species frequented the same trap exactly the number of times that would be expected by chance. A coefficient smaller than 1.0 would indicate less frequent association than expected by chance and one larger would indicate more frequent association than expected. To determine whether the association coefficients were effected by population levels of *Microtus* or *Blarina*, linear regression analyses were done.

When introduced or when first captured each animal was toe clipped for identification. Date, time and general weather conditions were recorded during trapping periods. At each capture the following data were also recorded: Species; individual number; trap number; sex; age, adult or juvenile; weight (except 1969); testes position in males; patency of the vagina, size of nipples, and evidence of lactation in females. Testes position and patency of the vagina were not recorded for *Blarina* since shrews do not have a scrotum and significance of vaginal perforation in shrews is unknown.

Sex ratios and adult-juvenile ratios for *Microtus* were determined for each trapping period. Chi-square analyses were performed on the sex ratios to determine whether they varied from the expected equal ratio more than would be expected by chance.

Survival of *Microtus* and *Blarina* was measured by calculating the percentage of animals known to be present one trapping period that were also known to be present the following trapping period. "Student's" t-tests were used to compare survival of *Microtus* and *Blarina*; of male and female *Microtus*; of adult and juvenile *Microtus*; of total *Microtus* on control and experimental sides in 1969 and 1971; and of juvenile *Microtus* on control and experimental sides in 1969 and 1971.

To determine the effect of the presence of *Blarina* on the home range size of *Microtus*, home ranges were calculated for all animals that were captured in at least three different traps during a trapping period. The minimum area technique, which assumes that the most extreme points of capture define the outermost limits of a home range, was the method used. Ambrose (1969) determined home range size of *Microtus* by inserting isotopic gold wire subcutaneously and tracing the movement of the voles with a Geiger-Muller probe. Comparing this with live trap methods of home range determination, he found that when using a small trap grid, the minimum area method yields a home range size most closely approximating that determined by the isotope method.

For the calculation of the home ranges the trap grid pattern of the enclosure was drawn on paper. The locations of capture for each animal during each trapping period were plotted on the trap pattern. Lines were drawn connecting the outermost points of capture and the enclosed area was considered the home range. The number of traps contained in this enclosed area was used as a general indicator of home range size rather than as an absolute measure.

An analysis of variance was performed on average home range size of *Microtus*, when *Blarina* was present and when it was not, for the months June to November. Also, multiple regressions were performed to determine if either month or population levels had an effect on average home range size of *Microtus* (total, adult, male, and female) and *Blarina*.

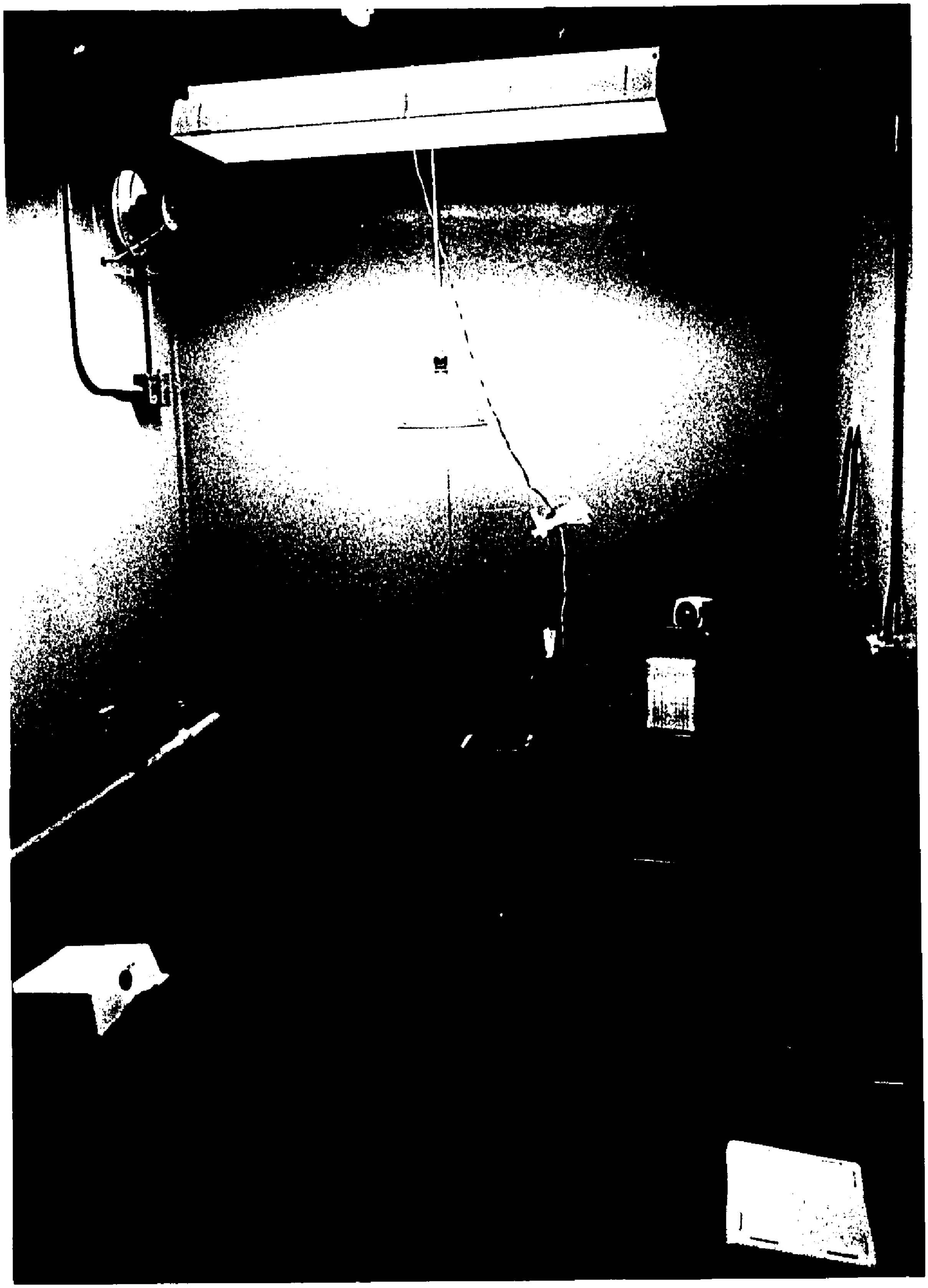
Trapping outside of the enclosure was conducted to determine if any animals were escaping. Four marked Microtus were captured outside the enclosure in April, 1971. These individuals likely escaped during the winter months when snow was high enough to allow them to escape over the fence. Three Blarina escapees were detected during the summer of 1971. Occasionally a Blarina would be captured on the control side and replaced into the experimental side. Lutz (1964) found that Blarina tunnel systems reach a depth of 20 inches. It seems probable, therefore, that shrews occasionally were able to burrow under the fence. Those escapees detected were only a small percentage of the 505 Microtus and 40 Blarina marked during the study.

Blarina droppings were collected and analysed for vole remains whenever found in the course of the study. In addition, general observations were made of runway development, nests, amount of vegetation and cover, and animal remains.

LABORATORY ENCLOSURE STUDY

A laboratory enclosure was constructed to allow direct observation of Blarina-Microtus interactions (Fig. 2). Approximately six inches of soil was put into two 7X9 foot rooms. Sheet metal on the walls and a concrete floor prevented escape of animals. The rooms were connected through a hole in the wall between the two rooms and a box containing four treadles monitored movements between the rooms. The treadles were connected to an Esterline-Angus graphic recorder which was set at a speed of 3/4 inch per hour. A con-

Figure 2. Laboratory enclosure-*Microtus* room B. Treadle box in back wall leads to similar *Blarina* room A.



trolled light cycle was established to simulate summer conditions (16 hr. light-8 hr. dark). Observation during dark hours was aided by red lighting. An attempt was made to grow grass in the rooms by seeding them but not a sufficient amount grew to provide cover for the animals. Food and water containers, plastic cages for nest boxes, and timothy hay were provided.

With the room connector closed, a *Blarina* was introduced into room A and a pair of *Microtus* into room B. The animals were allowed to establish burrow systems before the connector was opened. A continuous record of movement of the animals between the rooms was provided by the graphic recorder. A record of activity and interaction of the two species was obtained through 94 hours of direct observation through a door in each room. An interaction was tabulated each time at least one species clearly responded to the presence of the other species (e.g., chase, retreat without chase, physical confrontation, vocalization). The animals were trapped periodically with Sherman live traps to check weight, breeding condition (of *Microtus*) and general physical condition (e.g., wounds). All animals involved in the study were toe clipped for identification and *Blarina* scats, when found, were checked for vole remains.

Shrews were normally fed about ten grams of Ken-l Ration dog food per day in the laboratory. An experiment to observe the effect of hunger on the predatory behavior of *Blarina* was performed. A *Blarina* in the enclosure was provided with diminishing amounts of dog food each day according to the following 12-day schedule: 10 gm., 8, 6, 5, 4, 3, 2, 1, 0, 0, 0, 0. Martinsen (1969) found that Blarina will eat a wide variety of foods. The plant matter available in the rooms probably supplied Blarina with another energy source. The experiment was performed six times using four male and two female Blarina. The number of Microtus present during the six experiments varied according to the schedule given in Table 12. To determine whether interactions increased significantly as the amount of dog food provided for Blarina was decreased, linear regressions of interactions per ten hours of observation on day of experiment or grams of dog food available were performed.

To determine if a female Microtus would show defensive behavior of her young against a shrew, a female with six 10 day old babies was introduced. Subsequently, a litter of young Microtus was born in the enclosure making further observation possible.

Upon completion of the study, all remaining animals were removed and the rooms inspected thoroughly to locate underground nests, burrows and animal remains.

RESULTS

STOMACH ANALYSIS

The diet of *Blarina brevicauda* is generally considered to consist mostly of soil invertebrates (e.g., insects, mollusks, and annelids), although quantities of vegetable matter are also eaten (Hamilton, 1941). It has been indicated previously that there is much disagreement concerning the number of mice eaten by shrews.

The results of the examination of the stomach contents of 209 shrews trapped during the months May to December, 1969 and April to December, 1970 are summarized in Table 2. Of the stomachs analysed, only 5.7% contained vole remains and these remains consisted only of hair. In 1969, 6 of 99 stomachs (6.5%) and in 1970, 6 of 116 stomachs (5.2%) contained *Microtus* hair.

A monthly breakdown of the analyses is presented in Table 3. There does not appear to be any monthly pattern in the occurrence of stomachs containing vole hair. The numbers of *Microtus* and *Blarina* trapped do not indicate relative population levels because the trapping efforts were not uniform. They do, however, give some indication of the ratio of the number of *Microtus* to the number of *Blarina* present each month. The proportion of shrew stomachs containing vole hair does not seem to be influenced by varying ratios of *Microtus* to *Blarina* since ratios of .12 to 6.9 were obtained for months

Table 2. Summary of the stomach analysis of 209 *Blarina brevicauda*.

Sex ratio	119 male:90 female	
Food items	No. of stomachs *containing item*	*%*
Soil invertebrates	131	62.7
Plant material	40	19.1
Microtus	12	5.7

Table 3. Monthly occurrence of *Microtus* hair in stomachs of *Blarina brevicauda* and numbers of each species trapped each month.

Month, year	No. of stomachs	% containing *Microtus* hair	*Microtus* trapped	*Blarina* trapped
May, 1969	15	20.0	2	15
June, 1969	7	0.0	22	7
July, 1969	14	0.0	32	22
Aug., 1969	23	4.3	24	23
Sept., 1969	12	0.0	12	12
Oct., 1969	10	10.0	68	10
Nov., 1969	10	10.0	69	10
Dec., 1969	2	0.0	41	2
April, 1970	3	0.0	5	4
May, 1970	8	0.0	24	14
June, 1970	9	0.0	8	20
July, 1970	26	11.5	19	49
Aug., 1970	23	0.0	10	37
Sept., 1970	10	0.0	3	11
Oct., 1970	17	11.8	15	18
Nov., 1970	17	5.9	20	20
Dec., 1970	3	0.0	7	3

in which vole hairs were found.

A detailed analysis of the 12 stomachs containing vole hair is given in Table 4. It is questionable whether most of the stomachs containing hair represent predation of voles by shrews because of the few hairs found. Only 43.1% of the 209 Blarina analysed were females whereas 75.0% of those whose stomachs contained vole hairs were females.

FIELD ENCLOSURE STUDY

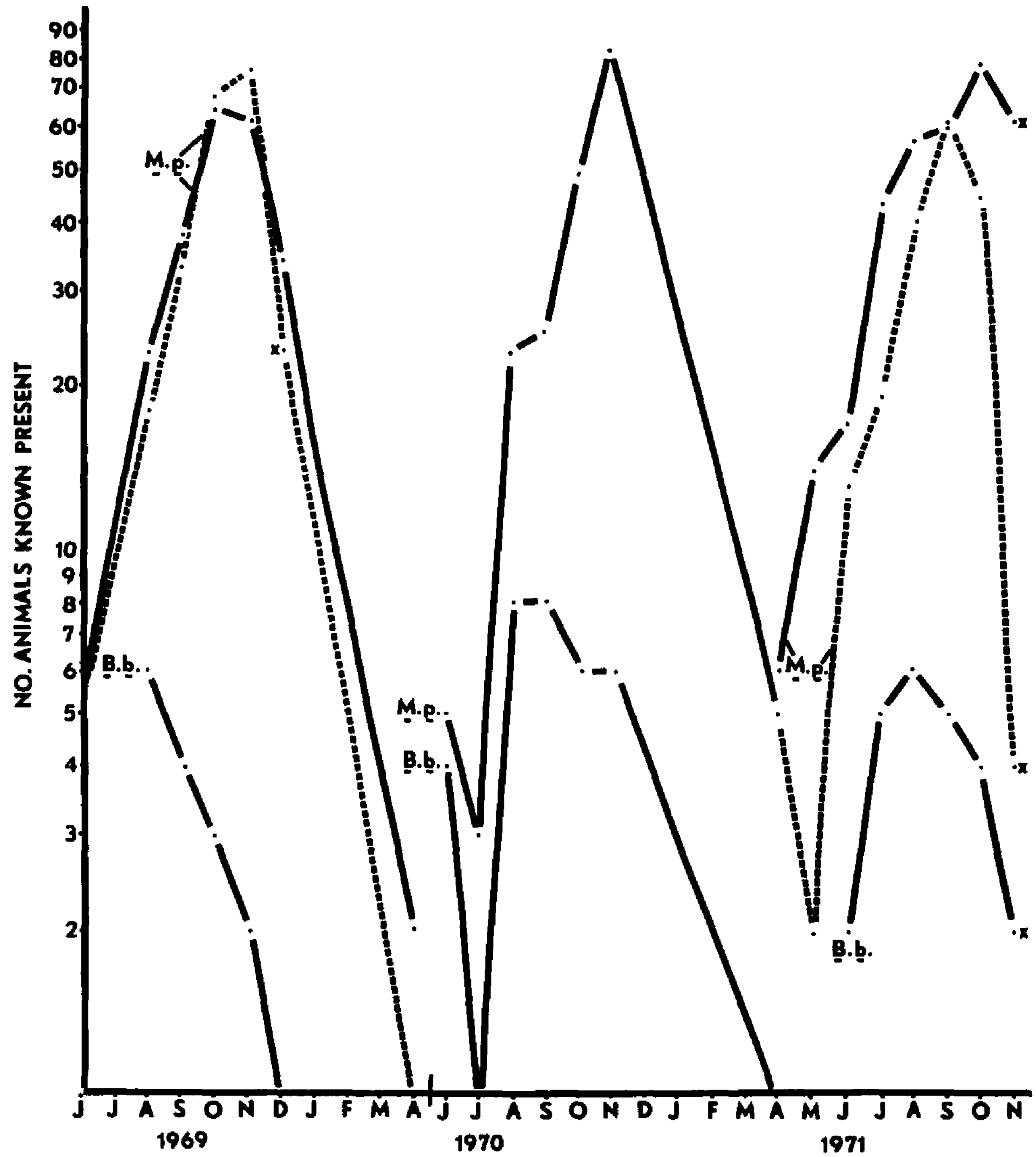
This study began with the introduction of Microtus pennsylvanicus into each side of the field enclosure in June, 1969. The number of animals (Microtus and Blarina) known to be present in the months studied is given in Figure 3.

In 1969, both sides A and B showed explosive increases in the Microtus populations until October (at least 65.2% per month). In November, the control side A showed a slight increase (11.9%) and the experimental side B a slight decrease (4.7%). A decrease of about 45% occurred on both sides in December. The decreases found can probably be attributed to predation by local domestic cats which began between the October and November trapping periods. The April, 1970 trapping period yielded no Microtus on side A and two males on side B. Therefore, both populations were virtually extinct.

The numbers of Blarina brevicauda, introduced in August, 1969, declined consistently in spite of periodic introductions, until only one individual remained in December.

Table 4. Data on 12 _Blarina_ _brevicauda_ stomachs containing _Microtus_ hair.

Stomach no.	No. of hairs found	Date _Blarina_ trapped	Sex of _Blarina_	_Blarina_ weight (gm.)
8	1	5/19/69	F	20.2
13	1	5/26/69	F	13.2
14	5	5/26/69	M	18.5
39	3	8/09/69	F	14.9
75	20	10/21/69	M	20.2
87	2	11/20/69	F	20.1
117	10	7/17/70	F	15.2
120	1	7/19/70	F	18.8
131	3	7/27/70	M	14.8
174	50+	10/02/70	F	17.1
179	7	10/07/70	F	14.3
194	1	11/05/70	F	16.2
			3M:9F	



x - Incomplete trapping period due to snow.

Figure 3. Number of Microtus pennsylvanicus and Blarina brevicauda known to be present. Solid- experimental side of enclosure; dash- control side.

In April, no Blarina were present. There was no indication that Blarina had reproduced in the enclosure.

The failure of the Microtus and Blarina populations to survive the winter months necessitated another introduction of animals in 1970. The experimental side A was the only side to yield useful data because of cat predation in the side without shrews. Except for an increase of only 8.7% between August and September, the Microtus population increased dramatically to a peak in November (Fig. 3). The population declined drastically overwinter (93.9% decrease), however, and only 5 voles remained on side A in April, 1971. Microtus on side A apparently were able to escape over the snow during the winter. Three marked individuals were trapped on side B and four outside of the enclosure in April.

Blarina were more successful in 1970. Reproduction was evident and a high of 8 shrews was present in August and September. Despite the presence of 6 shrews when trapping ceased in November, trapping in April revealed that Blarina again was not able to overwinter in the enclosure. Even though potential prey (Microtus) were able to survive the winter, Blarina apparently were not able to find enough food to survive.

In 1971, overwinter survival of Microtus allowed trapping from April to November. The vole population on the experimental side B, except for an increase of only 5.4% from August to September, showed substantial increases throughout the months studied. The control side A declined from April to May, rapidly increased until September when the population equaled that of side B, then decreased in October and November (Fig. 3).

Blarina were introduced from May to August, 1971. A high of 6 shrews was obtained in August, but subsequently numbers declined. No evidence of successful reproduction was found.

Using the "Student's" t-test, no significant difference was found in the number of Microtus known to be present each month in sides A and B, 1969. Comparisons of the experimental side A, 1970 with both the control and experimental sides of 1969 also revealed no significant differences. Comparisons of the experimental and control sides of 1971 indicated that the Microtus population on the experimental side B was significantly larger ($P < .05$) than the population on the control side A.

Linear regression analysis of the number of Blarina and the number of Microtus present each month during the study (Fig. 3) revealed no linear relationship. Therefore the number of Blarina present did not influence numbers of Microtus in this study.

Comparisons of monthly Schumacher-Eschmeyer population estimates of Microtus (Table 5) displayed no definite pattern of significance which would show that the presence of Blarina affects population levels of Microtus.

The coefficients of association, chi-square tests of significance of association, and the numbers of Blarina and Microtus present during each trapping period are summarized in Table 6. The coefficients of association include several

Table 5. Three year comparison of monthly Schumacher-Eschmeyer population estimates of *Microtus pennsylvanicus* in sides A and B of field enclosure using the ratio: (1 *Blarina brevicauda* present)

$$\frac{N_1-N_2}{\sqrt{S.E._1^2+S.E._2^2}}$$

Month	N_1	N_2	P	N_1	N_2	P
	A-1969	B-1969		A-1969	A-1970	
Aug.	18.20± 2.80	27.56± 7.90	< .05	18.20± 2.80	29.84± 7.87[1]	< .05
Sept.	34.08± 2.38	37.38± 2.62[1]	NS	34.08± 2.38	28.18± 6.14[1]	NS
Oct.	72.23± 5.64	66.09± 3.90[1]	NS	72.23± 5.64	51.10± 6.02[1]	< .05
Nov.	80.33± 6.10	58.85± 5.92[1]	< .05	80.33± 6.10	90.32± 8.00[1]	NS
Dec.	41.21±15.50	36.53± 2.58[1]	NS			
	B-1969	A-1970		A-1971	B-1971	
April				6.18± 3.14	6.17± 1.84	NS
May				2.50± 1.76	16.26± 4.40[1]	< .05
June				13.91± 1.44	19.45± 4.56[1]	< .05
July				18.77± 0.84	60.14±18.02[1]	< .05
Aug.	27.56± 7.90	29.84± 7.87[1]	NS	39.75± 3.94	61.08± 8.16[1]	< .05
Sept.	37.38± 2.62[1]	28.18± 6.14[1]	< .05	58.68± 5.23	55.00± 4.83[1]	NS
Oct.	66.09± 3.90[1]	51.10± 6.02[1]	< .05	48.74± 5.65	72.48± 5.74[1]	< .05
Nov.	58.85± 5.92[1]	90.32± 8.00[1]	< .05			

Table 6. Measurements of association between _Blarina_ and _Microtus_ based on joint use of traps; numbers of both species present during each trapping period.

Trapping period		Association Coefficient	Chi-square[1]	_Microtus_ present	_Blarina_ present
Sept.	1969	0.24	3.43	38	4
Oct.	1969	0.84	0.01	64	3
Nov.	1969	1.53	--	61	2
Dec.	1969	0.44	0.64	34	1
Aug.	1970	1.80	2.33	23	8
Sept.	1970	0.90	0.00	25	8
Oct.	1970	1.39	1.29	49	6
Nov.	1970	0.96	0.00	82	6
May	1971	0.00	--	14	1
July	1971	0.98	0.19	43	5
Aug.	1971	0.88	0.00	56	6
Sept.	1971	0.99	0.07	59	5
Oct.	1971	0.70	2.59	77	4

1 None of the chi-square test values were significant.

that show positive or negative association between *Blarina* and *Microtus* but chi-square analyses indicated no significant deviations from a random distribution. Linear regression analyses of the coefficients of association and the number of *Microtus* or *Blarina* present revealed no linear relationships. Since in November, 1969 *Blarina* was not captured in a trap in which a *Microtus* had not been captured and in May, 1971 *Blarina* was not captured in a trap in which a vole had been captured, chi-square could not be calculated for those months. The foregoing analyses indicate that the two species are not associated more or less frequently than would be expected by chance in the months studied and at the population levels studied.

Only 25 times during the course of the study were both species taken at the same trap during the same day. This would indicate temporal isolation of the two species. *Blarina* was taken 16 times in a trap in which a *Microtus* had already been taken while *Microtus* was only taken 9 times in a trap in which a *Blarina* had been taken earlier. This would indicate either a positive response to vole odor by shrews or more probably a negative response to shrew odor by voles. A *Microtus* did not enter a trap in which a shrew had been captured on the same day when the number of *Microtus* known to be present was less than 56. When 56 or more *Microtus* were present, voles entered traps in which shrews had been captured as many times as shrews entered traps in which voles had been captured. A change in vole response to shrew odor at high population levels is indicated.

The sex ratios for Microtus known to be present in each month are presented in Table 7. Chi-square analyses indicate that the ratios do not vary from 1:1. The experimental sides had a total sex ratio of 155 males to 153 females and the control sides a ratio of 96 males to 101 females.

The adult-juvenile ratios for Microtus known to be present in each month are given in Table 8. There appears to be no pattern in the occurrence of juveniles on either side or in any month, and the total number of juveniles captured on the experimental sides does not differ appreciably from the number captured on the control sides. In 1969, 57 juveniles were captured on the control side and 53 on the experimental. In 1971, 47 juveniles were captured on the control side and 46 on the experimental. No comparison can be made for 1970. The number of juvenile Microtus per breeding female was larger on the experimental side in 1969 and was larger on the control side in 1971. The high populations of Microtus sustained on the experimental side in 1971 likely decreased breeding success due to interspecific factors.

In Table 9, the percentage survival of Microtus (total, adult and juvenile) and Blarina is presented. A t-test showed no significant difference between survival of male and female Microtus and therefore the survival percentages are not included. Total female survival was 3.9% higher than total male survival. A comparison of survival of Microtus and Blarina using the t-test indicated that vole survival was significantly higher ($P < .05$). An average of 95.9% of the

Table 7.. Sex ratios of *Microtus pennsylvanicus*.

Month	A-1969 M:F	B-1969[1] M:F	A-1970[1] M:F	B-1970 M:F	A-1971 M:F	B-1971[1] M:F
April			0:0	2:0	3:2	3:3
May					1:1	5:9
June	2:3[2]	2:3[2]	2:3[2]	2:3[2]	6:7	6:11
July			0:3	0:0	9:10	20:23
Aug.	5:13	13:10	11:12	2:1	21:19	25:31
Sept.	17:16	19:19	11:14	5:1	29:31	30:29
Oct.	28:39	29:35	27:22	2:2	22:22	35:42
Nov.	37:38	30:31	45:37	4:9	0:4[3]	28:33[3]
Dec.	13:10[3]	17:17				

[1] Experimental side.
[2] Introduced animals.
[3] Incomplete trapping periods.

Table 8. Adult-juvenile ratios of *Microtus pennsylvanicus*.

Month	A-1969 A:J	B-1969[1] A:J	A-1970[1] A:J	B-1970 A:J	A-1971 A:J	B-1971[1] A:J
April			0:0	2:0	5:0	6:0
May					2:0	4:10
June	5:0[2]	5:0[2]	5:0[2]	5:0[2]	3:10	14:3
July			3:0	0:0	12:7	32:11
Aug.	7:11	13:10	14:9	3:0	28:12	49:7
Sept.	29:4	19:19	23:2	3:3	45:15	51:8
Oct.	35:32	46:18	41:8	4:0	41:3	70:7
Nov.	65:10	55:6	56:26	10:3	4:0[3]	61:0[3]
Dec.	23:0[3]	34:0				

1 Experimental side.
2 Introduced animals.
3 Incomplete trapping periods.

Table 9. Percentage survival from trapping period to trapping period for Microtus pennsylvanicus (total, adult and juvenile) and Blarina brevicauda.

Side, year	Surv. period	Total M.p.	Adult M.p.	Juvenile M.p.	Blarina
	Au/J	5/5 -100	5/5 -100	0/0	
	S/Au	14/15-93.3	9/10-90.0	5/5 -100	
A-1969	O/S	30/33-90.9	26/29-89.7	4/4 -100	
	N/O	53/67-79.1	29/35-82.9	24/32-75.0	
	D[1]/N	23/74-31.1	23/65-35.4	0/9 - 0.0	
	A/D	0/23- 0.0	0/23- 0.0	0/0	
	Au/J	3/5 -60.0	3/5 -60.0	0/0	0/0
	S/Au	17/22-77.3	9/13-69.2	8/9 -88.9	4/6-66.7
B-1969	O/S	37/38-97.4	21/21-100	16/17-94.1	2/4-50.0
	N/O	49/64-76.6	39/46-84.8	10/18-55.6	1/3-33.3
	D/N	31/61-50.8	30/55-54.5	1/6 -16.7	1/2-50.0
	A/D	1/34- 2.9	1/34- 2.9	0/0	0/1- 0.0
	Ju/J	3/5 -60.0	3/5 -60.0	0/0	0/4- 0.0
	Au/Ju	5/5 -100	5/5 -100	0/0	3/5-60.0
A-1970	S/Au	22/23-95.7	14/14-100	8/9 -88.9	6/8-75.0
	O/S	24/24-100	22/22-100	2/2 -100	5/8-62.5
	N/O	44/49-89.8	37/41-90.2	7/8 -87.5	5/6-83.3
	A/N	3/81- 3.7	2/56- 3.6	1/25- 4.0	0/6- 0.0
	M/A	1/4 -25.0	1/4 -25.0	0/0	
	J/M	2/2 -100	2/2 -100	0/0	
A-1971	Ju/J	12/13-92.3	2/3 -66.7	10/10-100	
	Au/Ju	17/17-100	10/10-100	7/7 -100	
	S/Au	35/40-87.5	25/28-89.3	10/12-83.3	
	O/S	39/59-66.1	34/44-77.3	5/15-33.3	
	N[1]/O	4/43- 9.3	3/40- 7.5	1/3 -33.3	
	M/A	4/5 -80.0	4/5 -80.0	0/0	0/0
	J/M	10/14-71.4	3/4 -75.0	7/10-70.0	0/1- 0.0
B-1971	Ju/J	14/17-82.4	12/14-85.7	2/3 -66.7	1/2-50.0
	Au/Ju	31/41-75.6	21/31-67.7	10/10-100	5/5-100
	S/Au	39/55-70.9	34/48-70.8	5/7 -71.4	5/6-83.3
	O/S	46/59-78.0	42/51-82.4	4/8 -50.0	4/5-80.0
	N[1]/O	59/77-76.6	57/70-81.4	2/7 -28.6	2/4-50.0

[1] Incomplete trapping periods.

Microtus known to be present in the experimental sides of the enclosure were trapped each month while an average of 96.0% was found for Blarina indicating that trappability of the two species was similar. T-tests showed no significant differences in survival of Microtus in the experimental and control sides of the enclosure in 1969 and 1971. In side A, 1970, the highest percentage survival of Microtus for the study was obtained coincidentally with the highest population of Blarina. Only 8 of 90 Microtus marked between June and November, 1970 were not captured in November, 1970. Adult Microtus survival was shown by a t-test to be significantly higher ($P<.05$) than juvenile survival. No significant differences were found between survival of juvenile Microtus on control and experimental sides in 1969 and 1971 using t-tests. Percentage survival over winter was very low for Microtus and zero for Blarina.

The average home range size of Microtus, when Blarina was present and when it was not, for the months June to November is given in Table 10. Using an analysis of variance, treatment effect alone (presence or absence of Blarina) was not significant, but level effect (month) and interaction effect were highly significant. Microtus home range size tended to decrease from June to November but did not appear to be affected by the presence of shrews. The average home range size of Microtus when Blarina was not present was slightly larger than it was when Blarina was present but the difference is only equivalent to about .003 acre.

In Table 11 is summarized the average home range

Table 10. Monthly average home range size of *Microtus pennsylvanicus* when *Blarina brevicauda* is present and when it is not. Number of animals for which average obtained indicated in parentheses.

Month	With *Blarina*	Without *Blarina*	Totals
June	5.00(5)[1]	7.00(6)	6.09(11)
July	8.80(5)	8.07(14)	8.26(19)
Aug.	4.87(15)	7.79(33)	6.88(48)
Sept.	6.43(49)	7.91(44)	7.24(93)
Oct.	6.03(78)	5.44(43)	5.82(121)
Nov.	4.70(40)	5.52(27)	5.03(67)
Totals	5.81(192)	6.90(167)	6.32(359)

1 Units equal number of traps enclosed.

Table 11. Average home range size for _Microtus pennsylvanicus_ (total, adult, male, female) and _Blarina brevicauda_ for various trapping periods. Number of animals for which average obtained indicated in parentheses.

Trapping period	Total _M.p._	Adult _M.p._	Male _M.p._	Female _M.p._	_Blarina_
April 1971	12.50(2)[1]	12.50(2)	12.50(2)		
May 1971[2]	6.00(1)			6.00(1)	6.00(1)
June 1971	7.00(6)		4.33(3)	9.67(3)	
1971[2]	5.00(5)	5.00(5)		5.00(5)	
July 1970[2]	10.00(1)	10.00(1)		10.00(1)	
1971	8.07(14)	8.64(11)	11.33(6)	5.63(8)	
1971[2]	8.50(4)	8.50(4)	4.00(1)	10.00(3)	4.00(1)
Aug. 1969	7.50(10)	7.60(5)	7.00(3)	7.71(7)	
1969	10.00(7)	11.60(5)	11.67(3)	8.75(4)	
1970[2]	5.25(4)	6.00(3)		5.25(4)	
1971	7.63(16)	7.63(16)	6.75(8)	8.50(8)	
1971[2]	4.73(11)	4.73(11)	6.67(3)	4.00(8)	7.50(2)
Sept. 1969	7.26(19)	7.26(19)	7.57(7)	7.08(12)	
1969[2]	6.18(17)	7.30(10)	5.89(9)	6.50(8)	8.50(2)
1970[2]	5.40(5)	5.40(5)	5.00(2)	5.67(3)	5.00(2)
1971	8.40(25)	8.77(22)	7.17(12)	9.54(13)	
1971[2]	6.78(27)	6.88(26)	8.82(11)	5.38(16)	8.00(3)
Oct. 1969	5.58(26)	6.05(19)	4.58(12)	6.43(14)	
1969[2]	5.69(26)	5.89(19)	6.00(10)	5.50(16)	10.00(1)
1970[2]	6.60(20)	6.74(19)	5.50(10)	7.70(10)	9.00(1)
1971	5.24(17)	5.31(16)	4.43(7)	5.80(10)	
1971[2]	5.94(32)	5.97(31)	6.07(14)	5.83(18)	19.00(2)
Nov. 1969	5.52(27)	5.68(25)	6.06(16)	4.73(11)	
1969[2]	4.88(16)	4.85(13)	4.75(8)	5.00(8)	
1970[2]	4.58(24)	4.80(10)	4.08(12)	5.08(12)	16.00(4)
Dec. 1969[2]	5.46(13)	5.46(13)	6.25(4)	5.11(9)	20.00(1)

1 Units equal number of traps enclosed.
2 Experimental sides.

size for *Microtus* (total, adult, male, and female) and *Blarina* for various trapping periods that yielded enough captures to determine home range size. Multiple regression of *Microtus* home range size on month (April to December) and number of *Microtus* present (Fig. 3) yielded a total F value (2 and 23 degrees of freedom) that was highly significant ($P < .01$). However, the partial regression coefficients due to month (1 and 23 d.f.) and to number of *Microtus* (1 and 23 d.f.) were not significant. Multiple regression of adult *Microtus* home range size on month and number of adult *Microtus* present (Table 8) also yielded a total F value (2 and 21 d.f.) that was highly significant ($P < .01$). In this case, however, the partial regression coefficient due to month (1 and 21 d.f.) was significant ($P < .05$) while that due to number of adult *Microtus* present was not significant.

Multiple regressions of male and female *Microtus* home range sizes on month (April to December and May to December, respectively) and number of male and female *Microtus* present (Table 7) were also performed. The total F value (2 and 19 d.f.) for the male regression was significant ($P < .05$) whereas the total F value (2 and 22 d.f.) for the female regression was not significant. The partial regression coefficients due to month and to number of animals present were not significant in either case.

A multiple regression of *Blarina* home range size on month (July to December) and number of *Blarina* present (Fig. 3) gave a total F value (2 and 7 d.f.) that was highly significant ($P < .01$). The partial regression coefficient due to month (1 and 7 d.f.) was also highly significant ($P<.01$) but that due to number of *Blarina* present was not significant.

The average home range size of adult *Microtus* was 6.57 units which is slightly larger than the 6.32 units (about .02 acre) obtained for total *Microtus*. Average male and female home range sizes were similar; male, 6.34 units, female, 6.30 units. The average *Blarina* home range was 10.85 units which is equivalent to about .03 acre.

Examination of the enclosure area during the winter months and in the spring after the melting of snow revealed evidence that a large population of *Microtus* survived much of the winters of 1969-1970 and 1970-1971. The snow was honeycombed with burrows that showed *Microtus* sign (droppings and pieces of vegetation). After snow-melt, many surface *Microtus* nests (Shull, 1907) were found. In April, 1971, 49 such nests were located in the enclosure.

Evidence was found that *Blarina* did feed upon *Microtus* during the winter months. Eight samples of shrew droppings collected in April, 1970 and 1971 (winter droppings) showed much hair and bone fragments of *Microtus*. Several *Microtus* nests showed evidence of usurpation by *Blarina*. These nests contained vole hair, skulls, bone fragments and pieces of carcass as well as the *Blarina* droppings mentioned above. Several *Microtus* carcasses with no apparent injury were discovered in nests or in the open each spring.

The amount of vegetation and cover during those months when trapping occurred was comparable for 1969 and

1970 but in 1971, the vegetation was sparser. Runway development generally increased with the *Microtus* population. In the fall, when populations were very high, the entire enclosure area was utilized for runway systems.

Four *Microtus* carcasses were discovered while trapping, none of which showed any injury. Thirty-six samples of *Blarina* droppings collected in the enclosure during the months May to December, 1969-1971 showed no *Microtus* remains.

LABORATORY ENCLOSURE STUDY

From December 18, 1970 to June 23, 1971 interspecific interactions were observed. Following introduction into the observation rooms, both species established burrow systems and before the room connector was opened on February 16, 1971, *Microtus* had reproduced. When the connector was opened, three large, adult *Microtus* (1F, 2M) including the sole survivor of the litter produced, and one *Blarina* (F) were present in the rooms.

The graphic recorder first showed treadle activity (movement between rooms) about 15 hours after the room connector was opened. Direct observation revealed that *Microtus* were crossing the treadles without hesitation and spending considerable time in room A, continuously for over one hour in one instance, but that *Blarina* was not entering room B. Also, trapping showed no evidence of movement of *Blarina* into room B. No interactions between the two species were observed and I therefore decided to try increasing the frequency of interaction through manipulation of available food.

To test whether reduced food would induce Blarina to display predatory behavior, experiments, in which the dog food on which the shrews were fed was reduced over a 12 day period, were begun on March 28. The dates of the experiments and the animals used in each test are given in Table 12.

Observation during the six test periods totaled 94 hours and an average of .59 interactions per hour of observation was recorded. A synopsis of the interactions observed is given in Table 13. Only direct observations of interactions are included. During the final three days of experiment #6, the shrew was observed to enter vole burrows in room B and to retreat immediately to room A. It is likely that the shrew encountered a vole in the burrows and was repelled by it. This pattern occurred 18 times but since interaction was only inferred it was not included in the analysis of direct interactions. A total of 55 direct interactions were observed.

It can be seen from Table 13 that most of the interactions were initiated by the shrews but the shrews retreated from the interactions almost as many times as the voles. Regressions of interactions per 10 hours of observation on day or grams of dog food available showed no linear relationship. However, 76% of the interactions were observed on the last four days of the experiments when the Blarina were receiving no dog food. All but 3 (5.5%) of the interactions observed occurred from the sixth day until the end of the test periods when Blarina's daily food supply was reduced to

Table 12. Dates of laboratory enclosure test periods and animals used in each test.

Test #	Dates	Animals used	
		Microtus	Blarina
1	March 28-April 8	2 males 1 female	1 female
2	April 11-April 22	2 males 1 female	1 male
3	April 28-May 9	1 male[1] 1 female 6 young[2]	1 male
4	May 10-May 21	1 male 1 female	1 female
5	May 22-June 2	1 male 3 females[3]	1 male
6	June 3-June 14	1 male 1 female 5 young[4]	1 male

1 Introduced May 8.
2 Disappeared after introduction.
3 2 females disappeared during test period 5.
4 Litter of 5 born in laboratory enclosure.

Table 13. Summary of interactions between *Blarina brevicauda* and *Microtus pennsylvanicus* for six, 12 day food reduction experiments.

Day	Grams dog food	Interactions initiated by: *M.p.*	*B.b.*	Retreats from interactions by: *M.p.*	*B.b.*	both	Interactions /10 hours observation
1	10		2	1	1		3.01
2	8						0.00
3	6						0.00
4	5	1		1			1.36
5	4						0.00
6	3		7	5	2		17.07
7	2	1			1		1.10
8	1		2	2			2.42
9	0		10	8	1	1	11.20
10	0	1	2		3		2.73
11	0		23	11	11	1	22.73
12	0	3	3	1	5		6.23
Totals		6	49	29	24	2	5.86

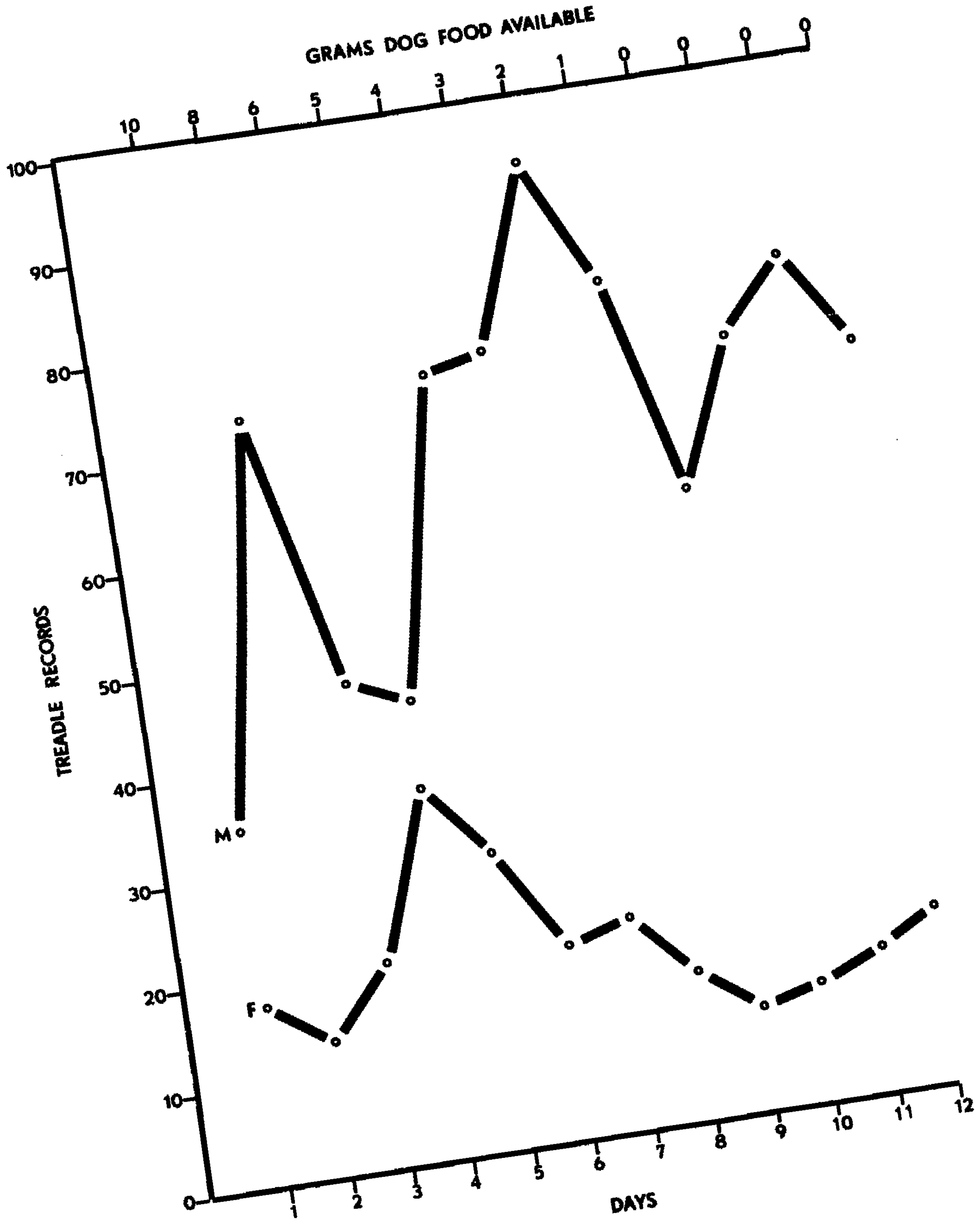
3 grams or less of dog food. There was a period from day 6 to day 9 when Microtus was observed to retreat from most encounters and a period from day 10 to day 12 when Blarina retreated more than Microtus. On the final day of the test periods Microtus initiated half of the observed interactions and retreated only once.

No interactions were observed in the vole room until the 7th day of the test periods. Of the interactions observed during the final three days, 66% occurred in room B.

From Figure 4, it can be seen that movement between rooms as indicated by treadle activity was greater when a male Blarina was present than when a female was present. Very little activity was observed during the two test periods in which female Blarina were used and only 3 (5.5%) of the observed interactions involved female shrews. The 3 interactions occurred in the shrew room and only one was initiated by the shrew. This interaction, from which both species retreated, occurred at the corner of a plastic cage which was used as a shelter by both species. Two interactions were initiated by Microtus which chased the Blarina into its burrows on the final day of test period #1. The female shrew used in test #1 was never observed to cross the treadles into the vole room and the one used in test #4 was observed to cross twice.

Most of the interactions (94.5%) and all of the predatory behavior observed occurred during those test periods in which male Blarina were used. During test #2, 4 interactions were observed. Two of these occurred on the first day

Figure 4. Daily average treadle activity for 6 test periods. M-male *Blarina* present (4 tests); F-female *Blarina* present (2 tests).


GRAMS DOG FOOD AVAILABLE
10
8
6
5
4
3
2
1
0
0
0
0
TREADLE RECORDS
100
90
80
70
60
50
40
30
20
10
0
M
F
DAYS
1
2
3
4
5
6
7
8
9
10
11
12

of the test period. Blarina initiated both encounters but was chased by a vole after one. One interaction was observed on the 7th day in room B in which the shrew was chased by a vole. The 4th interaction is noteworthy because the Blarina was successful in capturing a Microtus. A detailed account of the capture is given since there are no similar descriptions in the literature.

On the 8th day of test #2, the water bottle in room B had been overturned forcing Microtus to enter room A to obtain water. The water bottle in room A, however, was undermined by a shrew burrow which opened from beneath it. The shrew was active in the area of the water bottle when a vole entered room A to drink. The shrew went into the burrow under the water bottle. The Microtus approached the water bottle and straddled the shrew hole to drink. The shrew made an unsuccessful lunge at the vole and the vole jumped away. The vole, however, returned to the water bottle and straddled the hole again. The shrew which was still waiting under the bottle this time was able to secure a holding bite on the left hind flank of the vole. Despite attempts by the vole to pull itself loose, the shrew was able to maintain its hold and drag the vole into the burrow after five minutes. Five minutes after the animals had disappeared into the burrow, I dug into the burrow to extricate the animals. The shrew had dragged the vole about a foot along the burrow and hung on tenaciously even after the burrow had been uncovered. When extricated the shrew lost its footing and the vole was able to drag it to the ramp leading to the treadle where it was able to free itself and escape to room B. For almost two hours after this encounter, the shrew was active, moving from room to room frequently. Very little vole activity was seen. The shrew weighed 19 gm. and the vole approximately 50 gm. but despite this great size differential the shrew was able to drag its prey into its burrow. Upon conclusion of the second experiment all animals were removed. All Microtus were still present including the one which had been bitten by the shrew.

A majority of the observed interactions (65.5%) occurred during test #3. The vole room had had its burrow systems excavated in order to locate the Microtus previously occupying the room. Therefore, when test #3 began, the female vole that had been introduced had not had time to establish new burrow systems. One interaction was observed on the 8th day and 9 interactions on the 9th day, all of which were initiated by the shrew and only one of which resulted in retreat by the shrew. A male Microtus was introduced on the 11th day. On day 11, 23 interactions were observed, all of which involved pursuit of the voles by the Blarina. However, whenever the pursuit resulted in a physical confrontation, the shrew would retreat. After one confrontation under the plastic cage in room A, the shrew was flipped on his back by the male vole. The two species retreated an equal number of times from the interactions. Three interactions were observed on day 12 two of which were initiated by Blarina and two from which Blarina retreated. The shrew pursued the female vole once and was chased by the male vole once.

During test #5, 7 interactions were observed. Five of these involved pursuit of a small female vole which was forced to spend much of its time in the shrew room due to intraspecific strife. This small female vole and another female disappeared during test #5. Two interactions (initiated by the shrew) between the shrew and a large vole resulted in the retreat of the shrew.

Five direct interactions were observed during test #6, 3 of which were initiated by Microtus and 4 from which Blarina retreated. Four interactions were in the vole room and involved the protection of a Microtus litter which reached weaning age during test period #6.

Microtus showed successful defense of young against a shrew during test #6. At the beginning of test #3, a female vole with six 10 day old young were introduced into room B. The young disappeared, apparently abandoned by the vole due to a lack of burrow systems. This female vole subsequently bred in the laboratory enclosure and dropped a litter at the end of test period #5. The young Microtus were first observed on the 10th day of test #6 at which time the Blarina was not provided with dog food. The shrew was observed to enter the vole room 10 times on day 10 apparently in search of food. On one occasion, the adult voles watched the Blarina enter the room from the openings of their burrows. After the shrew had moved around the room for several minutes, it entered the burrow in which the male vole was located. The shrew chattered, retreated across the room toward the treadles and in doing so, passed the burrow in which the female vole was situated. The female Microtus attacked the shrew and the two animals battled across the room, with the shrew chattering, until the shrew was able to escape through the treadles into room A. The female vole was again observed attacking the shrew on day 12.

The shrew was not observed or trapped after the 12th day and two days later room A was excavated to locate it. It was found in an underground nest, apparently having starved to death. Live trapping of room B yielded the two adult Microtus and five 10-12 gm. juveniles.

Microtus and Blarina received wounds at various times during the study. The Blarina of test #2 had a wound on its ventral gland on day 5, on its throat on day 9 (possibly the result of its capture of a vole on day 8), and over its eye on day 12. The vole, when trapped a week after the capture, had no wounds. On day 11 of test #3 the shrew that had been flipped by a vole was found to have a wound under its left eye. At the conclusion of test #6, the female vole that had defended her litter had scabs on her snout.

The treadle records indicated that there was more activity between rooms during the dark hours than during the light hours (Fig. 5). Observation revealed that both species were more active during the dark hours but that activity of Blarina during the light hours increased when they were provided with less dog food.

The treadle activity records (which corresponded generally with observed activity of the animals) for the six experiments are given in Figures 6 and 7. The female Blarina

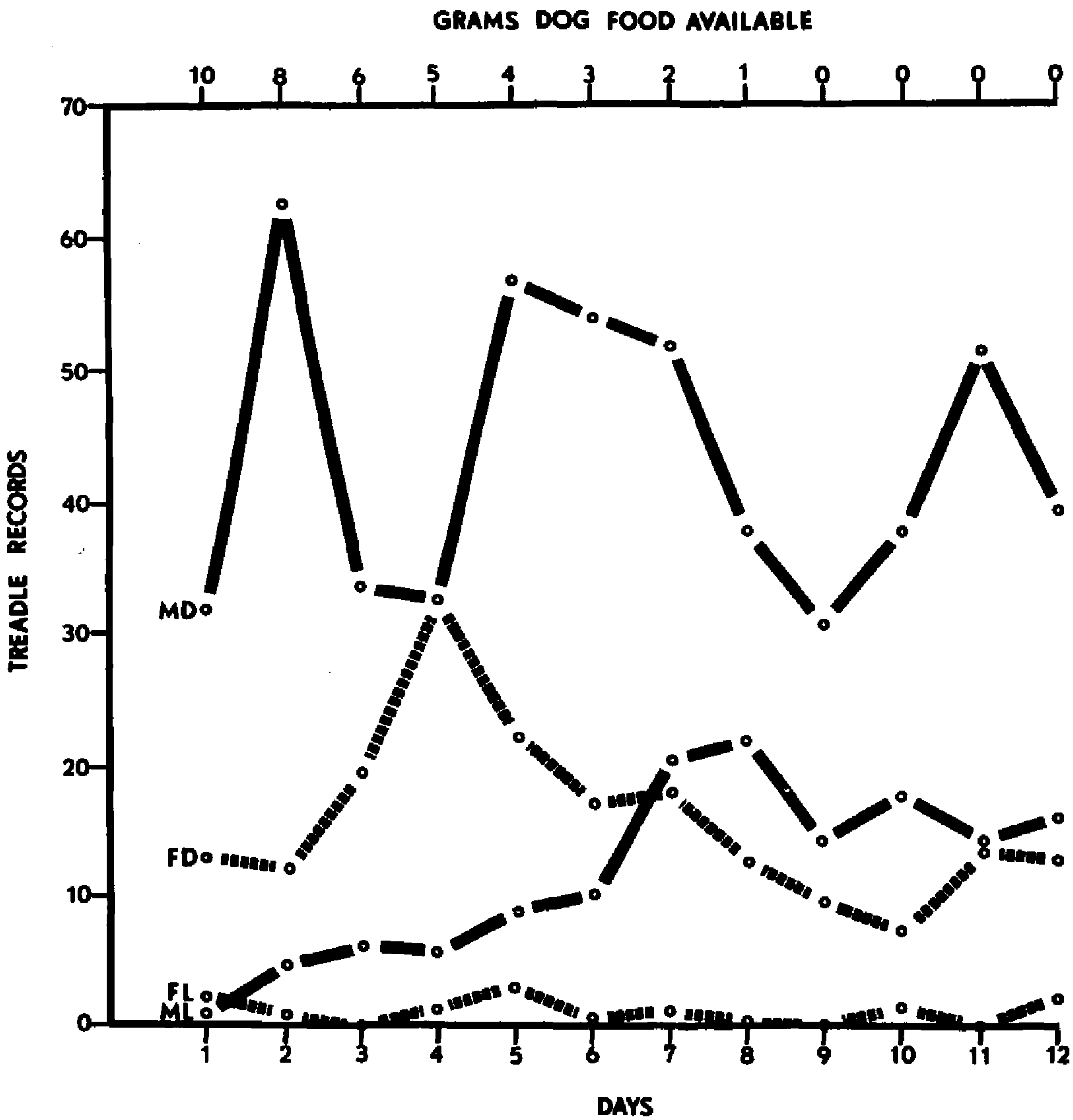


Figure 5. Daily average treadle activity for 6 test periods. Male *Blarina* present during dark hours (MD) and light hours (ML) and female *Blarina* present during dark hours (FD) and light hours (FL).

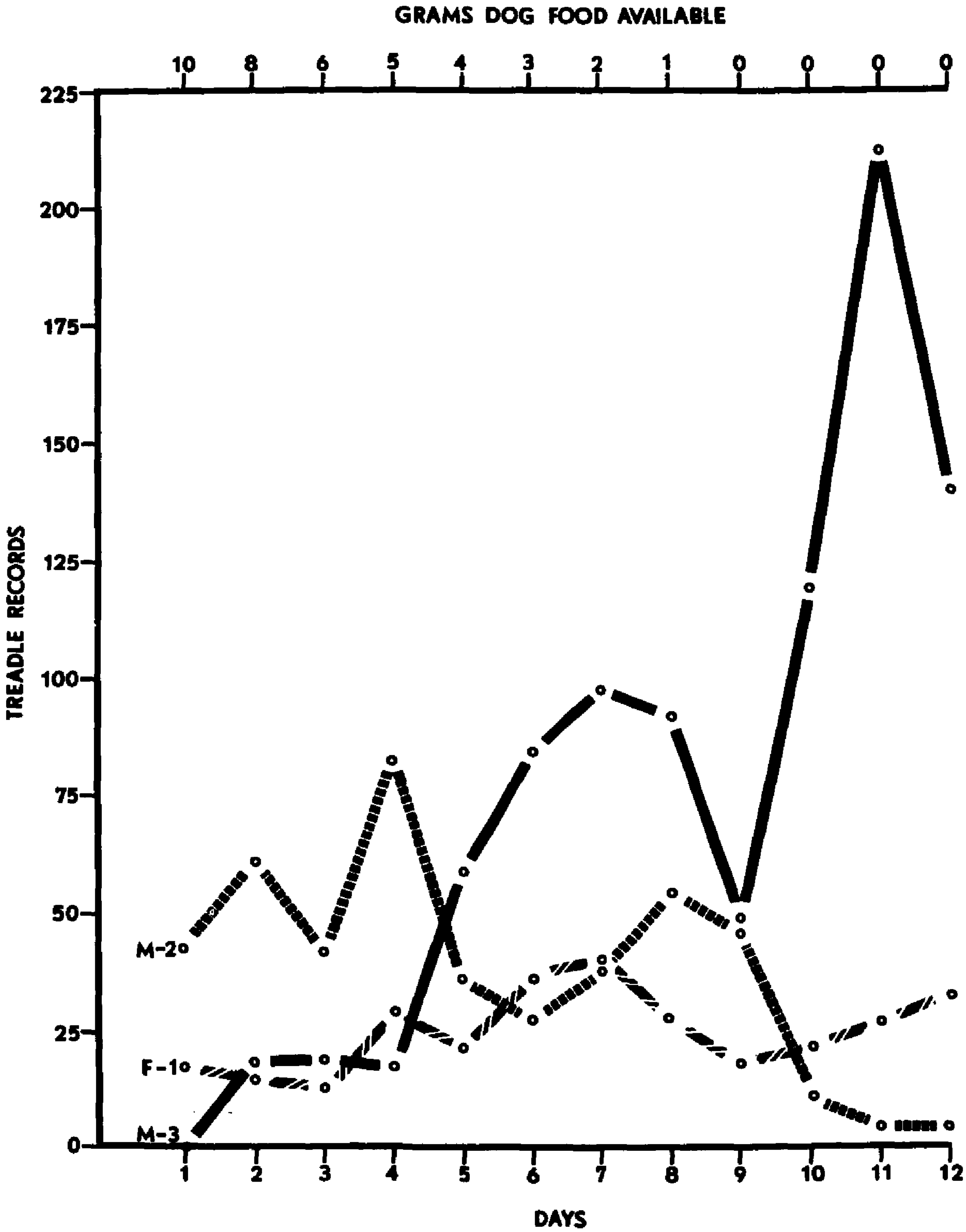


Figure 6. Total treadle activity for test periods 1 to 3. Sex of Blarina and test number indicated.

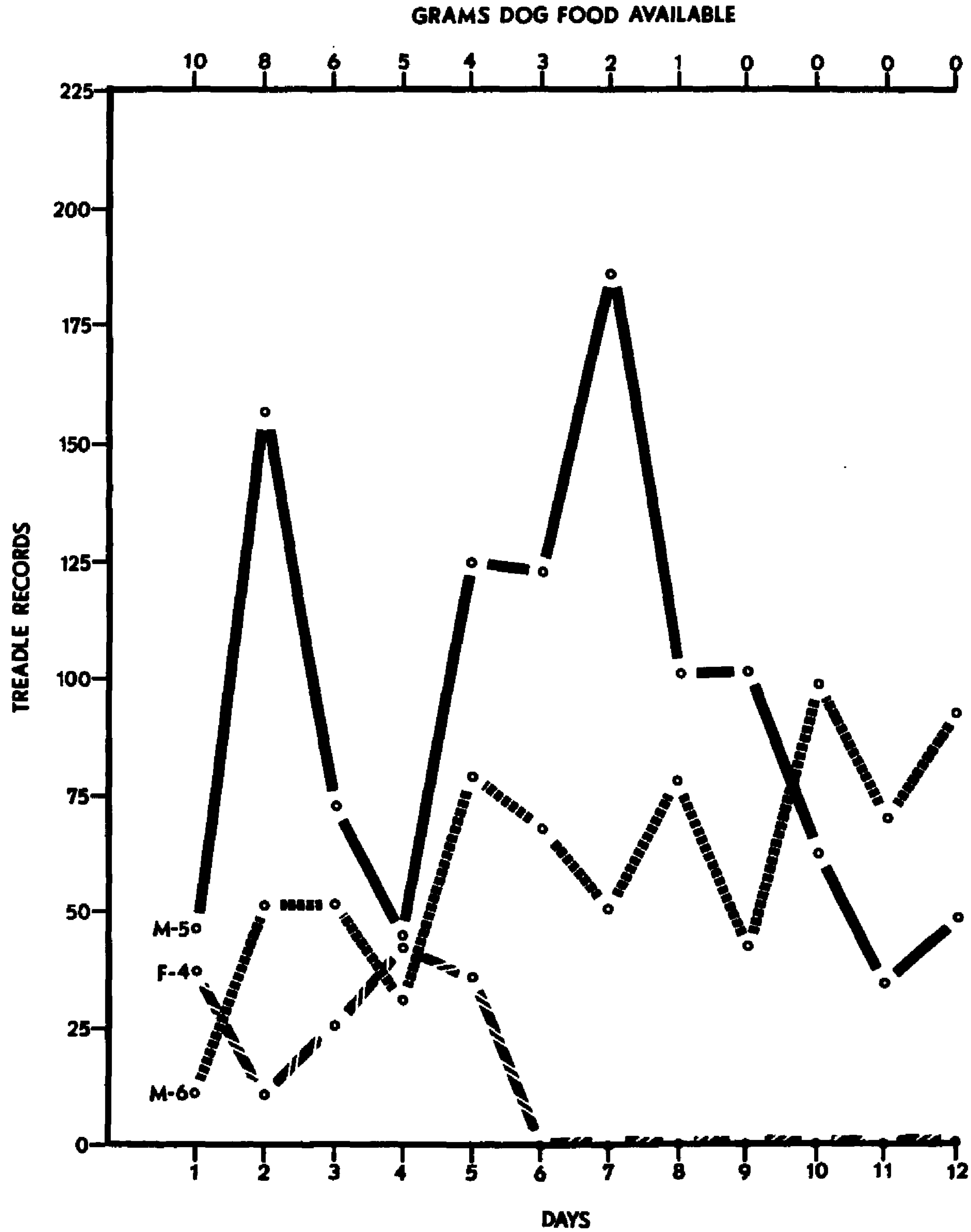


Figure 7. Total treadle activity for test periods 4 to 6. Sex of Blarina and test number indicated.

in test #1 was not observed to cross the treadles and therefore the treadle records probably can be attributed to Microtus (Fig. 6, F-1). If the treadle activity of test period #1 is vole activity, the decrease from day 7 to day 9 and the increase from day 10 to day 12 could indicate a change in response of the voles to an increasingly hungry shrew. Blarina were first observed to cross the treadles on: day 6, test #2; day 4, test #3; day 4, test #4; day 4, test #5; and day 7, test #6. An increase in number of treadle records occurred subsequently in each case except in test #4. Day 4 of test #4 was the only day during the test period in which the Blarina was observed to cross the treadles. A decrease in treadle activity occurred after the capture of the Microtus on day 8 of test #2 (Figure 6, M-2). Marked decreases in treadle activity occurred also after days 2 and 7 of test #5 (Figure 7, M-5) each of which corresponded with the disappearance of a Microtus. Wounds on Blarina were discovered on days 5 and 9, test #2 and on day 11, test #3 and on the following days a decrease in treadle activity occurred (Figure 6, M-2, M-3).

The weight changes of the six shrews used in the study are presented in Figure 8. All Blarina weighed less at the end of the tests than when introduced. Four of the shrews were observed digging in the turf at various times apparently eating plant material and most of the weight gains shown in Figure 8 correspond with these observations. The Blarina of test #5 showed slight weight gains at the times when two Microtus disappeared. The shrew of test #6

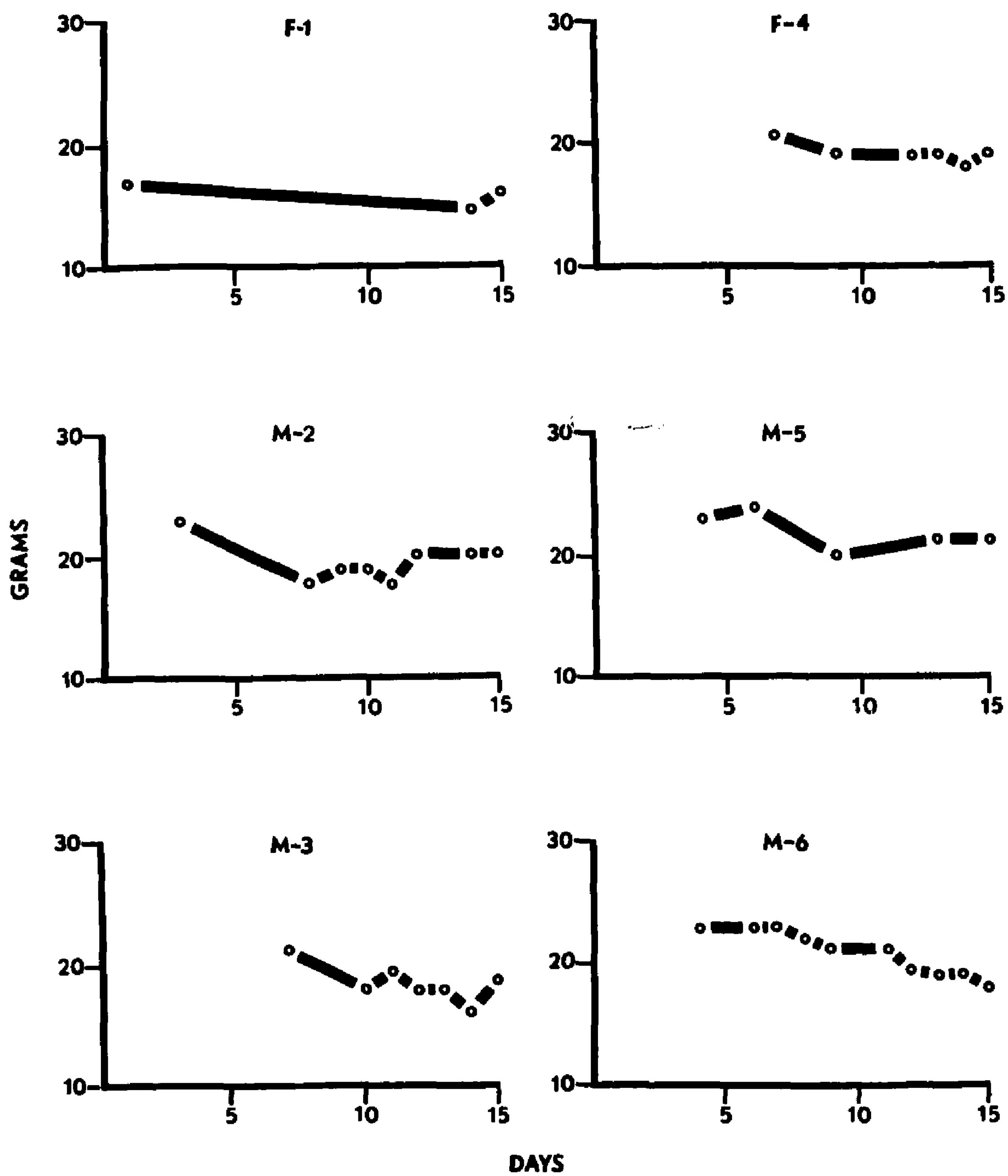


Figure 8. Weights of <u>Blarina brevicauda</u>. Food was reduced from day 4 to day 15. Sex and test number are indicated.

showed consistent weight losses and apparently died of starvation at the end of the test period.

Both room A and room B were completely excavated after termination of the study in an attempt to discover *Microtus* remains. No remains of the missing *Microtus* were located. Also, no *Blarina* droppings found during the course of the study contained vole remains.

DISCUSSION AND CONCLUSIONS

All aspects of this study indicate that *Blarina brevicauda* is not an efficient predator of *Microtus pennsylvanicus*.

The stomach analyses performed reveal that *Blarina* in a natural habitat do not prey upon *Microtus* to any great extent in the months studied. The only vole remains found were hair and the vole hair seldom occurred in large quantities. Since the two species use the same surface runways, it is possible that a few *Microtus* hairs could be ingested by shrews along with its soil invertebrate and plant food. For the few stomachs that contained more than several hairs, there is the possibility that the *Blarina* were acting as scavengers rather than as predators.

Rood (1958) found that male *Blarina* were generally more pugnacious than females and those individuals most quarrelsome with their own kind were most likely to kill a mouse. In my laboratory study, predatory behavior of female *Blarina* was not observed. Therefore, it would be expected that *Blarina* which prey upon voles would be mostly males. Of the stomachs containing vole hair, 75% were from females. The small number of *Blarina* that were found to have vole hair in their stomachs makes it difficult to draw valid conclusions about the role of sex in the predation on voles by shrews. However, concluding that the 12 stomachs containing vole hair actually represent predation would be tenuous.

The data obtained from the field enclosure study contradict Shull's (1907) belief that Blarina preys heavily upon voles and has the capacity to keep their populations in check. With or without the presence of a supposed predator, confined Microtus populations showed explosive increases in numbers in each year studied and conversely, the Blarina populations, in spite of very high populations of potential prey, showed poor survival.

The lack of control of a confined Microtus population shown by Blarina is in marked contrast to the effect of predation by domestic cats which was evident between October, 1969 and July, 1970. Two days after introduction of Microtus and Blarina in June, 1970, a cat was seen carrying a dead vole in its mouth in side A of the enclosure. Two weeks after introduction only three voles and one shrew remained (all in side A) of the ten voles and four shrews introduced. The occurrence of greater cat predation in side B than in side A in 1970 could indicate that it was easier for the cats to gain access to side B because of a slightly lower fence. In the fall of 1969, there was a decline in numbers of voles earlier in side B than in side A which can probably also be attributed to easier access to side B for the cats.

Barbehenn (1958) found unusually low survival of young Microtus between August and September associated with a change to positive association at trap sites between Microtus and Blarina. He inferred that predation on nestlings by Blarina was responsible for low survival of young Microtus.

The experimental sides in 1970 and 1971 in my study showed only slight increases in numbers of Microtus between August and September (8.7% and 5.4% respectively) and concomitant small numbers of juveniles for August and September (11 in 1970 and 15 in 1971). The control side in 1971 showed a large increase in numbers (50%) and a larger number of juveniles (27). A study of the weights of Microtus in the experimental sides for October in 1970 and 1971 revealed that many young voles trapped in October were likely juveniles in September but did not enter the trappable population until just after the conclusion of the September trapping period. From the weights obtained in 1970 and 1971, it appeared that there was a synchronization of breeding of Microtus which allowed the determination of age of the voles to a certain extent. The slight increases in the populations from August to September followed by the sharp increases from September to October shown for the experimental sides in 1970 and 1971 are deceptive. There actually were consistent increases in numbers between August and October which were masked by the timing of the trapping periods because most juveniles born in September were not trappable until October. The coefficients of association determined in this study do not show the change from negative to positive association between Microtus and Blarina from July to September that was found by Barbehenn (1958).

In 1971, the experimental side had Microtus populations consistently higher than those on the control side. The initial cause of the differences in numbers was the number of females present in April. Side B had three and side A had two females present. One of the females in side A was missing a hind leg and was not trapped after April. Therefore, only one female remained in side A in May from which all of the voles trapped for the remainder of 1971 must have descended. The vole population on side A (which proved throughout the study to be the better habitat) did, however, expand rapidly and overtook the population in side B in September. A subsequent decline in numbers occurred, however, which can possibly be attributed to excessive inbreeding.

From the discussion above, there does not appear to be any deviation from a pattern of rapid population growth of Microtus that can be attributed to the presence of Blarina. Also, linear regression analysis showed that the numbers of each species were not related linearly. Twelve comparisons of monthly Schumacher-Eschmeyer population estimates of Microtus proved the population levels to be significantly different, but only two of these comparisons showed a higher population on the control side than on the experimental side. The significantly higher population in November, 1969 can be explained by differential cat predation which was discussed previously. The second significant difference was between side A, 1969 and side A, 1970 for the month of October which can probably be explained simply by the fact that two years were compared.

The tests performed to determine association between Microtus and Blarina were probably affected by the confinement of the populations to a limited area. When populations of Microtus became very high it was difficult for the two species to avoid being associated. The association test used would not show temporal isolation of the two species. Microtus did not enter a trap in which a shrew had been captured on the same day when the population of voles was 224/acre or less. When a shrew was captured in a live trap, it usually left its droppings and pungent odor in the trap. Fulk's (1971) discovery that Microtus shows a negative response to shrew odor and that this avoidance decreases with experience might be relevant to my study. At populations of 224/acre or greater, Microtus did not show a negative response to shrew odor in the traps. Voles would be likely to have more shrew experience at high population levels than at low levels. Fulk (1971) suggested that a decrease in avoidance of shrew stimuli with experience prevents voles from sacrificing the use of space occupied by shrews. My study supports this.

Blarina did not affect the size of Microtus home ranges significantly. Intraspecific competition for space probably determined the small home range size found for the confined Microtus. The overall average home range of 6.32 units for Microtus, which is equivalent to an area of about .02 acre, is smaller than any estimates recorded in the literature. The smallest home range recorded in the literature was .04-.09 acre for female Microtus (Getz, 1961a). All estimates recorded in the literature, however, were obtained from trapping unconfined populations of voles.

Blair (1940) demonstrated that home ranges of a dense population of Microtus were smaller than home ranges of less-dense populations. The dense populations he described were only 8-12 voles per acre. The introduction of voles into the enclosure produced a density of 20 per acre. Density of Microtus was not found to affect home range size significantly. The fact that home range size does not decrease appreciably after a certain density of animals is obtained may explain why density was not found to be more important in determining home range in this study. Van Vleck (1969) showed that home ranges of females were not correlated with density. In my study, it was found that female home range was unaffected by both density and month but that month or a combination of month and density influenced the home range size of male Microtus. Perhaps, habitat changes or increased male aggression affected a decrease in male home range size.

The number of Microtus present did not appear to affect the home range size of Blarina. The home range size of Blarina was actually larger when the populations of voles were higher. The average Blarina home range size of 10.85 units, which is equivalent to about .03 acre, is much smaller than those reported in the literature. Lutz (1964) determined the average Blarina home range to be 1.0 acre for males and .75 acre for females, but does report a home range of .01 acre for one female. Month was found to be very important in determining size of home range of Blarina in my study. Perhaps an increase in home range size is necessary in order to obtain enough of its soil invertebrate food which becomes less available toward winter.

The comparative success of the two species within the enclosure could be related to home range size. Brown (1962) stated that *Microtus* can establish a colony on a much smaller area than can *Blarina*, since *Microtus* is present on small islands even if habitat is not suitable while *Blarina* is never common on small islands even if the habitat is suitable. He believes the ability to become established on small islands is linked with home range size required to ensure sufficient food and with reproductive potential. If *Microtus* is an important food source of *Blarina*, the high populations present in the enclosure should have ensured a sufficient food supply.

Blarina was more successful and showed evidence of reproduction on side A. Getz (1961b) found that the most important factor influencing the distribution of *Blarina* is moisture and side A was more moist than side B. Werner (1956) felt that a small population of *Blarina* on a small island can be extirpated rather easily by adverse factors. The *Blarina* populations in the enclosure became extinct during the winter months. Perhaps, *Blarina* requires a larger range than provided in the enclosure to obtain enough food during the winter months.

Blarina did not have any affect upon the sex ratios and age composition of the *Microtus* populations. It has been shown also in this study that the survival rates of *Microtus* are not lower when *Blarina* is present. Survival was influenced by habitat, cat predation and intraspecific factors.

The discovery of winter shrew droppings containing vole remains corroborates Eadie's (1944, 1948, 1952) findings. In my investigation, I believe that populations crashed overwinter on both experimental and control sides of the enclosure because of environmental conditions (e.g. food supply, weather factors) and intraspecific factors rather than to predation by Blarina. It is my opinion that the voles eaten by Blarina were either already dead or were weakened by hunger or disease. The availability of Microtus carcasses which showed no apparent injury indicated that Blarina could have fed upon Microtus as a scavenger.

Winter depletion of food appeared to be a problem for Microtus. Vegetation was sparse by spring and there was much evidence that the voles had to dig for roots. One Microtus nest found in April, 1971 contained a cache of root pieces. A depletion of vegetation also caused a lack of cover for the animals. This likely made them very susceptible to aerial predation. An owl pellet containing vole hair, skulls and bone fragments was discovered in side A of the enclosure in the spring of 1970.

The amount of snow cover could have been a factor in the better survival of Microtus in the winter of 1970-1971. The winter of 1970-1971 had a total of 90 inches of snow compared with a total of 62 inches for 1969-1970. Also, there was a continuous snow cover from early December, 1970 until the beginning of April, 1971. The winter of 1969-1970 did not have a snow cover until the middle of December, had a February thaw and did not have snow beyond the middle of

March. The average maximum and minimum temperatures for the months December through April were about 2°F warmer in 1969-1970. There was 20.38 inches of rain in the months December through April, 1969-1970 and 15.42 inches for the same months in 1970-1971. Parts of the enclosure were flooded after heavy rains in the spring. The large number of surface Microtus nests found in the spring was probably due to saturation of the soil.

Cat predation could have been a factor in the winter mortality that occurred. Deep snow would allow cats to enter the enclosure during winter months but would also provide protection for the voles and shrews except infrequently when they were active on the surface of the snow. During the winter of 1969-1970, when there was not a continuous snow cover, the enclosure fence was not high enough to exclude cats and therefore cat predation could have been substantial.

The amount of vegetation and cover during those months when trapping occurred was comparable for 1969 and 1970, but sparser for 1971. This could have been due to two previous winters depletion of vegetation, a high population of Microtus sustained for a longer period of time, and less precipitation. For the months May to November, there was 25.13 inches of rain in 1969, 23.01 inches in 1970 and 21.71 inches in 1971.

Blarina predation on voles was not detectable by the analysis of shrew droppings collected in the enclosure during the months May to December, 1969-1971 since no Microtus remains were found.

The laboratory study supports Rood's (1958) observation that shrews show a great deal of individuality in their encounters with *Microtus*. There was an obvious difference in behavior of male and female *Blarina*. The female *Blarina* were never observed to pursue a vole and only three interspecific interactions were noted. A female shrew was observed entering the vole room only once during two test periods. On the final day of the first test period, when the female shrew appeared very hungry (digging in turf for plant material, trying to climb walls of enclosure), it did not attempt to capture the voles which entered the shrew room nor did it enter the vole room in search of food.

The majority of instances of activity and interactions observed occurred when male *Blarina* were used in the experiments. Male *Blarina* pursued *Microtus* in both rooms of the laboratory enclosure indicating that they were more aggressive than females. They retreated nevertheless from 46% of the observed interactions with *Microtus*. The first encounters that resulted from active pursuit of prey by *Blarina* were not observed until the 6th day. These all occurred during one test period in which a young female vole was forced by intraspecific aggression to reside in the shrew room. The first pursuit of prey that resulted in interactions in the vole room was not observed until the 9th day when the shrews were no longer receiving dog food. Martinsen (1969) fed *Blarina* a restricted diet of 1/10 their weight in mealworms and they survived well. One-tenth of the weight of the *Blarina* used in this study would be about 2 gms. It is indicated above that Blarina will pursue Microtus as a food source when its daily food supply is reduced to 3 grams or less of dog food or other food with equivalent caloric content. It appears that Blarina does not pursue Microtus unless a certain level of hunger is reached. Interactions that occurred while the shrew was still being supplied food probably were due to mutual utilization of space (i.e. shrew room).

The response of Microtus to increased attacks of Blarina was initially one of retreat and avoidance. Eventually, however, Microtus became more aggressive toward its pursuer. Throughout the study, it appeared generally that the Blarina feared Microtus. If a vole did not retreat from an attack and was aggressive toward the shrew, the shrew would invariably retreat. I concur with Fulk's (1971) observation that the behavior of shrews toward voles in paired encounters does not represent specialized prey catching behavior. When hungry, Blarina would simply race about searching for the voles. In a small cage, a shrew may eventually tire and subdue a mouse but in the rooms used in this study such chasing appeared to be futile. Shull (1907) described "clumsy" voles that were killed by Blarina in the small cages in which the shrews were kept. Observation of Microtus in habitat in which they are familiar (laboratory and field enclosures) indicated that rather than being clumsy they were elusive enough to avoid attacks by shrews.

Although the short-tailed shrew's poor eyesight does not allow it to distinguish objects and its sense of smell is poorly developed (Rood, 1958), during my informal laboratory observations it appeared able to distinguish whether a Mus or a Microtus was placed in its cage. If a Mus were introduced into the shrew's cage, the shrew would immediately pursue and eventually kill the mouse. When Microtus were introduced, however, the shrew would not leave the bottle which it used as a shelter. The shrew's sense of hearing is acute and the sense of touch is the most highly developed (Rood, 1958). An animal with poor sight and smell would appear to be handicapped in its attempts to capture a vole which has these senses highly developed. Observation revealed that the shrews did have a difficult time locating the voles and several times ran by them without showing signs of awareness. The one observed capture of a Microtus by a Blarina showed that the shrew has sufficient strength to overcome a vole much larger than itself. However, the submaxillary, salivary gland toxin of Blarina, did not prove to be fatal to the vole even after a ten minute holding bite. The informal laboratory observation of Blarina killing house mice indicated that the shrew did not use its toxin but killed the Mus by mutilation.

The treadle activity records obtained in the laboratory study, although not purely records of shrew activity, did reveal changes in behavior of the shrews and consequent changes in behavior of the voles. Changes in treadle activity correlated closely with direct observation. The shrews were never observed to cross the treadles before the 4th day. This could have been because the shrews were receiving enough food so that they did not have to cross the treadles in an attempt to obtain more, or perhaps, because they had to ascend a ramp in order to reach the treadles, there was a lag before they discovered that there was a room connector. In all but one case, an increase in treadle activity was recorded the day following the first observation of a shrew crossing the treadles. This could be an indication of an increase in exploratory behavior of Blarina or an increase in pursuit of prey. Treadle activity records for the early portions of the test periods probably were due to Microtus activity. Microtus activity in the shrew room generally decreased as Blarina hunger increased. Decreases in treadle activity were correlated with disappearances of voles, interactions that resulted in wounds to Blarina and the one observed capture of a vole.

Weight of Microtus was affected by the presence of Blarina in only one instance. The female vole in test #3 which did not have runways available showed a weight loss of 7 grams which was likely due to constant pursuit by the shrew. The weights of Blarina were lower at the end of a test period than they were at the time of introduction in each experiment. Increases in weight were observed with disappearance of Microtus and the utilization of plant food by shrews. Martinsen (1969) found that a fundamental factor in the success of Blarina in cold temperate climates is its "proclivity to eat almost anything of energy value". The survival of Blarina for four days without food supplied in this study attests to this proclivity.

The disappearance of two Microtus and observed capture of another would indicate that Blarina is occasionally successful in preying on voles. The observed capture, however, was under unnatural conditions and generalization to the wild would be suspect. It does indicate, though, that Blarina could, under certain conditions, successfully obtain a holding bite and subdue a vole in the wild. One Microtus did not appear to be healthy at the time of its disappearance. It could not be ascertained whether its disappearance indicated behavior of Blarina as a predator or as a scavenger. The second Microtus that disappeared was a young female. Its exclusion from the vole room due to intraspecific aggression might be compared to the situation in the wild. However, in the wild situation, the vole would not be forced to remain in such close proximity to a shrew nest. Even when compelled to remain in the shrew room, the young vole was able to survive for eight days.

The successful defense of a Microtus litter from predation by a hungry Blarina was observed in the final test period. The Blarina was repelled each time it entered the vole burrows in search of food. The female Microtus twice was observed to attack the shrew and chase it from the vole room. The female vole did, however, obtain wounds about its snout while defending its litter. The Blarina, with two adults and five juveniles of its supposed prey available, died apparently from starvation. This female Microtus which demonstrated tenacious defense of its litter during the final test period apparently abandoned its litter during the third test period. The female vole and her litter were introduced into the laboratory enclosure at the beginning of the third test when there was not an established vole burrow system. The introduction of a female vole into an unfamiliar, disturbed environment would probably be sufficient cause for abandonment of her litter.

The laboratory enclosure study revealed that _Blarina_ is capable of capturing a _Microtus_ occasionally in a restricted area. How applicable this study is to the relationship of the two species in the wild is open to question. However, it would appear to be much more applicable than the previous observations of encounters in small cages. My informal observation of encounters in a 3X3 ft. cage showed that a large male _Blarina_ was not always able to kill a _Microtus_. Even in this restricted space, a _Microtus_ was able to survive for a week without harm in two instances. Generalizations from the small cage encounters to the natural situation would be illogical. It is not uncommon that, when two wild-caught _Microtus_ (especially adult males) are placed in a small cage, one will kill and partially devour the other. Also, if one puts two _Blarina_ into a small cage, one will usually kill and completely devour the other. It is doubtful that this occurs frequently in the wild, for if it did, the two species would not be as successful as they are. It appears that as the area available for these two species increases the chances of interaction and predation decreases.

Fulk (1971) describes _Blarina_ _brevicauda_ as an occasional predator of _Microtus_ _pennsylvanicus_. This is substantiated by the data collected in the three facets of this study. It has been demonstrated that *Microtus* is little affected by *Blarina* but that there may be occasional fortuitous predation. *Blarina* and *Microtus* co-occur due to preference for similar environments rather than to relationships to each other. Although it is speculated that *Blarina* acts mostly as a scavenger and not as a predator during the winter months, a definite conclusion about the winter relationship would not be reasonable without further study.

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APPENDIX

Table 1. Monthly stomach analysis data for *Blarina brevicauda*. Number of stomachs containing food item and percent of number examined containing each item.

Month	Food Item				
	Insects	Snails, slugs	Annelids	Plant material	Vole hair
1969					
May	9-60.0	1- 6.7	0- 0.0	1- 6.7	3-20.0
June	4-57.1	2-28.6	0- 0.0	2-28.6	0- 0.0
July	9-64.3	0- 0.0	5-35.7	4-28.6	0- 0.0
Aug.	17-73.9	6-26.1	9-39.1	6-26.1	1- 4.3
Sept.	6-50.0	4-33.3	5-41.7	0- 0.0	0- 0.0
Oct.	8-80.0	3-30.0	4-40.0	3-30.0	1-10.0
Nov.	9-90.0	4-40.0	7-70.0	2-20.0	1-10.0
Dec.	1-50.0	1-50.0	1-50.0	1-50.0	0- 0.0
1970					
April	1-33.3	1-33.3	1-33.3	1-33.3	0- 0.0
May	0- 0.0	0- 0.0	0- 0.0	0- 0.0	0- 0.0
June	4-44.4	1-11.1	1-11.1	0- 0.0	0- 0.0
July	13-50.0	1- 3.8	4-15.4	6-23.1	3-11.5
Aug.	11-47.8	1- 4.3	2- 8.7	0- 0.0	0- 0.0
Sept.	9-90.0	4-40.0	5-50.0	7-70.0	0- 0.0
Oct.	6-35.3	1- 5.9	3-17.6	4-23.5	2-11.8
Nov.	10-58.8	3-17.6	5-29.4	2-11.8	1- 5.9
Dec.	1-33.3	0- 0.0	1-33.3	1-33.3	0- 0.0
Total	118-56.5	33-15.8	53-25.4	40-19.1	12- 5.7

Table 2. Percentage survival from trapping period to trapping period for male and female *Microtus pennsylvanicus*.

Side, year	Survival period	Males	Females
	Aug./June	2/2 -100.0	3/3 -100.0
	Sept./Aug.	4/4 -100.0	10/11- 90.9
A-1969	Oct./Sept.	15/17- 88.2	15/16- 93.8
	Nov./Oct.	23/28- 82.1	30/39- 76.9
	Dec.[1]/Nov.	13/37- 35.1	10/37- 27.0
	April/Dec.	0/13- 0.0	0/10- 0.0
	Aug./June	1/2 - 50.0	2/3 - 66.7
	Sept./Aug.	9/12- 75.0	8/10- 80.0
B-1969	Oct./Sept.	18/19- 94.7	19/19-100.0
	Nov./Oct.	22/29- 75.9	27/35- 77.1
	Dec./Nov.	17/30- 56.7	14/31- 45.2
	April/Dec.	1/17- 5.9	0/17- 0.0
	July/June	0/2 - 0.0	3/3 -100.0
	Aug./July	2/2 -100.0	3/3 -100.0
A-1970	Sept./Aug.	10/11- 90.9	12/12-100.0
	Oct./Sept.	11/11-100.0	13/13-100.0
	Nov./Oct.	24/27- 88.9	20/22- 90.9
	April/Nov.	1/44- 2.3	2/37- 5.4
	May/April	0/2 - 0.0	1/2 - 50.0
	June/May	1/1 -100.0	1/1 -100.0
A-1971	July/June	5/6 - 83.3	7/7 -100.0
	Aug./July	9/9 -100.0	8/8 -100.0
	Sept./Aug.	19/21- 90.5	16/19- 84.2
	Oct./Sept.	18/28- 64.3	21/31- 67.7
	Nov.[1]/Oct.	0/21- 0.0	4/22- 18.2
	May/April	2/2 -100.0	2/3 - 66.7
	June/May	3/5 - 60.0	7/9 - 77.8
B-1971	July/June	5/6 - 83.3	9/11- 81.8
	Aug./July	13/18- 72.2	18/23- 78.3
	Sept./Aug.	19/25- 76.0	20/30- 66.7
	Oct./Sept.	20/30- 66.7	26/29- 89.7
	Nov.[1]/Oct.	28/35- 80.0	31/42- 73.8

1 Incomplete trapping periods.