Good Job, Joe!

ECOLOGY AND LAND-USE RELATIONSHIPS OF SMALL MAMMALS ON A MICHIGAN FARM

By

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INTRODUCTION

Interest in ecological research has been concerned mostly with wild or native plants and animals in non-agricultural areas. However, this has not been without the recognition that many long-standing problems of the farm and range probably will await final solution through ecological inquiry. In a presidential address to the Ecological Society, Hanson (1939) emphasized the need for research in croplands particularly as regards the possibilities for minimizing losses to noxious species. Recent trends in agriculture and the growing concept of multiple-use of all lands further emphasize the need for comprehensive ecological studies of farmland.

According to figures made public by the Land Planning Committee of the National Resources Board (1935), nearly seven million acres of Michigan farmland are affected by accelerated erosion. This constitutes more than a third of the land in farms. On a national scale, the situation is equally critical. The Reports and Records Division, Soil Conservation Service, U. S. Department of Agriculture, estimated that a billion acres, of the one billion, 142 million acres of agricultural land in the United States, were in need of some remedial treatment. As of January 1, 1949, about 93 million acres (less than 10 percent) had received full treatment under the Soil Conservation Service program, and about an equal acreage had benefited by independent programs. It can be expected that the easily demonstrated values of sound farm planning eventually will encourage most of the farmers in this country to adopt these new principles of land-use. The departures from conventional farming methods, in effect, will constitute a major ecological change on many millions of acres of land. Most species of farm wildlife will be markedly affected.

Economic biologists recognize the possibilities in this program for managing wildlife and some studies dealing directly with the subject have been made. Dambach and Good (1940) and Good and Dambach (1943) have reported on the songbird populations of farms planned for soil conservation as compared with the numbers on farms outside of soil conservation districts. Moss (1939) has shown the relationship between upland game bird populations and agricultural land-use. The effects of grazing of woodlots on songbirds have invited the attention of several workers, all of whom have reported conspicuously higher populations in protected woodlands (Saunders, 1936; Mayall, 1938; Dambach, 1940). A few basic studies, which might be exemplified by those of Allen (1938), Smith (1940a, 1940b) and Dambach (1944), contribute to the picture of wildlife and land-use.

To provide needed information for the management of small game on farmland, the Game Division, Michigan Department of Conservation, established the Rose Lake Wildlife Experiment Station in 1939. One of the main functions of the station has been to determine the response of farm wildlife to the new conditions established in converting from exploitive to conservation farming. The intentions for long-term study, and the broad scope of the work, distinguish the project from anything heretofore attempted in ecological studies of vertebrates in agricultural areas.

The economic importance of farm rodents and their significance as key organisms in the wildlife complex justified their inclusion in the program. It is the purpose of this paper to give an insight into the status of small mammals on this representative unit of Michigan farmland. Presentation of the data will include four major considerations: (1) the comparative population levels of associated species of small mammals; (2) the effects of various land-use and farming practices on the numbers of small mammals; (3) interrelationships within the group and with other wildlife species; and (4) species discussions to include such biological information as might contribute to a better understanding of this study and to the ecology of farm wildlife in general.

ACKNOWLEDGMENTS

Grateful acknowledgment is made to Mr. H. D. Ruhl, Chief of the Game Division, Michigan Department of Conservation, for making possible this study and publication of the results. Other personnel of the Game Division, and particularly members of the Rose Lake staff, contributed to the investigation in many ways. Much assistance in the small mammal trapping in 1941 was given by Mr. I. J. Thompson, and in 1942 by Mr. R. R. Rafferty. Field studies of predatory birds in 1941 were conducted by Dr. C. T. Black with the assistance of Mr. P. S. Baumgras, and the work was continued in 1942 by Dr. G. J. Wallace. Accounts of these investigations in Rose Lake reports have been drawn upon freely in the preparation of this paper. Mr. H. D. McGinley, Mr. W. W. Shapton, Mr. Wilmur Bartels, Mr. M. E. Cooley, Mr. Oscar Warbach, and other former members of the Rose Lake staff, participated in the extensive program of box-trapping. These data have provided a basis for the portion of this report dealing with small mammal populations of woodlots.

A special debt of gratitude is owed Dr. D. L. Allen, formerly biologist in charge of the Rose Lake station, for his constant aid and encouragement in the study, and for a critical reading of the manuscript. Dr. G. W. Bradt, biologist in charge of the Rose Lake station, and Dr. D. W. Douglass have been helpful in various ways. Dr. W. H. Burt of the Museum of Zoology, University of Michigan, gave generously of his time in discussions of the work and, also, loaned a number of traps in the first year of study.

For guidance, gratitude is here expressed to Professor J. W. Stack, Chairman of the Graduate Committee; to Dr. H. R. Hunt, Head of the Department of Zoology; and to Dr. B. T. Ostenson, then a member of the Department of Zoology staff of Michigan State College, who gave much assistance in the initial planning of the work. Acknowledgment also is made of the helpful editorial suggestions by Dr. R. H. Manville, and by Dr. G. J. Wallace, whose earlier participation in the Rose Lake program provided an over-all familiarity with the work and made of him an especially valuable critic.

THE AREA

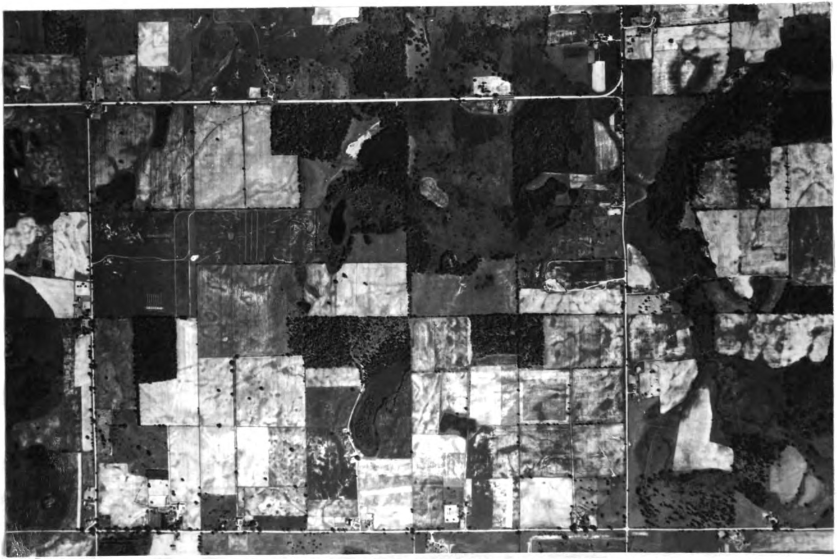

Fig. 1. Aerial view of a portion of the Rose Lake area. The central 800-acre unit enclosed by roads includes the principal farm fields and was the area of most intensive study.

SOILS AND CLIMATE

The Rose Lake Wildlife Experiment Station, principal locale of this study, lies mostly in the southeast corner of Bath township, Clinton County, Michigan. The land area in state ownership was 1,172 acres at the time studies were started in 1940. Additional acquisitions increased the total project size to nearly 2,000 acres in 1946.

Topography of the area varies between comparatively level and rolling. The steepest slopes are wooded in most cases, but early settlers cleared much of the rolling terrain that since has become badly eroded. Many level areas that might have withstood these early exploitive farm practices were left in woodland.

Soil fertility is moderate to low, and the land averages second- to third-class for agricultural use. The soil pattern is complex as characteristic of heavily glaciated areas. Twenty-seven soil types have been recorded. In the well-drained uplands, Newago loam, Bellefontaine sandy loam, and Caloma loamy sand appear in the order named. The poorly-drained soils of kettle-holes, marshes, and lake and stream bottoms are predominantly Rifle and Greenwood peats, and Kerston and Carlisle mucks.

Considering the project as a whole, cropland and pasture constitute 64 percent of the total area; marsh, swamp and swale comprise 24 percent; and woodlots make up 12 percent. However, in the 800-acre area of most intensive study, about 71 percent of land is in pasture and crops; 16 percent is in the marsh-swamp-swale category; and the remaining 13 percent is in woodlots. The latter land-use percentages are fairly typical of most private farms in the immediate area, and in this respect the Rose Lake farm is representative of many southern Michigan farms of comparable productivity.

Farming of the region is diversified except for limited development of muck lands for the growing of mint and truck crops. Corn, oats, and wheat are the principal cash crops grown. Dairying and beef production provide a considerable share of the income on most farms, and the conversion of these lands to conservation farming usually requires that these phases be intensified.

The climate in this region is favorable to diversified farming. The mean length of the growing season is 158 days between May 5, the mean date of the last killing frost in spring, and October 10, the mean date of the first killing frost in autumn. Precipitation is fairly well distributed throughout the year.

During the period of study, certain notable departures from "normal" conditions were recorded. Average snowfall for the calendar year 1940 was the greatest on record, amounting to 82.7 inches, compared with a normal of 56.4. August rainfall in that year also established a new record with a total of 9.21 inches measured in the immediate area of study. This precipitation was 6.39 inches above normal. Conditions in 1941 were about average, although October precipitation was 4.86 inches above normal with a total rainfall of 7.33 inches. The year 1942 was characterized as the wettest on record and the total precipitation of 37.02 inches at East Lansing was 5.59 inches above normal. The year's snowfall was about a third heavier than normal. Details of meteorological conditions during the period of investigation are given in the appendix.

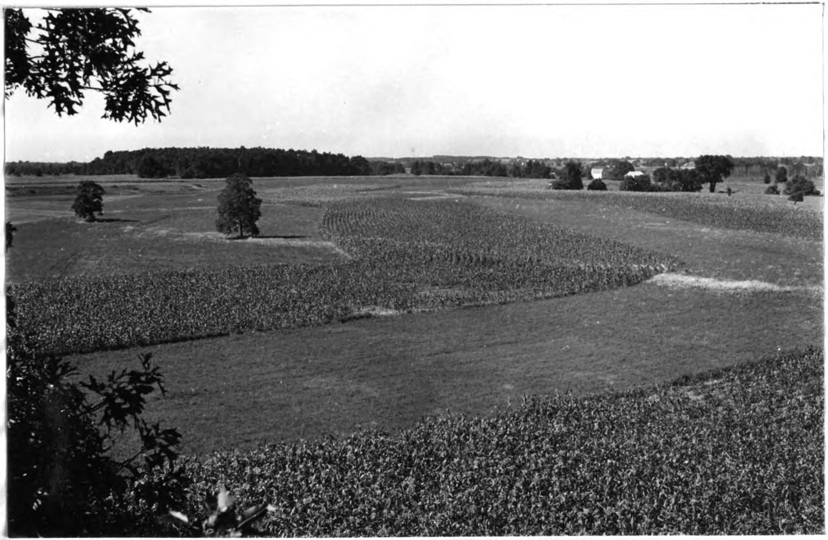

Fig.2.A unit of strip-cropped farmland on the Rose Lake Wildlife Experiment Station. Photo by D. L. Allen.

FAUNA OF THE AREA

The bird and mammal life of the Rose Lake area is varied. Among game species the cottontail rabbit (Sylvilagus floridanus mearnsii Allen) ranks first in abundance. The average hunting season kill of this species for the years 1940 to 1942 was 12 individuals per 100 acres. Hunting pressure in these years averaged 270 gun-hours per 100 acres for the entire open season for rabbits which runs from October 15 to December 31. During the first 22 days of the season (October 15 - November 5) hunting is legal also for pheasants and fox squirrels, and during this period a major share of the hunting effort is devoted to these species. Hunting removes nearly half the fall population of rabbits which, before the start of the season, number about 30 to 40 individuals per 100 acres.

Pheasants (Phasianus colchicus Linnaeus) occur in fair numbers. A peak population in 1941 allowed for a harvest of 17.4 cocks per 100 acres. A general decline beginning in 1943, which apparently occurred over the entire North American pheasant range, resulted in a much reduced population after that year. For the years 1940 to 1942, the average hunting season kill was 13.0 cocks per 100 acres. Hunting pressure for the October 15 - November 5 period averaged 218 gun-hours per 100 acres during these same years. Hunting removed about three-fourths of the cocks and pre-season populations consequently averaged close to 17 cocks per 100 acres. A nearly even pre-hunting sex-ratio was usual on the project. This period included a year of unusually high productivity for the pheasant and it is believed that average hunting season productivity for the area is closer to 10 cocks per 100 acres.

During the same open season as given for pheasants and under the same hunting pressure, the 1940 to 1942 kill of fox squirrels (Sciurus niger rufiventer Geoffroy) averaged 39.8 individuals per 100 acres of woodlot. Pre-hunting populations were judged to be about twice this figure or approximately 80 - 100 fox squirrels per 100 acres of woods. Populations of this species varied widely within the period of the study and the 1942 level was well above that of either of the two preceding years. A harvest of more than a squirrel per acre was recorded in 1942 for seven woodlots totaling 102 acres.

Other game species and their approximate fall densities included: bobwhite (Colinus v. mexicanus Linnaeus), 3-4 covies for the entire station; woodchuck (Marmota m. monax Linnaeus), 35 to 40 per section; and white-tailed deer (Odocoileus virginianus borealis Miller), 10-12 for the entire station and immediately adjoining lands. The status of other game and non-game residents which interact more intimately with the small mammals of the area will be discussed at various points in the text. The nomenclature of mammals is taken from Burt (1946) and of birds from A.O.U. check lists for the years 1944-48.

The studies reported here include observations on the small mammals of farm woodlots and those of cropland. Small mammal associations in the two general types (woodlands and fields) are mutually exclusive to a considerable degree. It appeared profitable to employ somewhat different study procedures and in other respects to consider them as distinct problems. The data are reviewed separately here, and discussions of methods and other information dealing with studies in these two major habitats appear in each section.

PART 1

STUDIES IN FIELD AND CROPLAND HABITATS

METHODS OF STUDY

One objective of this study was to measure the comparative numbers of small mammals in various habitats and at various times of the year. To accomplish this, live-trapping was employed principally and according to procedures to be described. Where other techniques were used to provide information on specific points, descriptions will be given at appropriate points in the text.

A wide variety of methods have been used in population studies of small mammals, and investigators have utilized some variation of the quadrat method of trapping in an attempt to show actual densities. It is evident, however, that economy in size of quadrats and removal of individuals from the plots have invalidated many of the population figures obtained in these studies. A failure to appreciate fully the extent of drift among small mammals, the size of individual ranges, and the speed with which depopulated areas are invaded, have been common sources of error. Recent discussions of the subject would seem to indicate that most short-cut procedures fail in their attempts to show real densities. In most cases, true censuses of small mammals require intensive live-trapping on quadrats several acres in size (Dice, 1938; Bole, 1939; Blair, 1941; and Stickel, 1946a).

With this procedure the size of the quadrat and the number and spacing of traps are variable depending on the species being studied, population density, size of the ecological unit under study, etc. At best, however, the method is laborious and probably has its greatest utility in intensive studies where the determination of actual population densities is a leading objective. For various reasons the procedure was not adaptable to much of this study. Many farm situations (fencerows, field borders, strip-crops, etc.) are of such shapes and dimensions that quadrats cannot be laid out. Furthermore, it proved desirable at times to sample concurrently the rodent densities in more situations than could be trapped conveniently by intensive means.

The types of comparisons planned in this study did not require a trapping method which would provide counts of actual densities. However, since some identical situations were to be sampled periodically, it appeared advisable to avoid any possible error that might result from removal of animals. Various other considerations necessitated the use of some compromise method which would permit a relatively quick and accurate sampling of populations without causing undue disturbance. The most practical approach to the type of study attempted appeared to be live-trapping along lines of measured length as suggested by Dice (1938) and successfully used in some of the work reported by Blair (1938).

Unless otherwise indicated, all population indices were obtained by using a series of 25 traps spaced at 22-foot intervals along a measured straight line 8 chains long. Trap-lines extended from the field border toward the field center and were located midway between the field edges paralleling the line of traps. A few larger fields, 25 acres or more in size, were trapped with two lines of traps. In this case each line was placed 2 chains in from the field border which it paralleled. Traps were left in operation for three successive nights.

The trap used was modeled after one developed and used by William H. Burt and his co-workers at the University of Michigan. Construction is of pressed fibre board and the inside dimensions are 1-3/4 x 1-3/4 x 6-1/2 inches. The trap mechanism, which operates without benefit of springs, proved to be efficient and was easily maintained in good working order. In preliminary tests the trap proved to be more effective than the spring-operated metal-type trap in common use for small-mammal work.

A few initial tests indicated that live-traps unbaited were about as effective in making catches as when several types and combinations of baits were used. However, a standard bait combination of sunflower seed and peanut butter was used through the trapping, and a small wad of dry non-absorbent cotton was placed in traps to provide nest material for trapped animals.

At the first capture, individuals were marked for future identification by ear-tagging with numbered fingerling tags, by toe-clipping, or both. Following each capture, the animals were given a routine examination and the sex, age, breeding condition, and other pertinent facts recorded (figs. 3, 4, and 5). Separate card files were maintained for each individual and also for each habitat trapped.

The standardized spacing of traps, length of line, and period of trapping followed here allow for various expressions of mammal densities. The "catch per trap-night" method of indicating abundance (Grinnell, 1914) has been used frequently. However, evidence presented by Dice (1938) indicates that the number of individuals taken along a given trap-line is more directly related to the length of the line than to the number of traps or the interval of operation. It appears that the records to be presented here should have the best comparative value through the use of an expression similar to that suggested by Dice (op. cit.), which considers the catch per unit length of trap-line. Trapping results consequently are given as individuals per trap-line.

From a computation of the average catch for two or more lines, fractional figures commonly were obtained. The conversion of the data to whole figures in some cases would introduce an appreciable error. Consequently, the one-decimal calculations have been retained without implying that level of accuracy for the data.

Fig. 3. Small mammals were transferred from the trap to a small cloth bag.

Fig. 4. The animals were grasped by the nape of the neck and pushed through the opening of the bag for marking and examination.

Fig. 5. Animals were marked by toe-clipping or with ear-tags.

COMPARATIVE POPULATIONS OF SMALL MAMMALS

Annual Numbers in Cropland

Practically all the small mammals listed by Burt (1946) for the southern portion of Michigan's lower peninsula were taken in the course of this work. Most of these, however, occurred so sparingly that a consideration of their numbers would be of doubtful significance. In the discussion to follow, particular attention is given to the prairie deermouse (*Peromyscus maniculatus bairdii* Hoy and Kennicott), the commonest small mammal in the area. The meadow vole, (*Microtus pennsylvanicus pennsylvanicus* Ord) and house mouse (*Mus musculus* Linnaeus) occurred in numbers sufficiently large in some situations to allow comparisons. The status of other species is dealt with at appropriate places later in the text.

Prairie deermouse

In his work on the prairie deermouse on the Edwin S. George Reserve, Livingston County, Michigan, Blair (1940*a*) made special note of "a very marked decrease in deermouse abundance from 1938 to 1939". On one plot studied by Blair, a maximum population in 1938 of 9.2 prairie deermice per acre was found. During a corresponding period in 1939 the density was only 2.9 per acre. On another study area, a mid-June, 1938, population of 2.0 mice per acre dwindled until none were living on the plot in late August of 1939. Blair suspected that the dry spring and failure of the bluegrass to set

seed may have accounted for the small prairie deermouse population in 1939. At Rose Lake the spring and summer population level of this rodent was at a low point in 1940, and it was the opinion of farmers and other observers in the area that it was less numerous than it had been for several years. Intensive studies were interrupted during the years 1943-1945, but there is some indication that prairie deermice in the area began an upward trend in 1941 and probably approached a peak in 1946.

Since the intensity of trapping over several years varied seasonally and with different habitats, a direct comparison of all trapping results would hardly give a valid demonstration of the population level. In fig. 6, however, an index to numbers is given for a 2-month period in midsummer. This has been based on individual catches from those lines considered to have been located in acceptable deermouse habitats. These results indicate a 1941 density twice that of 1940 and a 1942 population that was more than five times as high as that of 1940. Limited trapping in the summer of 1946 indicated that the trend had continued upward, since the catch for that year was over seven times as great as that of 1940.

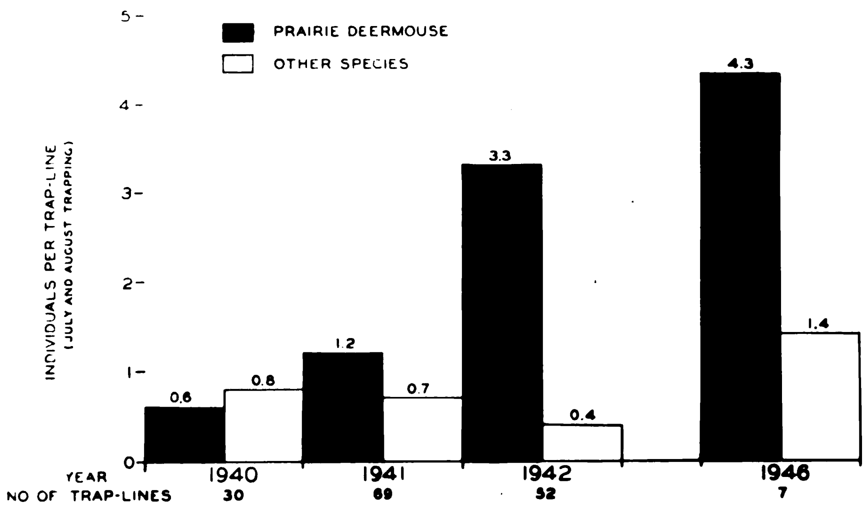

Fig. 6. An upward trend in numbers of the prairie deermouse was indicated by the marked increase of live-trap catches in each succeeding year of study.

Other species

Species other than the prairie deermouse occurred only sparingly in the upland fields. However, among these "incidental species" (mostly the house mouse) a drop in numbers was noted from 1941 to 1942 at the time when the deermouse was showing evidence of increase (fig. 6).

At no time during the study did the meadow vole appear in any numbers in cropland during the summer months. However, populations of this species at Rose Lake were conspicuous in some habitats during autumn and winter and showed an unorthodox behavior which will be discussed separately.

Relative Numbers in Various Crop Types

Although the literature dealing with small mammal populations is extensive, the reported studies invariably have dealt with natural associations. A few investigations have contributed incidental notes concerning the numbers of small mammals in and around farmlands.. Hanson (1944) working in Wisconsin found populations of the prairie deermouse to be conspicuously higher in a prairie-relic situation than in any of several farm habitats (grain stubble, alfalfa, and bluegrass-sweet clover fields). Hanson's trapping also showed a fallow field heavily grown up with beggar's tick (Bidens), smartweed (Polygonum), yellow foxtail, and ragweed to have been one of the most productive situations studied for several species of small mammals. Johnson (1926) commonly took the prairie deermouse in fields of grain and alfalfa in Illinois but indicated it was uncommon in "neglected areas such as the matted grass of roadsides". Calhoun (1941), in Tennessee, found greater numbers of house mice in a *Lespedeza* planting than in any other of a variety of situations trapped, and Southern and Laurie (1946) in England found greater densities of house mice in wheat ricks than in either oats or barley. A program of winter trapping in Ohio by Dalmbach (1945) showed small mammals to be somewhat more plentiful in fields of shocked and machine-picked corn than in several other crop fields.

Prairie deermouse

In 1940, preliminary trapping was done in fields of wheat, oats, timothy-clover pastures, and sedge meadow. Among these habitats, the greatest numbers of prairie deermice were taken in wheat fields. During midsummer of the years 1941 and 1942, a number of fields of each of several common crops were live-trapped to determine the relative numbers of small mammals. Trapping was done at a time when the crops were at or near maturity. However, an attempt was made to adjust trapping dates so that all fields could be sampled as nearly concurrently as possible. In addition to the work in cropland, several units of idle ground were also trapped. In each case these idle areas were grown up principally with bluegrass (*Poa compressa* and *P. pratensis*), although there was considerable variation with respect to species and amounts of other herbaceous types.

Fig. 7. The prairie deermouse ranked first in abundance among the small mammals of the area.

Fig. 8. Of the common farm crops, corn fields were among those most heavily populated by prairie deermice.

During both years (1941 and 1942) the only small mammal taken in sufficient numbers to permit comparisons was the prairie deermouse. The relative densities as found for this species are shown in table 1. With the extremely low population present in 1941, no real difference is evident among the numbers taken in each of three types of grain fields or in alfalfa fields. The numbers in idle ground, however, were considerably fewer than in any of the adjoining croplands studied. With a considerably higher (but still low) population in 1942, there was still no convincing evidence of any crop-type preference by the prairie deermouse.

As was found to be the case the previous year, idle-land habitats supported appreciably smaller populations than did farm fields. It is of possible significance that among croplands, red clover fields had the lowest numbers of deermice in both years. In 1942 a dense, 20-acre stand of red clover which immediately joined fields of alfalfa and wheat was trapped concurrently with the other two. No prairie deermice were taken in the clover, whereas trapping of equal intensity accounted for 18 deermice in the alfalfa and 8 in the wheat fields. Hanson (1944) in referring to the prairie deermouse commented that: "....this species seemed to prefer situations where the immediate ground cover varied from light to moderate densities". It is not unlikely that this factor was important in limiting deermouse numbers in red clover fields which, in each case, were extremely dense and matted.

Table 1. Comparative numbers of the prairie deermouse in various crop and idle-land habitats in summer.

Crop	July-August, 1941		July-August, 1942	
	No. of fields sampled	Individuals per trap-line	No. of fields sampled	Individuals per trap-line
Oats	22	1.3	15	2.9
Wheat	6	2.0	10	3.9
Corn	12	2.1	5	4.6
Alfalfa	17	1.3	9	5.0
Red Clover	6	1.2	2	0.0
Idle ground:				
Mixed herbaceous	7	0.3	7	1.9
Bluegrass sod	5	0.0	4	1.5
Brushland	-	-	4	1.0

In the late fall of 1942, most rodents in the area were considerably more plentiful than they had been at any time during the summer. A number of the same situations which had been studied several months earlier were trapped again in October and November to determine possible habitat preferences. In these data, which are summarized in table 2, the relative ratings of various crops with reference to deermouse numbers did not show any marked changes over conditions found in the two previous summers. Trapping results suggested a greater preference for alfalfa and wheat to oat fields, and in one area of strip-cropping a rather remarkable difference in populations in these three types was observed. The three crops were in adjoining strips, each 100 feet in width. Both the oats and wheat had been harvested with a combine, and the alfalfa was about 10 inches in height following regrowth from a second cutting. All were trapped in an identical manner during the period November 3 - 5. The comparative numbers of deermice for each was indicated by a take of 23 individuals per line in the alfalfa, 22 in the wheat, and only 4 in the oats.

The data shown in table 2 were obtained following the harvest season. Certain characteristics of specific fields, such as crop residues, type and density of ground cover, etc., remained to distinguish the particular crops grown on these fields. It would be well to point out, however, that the croplands in this late-fall period were similar in many respects to the annual weed stage in succession from plowed ground, which Allen (1938) describes; and in a large part to the smartweed-foxtail situation studied with

Table 2. Comparative numbers of the prairie deermouse in various crop and idle land habitats in late autumn (October - November), 1942.

Crop	No. of fields sampled	Individuals per trap-line
Oats (stubble)	3	6.3
Wheat (stubble)	1	22.0
Rye (seeding)	2	21.0
Corn (mechanically picked)	6	11.0
Alfalfa	2	14.5
Red clover (cut)	1	4.0
Pasture	2	5.0
Idle ground: Mixed herbaceous	3	5.7
Fencerows (sod)	4	0.8

respect to its small mammal inhabitants by Hanson (1944). At the time of trapping, most of the fields were vegetated with lesser ragweed (Ambrosia elatior), foxtails (Setaria lutescens and S. viridis), lamb's quarters (Chenopodium album), smartweed (Polygomum spp.), and to a lesser extent by barnyard grass (Echinochloa crusgalli), redroot pigweed (Amaranthus retroflexus), tumbling pigweed (A. graecizans), black bindweed (Polygonum convolvulus), and old witch-grass (Panicum capillare).

In 1946, populations of most, if not all, small mammals at Rose Lake were conspicuously higher than they had been for a number of years. A limited amount of trapping was done through the spring and summer to determine whether relationships noted during the period of low-to-medium population density still existed.

In March and April, two fields of corn stubble, which still contained a number of shocks, had the highest population of the several situations trapped. The average catch was seven prairie deermice per trap-line. The second-highest density, averaging 4.6 individuals per line, was observed on three trap-lines located in fields which had not been cultivated for several years. Vegetation on these plots was similar to the annual weed association already described. In two rye stubble fields an average of two deermice per line were taken, and in five field and roadside situations of typical grassland habitat the lowest take, of 0.6 individual per line, was recorded. In June, four of these same bluegrass associations were again trapped without taking a deermouse.

During early August of this same year, adjoining fields of corn, oats (two fields recently cut), alfalfa, red clover, and bluegrass sod (two fields) were trapped with the following results: corn - 10 prairie deermice per trap-line, alfalfa - 7, oats - 5.5, red clover - 1, and bluegrass fields - 0.5.

In considering the over-all results from trapping— conducted intensively during two summers and periodically in two other years— prairie deermouse preferences for specific crops are not strongly shown. However, certain consistencies appear in the data which seem to have significance. In general, grain fields supported higher populations than other habitat types, and in this category corn, wheat, and rye fields were more densely populated than fields of oats. Trapping in alfalfa regularly produced catches which indicated densities comparable to those in grain crops. The numbers taken in red clover plantings showed it to be the least acceptable to the deermouse of any of the annual crops. Idle-ground situations, which were mostly covered with bluegrass, maintained the lowest populations of any of the farmland habitats.

In the area of this study the natural plant succession on lands permanently retired from cultivation would lead in a decade or so to brushland and later to oak-hickory woodland, the most advanced seral stage present. Much of the idle ground in proximity to cropland is maintained as a grassland habitat, however, due to various human disturbances (burning, pasturing, cutting, etc.). The comparatively low populations of prairie deermice in these areas is not surprising in view of the observations by Dice (1923a, 1923b), Johnson (1926), Allen (1938), Hanson (1944), and others.

Johnson (1926) has indicated that the species originally belonged to some sub-climax communities in the Andropogon prairie-climax association. In Michigan the prairie climax was present in only limited portions of the southwestern part of the state, and the distribution of the species was undoubtedly confined to those openings. As has been shown by Hooper (1942) its spread over most of the southern peninsula of Michigan was a result of deforestation and cultivation.

Recommendations for the progressive operation of Michigan farms call for increased acreages of permanent pasture, and the retirement of many hilly areas now in cultivated crops. The effect will be that of placing a substantial percentage of untilled land in a seral stage successionally advanced from the "annual weed-cropland association," the type of idle ground observed to be most favorable for the prairie deermouse.

Other species

Aside from the prairie deermouse, the house mouse was the only other small mammal to appear consistently in cropland studies. While the numbers of this animal handled were too few to justify any detailed consideration of its status, certain observations are of interest.

In general, the comparative population levels of the house mouse in major farm habitats indicated the preferences of this species to be similar to those of the prairie deermouse. Of the few individuals trapped in summer and fall studies, most were taken in grain fields and the fewest in idle ground (table 3). On the basis of frequency distribution rather than actual density, a similar tendency is noted in the data, the species having been taken in 18 (40%) of 45 grain fields studied in summer, 8 (35%) of 23 alfalfa and clover fields, and in only 3 (16%) of 19 idle land situations.

In discussing the status of the house mouse on English farms, Southern and Laurie (1946) state that farmers usually report more damage in oat ricks than in other types of grain. Their studies indicated, however, that these mice may have been more plentiful in wheat than in other kinds of ricks. On the basis of summer trapping at Rose Lake the species appeared to be of more general occurrence in oat fields than in other farm habitats. Their frequency distribution in various situations was as follows: oats - taken in 10 (53%) of 19 fields studied, corn - 6 (50%) of 12, alfalfa - 6 (32%) of 19, idle land - 3 (16%) of 19, and wheat - 2 (14%) of 14.

Numbers with Reference to Land Uses and Farm Practices

Strip-cropping

On erosion-susceptible farm land, strip-cropping is being used widely as a soil- and water-conserving measure. The technique results in fields which are in marked contrast with the pattern on conventional farms. Crop types are closely interspersed, and cultivated fields are alternated with close-growing crops which in many cases, are undisturbed by cultivation and plowing for extended periods of time. The extent to which such intermixture of several

Table 3. Comparative numbers of small mammals in three major types of farmland habitat.

Dates	Type of habitat	No. of trap-lines	Catch: Individuals per trap-line P.d.m.	H.m.	M.v.	S.t.s.	B.l.	W.m.	All spp.
July-August, 1941	Grain crops	40	1.6	0.4	0.0	0.0	0.0	*	2.1
	Hay crops	23	1.3	0.4	0.0	0.0	0.0	0.0	1.7
	Idle ground	13	0.2	0.0	0.3	0.8	0.0	*	1.4
July-August 1942	Grain crops	30	3.5	0.5	*	0.0	0.0	0.0	4.1
	Hay crops	11	4.1	*	0.0	0.0	0.0	0.0	4.2
	Idle ground	15	1.5	*	*	*	*	*	2.0
October-November 1942	Grain crops	12	12.4	1.3	0.6	*	0.0	0.0	14.4
	Hay crops	5	8.6	0.8	1.0	0.4	0.0	0.0	10.8
	Idle ground	7	2.9	0.7	8.9	1.7	1.0	0.9	16.1

* Average less than 1 per 5 trap-lines

Pdm - Prairie deermouse
Mv - Meadow vole
Hm - House mouse
Sts - Short-tailed shrew
Bl - Bog lemming
Wm - White-footed mouse

crop types might encourage rodent numbers has not been investigated. Neither has it been determined if relatively undisturbed habitats, as represented by hay strips, would maintain populations and serve as centers of infestation to the adjoining crops.

An attempt was made to compare the relative populations of small mammals under the two methods of farming. Using identical procedures, fields of oats, wheat, and alfalfa in an area of strip-cropping were trapped concurrently with fields of the same crop grown under conventional methods. In each case fields under comparison were in comparable stages of growth and were located in the same immediate area— frequently in adjoining quarter-section land units. Results of this study are shown in table 4.

Since the cover requirements of the meadow vole would appear to be more exacting than those of other species in the area, it might be expected that populations of this mouse would show the greatest response to differences associated with the two methods of land use. It was especially regrettable that significant summer populations of the species were not available for the comparison. In the case of the prairie deermouse, however, it will be seen that the variety of habitats provided by strip-cropped plantings gave no evidence of encouraging populations of this species. And, in fact, the catch in both grain and hay fields was somewhat higher under conditions related to the conventional "block" fields. This apparent lack of response of the prairie deermouse to the greater interspersion of herbaceous types was further shown by other work summarized below.

Trap 4. Comparative numbers of prairie deermice in crops conventionally grown and strip-cropped.

Crop	Farming method	No. of Fields	No. of Trap-lines	Catch per Trap-line
Small grain: (oats and wheat)	Strip-cropped	12	25	2.0
	Conventional	12	25	3.2
Hay: (alfalfa)	Strip-cropped	8	14	2.4
	Conventional	9	12	2.8

<u>Field distribution of prairie deermice</u>.- In the summer of 1940, a number of fields, selected for having dense marginal growths, were trapped, using lines which extended from the edge of the field to a point beyond the field center. In this preliminary work the number of mice caught in traps located well within the field was actually higher than in traps located near the field border (Linduska, 1946).

To determine further whether or not the field distribution of prairie deermice bore any relationship to the edges, trapping returns for 1941 and 1942 were analyzed. It will be recalled that a standardized procedure of trapping was used in practically all of this study, and that one requirement concerned the placement of 25 traps in a straight line beginning at the edge of the field and extending in the direction of the center of the field. The first trap in the line was set at the field edge, and, in each case, the 25th trap was 528 feet from the edge. In many cases the crop margin was adjacent to a fencerow, roadside, ditchbank, or other uncultivated land. These supported a variable type of vegetation which included successional stages from annual weeds to mature oak-hickory. The primary function of the trapping was to establish comparative population levels in particular crops. Consequently, the first trap in each line was placed in the edge of the crop rather than in the marginal vegetation. While the trapping returns can be expected to show possible influences of crop-border vegetation, they do not allow for a comparison of rodent numbers in fields as compared with numbers in the field margins.

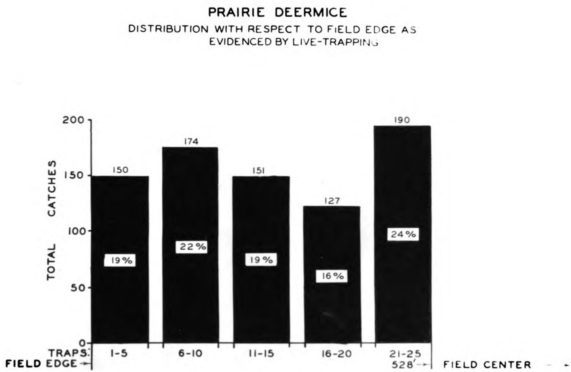

Fig. 9. An analysis of catch records for the prairie deermouse failed to show any evidence of a concentration of numbers at field edges.

If a diversity in food and cover types presents conditions favorable for prairie deermice, it would be expected that some concentration of their numbers would be found near field edges. An analysis of 792 catches for the species failed to demonstrate any response to such conditions during the summer months (fig. 9). The numbers taken in the five traps (20 percent of the total) nearest the edge, represented 19 percent of the total number of catches made in the line. Also, the number caught in succeeding groups of five traps did not deviate appreciably from the expected catch if a random distribution of mice in the field is assumed. The 22-foot interval followed in the spacing of traps, was considerably less than the diameter of the home-range for individuals of this species. Consequently, competition for catches existed between traps. On this basis it might be theorized that traps 1 and 25, since they lacked competing traps on one side, would show a greater number of catches. The catch records for individual traps failed to indicate that the traps so located were appreciably more efficient than other traps in the line.

Field borders

In a comprehensive study of field borders in relation to conservation practices, Dambach (1945) found the greatest winter density of small rodents and shrews in cropland borders of bluegrass, and fencerows of mixed shrubs and grass. Borders of weeds, shrubs, and osage orange supported conspicuously smaller populations. While a detailed study of field-border vegetation was not attempted in this

work, some trapping was carried on in two representative types of fencerow and roadside cover.

One type of border which occurs with some frequency in the area is made up of almost pure stands of dense bluegrass (Poa pratensis and P. compressa). Elsewhere, and occasionally continuous with the bluegrass type, can be found brushy roadside and fencerow borders representing the other extreme (figs. 10 and 11). In some of these the woody vegetation has closed in to such a degree that little or no herbaceous undergrowth is present. The principal trees and shrubs in these situations included white and black oak (Quercus alba and Q. velutina), hickory (Carya ovalis and C. ovata), wild cherry (Prunus serotina and P. virginiana), maple (Acer rubrum), hawthorn (Crataegus sp.), staghorn sumac (Rhus typhina), elderberry (Sambucus canadensis), wild grape (Vitis sp.), and others.

During early August of 1942, four representative units of sod borders and four of brush-tree borders were sampled for their small-mammal populations. The unit of trapping standard for most of this study was used. Small-mammal populations in both types of border vegetation were lower than those found in cropland during the same period. Trapping in the four wooded borders produced only five individuals, of which four were prairie deermice and one a white-footed mouse. In the four sod borders 11 individuals were taken including 6 prairie deermice, 2 meadow voles, 2 bog lemmings, and 1 short-tailed shrew. During late October and early November of the same year, four sod borders, which included two of those described above, were trapped again. The total catch in this period was 77 small mammals, which included 50 meadow voles, 19 short-tailed shrews, 3 bog lemmings, 3 prairie deermice, and 2 house mice. Concurrent October and November trapping in croplands resulted in a higher catch of prairie deermice but a far lower catch of meadow voles. On 19 lines operated in harvested grain fields, pasture, hay, clover, and fallow fields, a total of 236 small mammals were trapped. These included 200 prairie deermice, or an average of nearly 11 per line. This compared with an average catch of less than one deermouse for each of the four lines located in sod borders. By contrast, the meadow vole catch of over 12 per line in sod border situations was well above the average of less than one per line in the 19 field lines.

During April, 1946, a few sod and wooded crop-border situations were sampled again. In this trapping, four lines in sod areas took an average of seven small mammals per line. The total of 28 individuals included 16 meadow voles and 6 bog lemmings. In this same period two lines in wooded borders caught only one white-footed mouse.

While these trapping data for field-border vegetation are not extensive, there appears to be little question but that the grassland type supports a more abundant small mammal population than does a predominantly woody type. Furthermore, the meadow vole, a species of considerable economic significance in farmland, appeared consistently in sod borders and at times was appreciably more abundant in this situation than in adjoining cropland. This fact would suggest that sod borders might serve as reservoirs for the species and at times operate as foci for infestation of adjacent cropland, a conclusion shared by Dambach (_op. cit._).

Fig. 10. Wooded fencerows and road borders supported few small mammals.

Fig. 11. Sod fencerows of this type are ideal habitat for the meadow vole. Under several feet of drifted snow these mice removed much of the bark from the sprout growth of wild crab in the foreground.

Fig. 12. Sodded areas such as this in fencerows and roadsides probably have high survival value for meadow voles in agricultural areas.

Fig. 13. In many areas on the Rose Lake station, woody cover is establishing in bluegrass sod through the medium of brushpiles. Droppings from birds which perched on the brushpile probably seeded this sod fencerow to the variety of vines and shrubs shown in the picture.

Harvest

The effects of various farm operations on small-mammal populations have received only casual attention from ecologists. Wood (1910) and Johnson (1926) noted that the prairie deermouse maintained itself in open fields in spite of various disturbances associated with crop production. Fenyuk (1937) observed that the numbers of rodents in fields declined rapidly following harvest, but he noted also that a careless harvest might increase numbers. Southern and Laurie (1946), in working with the house mouse in England, showed that populations of this species declined rapidly after harvest.

In this study an index to small mammal densities was obtained in 30 separate crop fields before and shortly following harvest in an effort to evaluate possible effects of the operation. In the case of prairie deermice, there was a slight average increase in the numbers caught following mowing of alfalfa, and a substantial increase in the catch following the harvest of grain crops and red clover which was cut for seed (table 5). The increased catch was not observed in all fields. However, the increase was found in a large majority of the grain fields and in both of two clover fields studied. Although the over-all average of trapping returns from six alfalfa fields showed increased numbers, the records for individual fields showed a slight decrease in four fields and an increase in two fields (table 6).

It seems unlikely that conditions associated with harvest would encourage increased numbers of the prairie deermouse in the short interval between periods of trapping. Probably the most that can be said for the data is that no immediate limiting effect resulted. The fact that the number of catches increased with the operation might be accounted for in several ways. With the marked reduction in cover caused by harvest it is likely that the shelter offered by live-traps would be more attractive. It is possible, also, that the removal of cover would result in increased movement of the mice, either through the elimination of recognition points delimiting home ranges, or through a reduced carrying capacity of the area. In this connection several studies have shown that home range dimensions can be modified appreciably by population density and environmental factors (Kalabukhov, 1935; Dice, 1938, 1941; Blair, 1940a, 1943; Burt, 1940, 1943; Linduska, 1942a; and Stickel, 1948).

A rather sparse population of house mice showed a reduction in numbers in response to conditions associated with harvest. In 1940, fields of hay, wheat, and oats were trapped just prior to harvest for a total of 700 trap-nights. The catch included nine house mice. Following harvest, the same fields were trapped with the same intensity and only one house mouse was taken. During 1941 and 1942, 51 trap-lines in crop fields took 40 house mice before and 18 after harvest. Fields of oats showed the greatest decline in house mouse populations as a result of harvest. In this crop, 18 trap-lines produced a catch of 18 house mice before and 5 following removal of the crop. The least reduction occurred in corn fields from which the corn had been removed by means of a mechanical picker. In this type of operation, which removes none of the ground cover, the house mouse population showed no significant change.

Table 5. The numbers of prairie deermice caught in 22 grain fields (wheat, oats and corn) and 8 hay fields (alfalfa and red clover) before and following harvest.

		Trap-lines	Individuals caught	Individuals per trap-line
Grain crops:	Before harvest	39	74	1.9
	After harvest	37	117	3.2
Hay crops:				
Alfalfa	Before harvest	10	21	2.1
	After harvest	10	25	2.5
Red clover	Before harvest	4	1	0.3
	After harvest	4	10	2.5

Table 6. Effects of harvest in 22 grain fields and 8 hayfields on populations of the prairie deermouse.

Crop		No. of fields studied	Population change following harvest: Increase	Same	Decrease
Grain:	Wheat	7	6	1	0
	Oats	12	7	2	3
	Corn	3	2	0	1
Total:		22	15	3	4
Hay:	Alfalfa	6	2	0	4
	Clover	2	2	0	0
Total:		8	4	0	4

Eleven were taken before and 9 after harvest on 14 trap-lines.

Southern and Laurie (1946) in England found house mice were common in fields of standing grain, but they failed to capture any in the stubble following harvest. Their conclusion that, "....it is clear that dense ground cover is most important for the wild-living house-mouse....", is borne out from observations in this study.

Shocking corn.- During each winter of this investigation, a series of corn shocks were examined to determine the extent to which they were being used by small mammals. In every year, meadow voles and prairie deermice were present in practically all shocks, and there was ample evidence of a considerable loss of corn. In 1941, a detailed study was made of the relationship of small mammals to shocked corn, and in addition to determining the economics of this practice, considerable biological information was obtained from more than 500 mice which were collected (Linduska, 1942a). The results of this study, together with information obtained in other years, gave every indication that financial losses resulted whenever shocked corn was allowed to remain in fields over the winter months. Furthermore, the high rodent populations, which this practice encourages, would appear to be a potential threat to other agricultural crops.

Fig. 14. Good esthetics but poor economics. If left out all winter, 20 percent or more of this corn may be lost to mice.

Fig. 15. Shocked grains usually are threshed before rodents make serious inroads.

Fig. 16. Shocks of corn in winter always were found well populated with rodents.

Fig. 17. Experimental corn shocks, some screened to admit only mice and others open and allowing access by all granivorous wildlife, showed that substantial losses were due almost entirely to feeding by mice. Photo by P. S. Baumgras.

Cultivation and plowing

By analogy, it appears that cultivation would be an important mortality factor for field-inhabiting rodents, and that a frequent disturbance of this type might discourage them from using crop fields. For the prairie deermouse, however, this does not appear to be a seriously limiting factor. In reporting on this species, Wood (1910) mentioned taking them commonly in large fields of young corn under intensive cultivation. Johnson (1926) remarked that: "Cultivation of the soil does not seem to disturb them in the least. It has been found that specimens might be secured readily by trapping in the winter in perfectly bare ploughed fields where corn had been raised the previous season."

Nothing in this study indicated that cultivation restricted appreciably the use of land by prairie deermice. In 1941, the numbers taken in frequently cultivated corn fields were higher than in any other habitat. During the summer of 1942, cultivated corn fields again were among the most intensively used habitats on the farm (table 1). Even the inhospitable bareness of fall-plowed ground did not exclude prairie deermice, and on several occasions individuals were taken from this type of situation. One field of nearly mature oats, which was live-trapped in late July, had a density of prairie deermice indicated by a catch of three individuals. The same trap-line took six mice shortly after harvest during the first week in August. The field was plowed in September and rye was sown. Shortly after the new rye growth appeared in October, the same portion of the field was again trapped and 20 deermice were taken from this essentially bare ground. An unusually heavy mortality occurred among the live-trapped animals in this period and only 12 of the 20 were released. When the same rye seeding was retrapped in the following week, 14 mice were captured of which 4 were repeat animals from the previous period of trapping. This recatch of one-third of the animals previously marked would indicate that the mice using the field were not entirely a vagrant population as might have been anticipated from the appearance of the field.

Fig. 18. Sparseness of ground cover did not discourage occupancy by the prairie deer-mouse. In October, the animals were common throughout a 10-acre field of fall-sown rye, a portion of which is shown here.

Fig. 19. Winter excursions were short and infrequent from the ideal food and cover combination of corn shocks.

SPECIES ACCOUNT AND INTERRELATIONSHIPS

Small Mammals

Prairie deermouse

Seasonal cycles of abundance have been reported for the prairie deermouse (Blair, 1940a) and the white-footed mouse (Burt, 1940). Both species normally show a three- to four-fold increase from a low period in early spring to an annual high in late fall. In this study intensive trapping was not conducted through the year to show all seasonal levels. However, the marked differences in yearly populations, previously noted, were reflected in summer-to-fall trends.

Seasonal numbers and biology.- In 1941 prairie deermice were scarce in the area, and in July there was an average of only 1.2 catches per trap-line. This same index of abundance was obtained in August, but in September the number of catches nearly doubled. In 1942 the beginning summer population evidently was about the same as it had been the previous year, since a catch index of 1.8 was obtained in July. In August, however, the average number of catches per line was 4.1, and in a period of fall trapping (October-November) the number of catches indicated a five-fold population increase from the July level (table 7).

Table 7. Summer increase of prairie deermouse populations as determined by live-trapping.

	1941		1942	
	No. of trap-lines	Catches per trap-line	No. of trap-lines	Catches per trap-line
July	37	1.2	15	1.8
August	32	1.2	37	4.1
September	8	2.5	-	-
Oct.-Nov.	-	-	23	8.8

Table 8. Summary of breeding notes for the prairie deermouse.

	Adult females 1/ 3/		Sub-adult females 2/	
	No. examined	Percent breeding	No. examined	Percent breeding
1941 (July-Aug.)	24	67	6	17
1942 (July-Aug.)	39	54	31	81
" (Oct.-Nov.)	30	40	95	9

1/ Overwintering animals. 2/ Young of the year.
3/ Breeding animals included those pregnant, lactating, or in oestrus.

Information summarized in tables 8 and 9 suggest that the 1941 prairie deermouse population was held at a low level largely as a result of a reduced breeding rate in spring and/or a low survival among young. A limited age ratio sample of the July population showed that less than 1 in 10 were young of the year. Although a high rate of breeding (67%) was found among adult females in midsummer, the continued low percentage of young animals through summer and early fall indicated a low survival. As has been pointed out, the 1942 population underwent a marked increase through summer and early fall. In July and August the percentage of adult females which were breeding was slightly lower than the year before. Among sub-adult females, however, a great majority (81%) were sexually active, and a good survival of young is indicated by the high percentage (95%) of young in the fall population.

The fact that breeding by the prairie deermouse was general during the summer in both 1941 and 1942 is possibly related to the comparative scarcity of the species in both of those years. According to Blair (1940a), midsummer is ordinarily a period of reduced sexual activity. In a year of "normal" numbers he found about 33 percent of the adult females breeding in July and August, but with a considerably lower population a year later he found 67 percent of the females breeding during the same months. The active period for another subspecies, artemisiae, is reported by Scheffer (1924) to extend throughout the year in central Washington, with most pregnancies occurring in January, June, and November. Brown (1945) reported having taken gravid females of the Nebraska white-footed mouse (nebrascensis) during the winter months in Kansas. In this study winter breeding was observed among prairie deermice inhabiting corn shocks. In January, 1941, 8 of 41 taken in shocks were pregnant or with litters (Linduska, 1942a) and in 1943, 4 of 14 sub-adult females collected in January and February were breeding, but none of five adults were sexually active.

In 1946 the summer populations of the prairie deermouse probably were higher than they had been for several years, and conspicuously higher than they were anytime during the period 1940-42. A few observations indicated that the "peak" populations of summer probably were due to an early breeding season and survival of young that was quite different from that in the years of earlier study. In mid-March of 1946, 15 animals taken by snap-trapping included 7 young, and one of two adult females taken was pregnant. The large proportion of young indicated that some breeding had already taken place by this early date. Between April 3 and 22, another snap-trapped sample included nine females, all of which were breeding. Eight of these were pregnant, and the embryo count averaged 4.2 per female, essentially the same as that reported by Blair (1940a). That this general breeding was accompanied by a good survival of young was indicated by a snap-trap sample from six habitats in August. Among 30 individuals taken at this time 28 were young. Even considering the limitations of the small numbers, the indicated ratio of 1 adult to 14 young in this year of high population provides interesting comparison with the ratios of 1 adult to 0.5 young and 1 adult to 1.7 young obtained during the same month in 1941 and 1942.

Table 9. Ages of prairie deermice taken in live-trapping.

	1941			1942		
	Adults	Young	Percent young	Adults	Young	Percent young
July	45	4	8	16	10	38
August	22	10	31	52	89	63
September	12	6	33	-	-	-
Oct.-Nov.	-	-	-	14	263	95

Table 10. Sex ratio of prairie deermice taken in live-trapping.

	Year			
	1941	1942	1943	1946
Total sexed:	104	601	57	67
Males:	69	355	34	38
Females:	35	246	23	29
Males/100 females:	197	144	148	131

In studies of small mammals where live-trapping was the method used it has been common to capture a high percentage of males. A greater mobility of this sex usually has been offered in explanation (Townsend, 1935; Burt, 1940; Blair, 1940a; Stickel, 1946b). In his studies of the prairie deermouse, Blair (1940a) found an essentially even ratio in one year (51 percent males) and a slightly higher number of males (55 percent) in a year when the population was considerably lower. Among 82 individuals collected (not trapped) from corn shocks at Rose Lake in the winter of 1941, the sexes were equally divided (Linduska, 1942a). On this same area, and with a very low population in the following summer, live-trapping accounted for twice as many males as females. The samples from which sex ratios were computed were not always as large as might be desirable. However, there appeared to be a tendency toward a more balanced ratio of sexes as the population increased in subsequent years (table 10). It is questionable whether the change in population levels and unbalanced sex ratio are related. Nevertheless, it is of interest that other studies have reported irregularities in the sex ratio coincidental with changes in population densities of mammals (Whelan, 1939; Allen, 1943; Linduska, 1947a).

Movements.- Blair (1940a) studied movements of the prairie deermouse, both as they occurred normally and as they were artifically induced by increasing and decreasing populations on certain areas. In undisturbed plots he found evidence of a nearly continuous population shift during spring and summer. An area deprived of its normal inhabitants was found to be quite rapidly repopulated by invading animals, and in an area overpopulated by releases, a rapid exodus of most of the introduced animals occurred.

During this study an attempt was made to determine something of the dispersal movements of small mammals on a seasonal basis. Continuous trapping and removal of all catches from a unit of idle ground was the procedure used. One series of 25 traps, evenly spaced, was located parallel to a field edge for a distance of 528 feet. A second line of equal length was located parallel to the first and 264 feet towards the field center. Trapping was started on August 25, 1942, and with a few exceptions was continued for 4 days of each week until March 31, 1943. All mammals taken during the trapping were removed from the area. The field in which the trapping was done had been retired from cultivation several years previously, and at the time of the study the following were among the commonest plants: ragweed (Ambrosia elatior), mullein (Verbascum thapsus), Canada bluegrass (Poa compressa), common milkweed (Asclepias syriaca), lamb's quarters (Chenopodium album), and spurge (Euphorbia corollata). A remnant of an earlier planting of sweet clover (Melilotus alba) also was present along one side of the plot (figs. 20 and 21). The results of this study are summarized in table 11, and fig. 22.

An interesting result of the trapping was the capture of four species that had not been taken in similar field situations during intensive studies in summer and early fall. These were the white-footed mouse (Peromyscus leucopus noveboracensis Fischer), bog lemming (Synaptomys c. cooperi Baird), short-tailed shrew (Blarina brevicauda kirtlandi Bole and Moulthrop), and masked shrew (Sorex

Fig. 20. Late autumn appearance of the "removal plot." Much of the down vegetation is sweet clover.

Fig. 21. Summer appearance of a portion of the "removal plot." Almost continuous trapping and removal of animals was conducted on the plot from August, 1942 to March, 1943. Results showed that small mammals undergo extensive distribution movements.

cinereus lesueurii Duvernoy). The area of trapping was a habitat not normally occupied by any of these species, and it would appear that distribution movements as observed here frequently involve terrain not suited for permanent occupancy.

Most of the species which appeared in the trapping were taken too infrequently to determine accurately the variations in rate of drift. However, with the possible exception of bog lemmings, the period of peak "population shuffle" appeared to be about the same (November) for all species (table 11). Spencer (1941), working with desert rodents in Arizona, found an intensified period of movement which was the same (July and August) for seven species.

Following removal of the resident deermouse population during the last week in August, the numbers of invading animals remained fairly constant for a period of about 1 month (fig. 22). There was evidence of an increased rate of drift during early October, and peak numbers were taken during the first 2 weeks in November. It is likely that this period coincided with the annual high in population density. The numbers of deermice caught after mid-November declined gradually and none were taken during four trapping periods in January and February. Two periods of trapping in March showed that invasion of the plot was again taking place. Probably movements during this time were associated with the beginning of sexual activity.

The resident population at the time trapping began in August consisted largely of adult animals, and the catch for the first two periods included 12 adults and 8 young. The relative number of old animals taken from the plot declined rapidly, and after early fall the catch involved mostly young animals (table 12). It would be expected that the shifting segment of the population would include a disproportionate number of young. While the data tend to bear this out, it is also true that other studies during this same period indicated that the population as a whole included an unusually high percentage of immature animals (table 9).

Homing instincts.- Results of experiments by several workers would indicate that small mammals are endowed in some measure with a homing instinct. The white-footed mouse (*Peromyscus leucopus noveboracensis*) has been observed to return to its home site after being moved for distances of 100 yards up to 1 mile (Johnson, 1926; Townsend, 1935; Hamilton, 1937*b*). Burt (1940) working with the same species, found that 76 percent of 37 animals returned to their home area when released at distances of 10 to 155 yards, and one-third of 51 animals removed 160 to 365 yards, returned to the site of original capture. Hamilton (*op. cit.*) observed that meadow voles failed to return when removed for distances of 250-500 yards. Murie and Murie (1931, 1932) transferred 176 individuals of *Peromyscus maniculatus artemisiae* for various distances from the capture point, and obtained returns from 4 individuals from a total of 40 that had been released 1 mile away. One individual returned from a release point 2 miles distant. Kendeigh (1944) has reported a good "homing" ability for another subspecies (gracilis), and McCabe (1947) has noticed evidence of this ability in flying squirrels (*Glaucomys v. volans*).

Table 11. Small mammals removed from a plot of idle ground in autumn and winter trapping (August, 1942 - March, 1943).

		1942					1943			
	Trap-nights:[1]	Aug. 200	Sept. 900	Oct. 900	Nov. 800	Dec. 350	Jan. 350	Feb. 300	Mar. 250	Totals 3750
Number of Individuals Caught:	Prairie deermouse	14	22	30	44	7			9	126
	White-footed mouse	1	5	3	7	1				17
	Short-tailed shrew		2	2	11	2				17
	Masked shrew				3	1		1	2	7
	Bog lemming				1		3		1	5
	Meadow vole				1	1				2
	House mouse			1						1
Individuals per 100 trap-nights:	Prairie deermouse	7.0	2.2	3.3	5.5	2.0			3.6	
	White-footed mouse	0.5	0.6	0.3	0.9	0.3				
	Short-tailed shrew		0.2	0.2	1.4	0.6				
	Masked shrew				0.4	0.3		0.3	0.8	
	Bog lemming				0.1		0.9		0.4	
	Meadow vole				0.1	0.3				
	House mouse			0.1						

1/ Trap-night figure is not adjusted for sprung or inoperative traps, but this number was comparable for each period of trapping and averaged less than 10 percent of the total (50) traps in operation.

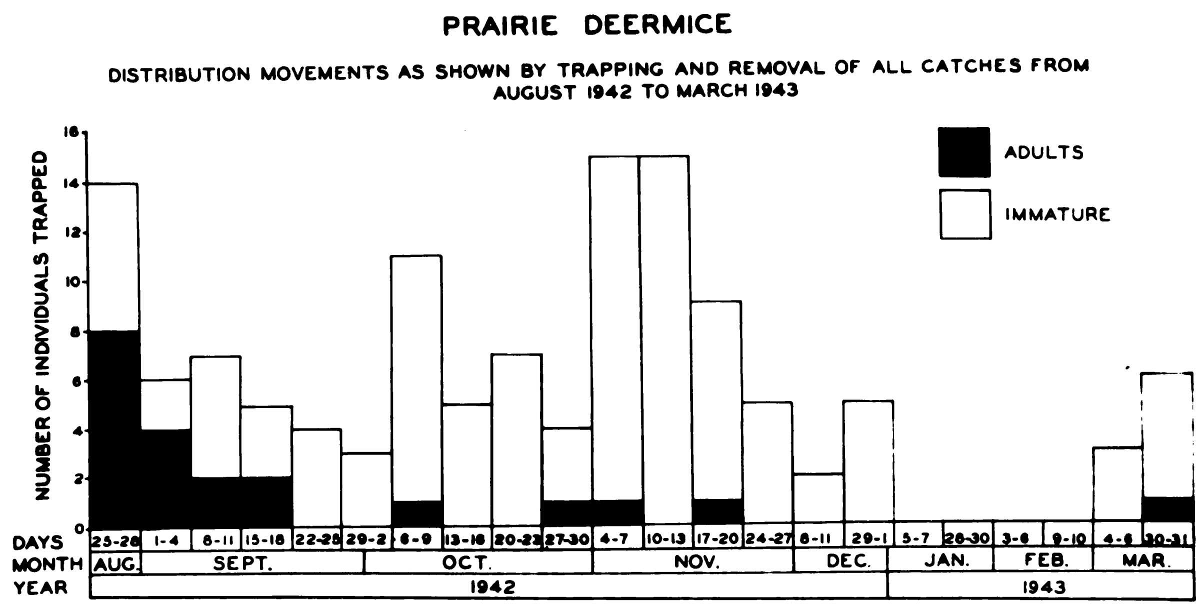

Fig. 22. The first two weeks in November appeared to be the period of peak distribution movement for the prairie deermouse.

The nearly continuous "removal trapping" to determine seasonal drift rates provided an opportunity for observing any "homing" tendencies in the prairie deermouse. Three release points were established along a line perpendicular to the lines of traps at distances of 200, 400, and 600 yards. A fourth was located in the direction of the trap-lines extended and 265 yards from the nearest trap. A total of 136 releases were made from one or another of these points. Records for all individuals which returned to the plot one or more times following release are given in table iv in the appendix, and the results are summarized in table 13.

Most of the animals released from points 1, 2, and 3 were taken in the first period of trapping and the remainder in the second period. Since presumably these were practically all residents in the area there would be an apparent incentive for a return to the plot. All of the individuals released from point 4, however, were animals taken on the plot after "removal trapping" had been in progress for about 6 weeks. Probably most if not all of this group were transients, and without having established home sites their return to the plot could be attributed largely to random movement and chance finding of the traps.

A total of 70 of these "non-residents" were involved in 99 released from a point 265 yards from the nearest portion of the trapped plot. A return of 38 percent of the adults and 30 percent of the immatures was obtained (table 13). Considering that most of these animals should have had no attachment for the area of their first capture, the rate of reappearance was unexpectedly high, and can be explained only on the basis of widespread and erratic movements. The fact that several days had elapsed before a number of them returned would indicate undirected movement. One of these individuals reappeared on the plot after 134 days, which included 39 days of trapping.

Animals which were resident in the plot had little difficulty in finding their way back from the release point 200 yards away. Returns were obtained from all of eight adult releases and from three of four releases, of young animals. The fact that 9 of the 11 which returned made the trip the first night (recaptured the morning following removal), and in many cases to the same or an adjoining trap, indicated well-directed movement. Over a distance of 400 yards their success was lower. Only slightly over half (four of seven) of the adults returned to the point of capture, and none of five young returned. In this case, however, a possible obstacle to their return was imposed. This was in the nature of two strips of marshland nearly convergent across a part of the route to the plot. However, the straight-line path from release point to the plot was unobstructed and at least 75 feet wide at the narrowest point where it passed between the projections of marsh. In the case of releases from the 600-yard station, no returns were obtained from six adults and seven juveniles. The 600-yard "point of liberation" was an extension of the distance of the 400-yard station and the same conditions of travel applied.

Table 12. Age groups of prairie deermice taken in trapping and removal of all individuals from a unit of idle ground from late summer (1942) to early spring (1943).

	1942					1943		
	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar. 1/
Adults	8	8	2	2	0	0	0	1
Immature	6	14	28	42	7	0	0	8
Percent Imm.	43	64	93	95	100	-	-	89

1/ All individuals taken by this date would normally be considered adults. While age determinations at this period of the year is not without error, the animals shown here were recognizable as immature and probably were from late fall or winter litters.

Table 13. Summary of results from "homing" studies with *Peromyscus maniculatus bairdii*.

Release point number:*	1		2		3		4	
Distance to nearest trap in plot:	200 yards		400 yards		600 yards		265 yards	
Ages of animals:	Ad.	Imm.	Ad.	Imm.	Ad.	Imm.	Ad.	Imm.
No. of individuals released from each point:	5	3	5	5	6	7	5	65
No. of individuals returning to plot:	5	2	3	0	0	0	2	18
Returning animals again released:	3	1	2	0	0	0	3	26
No. returnees again captured at plot:	3	1	1	0	0	0	1	9
Total releases at each point:	8	4	7	5	6	7	8	91
Total recaptured at plot:	8	3	4	0	0	0	3	27
Percent returning from each point:	100	75	57	0	0	0	38	30

* Release points 1, 2 and 3 were located on a line perpendicular to the line of traps. Release point 4 was on a line parallel to and midway between the two traplines.

Food habits.- The food habits of many species of small mammals are imperfectly known, and in this respect the prairie deermouse is no exception. Since an appreciation of the economic importance and ecological status of the species presumes some knowledge of its food habits, a few observations were made and these are recorded.

Attempts to establish food preferences through examination of the stomach contents were mostly unsuccessful. Materials were always finely macerated, and the method would permit only rough comparisons of the relative amounts of insect and plant remains. It appeared likely that the storage traits of the species might provide means for food-habits studies. In this connection, 94 chalk boxes, and other boxes of similar size, were distributed over the study area. These were provided with a hinged top and had a 1-1/2 inch hole near the upper margin of one end. About half of the boxes were buried to a depth of 1 foot or more and provided with a wooden tunnel leading to the surface. Most of these were set out during the summer, the remainder during early fall, of 1942. Examinations of a few boxes were made at frequent intervals, and systematic inspections were made of the entire group during the third week of September and second week of November of the same year.

Although there was ample evidence of the boxes being used for protection and shelter, they received only limited use for storage of food. Among 30 which had been placed in woodlands or woody situations, eight included food and food remains which probably were the property of white-footed mice. Only 4 of the 64 boxes, which had been located in the habitat of the prairie deermouse (crop fields, fallow ground, etc.) contained food items. Two of these four had been placed near an isolated hickory tree (Carya ovalis) in the center of a strip-cropped field. Except for a few insect remains, the nuts of this tree were the only items stored. It could not be definitely established that this was the work of prairie deermice. A third box in a fencerow adjoining a corn field contained about 50 c.c. of shelled corn and a few pieces of unidentified fungi. The fourth cache was taken from a box located in a strip-cropped field. While the volume of the stored food items was not large (80 c.c.), it included the same wide variety of materials in two natural caches which had been found previously while excavating woodchuck dens. The contents of the storage box last mentioned together with items identified from the two natural caches, are listed in table 14.

During the fall and winter of 1940-41, Baumgras (1943) made quantitative studies of the weed-seed and crop residue on the Rose Lake area. During October the rather remarkable quantity of 211.5 pounds of weed seed per acre was present in wheat stubble, which was the most productive farmland habitat studied. Ragweed was the most abundantly available species through most of the winter. Leedy (1939) also found ragweed one of the commonest fall foods on Ohio farmland. He reported an average production of 85.9 pounds per acre of ragweed seed on 15 wheat fields sampled.

It is interesting to note that of the 10 species of weed seeds found by Baumgras to be most common on the Rose Lake area, 8 were included in the 10 species found in caches of the prairie deermouse.

Table 14. A list of food items taken from three caches of the prairie deermouse.

Food Item		Frequency Occurrence
Ambrosia elatior	Ragweed	3
Chenopodium album	Lamb's-quarters	2
Polygonum Persicaria	Lady's thumb	2
Polygonum convolvulus	Black bindweed	2
Melanoplus spp., *Gryllus* spp.	Misc. insect remains	2
Amaranthus retroflexus	Redroot	1
Amaranthus graecizans	Tumbling pigweed	1
Setaria lutescens	Yellow foxtail-grass	1
Setaria viridis	Green foxtail-grass	1
Carya ovalis	Small fruited hickory	1
Panicum capillare	Old witchgrass	1
Nepeta Cataria	Catnip	1
Prunus sp.	Cherry (pits)	1
	Wheat	1
	Corn	1
	Misc. plant remains	1

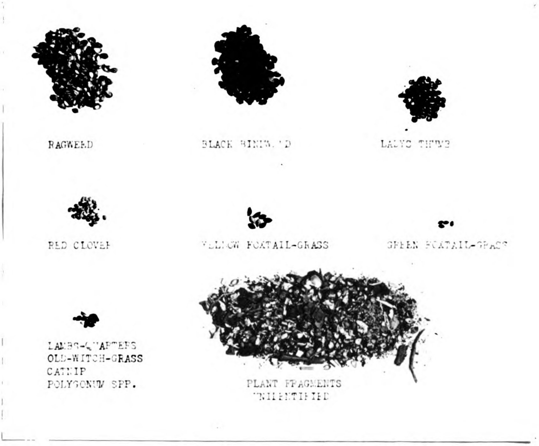

Fig. 23. The contents of a prairie deermouse food cache.

A random collection on the part of the mice was further suggested by the fact that ragweed and lamb's quarters, the two most plentiful species on many parts of the area, were also greatest by volume in the food caches examined. Allen (1938) found these same two species were among the most available, and by far the most frequently used by songbirds in winter.

There was no evidence during any of the winters of this study that shortages developed in the supplies of wildlife foods. The observations of other workers have shown, however, that prolonged periods of deep snow may bring an acute competition among various species of wildlife (Allen, op. cit.; Errington, 1931). In these periods, the food-gathering of the prairie deermouse and other rodents might contribute to privation for more desirable game and songbird species.

Meadow vole

In each of four years of study the meadow vole at Rose Lake followed a definite pattern of late-autumn increase and spread into the uplands. Various circumstances associated with the winter population peaks and movements of these mice appeared to be atypical of its usual behavior as reported from other areas.

Seasonal numbers.- Throughout the period of the study meadow voles rarely were taken in cropland during the summer months. In 1940, summer trapping for 2,446 trap-nights failed to take any voles, even though the work included habitats known to have had substantial populations during the previous winter and in early spring. As late as the first week in September, 1940, no voles had appeared in trapping, and indication of recent activity could not be found. A note by D. L. Allen at this time stated, "Meadow voles have been conspicuously scarce at Rose Lake during the past year. It appears that the species is at a cyclic low." In late September the first evidences of voles were noted in low areas of dense bluegrass growth, and on October 17 a nest of seven young was found in the uplands by Clare File. Notes by several staff members reported a rapid increase during November, and by December these mice were common in many situations. Fields of shocked corn, which were uninhabited by voles in September, were supporting an abundant population in late January (Linduska, 1942a). Over 300 individuals were taken from 315 corn shocks on 28 acres, and over 70 percent of the mature females were breeding.

The substantial winter populations of this mouse continued through the winter and early spring of 1941. By the time the last snow covering had left the fields (early April) signs of a decline were apparent. Snap-trapping in stubble fields, which a month previously were well populated with meadow mice, failed to produce catches. By the time farming activity had begun in spring, even the favored winter situations were without voles, and in the first two weeks of July only one animal was taken in over 1,200 trap-nights in fields of alfalfa, red clover, wheat, oats, and grassland. This adult female was taken in a retired bluegrass pasture immediately adjoining the field of shocked corn which during the winter had a very high population, and in which a heavy loss of corn was measured. Intensive trapping through the remainder of the summer, for a total of over 6,000 trap-nights, resulted in the taking of only three additional animals. All three of these were taken in late August on a trap-line located in dense bluegrass sod in an upland oak-hickory woodlot (woodlot number 6). In this same locality 11 short-tailed shrews were trapped, the only individuals of that species taken in summer trapping.

Although intensive summer trapping failed to reveal any other colonies of meadow voles, there was some evidence that the summer population in 1941 had not dropped to the extreme low of the previous summer. Careful examination of most of the marsh and lake-edge habitats in the area disclosed a scattered population, and four individuals (three of them breeding females) were taken in a sedge-cattail marsh. This summer population exhibited the same behavior as was observed the previous year, i.e., an autumn increase and spread into permanent sod areas and meadows, and in the winter an invasion of most of the cropland on the farm. In one cropland habitat, 19 snap-traps operated for 1 night in February took eight sub-adult voles. The decline during the spring of 1942 followed the same pattern as described for the previous year.

A concerted attempt was again made during the summer of 1942 to locate possible colonies in the area by field observation and by trapping in suitable habitats. Of the season total of over 9,000 trap-nights, nearly a third was directed at this species, but only three individuals were caught from July through September. During the first 2 weeks in October signs of these animals were noted in several upland sod areas and an occasional specimen was taken in trapping. The first nest of the season, one of five young, was found by D. L. Allen on October 23. By late October Microtus was present in fields of clover and oat stubble as well as in many of the bluegrass areas, and in the period October 28-31, 56 were caught on 10 trap-lines operated for a total of 727 trap-nights. As in previous years a rapid increase followed with an annual high being reached in late January or February. In mid-February, 50 snap-traps operated for 4 nights took 36 voles from less than half an acre of timothy-bluegrass pasture which had been uninhabited as late as September (figs. 28 and 29). By April of 1943 croplands again were practically devoid of meadow voles. Only occasional individuals could be located and these were in the low marsh areas.

In 1945 and 1946, meadow voles were reported to be more plentiful over many parts of Michigan than they had been for several years (personal communications from Game Area Managers of the Game Division, Michigan Department of Conservation). Although an intensive study was not made, sufficient work was done at Rose Lake to determine something of seasonal population trends in a year when the numbers were appreciably higher than they had been at any time during the 1940-42 period.

Fig. 24. The meadow vole was never abundent in cropland during the growing season.

Fig. 25. In late fall and winter Microtus was common in most situations.

Fig. 26. A part of more than 500 mice taken from corn shocks in the winter of 1941. Photo by W. W. Shapton.

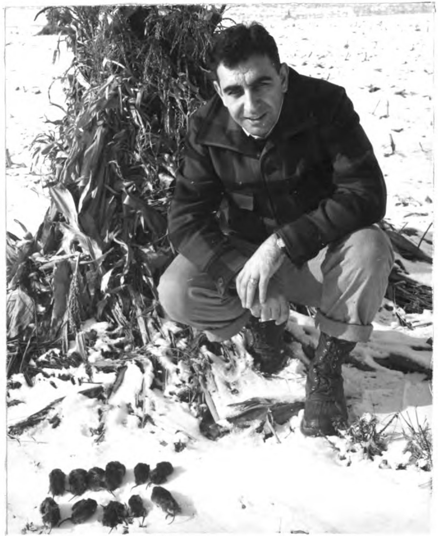

Fig. 27. As manyas 11 meadow voles were taken from one shock. Photo by W. W. Shapton.

As in earlier years the population in 1945 increased rapidly in late fall and rose to a peak in midwinter. There were indications, however, that the spring decline occurred somewhat later than usual. As late as the last week in April, 1946, voles were still common in all cropland, and during the last 2 days in March and through April, an average catch of over five per trap-line was made on nine lines of 25 traps operated for 3 days. In one field of rye stubble, trapping of this intensity produced 17 voles in a 3-day period of trapping from March 28 through 30. The results from one line of 50 traps operated periodically in a dense roadside sod give an indication of the subsequent rate of decline. During the first week in April, the 50 traps took 12 animals during a 3-day period. The same intensity of trapping produced eight individuals in mid-April, and four in the last week of April. None were caught when the area was trapped during the first week in June. That this reduction in numbers was not a result of a beginning period of sexual inactivity was shown by a high rate of breeding in a sample of snap-trapped animals taken during this interval. Among 23 mature females taken in March and early April, 17 were pregnant and the other 6 either were lactating or showed other signs of sexual activity.

There was some evidence that the 1946 decline was not as pronounced as in other years. During midsummer, voles again were scarce in cropland but apparently not at the extreme low of the 1940-42 period. Less than 500 trap-nights of operation in cropland produced four in August, whereas trapping of from 5 to 12 times this intensity in the same areas yielded none in 1940, four in 1941, and three in 1942. Signs of activity in wet marsh areas were noted throughout the summer of 1946, and there is no doubt but that a greater population carried over than in any of the preceding years of study.

It has been reported that the meadow vole arrives at an annual population high about September, and cessation of breeding in winter, together with a somewhat higher mortality rate through this season, brings the annual level to a low in March (Hamilton, 1937a). At Rose Lake the annual peak appeared to be reached in late January or February, and the reduction of this population in early spring, rather than being a dwindling process, occurred rather rapidly. The factors responsible for this sudden elimination were not entirely evident. The crash decline of plague populations is usually attributed to epizootics (Piper, 1909; Howell, 1923; Wayson, 1927; Selle, 1928; Findlay and Middleton, 1934; Elton et al., 1935; Hamilton, 1937a). Pathological causes were not given detailed consideration in this study, but certain characteristics of the population suggested that factors other than a contagion were instrumental in the decimation of these animals. Voles, while abundant, did not approach the outbreak level usually associated with the appearance of epidemic diseases. Also, the fact that the drop occurred in several successive years would suggest that factors other than disease were involved.

In each year the reduction, and in some cases nearly complete elimination, of voles from the area, was identified with the period of early spring thaws. It is conceivable that conditions resulting from repeated flooding and freezing would be critical for these animals, and the relationship is held to be of considerable importance by at least two students of small-mammal populations. Sviridenko (1934), working in Russia, found the temperature regulatory mechanism of mice and voles to be relatively unstable, and noted that, "....any great deviation from optimum conditions rapidly upsets the balance of its biological functions, and often leads to death." He has applied these findings to field conditions in explaining the sudden disappearance of large rodent populations by abnormal weather conditions. In considering an abrupt decrease of Microtus in Norway in 1935, Jessen (1937) rejected epidemic diseases as the primary cause. The true reason, he thought, was a sudden thaw which directly killed many by drowning and freezing, and produced conditions leading to the loss of many more through a combination of loss of body heat and deficiency disease. Jessen theorized that, "....meteoropathology and deficiency diseases first and foremost, not epidemiology, ought to be focussed upon when dealing with the problems of fluctuations in the populations of small game."

Movements.- Much of the attention given to Microtus has centered around its cyclic behavior and economic importance during epidemics. While many studies report on movements, and/or extensions of the range of the animals from what is ordinarily considered to be their normal habitat, the incidents usually are associated with cyclic peaks, a heavy cover of snow, or some prominent change or disturbance in the preferred habitat. The occasional appearance of these animals in uplands during winter is well-known. At these times damage to shocked grain and orchard trees or other woody vegetation is a common occurrence. The factors responsible for these winter movements usually are assumed to be a shortage of food in the summer range and a blanket of snow which provides needed cover. Hatt (1930) said, "The inhospitable winter conditions in these areas [swamps] are a major factor in keeping down the mouse populations, and in causing them to move to the uplands in the winter." This view is shared by Hamilton (1940), who also indicates that the movements are facilitated by a covering of snow. Numerous other authors reporting on winter damage by Microtus have suggested a relationship between deep snows and winter movement (Lantz, 1906, 1907, 1918; Bailey, 1900, 1924; Siegler, 1937; Allen, 1940, 1941; Parker, 1941).

The invasion of upland areas by the meadow vole at Rose Lake represented a situation somewhat different from that described by other writers and is of interest from several standpoints. It was observed in each year of study under a variety of weather conditions, and appeared to be of usual occurrence. The earliest signs of activity, were noted in uplands prior to the first killing frosts, which in 1940 and 1941 were recorded on October 16 and 27 respectively (table iii, appendix). In 1942 a killing frost occurred on September 29. However, no appreciable change in marsh vegetation was noted until after repeated frosts in late October. By this time voles were common in cropland. It was evident also that a snow covering was not a requirement for movement of these mice, since in each year the species was established in cropland before permanent snows. It is possible, however, that winter snow was important in promoting the substantial population increases that followed.

The factors which initiated movement to uplands and also encouraged high winter populations on this area are not well-known. It has been shown, however, that Microtus has strong "migratory" tendencies. Blair (1940b) found that transient animals made up about 12 percent of the total population in July and August trapping periods. These wandering habits also were noted by Harper (1929), who found a colony in a small, well-isolated area of favorable environment. Townsend (1935: p. 99) cited instances in which the animals apparently had crossed fairly wide stretches of hostile ground to colonize remote and isolated patches of their habitat. He states, "The examples cited suggest that occasionally Microtus may travel relatively long distances in search of new locations..... Such a 'pioneering' tendency might have an important bearing on the successional changes in the small-mammal population of the meadows--for example." In connection with these early fall population shifts, some observations by Blair (op. cit.) are of interest. In his work with Microtus on the Edwin S. George Reserve, he noted from trapping on dry grassland habitat that the first vole appeared in mid-June. With further reference to numbers in the dry grassland he stated, "The late September maximum is in marked contrast with the decline at that season in the moist grassland, and suggests movement from the moist to the dry habitat." These studies by Blair did not extend beyond September and the population trends through late fall and winter were not determined.

Fig. 28. Devoid of meadow voles in September, this timothy-bluegrass pasture supported an abundant population in mid-winter.

Fig. 29. Close-up of a portion of the field in fig. 28. The moth-eaten appearance of the sod is indicative of the subnivean activities of these animals.

Fig. 30. In each year of study the first voles found in uplands in autumn were taken from this sod fencerow.

At Rose Lake the first individuals were noted in upland dry-grass areas in September and October (fig. 30). In general this movement to high ground was observed coincidentally with evidences of a population increase in adjoining marsh and swamp areas and probably was related to it. While these earliest appearing individuals probably were invaders from the wet grassland, it is very likely that the subsequent high populations of fall and winter resulted from multiplication in the uplands and not from a mass population shift.

The fact that voles did not appear in cropland until the autumn months, after increased populations were noted in marshland, would suggest that the uplands in this area are in some way unfavorable during the summer. It is possible that the comparative dryness of even the bluegrass habitat in this morainic farmland is a factor in some summers. Although June to August precipitation in the area tends to be comparable in monthly amounts (table ii, appendix), the cooler temperatures of early autumn produce more humid ground conditions. It is usual at this time for many of the herbaceous plants to undergo a short period of rapid growth, and the vegetation during early fall appears to be in a condition generally favorable to voles. Furthermore, many of the upland grasses remain succulent under the winter snow which normally persists from December to March.

It is possible that the autumn movement to uplands, and the unseasonal breeding, with its resultant delayed annual population peak, is a reflection of the xerophytic conditions in this area. An observation of Hamilton's (1941<u>a</u>) would tend, in part, to bear this out: "Drought conditions at any period during the most active breeding season (March through October) would limit the growth of suitable foods and reduce the cover to such an extent that the mice might migrate to a more moist area and thus conceivably disrupt the normal processes of reproduction. It is well-known that field mice do leave areas when such areas become unusually dry, to take up their residence in more favored localities. While it can be demonstrated readily that severe drought conditions result in a reduced mouse population, the reduction appears often to be of a rather local nature."

Breeding.- It was obvious throughout the study that vole populations under the xerophytic conditions of the morainic Rose Lake farmland differed from the behavior of the species elsewhere. Although a detailed investigation of the biology of the many small mammals dealt with was not within the scope of this study, it was evident for the meadow vole that certain life history incidents were atypical. In the summers of 1940 and 1941, when scarcely an animal could be found at Rose Lake, Don W. Hayne of Michigan State College was studying a substantial breeding population less than 12 miles distant. One small alfalfa field in this mesophytic situation being studied by Hayne had a population of about 40 voles per acre.

In spite of repeated efforts, spring and summer colonies could not be located at Rose Lake, and the extent of breeding in the normally active period, consequently could not be determined. It would seem logical, however, that if production of litters had begun in early spring and continued at a high rate, some evidences of voles would have been noted in favorable habitats by July or August. With minor exceptions this was not the case. In this connection observations of other workers offer a possible explanation. Bailey (1924) says, "Scarcity of individuals may often tend to retard or entirely to check reproduction. The mice may be left stranded out of reach of mates, when breeding perforce ceases until stimulated by a gradual influx from other localities." Hamilton (1937a) also has suggested that the chances of females in oestrus meeting fertile males is greatly lessened in a low population, and under such conditions females might repeatedly pass through receptive periods before mating occurs. In this connection Hamilton observed that following the crash decline of the vole population from the winter of 1935-6 peak, "....a smaller share than usual of the surviving mice were breeding." However, his tabulation of percentage of nursing mice that were gravid during each month in a 4-year period, shows that the reduced 1936 population bred at a high rate in October (73.3 percent). In the period of cyclic increase (1933-35) the breeding rate in October was appreciably lower in all 3 years (37.5, 20.0, and 46.7 percent).

Considering the extent of the late-fall to winter increase of voles noted in this study, a high rate of breeding must have been maintained over this period. While the details of this unseasonal breeding were not investigated, some observations were made. In connection with a crop damage experiment in 1940, 288 individuals were collected for study in January, 1941. Among 150 females, 70 percent of those judged to be mature (weighing 26 grams or more) were pregnant or lactating. Although these animals were taken in or near shocked corn, limited samples from other habitats indicated a general reproductive activity (Linduska, 1942a). Sufficient trapping to establish possible differences in the breeding rate of individuals living in shocks as compared with those in other situations was not carried on. The studies of Venables and Leslie (1942) in England have shown, however, that winter populations of the brown rat in grain ricks breed at a significantly higher rate than those in non-rick environments.

In 1943, 80 individuals were snap-trapped at intervals from January 29 to March 5. Of 16 mature females taken, 12 (75 percent) were breeding and of these 8 were pregnant. The litter size for the series averaged 4.6. Five of the mature females were taken during the period February 1-5 and of these, four were pregnant. The relative number of young mice (54 of 80) also would indicate that breeding was general. There was evidence that the 1945-46 population, which was somewhat higher than usual, also bred throughout the winter. A midwinter sample was not obtained, but among 25 mice taken early in March, 7 of 12 females were pregnant and 4 others were either lactating or in oestrus. A month later 10 of 11 females trapped were pregnant. The average litter size for both groups was 5.4.

This anomalous picture of seasonal population levels and breeding schedule is of interest in that it finds a reasonable parallel in the behavior of Microtus populations at the crest of the cycle.

Hamilton (1937a) observed the annual peak in September of most years of his New York work, although during the cyclic high he found the greatest densities in December. The intensive studies by Hamilton also showed the breeding season to be variable depending on the density. He noted that voles usually breed in central New York from mid-March until mid-November, but in years of abundance, some of the animals produce young throughout the winter, although the litter size and frequency of breeding is reduced.

Causes of winter breeding.- While instances of unseasonal breeding have been reported for a number of species of small mammals, few attempts have been made to determine the factors responsible for such behavior, and no one has yet satisfactorily explained the phenomenon for wild populations. Baker and Ranson (1932a, 1932b) attempted to correlate various climatic factors with the normal reproductive period of the vole (*Microtus agrestis*) in England. Under field conditions they found no particular relationship between the period of breeding and rainfall or temperature, but a fair agreement with total monthly hours of sunshine. The obvious seasonal factors - light, temperature, and food - when studied in the laboratory, were all found to have some affect on breeding. Animals on a diet of summer food, and kept in "summer" light (15 hours daily) bred to only a limited extent at low (winter) temperatures. Breeding was general when the animals were held under conditions of winter food, winter temperature, and summer light. These same authors concluded that light was the limiting factor, since voles bred consistently when maintained under conditions of summer food, temperature, and light (15 hours daily), but had few successful matings when under the same conditions the light was reduced to 9 hours daily.

Among wild populations of Microtus pennsylvanicus, Hamilton (1941a) was unable to correlate winter breeding with such climatic factors as light, temperature, snowfall, and summer precipitation. He observed that winter-breeding individuals appear in numbers only during a period of high population and assumed that dense populations are a requirement for reproduction in winter. In a 3-year study of small mammals in Bagley Wood near Oxford, England, Baker (1930), and Elton and others (1931), found considerable yearly variation in breeding rhythm for two common woodland species, the wood-mouse or long-tailed field-mouse (Apodemus sylvaticus) and the bank-vole (Clethrionomys glareolus). During the first winter of study a complete cessation in breeding occurred from October to March. In the second year, breeding stopped during winter but continued later into the autumn and began earlier in the spring than it had the year before. In the third year a normal summer increase was followed by a winter of nearly continuous breeding. With reference to population fluctuations, dominated by this variable breeding behavior, and occurring simultaneously for two unrelated species, Elton (1942: p. 166) remarked, "Like all 'explanations' in science, and in ecology particularly.... this explanation of fluctuations leaves one with a further, in this case physiological, mystery. As a matter of fact, we still do not know what factors control the breeding season of Apodemus or

Clethrionomys. Baker [1930] was able to show that temperature differences were certainly not responsible."

Explanations of modified mammalian reproduction in the wild, to a large extent have been looked for in climatic or other conditions in effect at the time. There is growing evidence, however, to indicate considerable flexibility in breeding behavior, and it appears (see Errington, 1946) that populations may respond at times to adversities of an earlier period by compensatory actions in the breeding cycles. For instance, Errington (1942) found that in a portion of a marsh where the muskrat population was markedly reduced, the animals bred later into the year and produced more young than in another section of the marsh where their numbers had not been so seriously reduced. Following a heavy winter kill of small mammals a similar prolongation of the normal breeding season was observed by Osgood (1935). Another example of how a species of mammal may modify its breeding habits in response to conditions that might otherwise prove critical has been summarized for the fox squirrel in Michigan (Allen, 1943). In 1940, populations of this species were high and a complete failure of the mast crop in autumn led to a winter of privation in many areas. In some habitats (farm woodlots) animals had access to an alternate food supply, were able to maintain themselves in fair condition, and normal breeding occurred. In some scrub oak habitats, however, the starving populations failed to produce young in the first (spring) breeding period. With the passing of the food crisis in summer, it was found that practically all females in these scrub oak habitats had produced young - a remarkable situation since the breeding population included yearling spring animals which ordinarily produce young the first spring but not in the summer. The result was a fall population that in numbers approached that of the previous year (Montgomery, 1941). There was further evidence that this compensatory reaction carried over into the following year. In the spring of 1942, summer yearlings produced young 4 to 5 months earlier than usual, during the same period as the adult females (Baumgras, 1942c).

Winter breeding of the meadow vole at Rose Lake, could not be correlated with any single factor. Climatic conditions would seem to be ruled out, since normal seasonal activity was observed in colonies just a few miles away. However, certain points were obvious. In each of three consecutive years, the early spring reduction in numbers was sudden and marked. The surviving population was sparse during the spring and opportunities for mating may not have existed even though the scattered population should have been receptive at this time. Also, the autumn-winter breeding and population increase may have been less of a supplement to summer breeding and more in the nature of a postponement of the annual period of repopulation. The fact that Rose Lake voles showed irregularities in breeding, and seasonal population levels, during most years of the study would suggest certain adjustments to local conditions. It is possible that the xerophytic habitats of this immediate area imposed certain conditions not present in other localities where the reproductive cycle, and seasonal densities of *Microtus* were quite different.

House mouse

Seasonal numbers.- Densities of the house mouse were never at a level which would allow for detailed biological considerations. Nevertheless, the species was found to be generally distributed through most farmland habitats and from this standpoint must be considered a normal component of the small-mammal community. During most of the growing season (late spring to early fall) it ranked second in abundance to the prairie deermouse. From late fall to early spring it was outnumbered by both the prairie deermouse and the meadow vole.

Movements.- Their partial abandonment of cropland in fall and winter probably is occasioned to some extent by lowered temperatures. There was evidence, however, that cover requirements of the house mouse are exacting, and movement from fields, to a large degree, is related to harvest. They were seldom found in roadside or fencerow sod during the summer months, but appeared in these areas following harvest of adjoining fields. Two individuals which had been ear-tagged in late summer in a strip-cropped field were snap-trapped in a farm residence nearly half a mile from the field following harvest in October. The fact that only one individual appeared in the "removal plot" (table 11) would suggest, however, that seasonal movements of the house mouse may not include the widespread wandering which was observed for other species.

The late fall exodus from fields is by no means complete and some individuals maintain themselves in cropland throughout the winter. Occasionally specimens were taken in densely vegetated areas where they were out of contact with habitations, and they were common in field-shocked corn in winter. Under the latter circumstance they frequently occupied the same shock with meadow voles and other species, but were never found in company with the prairie deermouse. In one field of shocked corn, house mice were recovered from 26 shocks, which frequently included other species but never the prairie deermouse. In 39 other shocks the prairie deermouse was taken alone or with other species but never in association with the house mouse. This would seem to indicate some measure of intolerance between the species.

Other species

In addition to the prairie deermouse, meadow vole, and house mouse, several other species of small mammals were taken periodically in cropland trapping. Most of these appeared so infrequently that their position in the over-all economy of the area is of doubtful significance. They will be dealt with only briefly here.

Bog lemming (*Synaptomys cooperi cooperi* Baird).- This species was taken regularly in many of the situations occupied by *Microtus*, and also showed similar annual and seasonal population trends. In common with the meadow vole the species appeared to be at a low in 1940 and 1941. Summer trapping failed to capture any during either

Fig. 31. Bog lemmings were common in this stream-border situation. The tree growth is mainly largetooth and quaking aspen; the herbaceous plants include wormwood, milkweed, mullen, St. John's wort, dewberry, and bluegrass.

Fig. 32. An abundant population of bog lemmings spread into this sparsely vegetated area of Caloma sand in the winter of 1942-43. The trees are mostly black and jack oaks.

of these years, but several specimens were taken from corn shocks during January of 1941. In the summer of 1942 they appeared in upland sod areas at about the same time as Microtus, and during the following winter were common in many places. In December of that year they were especially numerous in a 3- or 4-acre opening beside a stream bottom which was grown up to largetooth aspen (Populus grandidentata) and quaking aspen (Populus tremuloides). In this area, and during mid-day, these animals could be seen running along the snow surface as they moved between tunnels. It was not uncommon to have four or five in view at one time on an area less than 100 feet square. The small clearing in which they were particularly active was grown up to Saint John's wort (Hypericum perforatum), dewberry (Rubus villosus), wormwood (Artemesia canadensis), milkweed, mullein, ragweed, and bluegrass (figs. 31 and 32).

Later in this same winter (1942-43), bog lemmings became increasingly abundant and were seen frequently in shocked corn. In February, 50 snap-traps were operated for 4 nights in an alfalfa-bluegrass pasture, and 18 were taken from less than half an acre.

As was found to be the case with Microtus, bog lemmings were more abundant in 1946 than they had been at any time in the 1940-43 period. These coinciding high periods, together with the parallel upward trend in populations noted during the years 1940-43, are of interest in view of other reports. Elton et al. (1931) observed parallel variations in breeding behavior and population levels for two unrelated species of English rodents - Apodemus and Clethrionomys. A similar agreement of cyclic population trends have been reported for the meadow vole and the pine vole, *Pitymys pinetorum*, (Hamilton, 1938*a*; Linduska, 1942*b*).

No particular effort was made to obtain life-history information on bog lemmings. However, among 14 individuals snap-trapped in the spring of 1946, four pregnant adult females had embryo counts of 3, 3, 3, and 2. These numbers are somewhat lower than would be expected from the range in litter size of two to six young given by Burt (1946).

Pine vole (*Pitymys pinetorum scalopsoides* Audubon and Bachman).- During August of 1940, four of these mice were taken in 227 trap-nights in an ungrazed woodland. Of several situations studied, this was the only one in which they were found. Later in the fall there were reports of damage to root crops in home gardens, and the species was fairly common in shocked corn during the same winter. None were taken by trapping in the two following years, and none were seen in shocked grain during the winter months. From all indications, this species underwent a decline in numbers beginning in 1941.

Jumping mouse (*Zapus hudsonius brevipes* Bole and Moulthrop).- Although only one individual was taken by trapping during the course of the work, jumping mice were known to be fairly abundant in some habitats on the area. In the summer of 1942, at least a dozen of these mice were taken from post holes which had been dug for the erection of a pasture fence. The fence line bordered on a portion of a marshy area which supported a dense stand of reed-canary grass (*Phalaris arundinacea*), and it is likely that this represented one of the most productive habitats on the area for this species. Blair (1940c) found that most of the jumping mice on a 9-acre plot occurred along the margin of wet or marshy areas, and in a similar situation, Erickson (1938) found surprising numbers of jumping mice trapped in holes which had been dug for a telephone line. In two holes which had been open for only one night he found seven in one and five in the other. He remarked that: "During the day a few jumping mice were seen, but judging from the numbers that were found in the pole holes the next morning, the population of the area was dense.....In nearly all of the holes there were jumping mice." Christian (1936) also found many of these animals trapped in post holes around swampy ground. He reported that while he took only four jumping mice by trapping in two years, 26 were taken in less than a month from 200 post holes.

Striped ground squirrel (*Citellus tridecemlineatus tridecemlineatus* Mitchell).- These animals were common in some situations but they avoided cropland entirely. Although seldom taken in the small live-traps, they readily entered larger box-traps used for the trapping of game mammals. Some records are available from this trapping.

From July 11 to August 9, 1941, 69 box-traps were operated in fencerows, and along swale margins that bordered on cropland. Only one ground squirrel was taken. During this same period a line of 21 traps, which included along its length a 2- to 3-acre piece of retired cropland, took five of these animals. While they appeared to be extremely intolerant of cultivated ground, it was noted that they would establish themselves rather rapidly in areas retired

from cultivation. Two such units were under observation on the Rose Lake area. One of these was an experimental sanctuary, last plowed in 1940, at which time one small plot was planted with alfalfa and another with sericea lespedeza. A second unit of land which had grown a corn crop in 1939 was retired after harvest to be used as an experimental rabbit management area. It was not replanted. A system of grid placement of traps was employed on these two units, and 58 box-traps were distributed over 145 acres. During the July 11 to August 9 trapping period noted above, 30 ground squirrels were taken in the 58 traps. This compared with the one animal taken with a slightly heavier trapping intensity along cover areas bordering cultivated cropland. Allen (1938) noted that burrows of ground squirrels were not present on cultivated ground, and that the animals confined their activities to undisturbed portions of the Kellogg sanctuary.

Intensive fall trapping, which included favorable habitats, failed to take any appreciable number of ground squirrels, and it appeared that the majority had entered hibernation by mid-September. In 1941, 6,028 trap-days took only 11 individuals in a September 11 to October 9 period. In 1940, trapping of half this intensity failed to take any animals over the same dates, and only one was taken in 1942 with 4,694 trap-days of activity in the same autumn period.

House rat (Rattus norvegicus Berkenhout).- This animal was never taken in the live-traps used for small mammal studies, but it was captured occasionally in box-traps, both in field and woodland situations. A few were taken in corn shocks. At no time were numbers

Fig. 33. A corn field in 1939, this area was densely vegetated with wormwood (Artemesia canadensis) and associated weeds in 1942. Spermophiles were abundant in this situation.

encountered which would suggest that it was important in this area as a feral form in cropland.

Prairie mole (Scalopus aquaticus machrinus Rafinesque).- No attempt at quantitative studies of the prairie mole was made although it was reasonably common in the area. On several occasions following heavy rains in spring and summer, individuals were brought in by dogs; others were taken by hand as they traveled along the ground surface. Their surface tunnels were observed more frequently in lawns and gardens than in any of the cultivated farm crops.

Short-tailed shrew (Blarina brevicauda kirtlandi Bole and Moulthrop).- With reference to the short-tailed shrew, Townsend (1935) stated that, "This species appears to show but little habitat 'preference'. It is equally at home in dry woods, moist woods, and wet meadows, provided food and burrowing possibilities are ample for its needs." Dambach (1945) found them in greatest abundance along borders of various types where runways of moles were numerous, and where the soil was loose and well-covered with litter. On the Prairie du Sac area in Wisconsin Hanson (1944) found that they were chiefly limited to areas of bluegrass and woodlands having much duff and litter.

Aside from woodland populations which will be considered separately, the short-tailed shrew at Rose Lake occurred most consistently in dense bluegrass associations, a type which Blair (1940d), also, found to be well populated by this shrew. Roadsides and fencerows commonly provided this type of habitat in the area, and the small mammals of these situations have been dealt with, in part, under the section on Field borders.

It is possibly of some significance that, except in woodlots, the short-tailed shrew was almost always found in association with the meadow vole. Although a number of sod areas with abundant tunnels, and otherwise apparently suitable for shrew occupancy were trapped, Blarina was never taken in the absence of voles. In August of 1940, three such areas were trapped without taking either of these species. In August of the following year, five areas of bluegrass sod with abundant but old signs of meadow vole activity were live-trapped and neither of these animals was taken. During this same period, two lines of 25 traps in an ungrazed woods caught nine short-tailed shrews. In 1942, with an increased population of voles, Blarina appeared in summer trapping of field habitats for the first time. One of these animals and two voles were taken in August of that year from one of four areas of bluegrass sod studied. This shrew increased along with the vole, and in October-November trapping in 1942, a total of 19 individuals were taken on four lines in bluegrass habitats. The vole population was represented by a catch of 50 animals on these same lines.

Studies in cropland during this same period showed that a few shrews had moved into these areas. Eight individuals of this species and 25 meadow voles were caught in four trap-lines located in crop ground. It is possible that this appearance of the short-tailed shrew on such sparsely covered ground was associated partly with late-fall distributional movements already noted for other small

Fig. 34. Prairie moles were common in lawns and home gardens.

Fig. 35. The short-tailed shrew was the most abundant insectivore in the area.

mammals. In the "removal" trapping (table 11), the greatest rate of population "shuffle" for Blarina occurred in November, when 11 were taken in 800 trap-nights. The area on which this trapping was conducted had little or no close ground cover, as is usually required by shrews, and as nearly as could be determined the plot did not support a resident population of this species.

Periodic trapping in the summer of 1946 gave further evidence of a shrew-vole relationship. In that year, Blarina made up part of the catch from five trap-lines which in each case included meadow voles.

The phenomenal food requirements of the short-tailed shrew are well-known (Merriam, 1884; Shull, 1907; Edgren, 1948), and a number of workers have testified to the ability of this animal to subdue mice (Plummer, 1844; Merriam, op. cit.; Bailey, 1923; Hamilton, 1930). The efficiency with which Blarina has been observed to dispatch small mammals is more readily understood in the light of a recent discovery of a toxic substance in its saliva (Pearson, 1942). The extent to which this ability as a mouse killer is utilized in the wild is not well-known. Hamilton (1930, 1941b), following a detailed study of stomach contents, concluded that the short-tailed shrew had a negligible predatory effect on mice in nature. Shull (op. cit.) and Eadie (1944), however, obtained evidence indicating that mice were a prominent staple in the diet of this shrew, and the following comments of Williams (1936) would suggest that Blarina might exercise strong regulatory influences on populations of white-footed mice and other small mammals of woodlands: "The reduction in numbers of mice must have reacted directly upon the numbers of shrews, as mice enter so largely into shrew diet.....The appearance of the pine mouse and the smoky shrew in the traps for the first time (1934), when the numbers of their arch competitor and probably deadly enemy the short-tailed shrew was reduced to a comparatively low figure, seems to indicate that these animals may prosper only when the numbers of the short-tailed shrew are relatively small."

The possible importance of shrews as a factor limiting vole populations was not established in this study. Shrews were not commonly taken from corn shocks, but in these restricted quarters, remains of mice were usually to be found whenever shrews were present. The fact that these insectivores occasionally entered live-traps and consumed trapped mice suggested possible habits in the wild. In any event, the consistency with which they were associated in this area, both by habitat and season, was highly suggestive of a predator-prey relationship.

Masked shrew (*Sorex cinereus lesueurii* Duvernoy).- Only 13 individuals of this species were caught during the entire period of study, and of these, seven were taken from the "removal plot" during the period November, 1942 - March, 1943 (table 11). The relative frequency with which they were trapped at that time may have been indicative of a beginning increase, since none had been taken in over 12,000 trap-nights during the three previous summers. They appeared to be somewhat more abundant in 1946, when six were taken by trapping in a sphagnum bog and in a sod fencerow. Of these, one

Fig. 36. Masked shrews were infrequently taken. A sphagnum bog yielded several and an occasional individual was trapped in woodlots.

Fig. 37. Close-up of the masked shrew - the smallest mammal in the area.

adult female taken on April 19 was lactating, and a second trapped June 1 had seven embryos.

Least shrew (Cryptotis parva Say).- Only two specimens of the least shrew were taken, both by snap-trapping. The species apparently is as rare at Rose Lake as it is elsewhere over its Michigan range.

Predators of Small Mammals

Most of the predators common in agricultural areas have been studied widely and their food habits have been publicized so generally that documentation here seems unnecessary. Few investigations, however, have provided more than casual information on the densities of both predator and prey species. In the broad program of research at Rose Lake attempts were made to obtain quantitative information on most of the vertebrate life of the area. While these measurements are not as detailed for some species as might be desirable, they, nevertheless, contribute to an understanding of some irregularities in predator food habits which were observed.

Before considering the food predilections of some of the predatory species, it will be advantageous to review briefly the status of the commoner prey animals during this period. The population levels of small mammals have been dealt with at various points in the text, and it is adequate here to recall that most of these were low throughout the period of study. The meadow vole, in particular, was characterized by summer densities so low that a measurement by trapping methods was precluded. Rapid fall and winter increases produced maximum numbers in late winter and early spring with probable densities in the more favorable habitats of 70-80, or more, per acre. A "crash" decline of the species was observed in March and April of each year, and from late May on through summer the animals were extremely sparse.

In contrast to populations of the commoner small mammals, one game species, the ring-necked pheasant, reached an all-time peak in numbers during the period of these investigations. Maximum annual densities of this bird were reached in midsummer, and on this pheasant range of "average" productivity, the summer population probably ranged between 40 - 50 birds per 100 acres for the years 1940 and 1942 and possibly as high as 60 - 70 birds per 100 acres in 1941. Cottontail rabbits were abundant each year of the study, and one rabbit for each 2.5 to 3 acres appeared to be a close approximation of the pre-hunting population. In all probability the better swale habitats supported a rabbit or more, per acre, in late summer. The non-hunted quail population at Rose Lake remained uniformly low over a 3-year period. Fall populations of one bird per 20 - 30 acres were recorded, and it is doubtful that peak summer densities ever exceeded a bird per 10 acres.

Table 15. Avian predator populations (1940-41), and the numbers of nests found (1940-42).

Species	Estimated populations on 2500 acres		Number of nests located		
	Winter 1940-41	Spring 1941	1940	1941	1942
Marsh hawk	2	10	2	4	2
Red-shouldered hawk	0	8	1	4	3
Cooper's hawk	4	4-6	1	1	1
Red-tailed hawk	2	2	1	0	0
American rough-legged hawk	2	0	0	0	0
Broad-winged hawk	0	2	1	0	0
Great horned owl	2	2	2	1	0
Screech owl	6	6	0	2	1
Long-eared owl	2	0	0	0	2
Saw-whet owl	? (present)	? (present)	0	0	0
Crow	6-10	40-60	17	15	6

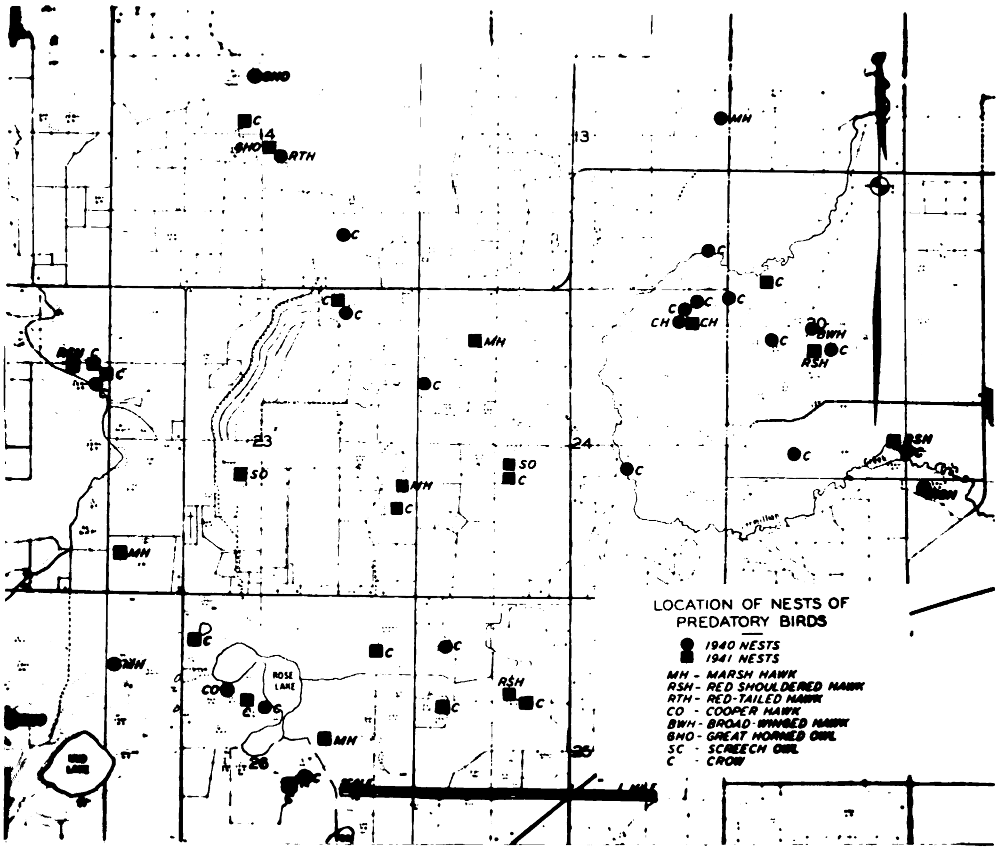

Fig. 38. Nest locations of predatory birds for the years 1940 and 1941.

Birds

During the winter of 1940-41 intensive field work was conducted over the station grounds and surrounding private land to determine the avian predator populations. Slightly less than 4 sections (2,500 acres) were covered and the estimated populations were as shown in table 15. A census the following year, while not as intensive as that in 1940-41, indicated that the winter population was about the same as that of the previous year. A detailed study of the breeding population of predatory birds also was made in 1941, and the results of these are given in the same table and fig. 38. With a few exceptions this breeding population remained about the same in 1942. It should be noted that, although the shooting of avian predators was not permitted on this experimental area, the density of these birds appeared to be entirely comparable to that on adjoining privately owned lands. Furthermore, the numbers remained essentially constant over the period 1940-43.

Marsh hawk (Circus cyaneus).- In 1940, two nests of this species were located, one with four eggs on May 18, the second with five eggs on May 25. On June 14, when collection of food items began, the first nest had four 1- to 2-week-old birds, and the other contained three newly-hatched young and one pipped egg. The nests and young were confined within pens 10 feet in diameter and constructed of inch-mesh poultry netting 2 feet in height. Gullet contents (see Errington, 1932b), prey remains, and a few pellets collected until July 1, provided a sample of the principal food items. The following

tabulation of 23 individual items shows that, by number, immature pheasants and rabbits made up 30 percent of the total during this period:

Pheasants (young)		3
Cottontails (young)		4
Songbirds		13
adults	4	
fledglings	9	
Meadow vole		1
Leopard frog		2

In 1941, four marsh hawk nests were located. One was deserted during the laying period, but the other three had a high rate of hatching success. One of the successful nests contained an unusual clutch of 10 eggs of which seven hatched (Baumgras, 1942a). Unfortunately it was not possible to follow up on the food habits of these nestlings. Only two collections were made from each of the three nests and these during the period June 23 - 30. Materials identified from these collections included one water snake (Natrix sipedon), five songbirds, two cottontails, and numerous insect remains (mostly of the family Carabidae).

In 1942, three of the 1941 territories were re-occupied. Two of these pairs failed for one reason or another to nest successfully, one after a re-nesting effort on a new site. The third pair, which located in the Rose Lake marsh, produced a nest of six eggs. These hatched intermittently over a 10-day period, indicating that oviposition and incubation were concurrent and that the eggs were laid at widely spaced intervals.

Fig. 39. Two nestling long-eared owls located in Chandler's marsh, west of the Rose Lake station. The remains of a cottontail can be seen at the extreme left.

Fig. 40. A shortage of meadow voles was reflected in the primarily avian diet of these young marsh hawks. Photo by P. S. Baumgras.

The above nest was reasonably satisfactory from a food habits standpoint, and 54 identifiable items were obtained in 30 collections of gullet contents and prey remains. Confining the young did not seem to interfere with their being fed by the adults (mainly, if not entirely, by the female), and the young continued to return to the enclosure from short excursions for 2 weeks after the first flight.

A list of the prey recovered from this nest is given in table 16. It will be noted that songbirds constituted 40 percent of the total, pheasants - 10 percent, and birds of all species over 60 percent. Cottontail rabbits made up nearly 25 percent of the total. The songbirds appeared principally during the early stages of growth of the nestling hawks, and up to the normal nest-leaving age of the brood a predominantly avian diet (nearly 100 percent) was observed. A majority of the pheasant remains were recovered in this period, also, and since they were all young birds they probably constituted an ecological equivalent of songbirds. At about the period of growth when the young were making excursions from the nest, cottontails became conspicuous in the diet and it was during this late fledgling period that most of the rabbit remains were recovered.

Food habits studies of this species have indicated a ready acceptance of murine items. Fisher (1893) found mouse remains in nearly half of 124 stomachs examined, and McAtee (1935) recovered mice (mostly meadow voles) from 211 of 601 stomachs. In a summarizing statement of food habits of marsh hawks Bent (1937) remarked that, "Meadow mice seem to constitute the bulk of the food, according to nearly all observers." Errington (1933) found

Table 16. Items identified in 30 food collections from a marsh hawk nest during the period June 23 to August 7, 1942.

	Species	Number of Individuals
AMPHIBIANS	Pickerel frog - *Rana palustris*	1
BIRDS	Heron (nestlings). Unidentified	3
	Bob-white - *Colinus virginianus*	1
	Ring-necked pheasant - *Phasianus colchicus*	6 (all young)
	Virginia rail - *Rallus limicola*	1
	Bobolink - *Dolichonyx oryzivorus*	1
	Eastern meadowlark - *Sturnella magna*	2 (young)
	Red-wing - *Agelaius phoeniceus*	4 (2 young)
	Cowbird - *Molothrus ater*	1
	Swamp sparrow - *Melospiza georgiana*	3 (1 young)
	Song sparrow - *Melospiza melodia*	1 (young)
	Unidentified passerines	10
MAMMALS	Striped ground squirrel - *Citellus t. tridecemlineatus*	1
	Fox squirrel - *Sciurus niger rufiventer*	1
	Meadow vole - *Microtus p. pennsylvanicus*	5
	Cottontail rabbit - *Sylvilagus floridanus mearnsii*	13 (7 young)

considerable variation in the frequency with which certain prey species appeared in food collections from marsh hawks. From June to August, 1929, during a period of peak abundance of meadow voles, he found that this species represented 89 percent of the total of 74 prey individuals collected. Only 4 percent of this total was birds. In 1931, vole populations were much reduced and 149 July collections by Errington included only 11 percent of voles and other mice. Birds (mostly passerines) represented over 21 percent of the total that year. Similar relationships between food habits of marsh hawks and the numbers (or availability with reference to condition of habitat) of prey species, were noted by Breckenridge (1935) and Errington and Breckenridge (1936).

The June-August food habits of marsh hawks in this study are of interest in that they reflect the extreme low in mouse numbers found by trapping during the same period of the year. Meadow voles made up only 8 percent of the total prey individuals recovered (1940 and 1942), whereas an abundant cottontail population was utilized with nearly three times this frequency (22 percent). Pheasants, which were at a fairly high density, appeared to have contributed disproportionately to the needs of marsh hawks, and this also was a probable consequence of the near absence of small mammals.

Red-shouldered hawk (Buteo lineatus).- In 1940, three pairs of these hawks were summer residents on or near the study area. The only nest located contained one egg on May 8 and a week-old bird on May 25. No gullet material was collected in four visits to the nest, but four pellets contained mouse hair, insect fragments, and snake scales. As found by Errington (1933), bones of prey were so completely digested by these hawks that neither qualitative nor quantitative determinations could be made reliably from pellet remains.

Between April 28 and May 8, 1941, four nests of this species were located. One of these was found destroyed on May 16, and the others hatched clutches of two, three, and four eggs. Two of these three failed shortly after hatching and the fate of the remaining nest was not determined. Only two pellet collections were made before the nests were destroyed. Numerous insect remains (mainly Carabidae) and two snake skeletons were the only identifiable items.

Of three nests found in 1942, one failed in its final stages, one fledged one young and lost one, and the other fledged three young from a three-egg nest. When the nestlings from the latter nest were about three-fourths grown (June 17) they were transferred to an observation cage which had been attached to the base of the nest tree, and daily collection of food items was begun. Seven days later, at about the normal nest-leaving age, two of the young escaped through the adjustable cage opening which had been left wide open when it was found that partial closure prevented proper feeding by the adults. The third young, which had been tethered, escaped several days later. Collections of prey remains from this nest, together with pellets from the other two nest sites, revealed the following items taken from June 3-25: snakes - 5, cottontails - 4, songbirds - 4, snapping turtle - 1, prairie mole - 1, fox squirrel - 1, red squirrel - 1, meadow vole - 1 (plus fur in a few pellets), crayfish - several (?), and numerous insect remains.

Fisher (1893) found small rodents in 65 percent of the 220 stomachs he examined, and Errington (1933) reported "....considerable quantities of pellet mouse fur...." from Wisconsin birds. The practical absence of mouse remains from the red-shouldered hawks under observation here was to be expected in view of the known low levels of these animals at the time food collections were made. This hawk's ready acceptance of snakes and crayfish also was noted by Fisher (*op. cit.*) and Errington (*op. cit.*).

Red-tailed hawk (*Buteo jamaicensis*).- One nest of this hawk was found in a dense lowland woods in 1940. Great horned owls preempted the nest in 1941, and it is possible that the above pair nested off the study area in 1941 and 1942, since they were not seen in the vicinity of the 1940 site in either of the subsequent years.

Irregular collections of materials at the 1940 nests, and gullet contents from two young yielded 12 prey items from May 5-June 14. These were as follows: pheasants - 5, fox squirrels - 2, cottontail - 1, bobwhite - 1, meadow voles - 2, and snake - 1.

Broad-winged hawk (*Buteo platypterus*).- One nest was found in 1940, none in 1941, and in 1942 one bird was seen periodically at the 1940 location but a nest could not be found. It is possible that it was an unmated bird.

The 1940 nest hatched three young, only two of which survived the first week of nest life. Gullet contents of the young plus a few pellets revealed the following identifiable items during the last week in May: wood frogs - 3, garter snakes - 2, jumping mouse - 1, mouse (unidentified) - 1, crayfish - 2, and insect remains - several.

Cooper's hawk (*Accipiter cooperii*).- A nest of this species, possibly belonging to the same pair of birds, was found in the same portion of a woodlot in each of 4 years (1939-42). In 1940 four young were fledged from a five-egg nest; a two-egg nest failed in 1941; and in 1942, three young hatched and two were fledged from a four-egg nest.

In an effort to obtain food records the young from the 1940 nest were tethered, and those from the 1942 nest were confined in a cage at the base of the nest-tree. In both cases adult birds fed the young satisfactorily, but due to the habit of parent birds of tearing up prey away from the nests and feeding mainly soft fleshy parts to the young, few identifiable prey items were obtained. Gullet contents most often yielded strips of meat, and much of this appeared to be avian in origin as judged by bone fragments.

Identifiable items near the nests and from gullet contents, included the following prey taken during the period May 12-June 25: pheasants - 5, songbirds - 5, fox squirrel - 1, ground squirrel (*Citellus*) - 1, and chipmunk - 1. The preference for an avian diet, claimed for the Cooper's hawk, appeared in several field observations in which this species was seen carrying songbirds and other avian prey. On one occasion, a Cooper's hawk was known to have made off with the entire nest, and included young, of a goldfinch (Linduska, 1943).

Other hawks.- The American rough-legged hawk, although principally a transient, was present on the area in most years from October to May. Not over two individuals were observed at any one time. Sparrow hawks and sharp-shinned hawks were present occasionally in migration, and ospreys were seen over Rose Lake at several times in spring and fall.

Great horned owl (Bubo virginianus).- In 1940 two nests were found, one with two young, the other with one. In an effort to obtain information on food habits, the young from the first nest were moved to a cage placed 5 feet above the ground on the nest tree. Faulty construction of the nest box allowed the young to fall out repeatedly, with the result that they were not fed by the parent birds and died. The single bird from the second nest was over half grown when found on May 5. It fledged successfully a short time later. One pair raised two young in 1941, the nest having been built over one used by a red-tailed hawk the year previously. No nests could be located in 1942, but one pair was known to have reared two young again in 1943.

Numerous pellets collected in and around the above nests in late winter and up to early April, gave a total of the following 226 items:

Species:	Meadow vole	Deermouse	Bog lemming	Cottontail rabbit	Norway rat	Fox squirrel	Red squirrel	Short-tailed shrew	Prairie mole	Ring-necked pheasant	Songbird	Mallard	King rail	Total
Number:	88	85	16	11	6	1	1	1	1	9	5	1	1	226
% of total:	Mice-84			Other mammals-9						Birds-7				100

In 1946 the young of a great horned owl were held well beyond the nest-leaving age by confining them in a caged artificial nest. A total of 92 prey individuals were recognized in pellets and food remains from this nest. A marked change in food habits was observed during the period of confinement. Among 57 individual items used by the birds prior to April 9, mice and voles (<u>Microtus</u>, <u>Synaptomys</u>, and <u>Peromyscus</u>) made up 89 percent of the total. Of 35 prey individuals identified from collections made during the period April 11-June 11, only 20 percent were mice. While this change in food habits probably resulted from a change in prey availability (decrease in mice, and increase in rabbits and others), it is possible also that growing food requirements of the young encouraged a selection of the larger prey common in later collections. Following is a list

of items taken during the active period of the nest: meadow voles - 32, deermice - 25, cottontails - 8, bog lemming - 1, long-tailed weasel - 1, songbirds - 12, pheasants - 7, chickens - 2, mallard - 1, blue-winged teal - 1, crow - 1, and great horned owl - 1.

Long-eared owl (*Asio otus*).- Nests of this bird were not located on the area prior to 1942, although two individuals were taken in pole traps in February and March of 1941. Of two nests found in 1942, one with five eggs in an advanced stage of incubation was broken up by crows; the other found on April 27 fledged four young.

Several pellet collections were made near the nest until May 7, when the young were placed in a cage fastened near the base of the nest tree. The adults regularly disemboweled the prey and left the entrails on the cage platform, but as the young matured, the collections of entrails ceased, indicating that the young were being offered the prey entire. Nearly daily collections of pellets and prey remains were made until May 29, when the young were released, since it appeared that the adults had deserted. The following items were recognized in the collections: meadow voles - 17, deermice - 14, bog lemmings - 9, short-tailed shrews - 7, house mouse - 1, jumping mouse - 1, and songbirds - 3.

In March and April, 1943, a collection of over 150 pellets from the vicinity of two long-eared owl nests, gave 141 prey individuals of which 86 percent were *Microtus* and 4 percent were *Peromyscus*. A comparison of these percentages with those of the previous year is of interest. At that time (late May, 1942) *Microtus* made up only

33 percent of the total items and Peromyscus 27 percent. As has been noted (see section on meadow vole), voles were abundant through March of both of these years, and a rapid decline which occurred in April left the species at a very low level from May on through the summer. The marked difference in incidence of Microtus in food collections from long-eared owls, undoubtedly is a reflection of this marked seasonal change in the density of this prey.

Considering the scarcity of voles in May of 1942 it is remarkable that the species appeared in the diet of these owls even to the comparatively reduced extent shown. What appears here as a persistent demand on Microtus by long-eared owls has been noted also by Errington (1932a): "Attention might be drawn to the surprising similarity of food habits for the winters of 1929-30 and 1930-31, despite the drastic reduction of meadow mice early in 1930. Although the deermice supplanted in part the meadow mice, the steady occurrence of the latter in the long-ear's diet leads one to suspect that the food habits of this owl are inexplicable in simple terms of availability of prey."

Fig. 41. Screech owls frequently were heard and occasionally were seen on the area.

Listed below are 193 items identified from long-eared owl collections from all sources during the dates March 5-May 29 for years 1940-42:

Species:	Meadow vole	Bog lemming	Deer-mouse	House mouse	Jumping mouse	Short-tailed shrew	Song-birds	Insects	Total
Number:	138	22	19	1	1	9	3	many	193
% of total:	Voles and mice - 94					5	1	--	100

<u>Screech owl</u> (<u>Otus</u> <u>asio</u>).- No nests were found in 1940, but in 1941 two were located, one with five eggs on April 7, and the other on May 7 with four pipped eggs and one newly-hatched young. The first nest, located in an artificial squirrel nest box, was deserted by April 14, when only one egg remained. Four of the five young from the second nest fledged successfully. The squirrel nest box used by one of the 1941 pairs again was occupied in 1942. Four young were raised from this five-egg nest. These young were confined in a cage at the base of the nest tree and held until about 6 days past the normal nest-leaving age. Daily collections were made of food remains and pellets.

A study of food residues and pellets from the caged young indicated an almost entirely insectivorous diet during the period of their confinement in late May. Ground beetles (Carabidae) and

June beetles (Phyllophaga sp.) were common in all pellets, and crayfish remains appeared regularly. The only sign of vertebrate prey from this nest was a decapitated woodmouse found at the base of the nest tree. A number of miscellaneous screech owl pellets collected near other nests and roosts, and representing winter (January to March) feeding included the following: meadow voles - 17, deermice - 7, bog lemmings - 5, short-tailed shrews - 2, and songbirds - 2.

Crow (Corvus brachyrhynchos).- In 1940, 17 crow nests were located in woodlots and wooded creek bottoms on approximately 2500 acres, indicating a minimum breeding population of one pair per 147 acres or about 4.4 pairs per square mile. The fate of all the nests was not definitely determined, but five are known to have failed before hatching of the young. One brood was shot from a nest, and seven others were successful in raising an average of 2.4 young per nest. Over the same area a total of 15 nests were found in 1941, a nesting density of one pair per 266 acres or 2.5 pairs per square mile. The clutches averaged slightly less than five eggs, and 3.6 young was fledged per successful nest. Eight of 11 nests examined regularly were successful. In 1942 the number of nesting crows was well below that of the two previous years. Only six nests were found. The numbers of crows appeared to be comparable to that observed in the spring of 1940 and 1941, and it is possible that the reduced number of nests may have been explained, in part, by large numbers of non-breeding individuals. Of the six nests in

1942, two were broken up so early that renesting undoubtedly occurred. The remaining four had average clutches of five eggs and hatched an average of 4.5 per nest. One group of nestlings was lost subsequently in an experiment, and the remaining three produced an average of 3.3 fledglings per nest.

Aside from routine observations, no attempt was made in 1940 to follow the food habits of crows on the area. However, in 1941, Philip Baumgras developed a method which would provide for quantitative studies of the food of these birds. Cages were made from nail kegs which had been sawed in half, the top covered with 2-inch-mesh chicken wire, and the bottom with 1-inch fox netting. These were attached to nest trees and the young were confined when they reached the age of 3 to 4 weeks (Baumgras, 1942b). Adults fed the young through the coarse top screen, and droppings and food remains which passed through the finer-mesh bottom screen accumulated in collecting trays or on a sheet of paper spread beneath the cage. Adult birds continued to feed the young throughout the period of confinement, which was 4 to 5 weeks in most cases. After this period, however, the young (about 2 months of age) became active and crowded, and hence were released.

Four cages of young handled by this procedure in 1941 provided 52 collections, totaling 3,225 grams of dried fecal material. Additional collections were made during the same period (late-May through June) in 1942. Due to the thoroughness of crow digestion, the analysis of these residues presents real difficulties, and a detailed study of the collections has not been completed. Cursory inspection

Fig. 42. A feral cat gave birth to a litter of young in this hollow apple tree. Photo by D. F. Switzenberg.

Fig. 43. A brood of screech owls raised in a squirrel nestbox in one of the woodlots.

of the material has revealed small-mammal remnants (mostly teeth and small bone fragments) in about 50 percent of the individual collections. By volume, vegetative remains were greatest and service berry seeds (Amelanchier canadensis) made up nearly 50 percent of the total. Insect remains were common in all collections.

That crows commonly prey upon farm rodents has been shown by the work of Barrows and Schwarz (1895) and Kalmbach (1918). The frequency with which mouse remains appeared in crow droppings would indicate that on the Rose Lake area, also, this bird utilizes appreciable numbers of such prey. Numerous sight records of crows carrying mice suggested that small-mammal predation by this species might be greatest in the fall and winter months.

Mammals

A primary aim of the Rose Lake station has been a study of wildlife reactions to various conditions of land use and in response to habitat changes. Large-scale collecting of predatory species for stomach analyses obviously would not be consistent with this objective. For this reason the limited studies on predation by mammals were confined mainly to observational methods.

Present consideration of mammalian predators will concern estimates of their density and population trends over the period of the study. A main basis for population estimates results from an intensive program of box-trapping which for the years 1940-42 totaled 63,780 trap-days. Differences in yearly trapping intensity and the fact that the total area involved was not the same each year (some additional units were trapped as new land parcels came into station ownership) invalidates a direct comparison of the total annual trapping returns. However, selected portions of the over-all trapping effort offer a comparison of average annual densities for several species during the years 1940-42. In the discussion which follows, reference will be made to the total individual catch from 15,989 box-trap days operation during the year July, 1940 to July, 1941, and from 17,531 box-trap days for the same July-to-July period which followed. The "box-trap day" is a 24-hour period of operation.

In each year, a standardized program of trapping was conducted just prior to the opening of the small-game hunting season on October 15. Traps were distributed with reference to the better habitats over about 1,100 acres, of which 12 percent was woodland; 24 percent marsh, swamp, and swale; and the remainder cropland and pasture. With a few exceptions trap operation extended over the period September 11 to October 10. These data, summarized in table 17, are offered as an index to year to year population trends for the common mammal predators.

Skunk (*M. mephitus nigra* Peale and Beauvois).- The status of the eastern skunk on this area was described in some detail by Allen and Shapton (1942). It will suffice here to point out that a state-wide decline of the animal which began in 1938 was apparent from fur dealer reports. Cellular inclusions in tissues of the brain cortex was found in sick animals, and an encephalitis epidemic was believed to have been responsible for the decline. At Rose Lake, populations

Table 17. Box-trap catch of mammalian predators during mid-September to mid-October trapping in years 1940-42.

Year	Number of of traps	Trap-days	Number of individuals caught: Skunk	Weasel	Opossum	House cat	Racoocn
1940	226	4609	8	5	12	4	2
1941	206	5765	9	4	25	11	9
1942	203	5536	4	8	16	1	7

were very low at the time this study was initiated in 1940 and continued low at least through 1942. The number of individuals taken in similar periods of trapping (table 17) indicated that the fall population in 1942 might have been even lower than in the two preceding years. However, comparable trapping over the 12-month period July, 1940 to July, 1941, and in the year which followed, indicated similar average yearly densities. A total of 15 individuals were taken during each of these year intervals. During the winter of 1936-37 prior to the die-off of skunks, Allen (1939) found a population in excess of nine per 100 acres in Kalamazoo County, Michigan. While the Rose Lake area would appear to be of about equal productivity for the species, it is doubtful if the density during the years 1940-42 ever exceeded one or two animals per 100 acres.

It is well-known that these animals are persistent hunters of mice and other small mammals. At the low density maintained during this study, however, it is doubtful that their net effect was an appreciable factor in limiting rodent numbers.

Long-tailed weasel (*Mustela frenata noveboracensis* Emmons).- Live-trapping data of the type obtained here have limitations in indicating actual densities of some of the wide-ranging predatory mammals. In the case of the long-tailed weasel, certain sizable acreages appeared to be uninhabited, whereas, other units occasionally were found to have what appeared to be local concentrations of six to eight animals per hundred acres. From all indications a fall

population of six to eight per section was close to the actual average for the 2 sections of most intensive study. Results from autumn censuses suggested a somewhat higher population in 1942 than in previous years (table 17). However, trapping totals for the July, 1940 to July, 1941, period showed a total of 21 animals taken in this period compared with only 12 taken from similar trapping in the following year.

In each year of study the sexes of trapped weasels ran heavily to males. From 1940 to 1942, a total of 50 individuals was taken 84 times and in the ratio of over five males to one female (42 males and 8 females). It is very probable that the high excess of males results from a differential activity of the sexes.

The prey of this carnivore is known to include considerable numbers of small mammals (Dearborn, 1932; Hamilton, 1933; Errington, 1936; Allen, 1938; Polderboer _et al_., 1941), and there is some evidence that the numbers of small mammals, to some extent, may regulate weasel populations (Middleton, 1930_a_). An instance of heavy winter predation on meadow voles by weasels has been reported for this area (Linduska, 1942_a_), and their is no question but that the weasel constitutes one of the most important mammalian predators of this group.

Opossum (_Didelphis_ _v_. _virginiana_ Kerr).- This animal was common on the area and trapping returns indicated that the population was increasing during the period of investigations. A total of 29 were trapped in a July-to-July period of 1940-41, and double this number were caught in the following year. Among the 58 taken in 1941-42 a high percentage of males was observed, the actual count being 38 males and 20 females. An autumn density of 8 to 12 per section is believed to be a fair estimate of the average population for the area.

Dearborn (1932) and Taube (1947) both reported more than 70 percent animal remains in stomachs of Michigan opossums taken in the fall of the year. Taube's study of 133 stomach contents showed that about 6 percent of the total was mice, and Allen (1938) found a similar percentage of mouse remains in 30 stomachs taken in Michigan during autumn. The well-known scavenging habits of the opossum make it difficult to apply such information to an evaluation of the species as a predator. The leisurely activity of the animal in the field, and a consideration of its habits in general, would not suggest an important predator effect on small mammals, except possibly on nestling young.

Raccoon (*Procyon l. lotor* Linnaeus).- Creek-bottom woodlands on the area supported what were probably average numbers of raccoons, but this habitat type was not extensive enough to provide for a generally high population. Trapping returns and observations indicated a marked increase in their numbers from 1940 to 1942. The best available information indicated a density of about 12 to 15 individuals per section during the fall of 1942. This population is about one-third that found by Stuewer (1943) on good raccoon range in Allegan County, Michigan.

Various investigators have reported that raccoons occasionally include mammalian prey in their diet, and Stuewer (*op. cit.*) found evidence of heavy feeding on *Microtus* during the spring (April-June). Considering the numbers and distribution of raccoons at Rose Lake, it is doubtful that they figure very prominently in determining small-mammal numbers on the area.

Red fox (*Vulpes fulva* Desmarest).- In common with conditions over most of its United States' range, fox numbers in this area exhibited an upward trend during the years of this study. Tracking studies in the winter of 1940-41 indicated that three individuals were using the area regularly. During the winter of 1941-42, four individuals ranged over the two sections of land included in the study unit. These animals invariably entered the tract from an extensive marsh adjoining the north boundary. One group of hunters killed six foxes in one week within a 10- or 12-mile radius of the station, and two other animals are known to have been taken within a mile of the study unit during the same winter of 1941-42. This degree of hunting success was considerably higher than what had been reported for the vicinity in previous years.

During January and February, 1941 and 1942, 37 miles of fox tracks were followed by various station personnel and evidences of 16 kills were observed. While numerous evidences of mouse-hunting were noted on the trails, the success of these attempts usually could not be determined. However, three short-tailed shrews were found uneaten, and considering the density of these in comparison

with mice, it is probable that the toll of the latter was high. Other prey remains indicative of kills by foxes included seven pheasants, two rabbits, one wing-clipped Canada goose, one bobwhite, one leopard frog (uneaten), and one prairie deermouse (uneaten).

Detailed food-habits studies of foxes have been reported for Michigan by Dearborn (1932) and Murie (1936), and for other regions in the mid-west by Errington (1935) and Scott (1947). These authors agree that food predilections of the fox are explainable in a large measure in terms of prey availability. Cottontail rabbits and meadow voles are reported as stock items wherever they occur in numbers, but other species have been preyed upon heavily where unusual population densities or adverse circumstances increased their vulnerability. In this study, limited evidences of a disproportionate take of pheasants by foxes might be a reflection of higher-than-usual populations of the bird and a comparative insecurity in the habitat. More complete observations on the feeding of several species of predatory birds suggested a similar relationship.

Mink (*Mustela vison* Schreber).- Fall densities of these animals probably were at a level of two or three pairs per section. Winter trapping accounted for two males in 1939, none in 1940, and three males and one female in 1941. The 1942 population was believed to be equal to if not greater than that of 1941, although due to unfavorable trapping conditions none were taken in steel-traps.

Badger (Taxidea t. taxus Schreber).- A 12-pound female of this species was taken in a box-trap in August, 1940, and a male weighing over 18 pounds was taken in September, 1942. Although badgers are known to be persistent hunters of small rodents, they probably were of little importance on this area due to their low numbers.

House cats and dogs.- The standardized period of fall trapping (table 17) indicated wide variations in the number of house cats present on the area at this time of the year. However, the total number of animals taken in July-to-July trapping was essentially the same in 1940-41 (23 individuals) and in 1941-42 (25 individuals). These totals probably represented a reasonable census of the number using the area at any one time. A majority of these were farm animals, but some were known to be living in a feral state, and at least one case was known of a litter having been reared to an independent age in the wild.

Quantitative measurements of the food habits of cats were not obtained in this study, but numerous sight records testified to their success at mouse hunting in the fields. Any possible utility that might have been claimed for the animals in this connection was placed in question, however, by frequent observations of a like aptitude for taking game species. One well-tended pet that frequently brought prey victims home, was known to have caught no less than 17 rabbits during the spring and early summer of 1942. McMurray and Sperry (1941) found that mammals composed from half to four-fifths of the food of cats in several habitats in Oklahoma,

and in one area cottontail rabbits made up one-fourth of the mammal diet. Couch (1928) reports the failure of introduced cats to suppress mouse populations in orchard areas of Washington, even though the animals were released in such numbers that "....it was not unusual to see ten or twelve cats on three or four acres."

About 14 dogs were resident on the area and on adjoining private lands. Most of these were allowed to roam at will and occasional losses of pheasants, rabbits, or other game species were known to have resulted. It is doubtful that their activities were reflected appreciably in the dynamics of small mammals.

SUMMARY AND DISCUSSION

1. Scope and methods of study. During the years 1940-42 and 1946, intensive live-trapping was employed to measure comparative populations of small mammals on an area of southern Michigan farmland. A total of 1,649 small mammals were handled, of which 1,042 were taken in 18,329 trap-nights of live-trapping, the remainder by snap-trapping or other means. A concurrent program of box-trapping provided information on the status of the larger associated mammals, and intensive observation was employed to indicate the numbers of predatory and game birds.

2. Annual population levels of small mammals. The prairie deermouse and meadow vole were at low levels in 1940 but increased markedly in both of the following years. Trapping results indicated that the 1941 prairie deermouse population was double that of 1940, and the 1942 catch records suggested a five-fold increase over the 1940 low. Studies in 1946 showed that both of these species were more abundant than they had been in the 1940-42 period, and limited records for the intervening years indicated that populations were maintained at a fairly high level during 1943-45.

3. Seasonal population trends. Early summer populations of the prairie deermouse were comparable in 1941 and 1942. In 1941, the summer population doubled by autumn, but in 1942 the numbers of this mouse had increased five-fold by autumn. The differences in rate of population increase were reflected in age ratios for the

two years. In 1942, significantly more young were trapped throughout the summer-fall period. In 1946, the prairie deermouse began breeding early and survival of young apparently was much higher than in either of the two earlier years. A high population in August, 1946, was in the ratio of 1 adult: 14 young compared with August ratios of 1 adult : 0.5 young in 1941 and 1 adult : 1.7 young in 1942. Although live-trapping took a high percentage of males each year, the unbalance in sex ratio was greatest in the year of lowest population and nearest normal in the year of highest population.

During each of four summers, meadow voles on this area were absent from croplands and only an occasional individual could be located in other habitats on the area. In each year it was mid-autumn before they were observed or trapped with any regularity, and a rapid fall increase was accompanied by a spread of the species into croplands. Peak annual numbers appeared to be reached in midwinter, and during each of three winters it was found that a considerable portion of the population was breeding. It is suggested that xerophytic conditions might explain the local departure from the usual breeding behavior reported for this species, since a "normal" trend of seasonal population levels was known for at least one area in the near vicinity.

4. Movements. A program of continuous trapping and removal of small mammals from a plot of ground was conducted over a period of 8 months. The rate of re-invasion of the plot was taken as an indication of distributional movements by small mammals. The greatest

movement into the plot occurred in November and it is likely that this month also represented the period of annual "population high" for most of the species. At least four species were taken from the plot, which was of a habitat type not considered acceptable for permanent occupancy by these same species. There was practically no movement through the area during January and February. Evidence of a population shuffle in March, which may have been related to increased breeding activity, was shown by additional catches of the prairie deermouse.

5. Small mammal interrelationships. During the summer and early fall months the prairie deermouse was the dominant small mammal in all farm habitats. At these seasons it was associated with the house mouse, the only other small mammal to be taken regularly. Evidence of possible intolerance between these two species was obtained, since both were found to be common inhabitants of corn shocks, but they seldom appeared together within the same shock. Similarly, house mice were most consistently taken in oat fields, whereas, the deermouse was less numerous in oats than in any other crop.

From December to March the meadow vole was the commonest associate of the prairie deermouse in cropland, and in those situations providing an abundant ground cover it greatly outnumbered the deermouse. The bog lemming and short-tailed shrew were important secondary species in these latter habitats.

6. Small mammal predators. No control efforts were directed at any of the predators, but mammalian species of sporting or fur value were hunted or trapped with an intensity approximating that on private farmland in the area. During the interval of study, skunks were extremely low in numbers as the result of a widespread die-off. Careful estimates placed their density at 20 to 30 percent, or less, of normal for the area. Another "mouser" of reputation, the red fox, was beginning an upward trend in populations that was to reach a peak level three to four years later. Other common mammalian predators occurred in numbers comparable to that reported for similar farmland habitats in the region.

Avian predators were studied for their population levels, nesting success, and food habits. Two species, the marsh hawk and long-eared owl, were of special interest for their food habits under conditions of reduced mouse populations. Food records for marsh hawks in particular appeared to reflect a known shortage of small mammals and higher-than-average populations of the pheasant and cottontail rabbit.

7. Farm crop preferences of small mammals. The prairie deer-mouse failed to show an outstanding preference for any given crop type. In general, however, populations in grain fields and alfalfa were comparable, and higher than in other farm habitats. Among grain fields, corn, wheat, and rye were more densely populated than fields of oats. Red clover plantings appeared to be the least acceptable of any of the annual farm crops. Idle ground areas

supported low populations generally, although variations were noted which appeared to be explainable on the basis of density of vegetation. Dense bluegrass sod was practically uninhabited by the prairie deermouse, whereas annual-weed associations of moderate density supported numbers approaching those in cropland.

The house mouse was taken in 40 percent of the grain fields studied, 35 percent of the hay fields, and 16 percent of the idle-ground situations. It was trapped more consistently in oat fields than in any other habitat. In this respect it differed from the deermouse, which was less abundant in oat fields than in other grain crops.

8. Strip-cropping and rodent numbers. Population studies of small mammals were conducted concurrently in crops grown on fields of conventional plan and in others laid out in crop strips. No significant differences were observed. Furthermore, an analysis of all trapping returns indicated that prairie deermice were distributed uniformly through fields and were not concentrated along margins, crop junctures, etc. The species did not appear to be noticeably responsive to the diversity in food and cover types which strip-cropping provides.

9. Populations in field borders. During the summer, field borders of sod supported higher populations of small mammals than did wooded borders. However, both of these types of border vegetation were less densely populated than the adjoining croplands. During the autumn months, fencerows and roadsides of sod held higher

populations of meadow voles than did any of the farm habitats. From all indications the high winter numbers of this species in cropland were traceable to a large extent to the scattered populations maintained in sod border vegetation.

10. Effects of harvest on small mammals. Live-trapping was carried on in 22 grain fields and 8 hayfields, before and following harvest. In the case of the prairie deermouse a somewhat higher catch was made in the trapping period following harvest and there was no indication of a reduction in population as a result of the operation. House mice were adversely affected by harvest as indicated by marked reductions in their numbers following combining and mowing. This response appeared to be accounted for on the basis of reduction in ground cover, since fields of mechanically picked corn which retained most of the ground cover showed no significant decline in the numbers of house mice.

11. Effects of cultivation and plowing. Corn fields, which were subjected to periodic cultivation, maintained some of the highest deermouse populations measured in farm habitats. Similarly, they were taken in relatively high numbers from fields recently plowed and in the sparse growth of fall-sown crops. While there is little doubt but some individuals were killed in the course of tillage, the marked modifications in habitat resulting from such practices were not reflected in any decrease in numbers as measured by live-trapping.

12. Economic considerations. Of the several species of small mammals dealt with in this study, the meadow vole generally is considered to be of greatest importance to agriculture. On this area certain departures from the usually reported population behavior of the animal were observed. This principally involved a projection of the period of annual population high to the midwinter months. Their numbers during the season of crop production were observed to be extremely low. It has not been established for the area that this represents the "normal" behavior of the species in all years. Nevertheless, it was observed in each of four years, and this anomalous trend of seasonal population levels undoubtedly minimized the importance of the species in crop and forage areas. Irrespective of its status in the present study, meadow voles are recognized as an actual or potential liability wherever they are present in agricultural land. On this area the maintenance of breeding stock during periods of adversity, and their periodic invasions of croplands, was facilitated by sod areas adjoining farm fields. The encouragement of woody vegetation in roadsides and fencerows should effectively minimize this objectionable function of such idle areas and, at the same time increase their utility for desirable forms of wildlife.

As has been noted in other areas, field-shocked corn in winter supported considerable numbers of meadow mice and other species. Aside from the appreciable economic losses which directly result, the practice would appear to contribute to the over-all prosperity of farmland rodents.

While the pest status of the vole in relation to agriculture is a demonstrated fact, the position of many other small mammals in the economy of the farm is not well-known. For the most part, shrews are credited with having a neutral effect if not actually being beneficial. Excepting voles, some species of field inhabiting rodents, also, are known to utilize insects readily (Aldous, 1931; Erickson, 1938; Linduska, 1942d; Telford, 1943); and in the case of forest rodents some are credited with exercising a measure of control on insect pests of the forest (Graham, 1929; Balch, 1936, 1937; Hamilton, 1938b; Hamilton and Cook, 1940; Bess *et al.*, 1947). A further value has been assigned to small mammals for their favorable effects on the soil, a relationship that has been reviewed in some detail by Van Dersal (1937), and Jacot (1940).

In this area, the prairie deermouse alone was of general occurrence during the period of crop production. However, it never appeared abundantly in any of the variety of habitats studied, and it is questionable that any of the new trends in land utilization, such as were covered in this work, will encourage its numbers appreciably if at all. The status of the species throughout this study does not justify conclusions on its economic status.

PART II

STUDIES IN FARM WOODLAND HABITATS

The farm woodlot represents a real, if not always appreciated, asset to the farmer. In addition to being important in providing fence posts, firewood, and rough lumber, these woodlands under proper management can contribute to the income of farms. Progressive land owners have recognized the advantages of applying forestry practices to their woodlots, and the proper management and utilization of the timber crop will establish new ecological conditions in this farm habitat. Principally, these changes will result from exclusion of livestock and a systematic program of harvest.

Most farm woodlots range in size from a few to 30 acres, and on this basis the area involved is not impressive. However, in terms of total farm acreage in southern Michigan, these units comprise about 10 percent of the land area and so constitute an important ecological type.

In addition to producing a major portion of the state's half million or more fox squirrels cropped annually by hunters, farm woodlots also contribute to the needs of other game animals. For this reason, detailed studies on the ecology of this habitat were included in the program of research at Rose Lake. A phase of these studies reported here concerns the relative population densities and habitat responses of several non-game species. By numbers and habits these forms are important as competitors of the fox squirrel, and otherwise are important for being the most numerous year-round inhabitants.

HISTORY AND DESCRIPTION OF STUDY UNITS

A century ago this region was covered with a relatively continuous stand of oak-hickory forest broken by lakes, marshes, and kettleholes. The land was cleared for farming beginning in 1837, when one of the earliest settlers homesteaded a tract on Rose Lake. By interviewing former land owners and older residents in the community, D. F. Switzenberg obtained information on some ecological events of the last 50 years or so, and notes on the past management of the remaining woodlands.

According to these reports, gray and black squirrels were common up to 50 or 60 years ago and began to disappear when the big timber was removed. Fox squirrels were seen occasionally, but did not increase noticeably until farming opened up most of the extensive forest stands. With continued clearing of the land, gray and black squirrels disappeared entirely and were replaced by increased numbers of the fox squirrel. Porcupines disappeared, and cottontail rabbits, which had been comparatively scarce, increased under the new conditions which also proved optimum for the fox squirrel. Red squirrels, chipmunks, and flying squirrels were reported to have been common then as now.

On the Rose Lake area, a central unit of one and one-quarter sections has been used for the most intensive studies of farm wildlife (fig. 1). Seven woodlots, 10 to 23 acres in size, are present in this unit. One additional woodlot lying outside the station limits, selected as a typical lowland type, was added to the woodlot study program in December, 1940. Limited selective cutting was done in this woods in 1941. These eight units constituted the main study areas for this work (fig. 44). The past history of these, as established by Switzenberg, showed that all were cut over for large timber at one time or another, and within the past 50 years all but one have been grazed with varying intensity. Notes on the use of the woodlands prior to 1938 are included in appendix table v. Since 1938 no additional cutting has been done in the central area woodlots and all have been protected from pasturing.

Of the eight woodlots used for study, six, totaling 86 acres, were of the typical upland, oak-hickory type. In these units the dominant species of trees were black, jack, and white oaks (*Quercus velutina*, *Q. ellipsoidalis*, and *Q. alba*), and hickories (*Carya ovalis* and *C. ovata*). The other two units, totaling 26 acres, were of a lowland type in which red maple (*Acer rubrum*) was the dominant species. These two fundamental differences in vegetative composition furnished one basis for comparison of the small mammal inhabitants. Among the six upland woodlots, three, totaling 41 acres, had been pastured intensively, and until fairly recently, so that they were representative of a grazed type of woodland. The remaining three, totaling 45 acres, had recovered from past effects of mostly light grazing so that, by appearance at least, they had again approached an "ungrazed" state. These differences in intensity and recency of grazing also were considered in population comparisons of the woodland fauna.

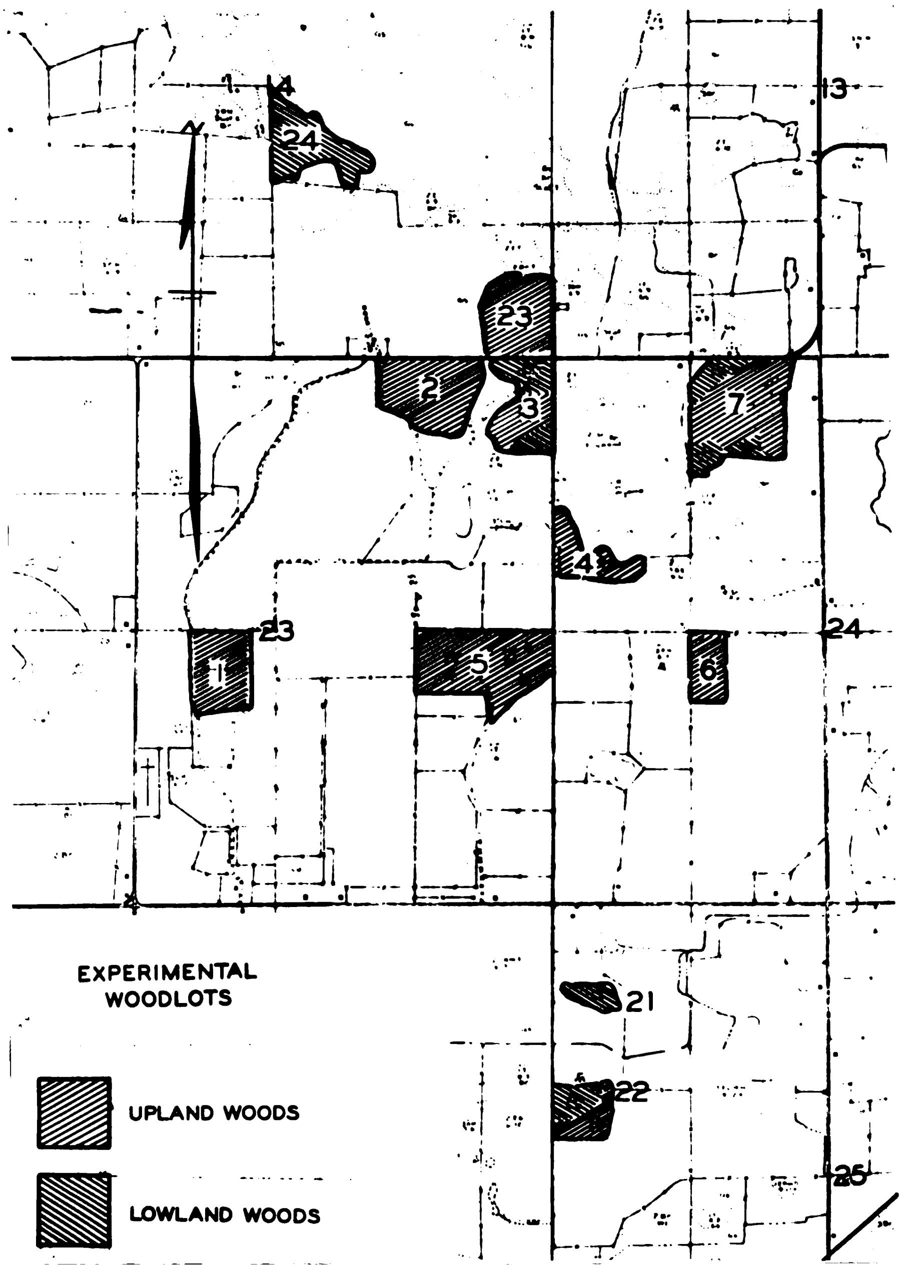

Fig. 44. Location of the Rose Lake woodlots. Units 1-7 were the areas of most intensive study.

Woodlot Analysis

For purposes of future comparison, an anylysis was made of all woodlots in 1940. A 5 percent sample of all woody vegetation was obtained by making a detailed examination of 0.5 square-chain plots at permanent box-trap locations. (The box-traps were spaced one to the acre on a grid pattern.) All samples were taken arbitrarily on the west side of each permanent trap location, with the trap marking the center of the long side of the quadrat. A detailed count of woody vegetation was made and recorded under the following size classes: 3 feet high to 1 inch in diameter (breast height); 1 to 3 inches d.b.h.; 3 to 10 inches; and 10 inches and up. The details of this analysis are not included here, but the results have provided the basis for the description of woodlots given in table v in the appendix.

Fig. 45. The box-trap used in the study.

Fig. 46. A series of soil temperature records was obtained by means of a Leeds-Northrup potentio meter and permanently located Constantan-copper thermocouples.

METHODS OF STUDY

The broad scope of this study imposed limitations on the number of specialized methods that could be employed effectively. Had the objective been a species study, some modifications in the procedure undoubtedly would have been profitable. Considering the inclusive nature of the work, however, the approach used was believed to be near optimum.

Since the principal aim was to establish comparative population levels of woodland mammals, intensive live-trapping and marking was the main technique used. The box-traps (fig. 45) measured 2 feet in length and 1 foot in height and width, and were covered with 16-gauge, galvanized hardware cloth of half-inch-mesh. The traps were spaced one to the acre on a grid pattern at permanently marked locations. Other traps located with reference to rabbits in swales, fencerows, etc., furnished additional information on woodlot species. Ear-corn was used as bait throughout the study. Dried herring also was included to attract the carnivores on the area.

Trapped mammals were marked with numbered tags fastened in the ears. For fox squirrels a tag of about half an inch length was used, and for red squirrels and chipmunks a somewhat smaller fingerling size was more satisfactory. To insure long-time recognition of fox squirrels one of the smaller tags also was attached to the outer toe of one hind foot (Linduska, 1942c). Flying squirrels were identified in subsequent handlings by means of a tag fastened to the patagium. These methods of marking proved satisfactory for all species except chipmunks. In some periods of trapping as many as 10 percent of the chipmunks which had been marked in some earlier trapping period were noted to have shed their ear-tags. However, duplication of animals in any given period of trapping as a result of such loss of identity was believed to be insignificant. Field records were maintained for individual traps which were numbered within separate trap-lines corresponding to the woodlot designation. In the laboratory, information was transposed to individual cards bearing the record of each animal caught.

In 1942 an index was obtained to the comparative numbers of mice and shrews in woodlots. The procedure was much the same as that which has been described for studies in cropland. An attempt was made, also, to obtain an actual census of small mammals (mice and shrews) in one upland woodlot. The intensive methods employed in this study will be described under the discussion dealing with these species.

Mast Crop Measurement

With the beginning of these studies in 1940 an attempt was made to develop a system for measuring mast yields which would provide an index for year-to-year comparisons. Refinements of method were made in 1941 and further changes in 1942 provided what appeared to be a reasonably workable system (Allen and McGinley, 1947). This evolution of method precludes any critical comparison of statistics on annual mast measurement. However, numerous observations are available to show in a general way the success of the mast crop during the period of the investigation:

1939: Excellent. Both oaks and hickories produced heavily, and the crop in this year probably represented near maximum for the area.

1940: Very poor. Oak and beech trees failed completely to bear mast. Isolated hickory trees produced a fair crop, but those in woodlots had very few nuts. The crop was probably minimum for the area.

1941: Good. Hickories, especially small-fruited hickory, yielded heavily. Oaks in open situations bore well and red oaks in woodlots had exceptionally heavy crops.

1942: Fair. Red and black oaks produced fairly good numbers. White oaks failed to bear. Hickory nut production was good and isolated trees had much heavier crops than woodlot trees.

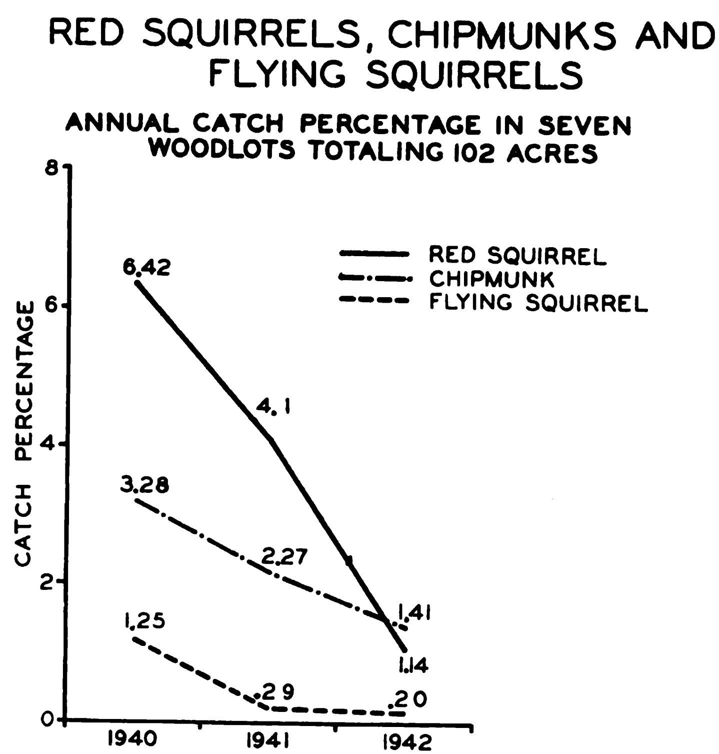

Fig. 47. Annual catch percentage index to comparative numbers of sciurids.

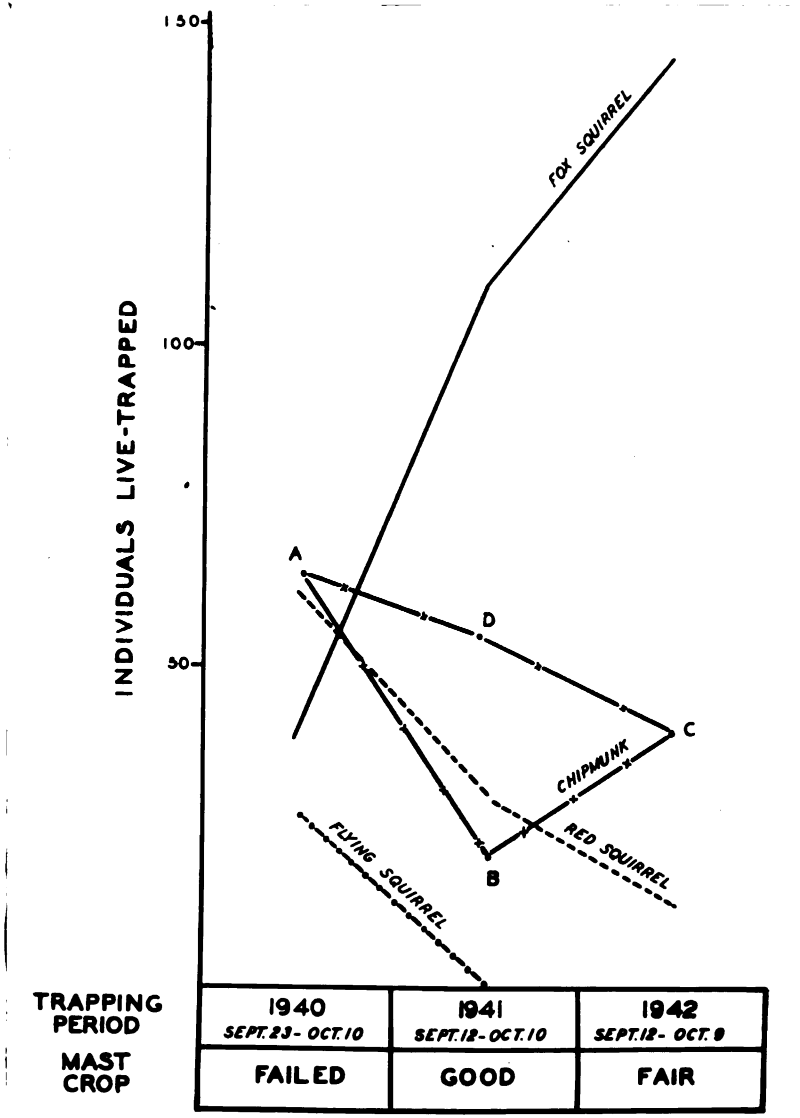

Fig. 48. Fall trapping index to annual numbers of sciurids. (See text for account of chipmunk catch).

COMPARATIVE POPULATION LEVELS OF THE SCIURIDAE

Annual Trends

During the 3-year period reported on in this study (1940-1942), additional land acquisitions by the experiment station increased the number of woodlands available for study. These were included in the over-all research program as they came into ownership. For purposes of comparing annual population trends, however, only the results from seven woodlands available at the beginning of the study will be used. In these seven units, which totaled 102 acres, the total trapping activity amounted to 29,748 trap-days. This was distributed by year as follows: 1940 - 11,801 trap-days; 1941 - 9,885; and 1942 - 8,062.

In fig. 47 the total annual trapping pressure and total catches for several species have been used to establish an annual catch percentage (the percentage of trap-days which were successful in effecting catches). While the figure suggests rather marked declines in numbers for all of the small Sciuridae, the extent of the decreases probably is exaggerated. It is believed that one explanation for these distorted population indices is to be found in mast crop records for the period.

Following a bountiful mast crop in 1939, the animals reacted about "normally" to traps, and in the ensuing winter and early spring, red squirrels, for instance, provided a catch index of 2.0 percent. In the following autumn, however, a food shortage developed. Supplies of the previous year were exhausted and the 1940 mast crop was a practical failure. The bait in traps was free from competition with natural foods and the catch index rose to over 8 percent. That this was the case is further borne out for some of these same species by recatch records which showed they were returning to traps frequently. These are given for the red squirrel elsewhere in the text (table 21).

Actual trap returns for the chipmunk in fig. 48 follow points A - B - C. This would indicate a marked drop in 1941 followed by a population rise in 1942. Such a trend is not consistent with the annual catch percentage shown in fig. 47 or with the findings in summer trapping for 1941 which indicated that the level should be more nearly at point D. In view of the much greater numbers of this species which were taken in woodlots just a month prior to the fall trapping interval, it was suspected that the animals may have entered hibernation earlier in 1941. Although September and October temperatures were near normal in that year (appendix table i), October precipitation was three times normal, and the 7.33 inches which were recorded made October, 1941, the wettest in the history of the East Lansing weather bureau (appendix table ii). It is possible too that the bumper mast crop in that year made possible an earlier hibernation for chipmunks.

It is of interest that over this same period which witnessed waning populations of the red squirrel, chipmunk, and flying squirrel, the fox squirrel was increasing in numbers. What is believed to be a reasonably accurate indication of annual trends for these species is shown in fig. 48. The trapping results upon which this figure is based are for 102 acres of woodlots trapped for about one month

prior to the start of the hunting season on October 15. In 1940, the duration of the fall trapping period was shorter than in the two following years. As has been pointed out, however, a shortage of mast increased trap efficiency, and it is likely that the shorter period in 1940 was about as effective as the fall trapping programs for 1941 and 1942.

Under conditions at Rose Lake the hunting season kill has been found to be comparatively reliable in indicating population levels for game species, and the fox squirrel harvest at Rose Lake has provided such an index. In 1941, however, the first killing frost did not occur until October 27 (appendix table iii), and it was near the end of the season (November 5) before oak leaves fell and offered good visibility for shooting. As was anticipated, the kill was much lower than would have been possible with normal conditions. Aside from the understandable discrepancy in the 1941 kill, hunting season data for the study woodlots agreed with trapping figures in showing a rising fox squirrel population. With similar hunting pressure, the harvest for the seven woodlots of 102 acres was 42 squirrels in 1940, 42 in 1941, and 107 in 1942.

Why three of these sciurids, the red squirrel, chipmunk, and flying squirrel, should suffer a depression in numbers, while a fourth, the fox squirrel, is enjoying marked prosperity is entirely conjectural. Fundamentally the food requirements of all four are similar enough so that any marked departure from the normal should affect all of them. Cover conditions throughout the period of study were unchanged except for normal successional changes, hardly apparent for the short interval involved. Evidences of incompatibility between the red and fox squirrel have been reported, and were observed in the course of this work. However, they were not of a degree to imply actual population influences.

It is possible that these population curves are unrelated. What may have been a somewhat parallel situation was noted in the British Isles by Middleton (1930b). With reference to the American grey squirrel (*Sciurus carolinensis* Gmelin) and the British red squirrel (*Sciurus leucorous* Kerr), Middleton observed that the increase of the grey squirrel coincided with a period of natural depression among the native species.

Relative Numbers with Reference to Type and Grazing of Woodlots

An analysis of trapping records for Rose Lake woodlots reveals marked habitat preferences among the woodland mammals. While these relationships will be considered separately in the species discussion which follows, a summary of results as they apply to one important game species, the fox squirrel, will be given here.

In fig. 49 the results of summer and fall trapping in upland and lowland woodlots are shown for a 3-year period. A description of these has been given elsewhere in the text. The upland woodlots which totaled 86 acres were in six isolated units varying in size from 10 to 23 acres. Trapping figures for the lowland woodlots are for a single unit of 16 acres in 1940, and for two units totaling 26 acres for the two following years. For comparative purposes the catch in both types has been converted to a base of individuals per 100 acres. Since trapping pressure was identical in all woodlots for any given period, the returns from the two types should be comparable. However, the separate trapping intervals frequently were of different duration, and a comparison of returns between the periods shown probably would not be valid even though the same months are represented in some years.

Fox squirrels were taken consistently in higher numbers in the upland woodlots, and appeared to be about three times as plentiful in this type of situation as they were in the lowland type. Preferences of other sciurids are not clearly shown. During the first two years a greater number of chipmunks, red squirrels, and flying squirrels were taken in upland situations, whereas trapping in 1942 took greater numbers in the lowland type.

Upland woodlots were found to support variable populations of sciurids depending on the condition of the stand with reference to grazing. A summary of catches for three ungrazed woodlots totaling 45 acres and three grazed units of 41 acres is shown in fig. 50. While the effects of grazing apparently was unfavorable to most of the smaller species, the fox squirrel appeared to benefit by the removal of ground cover. In general, the relative numbers in the two situations agree with what would be expected in considering the habits of fox squirrels as compared with those of more terrestrial habits such as the chipmunk and possibly the red squirrel.

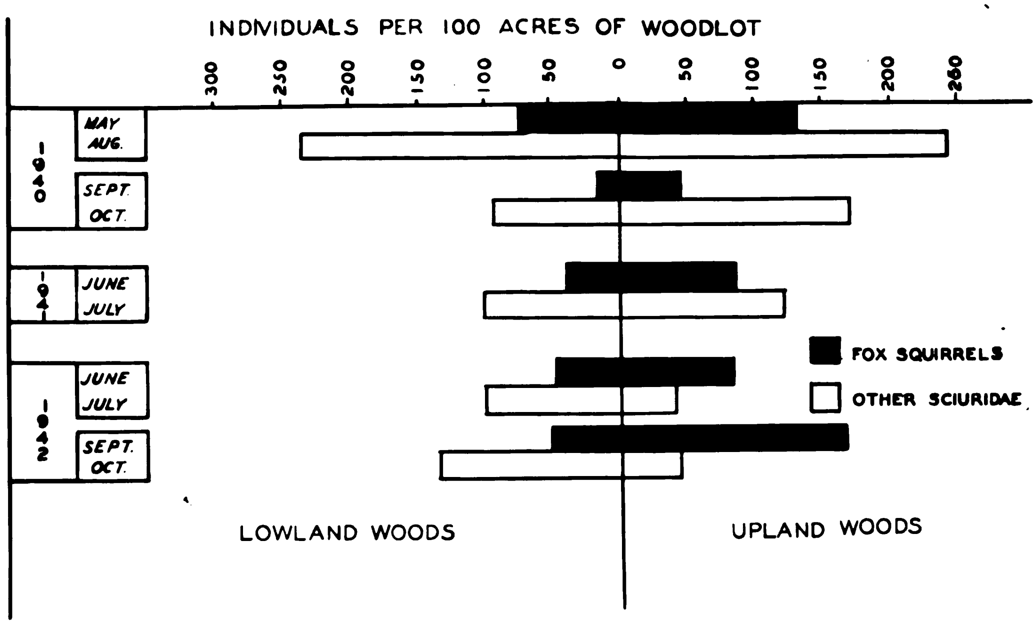

Fig. 49. Comparative catch of fox squirrels and other sciurids in upland and lowland woodlots.

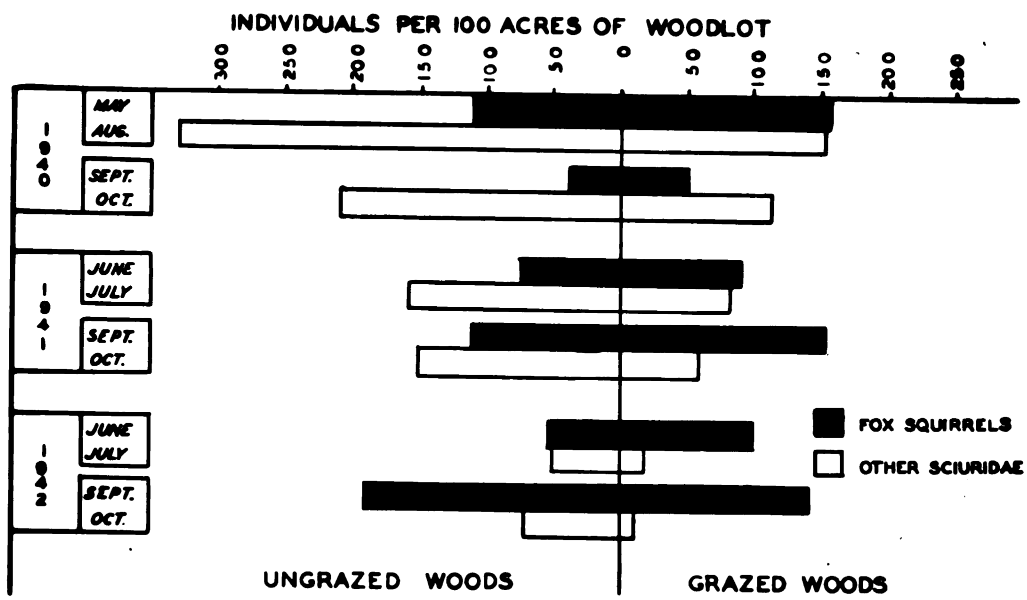

Fig. 50. Comparative catch of fox squirrels and other sciurids in grazed and ungrazed woodlots.

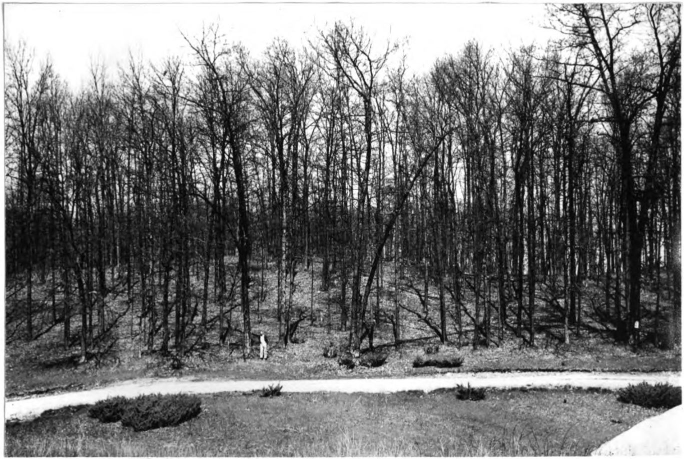

Fig. 51. Marginal clumps of ground juniper were the only cover in this grazed oak-hickory woodlot. Fox squirrels were not adversely affected by such immediate results of grazing.

SPECIES DISCUSSION

Fox Squirrel
(*Sciurus niger rufiventer* Geoffrey)

Observations on general habitat preferences and annual population trends for the fox squirrel have been given above. Various details of the biology of the fox squirrel at Rose Lake during the period of this study are included in a comprehensive report on the species by Allen (1943). The reader is referred to that source for any additional information on the status of the fox squirrel under conditions outlined here.

Red Squirrel
(*Tamiasciurus hudsonicus loquax* Bangs)

Populations

Observers of the red squirrel agree that the numbers of these animals vary widely with the seasons, years, and in different habitats. While some figures of density have been reported, these frequently are rough estimates and in many cases concern local concentrations or counts prompted by some unusual circumstance. Klugh (1927) estimated the numbers of this species at about one per 20 acres in the original pine forests of Ontario and about the same for the original beech-maple woods. The greatest density which Klugh reports is a spring population of nine per acre in a stand of mixed hardwoods and conifers at Grand Bend, Ontario. Hatt (1929) estimated summer populations ranging from one red squirrel per 0.5 acre to one per

3 acres in several coniferous habitats. Hamilton (1939) counted nine family groups totaling 44 individuals on about 30 acres of hardwood forest, and Bole (1939) reports a peak population of 1.7 red squirrels per acre in beech-maple forests of Ohio.

A principal objective of this investigation was a measurement of red squirrel populations, and a determination of their variability in time and in response to various habitat types. In the course of the study certain characteristics of population behavior were revealed which precluded making these measurements with the desired accuracy. A conspicuous source of error was the relatively large segment of the population which was unstable with reference to fixed home sites. While these apparently vagrant individuals were nearly always present, as would be expected the numbers were greatest in the annual peak populations of summer and early fall.

The extent of the population turnover is indicated by trapping returns summarized in table 18. These data are for 340 red squirrels taken in seven woodlots on the central study unit of 800 acres. It will be noted that slightly more than a third of the animals were handled only once, i.e., failed to reappear in trapping after the first capture. Over 50 percent of the total, either failed to reappear in trapping after the initial capture, or were recaught only once. It cannot be assumed, of course, that all of the animals not recaught were transient individuals. Some probably were victims of accident or disease; a few probably continued in residence on the area but failed to come to the traps; and other are known to have lost their identity by losing their ear-tags. The latter source of error was minimized by tagging both ears and replacing tags as they showed signs of insecure attachment. Some animals were marked by toe-clipping in addition to being ear-tagged.

There is no good way of evaluating all these sources of possible error. It is obvious, however, that even if 50 percent of these "lost" animals were credited to factors of the type discussed, a considerable number still remain which can be accounted for only on the basis of widespread movement. It was fortunate from the standpoint of this work that the area under observation was large enough to permit obtaining some information on the extent of such activity. In table 19, the residence records are summarized for 108 red squirrels which were handled five or more times. While the data are for a 3-year period, the number of individuals known to carry over from one year to the next (see section on Population turnover) is so few that the movements shown can be considered as having occurred within a year's time. It will be seen that less than half of all squirrels with a record of five or more catches confined their activities to a single woodlot, and slightly more than 50 percent were apparent residents of either a single woodlot, or of a swale, fencerow, or isolated group of trees (shown as "Field line" catches in table 19). About 18 percent of the animals moved between two or more woodlots, and an additional 28 percent of the total divided their residence between a woodlot, and a fencerow, swale, or other outlying cover where they were taken in "field" traps.

Table 18. Frequency with which
340 red squirrels were trapped.

	Number of times trapped									
	1	2	3	4	5	6-10	11-15	16-20	20-30	Over 30
Number of individuals	122	56	32	22	20	42	19	10	8	9
Percent of total	35.8	16.5	9.4	6.5	6.0	12.3	5.6	3.0	2.3	2.6

Table 19. Permanency of residence of
108 red squirrels handled 5 or more times.

	Situations where caught				
	One woodlot	Two woodlots	Three or more woodlots	Woodlot and field line	Field line only
Number of individuals	46	15	5	30	12
Percent of total	42.6	13.9	4.6	27.8	11.1

Table 20. Calculation of red squirrel populations by means of "tagging-return" ratios in seven woodlots of 102 acres.

	1940			1941			1942		
	June 24-July 7	July 25-Aug.7	Sept.23-Oct.7	June 17-July 3	Aug.16-Aug.29	Sept.11-Sept.24	April 1-April 14	June 13-June 26	Sept.12-Sept.26
(a) No. tagged-1st week	17	36	39	18	1	10	9	6	1
(b) No. recaught-2nd week	11	23	20	8	0	0	2	0	1
(c) Total catch -2nd week	29	45	32	25	3	1	7	3	3
(x) Calculated population	45	70	62	56	-	-	32	-	-
* Total trapped	35	58	51	35	4	11	14	9	3

(a) Number of red squirrels ear-tagged in one week of live-trapping.
(b) Number of the above tagged red squirrels retaken in the following week of trapping.
(c) Total animals handled in the second week of trapping.
(x) Apparent population calculated from ratio: $\frac{a}{x} = \frac{b}{c}$

* Total individuals caught in two weeks trapping.

These movements were reflected in population trends for individual woodlots in a way which makes it virtually impossible to establish accurately the red squirrel population density for any single woodlot. An example of the error involved can be shown by results obtained in three consecutive trapping periods in June and September, 1941, and in January, 1942. The duration of trapping was 18 days in the June and January periods and 28 days in September. While the total number of red squirrels taken in the seven study woods was similar in each instance (35 individuals in the June interval, 30 in September, and 25 in January), the catch records for individual woodlots showed marked variations between periods. In woodlot 2, for instance, the numbers taken were as follows: June - one red squirrel, September - four, and January - seven. In the same trapping, woodlot 3, which was adjacent to number 2 and comparable to it (both were grazed upland woods), the trend in numbers was the opposite, with six individuals taken in June, three in September, and one in January. Woodlot 6 (ungrazed) also showed a marked decline in numbers, and the catch in the June, September, and January periods was respectively nine, six, and one. Woodlot 7, an ungrazed lowland woods, yielded catches in the three periods of 6, 14, and 6 individuals.

In view of the behavior discussed above, it is obvious that a census of these animals will have the best accuracy when it concerns the largest possible area and is accomplished in a minimum of time. In table 20, trapping data for peak population periods are utilized in a way which should minimize the complications posed by a shifting population. The data apply to the seven study woodlots which constituted all of the true woodlands on more than a section of land. Trapping returns used in calculations are limited to two weeks of each of the trapping periods. By a simple algebraic ratio explained in the table, the apparent population was calculated whenever returns were adequate to allow for such computations.

It is believed that the 1940 figures are reasonably accurate and the late-summer population shown for that year undoubtedly was the highest dealt with in this study. The calculated density for 102 acres was 70 individuals or about one squirrel to 1.4 acres of woods. As will be shown later, however, red squirrels showed rather well-defined habitat preferences, and this summer density would hardly represent the average for individual woodlots. As a matter of fact, within this period of peak population, the density for single woodlots ranged from a maximum of two per acre in one 12-acre woods to a minimum of one per 12 acres in another unit of the same size.

Most recorded observations on reproduction in the red squirrel indicate that the time of birth is April to June and fail to mention the possibilities of a fall litter (Merriam, 1884; Mearns, 1898; Preble, 1908; Dice, 1921; Hatt, 1929). Klugh (1927) noted half-grown young in September and October, and suggested that while these young might indicate second broods such occurrences are the exception and not the rule. Hamilton (1939) found in New York, however, that most adult females have both a spring and fall litter, and Lyon (1923: p. 198) believed that two litters probably were produced in Indiana.

Observations on marked animals in this study indicated that two broods probably are produced, in which case peak annual populations would be expected in autumn. It will be noted from catch records, and from calculated populations of red squirrels in 1940, that the fall density actually was slightly below that of the summer months. Allen (1943) reports reduced breeding in the fox squirrel in times of food shortage, and the failure of the mast crop in 1940 may have helped to account for the waning population of red squirrels in the fall of that year. The fact that the decrease continued through the following years of fair to good mast production would suggest, however, that any effect of a food shortage in 1940 probably was superimposed upon more fundamental limiting factors.

Habitat preferences

For reasons already discussed, attempts to correlate population responses of the red squirrel with ecological conditions in a specific woodlot did not prove profitable. Nevertheless, certain predilections were shown which can be expressed more or less quantitatively.

Effects of grazing.- In appendix table vi, the catch records for red squirrels are shown for three grazed upland woodlots totaling 41 acres and three ungrazed upland woodlots of 45 acres. Since trapping in the two types was conducted concurrently, comparisons of the catches for any given period should give an index to the effects of grazing. It should be pointed out, however, that trapping periods were of different length, and the data do not provide for valid estimates of actual densities or population trends from one period to the next.

For purposes of ready comparison, the data have been converted to a catch-per-unit-area basis, and the results shown graphically in fig. 52. While the relative numbers taken in the two types of woodlots do not vary widely, a fairly consistent preference for the ungrazed condition is shown. This was most evident in 1940, and it is possible that the mast failure in that year may have been a further influence. Several authors have reported on the great variety of foods accepted by red squirrels (Klugh, 1927; Murie, 1927; Hatt, 1929), and the animals are known to be adaptable in the face of food shortages (Hosley, 1928; Williams, 1936). Most ungrazed woodlots with their abundant variety of shrubs provide greater quantities of supplementary food than do the grazed type. In years of mast failure it might be expected that ungrazed units would maintain a higher carrying capacity for species of diverse food habits.

Upland and lowland types.- The red squirrel catch for 86 acres of upland and 26 acres of lowland woodlots is given in appendix table vi. This information provides the basis for fig. 53 in which the comparative numbers of individuals using two lowland and six upland woods are shown. As in the comparison of grazed and ungrazed woodlands the data have been computed to a standard area of 100 acres for each type.

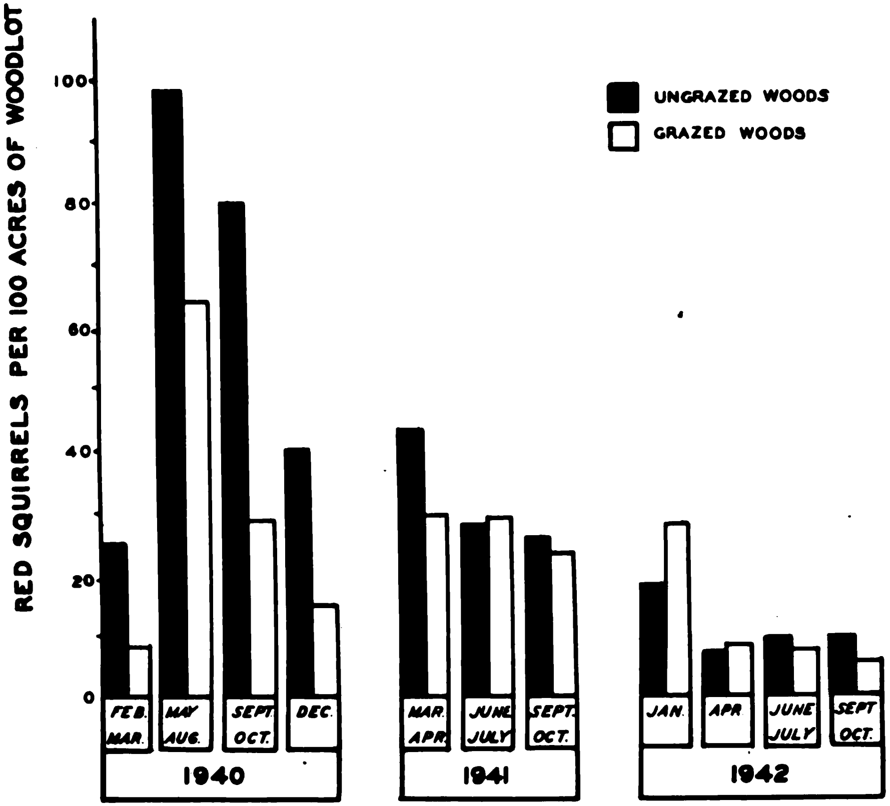

Fig. 52. Comparative numbers of red squirrels trapped in grazed and ungrazed woodlots.

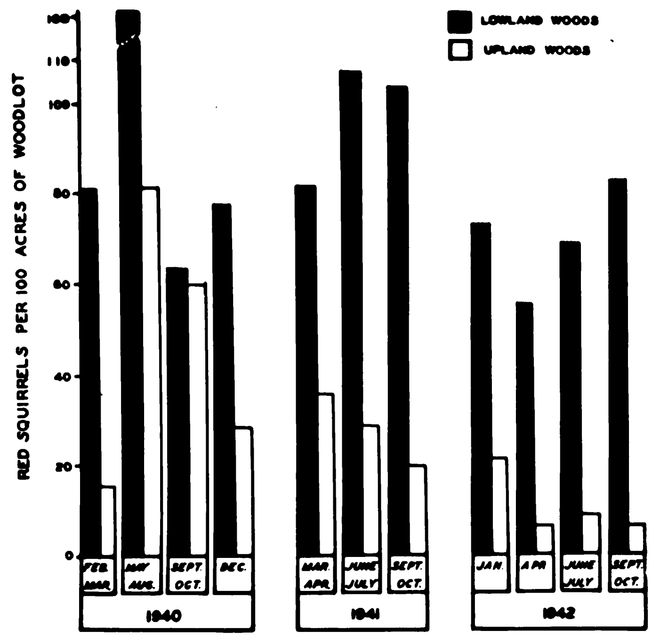

Fig. 53. Comparative numbers of red squirrels trapped in upland and lowland woodlots.

Fig. 54. Not all of the red squirrels were woodlot dwellers. These grass nests were constructed in isolated fencerow trees.

The red squirrel's preference for a lowland woods habitat is clearly shown. With the exception of the trapping period, for September-October, 1941, when the catch was about equal in the two types, the numbers taken in lowlands were 2 to 8 times that of the upland situations. In this same fall period, an individual catch of 80 red squirrels per 100 acres in ungrazed upland woodlots indicated a higher density for this type than was found in lowland areas (62 per 100 acres). This can be attributed in a large measure to a temporary concentration of 24 individuals in one 12-acre ungrazed woodland (woodlot number 6).

The conditions in lowland woodlots which contributed to higher populations of this species are not entirely known. In these study plots, the greater number of species of trees and shrubs, and the denser ground cover in the lowland types undoubtedly were important factors. An abundance of red maple (*Acer rubrum*) in both lowland woodlots, and sugar maple (*Acer saccharum*) in one, may have contributed to the greater acceptability of this type. Various parts of both of these trees are known to be eaten readily (Hatt, 1929; Klugh, 1927), and referring to the latter, Hatt states, "This tree is among the most important food sources for the red squirrel where their ranges coincide."

Outlying habitats.- Red squirrels in this farming area were not restricted to woodlots. Practically every swale area had several inhabitants, and in many cases a few isolated trees, or a strip of brushy fencerow or roadside cover, maintained one or more of these

animals. While it is difficult to express quantitatively the extent to which such habitats were used, some indication of their importance can be obtained by reference to the red squirrel catch in rabbit lines.

It is very likely that many of the animals taken in rabbit traps were using outlying cover as travel lanes between woodlands. However, a considerable percentage of red squirrels for which five or more capture records were obtained were known to utilize such areas regularly. Over one-fourth of the individuals handled five or more times appeared in rabbit trap-lines as well as in the woodlot trap-lines. An additional 11 percent were taken only in rabbit traps and can be presumed to have spent the greater part of their time in these habitats away from woodlots (table 19).

Some evidence was obtained to indicate that red squirrels in marginal habitats had a greater tendency towards stability in numbers than did those in woodlands. The population decline of red squirrels during the three years of this study has been discussed. On 102 acres of woodland, comparable periods of fall trapping took 62 individuals in 1940, 30 in 1941, and 13 in 1942. Over these same trapping periods, six rabbit lines which included 124 traps in 1940, and 104 in 1941 and 1942, were in operation in fencerow, roadside, and swale habitats. The autumn red squirrel catch on these lines was 22, 16, and 14 in successive years.

A further indication of the red squirrel population trends in the two environments can be shown by a comparison of the total annual trapping success. From fig. 55 it can be seen that the catch percentage for woodlot inhabitants declined from a level of 6.4 percent

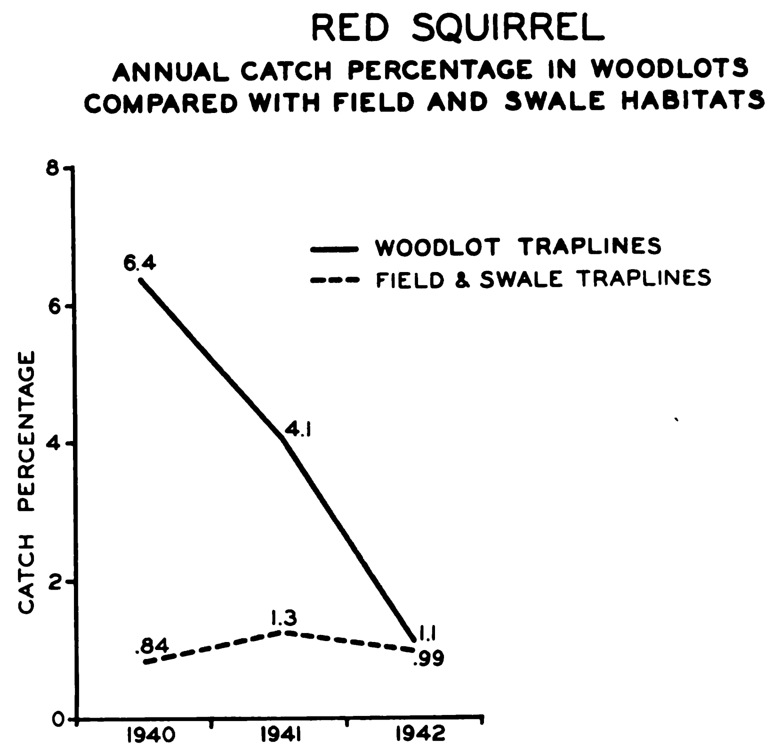

Fig. 55. Annual catch percentage as an index to the population trends of red squirrels in woodlots compared with those inhabiting the scattered woody situations in fencerows, road sides, etc.

in 1940 to 1.1 percent in 1942. In outlying habitats the trapping success, while lower, was maintained at a fairly uniform level during this same period and varied in extremes only from 0.8 to 1.3 percent. Trapping pressure which formed the basis for these latter catch percentages amounted to over 8,000 trap-days in 1940 and 1942, and 17,000 trap-days in 1941.

Without knowing what forces operated to bring about the decline in the red squirrel population, it is difficult to estimate the full significance of the relationship discussed above. However, certain features of the non-woodlot habitats were in contrast with woodlot conditions. For instance, isolated trees were found to produce mast more abundantly and consistently than did those in woodlots. Also, outlying units of brush included a variety of fruiting shrubs that undoubtedly provided important supplementary feed in times of mast shortage. The fact that many of these marginal areas bordered cropfields gave additional opportunity for providing against food shortages. Except for the year 1940, there was no good evidence that a food shortage actually existed in any of the woodlots, and it is doubtful that this factor figured prominently in the population decline. Nevertheless, the greater consistency in food production which characterized the outlying habitats must be considered a stabilizing influence in the lives of animals occupying such areas.

There is no good basis for a quantitative comparison of red squirrel numbers in the two types of habitats. With generally high populations the density of animals undoubtedly was far greater in the woodlands. Under such circumstances they might be more vulnerable to epidemic diseases, and possibly other decimating factors, than would the inhabitants of discontinuous units of cover.

In any event these evidences of wide variations in population trends between habitats are such as to suggest a survival value for low capacity habitats. In this connection, a conclusion reached by Evans (1942) following an intensive study of several woodland mammals in England is of interest: "The distribution of Clethrionomys appeared to be associated with its relative density. The population 'survival' from a period of high density to one of low density appeared to be greatest in those habitats which had normally maintained a low population density. It is suggested that habitats which will maintain only low densities may be essential to the ultimate survival of a species."

Biological notes

Population turnover.- The widespread movements which red squirrels underwent in this study make it virtually impossible to determine the rate of die-off and replenishment in the population. However, the combined effect of losses due to mortality, and losses due to movement from the area, were observed to result in a marked annual turnover in individuals composing the population.

In 1940, trapping was confined largely to an area of 800 acres. Following land acquisitions in 1941 and 1942, additional habitats around the central 800-acre area also were trapped, and the total area under study was nearly 2 sections. For purposes of the present comparison the data probably are most significant if the sum total of all trapping in each year is considered. On this basis it was found that 21 percent of 169 red squirrels marked in the calendar year 1940 were retaken in 1941, and only 3 percent of the 1940 population were still present in 1942. Of 197 animals marked in 1941, only 9 percent were included among the 112 individuals trapped during the following year.

Recoveries of marked animals away from the study area were too few to provide a basis for estimating the extent to which population turnover can be attributed to this factor of movement. Considering the extent to which it occurred between individual woodlots, however, it appeared to be appreciable. A single recovery of a juvenile female 5.5 miles from the study area indicated that such movements may be extensive. This animal (no. 5630), last handled on July 5, 1940 at Rose Lake, was found dead in the road on February 26, 1941 in Victor township, Clinton County. In the case of game species, hunting returns often are helpful in revealing the extent of such movements. From this source of information it has been established that fox squirrels may move for distances of 30 or 40 miles (Allen, 1943).

Longevity.- Several red squirrels were known to have lived for over two years, but only a single record was obtained to show a longer age. An adult male red squirrel (no's. 5163-14587), first trapped on March 18, 1940, was last handled in the same woodlot on June 29, 1942, at which time it was at least 3 years old. During this interval it was trapped 47 times and changed its woodlot residence twice. On two other occasions it was trapped in a "field line". Klugh (1927) reports a record of a pet red squirrel which apparently reached the age of 9 years, and Walton, 1903 (in Hatt 1929) refers to a tame though free animal whose record extended over 10 years. A very few fox squirrels reach the age of 6 or more years in the wild (Linduska, 1947b). By analogy it is to be expected that red squirrels, with a higher biotic potential, would even less frequently attain a similar life span.

Trapability.- When confined in box-traps, red squirrels appeared to be far more excitable than any of the other sciurids. However, there was no indication that such an experience discouraged subsequent entry of traps. The same animal frequently was recaptured on several successive days, and on a few occasions the animals re-entered the same or an adjoining trap a few minutes after release. Nine individuals were handled 30 or more times (table 18), and several animals had trap records showing 50 or more recatches. In one 3-week period of December trapping, six individuals in one woodlot were trapped a total of 39 times; and in an extended period of summer trapping, seven individuals in another woodlot were handled a total of 75 times.

Due to differences in trapping pressure it is not possible to show accurately any yearly differences in their susceptibility to trapping. However, the animals were trapped more readily in 1940 than in either of the later years. This was explainable on the basis of a critical shortage of natural foods, a situation that has been discussed elsewhere. From 1,883 capture records for red squirrels

Table 21. Catch totals for red squirrels and averages for each sex.

	Males			Females		
	Individuals	No. of catches	Catches per individual	Individuals	No. of catches	Catches per individual
1940	75	520	6.9	73	468	6.4
1941	95	284	3.0	87	349	4.0
1942	55	128	2.3	46	134	2.9
Totals	225*	932	4.14	206*	951	4.61

*Includes some duplication of individuals between years.

no significant difference is noted in recatch records for the sexes (table 21). In the 3-year period, males were trapped an average of 4.14 times and females 4.61 times.

Sex ratio.- The over-all total of animals handled during the study showed that males were taken in slightly greater numbers than females. Although the annual differences were not great, the sex ratio was most nearly even during the year (1940) of highest population density. In the following two years of population decline, an increasingly larger percentage of males was taken (table 22).

Age ratio.- Considerable difficulty was experienced in distinguishing ages of red squirrels in late summer and fall, and the results are offered only for their possible value in indicating trends between years. This information, obtained mostly from examination of females, is summarized in table 23. The most that can be said for these data is that the indicated production and survival of young is in agreement with population levels for the same periods.

Table 22. Sex ratio of red squirrels taken in live-traps

	Year 1940	1941	1942	Total*
Number examined:	169	197	112	478
Males:	89	105	61	255
Females:	80	92	51	223
Males/100 females:	111	114	120	115

*Includes some duplication of animals between years.

Table 23. Age ratios of red squirrels taken in summer and fall trapping.

Year	Total examined	Adults	Young	Age uncertain	Percent young Known 1/	Percent young Estimated 2/
1940	135	39	61	35	61	71
1941	62	29	21	12	42	53
1942	24	15	5	4	25	38

1/ Among animals of known age.
2/ Assuming questionable group included all young.

Eastern Chipmunk
(*Tamias striatus rufescens* Bole and Moulthrop)

Populations

Relatively few population figures are available for this species. Over a 4-year period (1932-35), Williams (1936) estimated autumn densities of 4 to 15 individuals per acre in a beech-maple woodland in Ohio. Bole (1939) reported what he thought was an exceptionally high population of 8.7 per acre for upland forests in Ohio in 1935. He remarked that "....similarly favorable conditions in 1937 resulted in but a very slightly higher figure (1.14 per acre) for 1938 than the lowpoint of the previous year (0.8 per acre)." On two small plots totaling 5.52 acres, Burt (1940) found populations in 1935-37 of 2.4 to 3.6 per acre following appearance of the first litters in May and June. He suspected that September populations, when second litters were out of the nest, would average somewhat higher.

Observations on the breeding behavior of the eastern chipmunk are not in full agreement. Condrin (1936) and Allen, E. G. (1938) report that two broods may be produced. Burt (1940) indicates that old females produce both a spring and summer litter, and that young females of the spring broods, also, may give birth to a fall litter. Schooley (1934) states that "....it is clear that it is the old females that breed in the spring and that the younger ones, even those born the preceding spring and summer, are the ones that breed during the July cycle. Old females that have not become pregnant from the spring mating may also breed at this time." Whatever the details of the summer breeding period may be, it seems obvious that peak annual populations would be reached in early fall after the summer litters become active.

On the seven study woodlots totaling 102 acres, summer trapping (June and July) for the years 1940-42 took 87, 76, and 33 animals respectively. September trapping during the same years accounted for only 65, 20, and 40 individuals. This summer-to-fall reduction in numbers during two years is not what would be expected from the animal's breeding history. However, it is not surprising in view of other marked variations in numbers noted from one trapping period to another. In 1941, for instance, only five animals were taken with the same intensity of trapping in August which a little more than a month earlier had produced 76 animals. It is doubtful that all such variations in catch can be accepted as representing true quantitative changes, since the chipmunk is known to enter into periods of inactivity during the summer months (Seton, 1909; Schooley, 1934; Williams, 1936). With reference to such disappearances of these animals near Ithaca, New York, Allen, E. G. (1938) observed that, "....there seems to be a definite tendency for chipmunks to disappear during warm, dry spells, especially after the midsummer litter is raised, but it has been noted also in July."

In this study, the trap spacing of one per acre may have been too sparse to effect a catch of all resident chipmunks. However, it is questionable that this was the case, since individual animals frequently were taken in more than one trap, indicating that their range extended beyond limits represented by the

distance between traps. Furthermore, studies by Burt (1940) and Blair (1942) indicate a home range of about 2 acres or more for these animals. In any case, it is doubtful that the average density for all woodlots at any time during the study was more than one animal per acre. In basing this figure on the highest of the over-all trapping returns, it should be mentioned that the average population for the majority of the woodlots was well below this density. There was nothing approaching an equitable distribution of the total catch through the seven woodlots, and during both the high periods of 1940 and 1941, a majority of the total was concentrated in a single woods. In 1940, 57 of the total of 87 animals caught in summer were from one woodlot (no. 5), and in 1941, 44 of 76 were taken in the same 23-acre woods. This distribution of the animals would indicate a population of 2.0 to 2.5 individuals per acre for this one woodlot, while other woodlots had as few as one animal per 8 to 15 acres.

Habitat preferences

As has been indicated above, chipmunks showed definite preferences in regard to type and condition of woodlots. A comparison of the total catch in woodlots trapped concurrently and with the same intensity will show the nature of some of these preferences.

Effects of grazing.- The catch records for chipmunks, during several periods when significant numbers were handled, are given in appendix table vii. These returns were obtained from three grazed and three ungrazed, upland woodlots which totaled 41 and 45 acres

Fig. 56. Over 20 years of grazing eliminated most of the reproduction in this upland, oak-hickory woodlot. After 5 years of protection, new seedlings are slowly becoming established in the bluegrass sod.

Fig. 57. Woodlots having a moderately dense understory and scattered clumps of ground cover supported high populations of chipmunks.

respectively. In fig. 58, the results have been converted to a unit area basis of 100 acres. It should be borne in mind that these data are offered only for the purpose of comparing the relative catch of chipmunks within each given trapping period. Since trapping periods were of variable length, comparisons between periods would not be entirely valid, and for the same reason, it is doubtful that actual populations are shown with any real accuracy.

Catch records at intervals over three years showed that these animals consistently were using ungrazed woodlands to a far greater extent than they were the grazed units. The numbers taken in each period were from three to six times higher in ungrazed woodlots, and with minor exceptions the trap returns for individual areas showed that each of the ungrazed units was supporting greater numbers than were any of those which had been grazed. The chipmunks' greater use of ungrazed woodlands indicates a preference also shared by the red squirrel. In view of the habits of the two species, it is not surprising that they would reach their greatest abundance in areas offering abundant ground cover.

Upland and lowland types.- Trapping returns for six upland woodlots of 86 acres and two lowland woodlots totaling 26 acres are given in appendix table vii. These data have been projected to a "catch per unit area" basis and the results shown graphically in fig. 59. During the summer and autumn of 1940, chipmunks were 9 to 12 times as abundant in upland woodlots as they were in lowlands. In the summer of 1941, a similar marked preference for the upland type was shown with a catch about 11 times as high as that in lowland woods. In 1942, however, about equal numbers were taken in the two types in summer trapping, and a slightly higher catch was made in autumn in the lowland type. Howell (1929) and Quimby (1944) have reported that this species shows a definite preference for upland woodlands.

As has been pointed out, the difference in length of trapping periods does not allow for close comparisons of populations from period to period, or from year to year. However, the longest trapping intervals occurred in 1940, and the fact that the lowland catch of chipmunks was highest in 1942 is some evidence that an increase may have occurred in these habitats. If the higher catches in 1942 in lowland areas did reflect an increase, or even a maintenance of numbers in face of a decline in upland areas, no satisfactory explanation can be offered. Food should not have been an incentive for a movement, since supplies appeared to be adequate in both types. Neither is there any reason to suppose that production or survival of young was greater in lowland situations. Weather conditions, also, were about normal during the summer and fall of 1942, and during the preceding winter. While it may be of no special significance, it is, nevertheless, of interest that Quimby (1944) observed somewhat the same situation for this species, and during the same years in Minnesota. He reported that, "*Eutamias*, which I have taken most often in swamps....was more abundant in 1942 than in 1941, while *Tamias*, which according to my records is more of an upland species....was less abundant in 1942. In general, the species and

individuals preferring swamps were able to maintain approximately the same populations for the two years whereas those preferring the more open uplands decreased considerably." In explanation of this situation, Quimby suggested that weather conditions were such as to cause a differential overwintering success in the two habitats.

Outlying habitats.- In contrast to red squirrels which inhabited, and frequently visited, small patches of woody cover and fencerows lying some distance from woodlands, the chipmunk seldom was taken away from woodlots. Only 34 of 296 individuals were taken in "field line" traps, and among 56 animals handled five or more times, only two were credited with residence outside of woodlands. Chipmunks also were observed to confine their activities to a given locality to a far greater degree than did red squirrels. In the case of the latter species, less than half the individuals handled five or more times limited their travels to one woodlot. Among chipmunks, 91 percent of those with a record of five or more catches were taken in only a single woodlot (table 24). In this farmland area, the failure of chipmunks to colonize outlying cover areas to the extent noticed for red squirrels probably can be attributed to their reluctance to cross open ground. Burt (1940) states, "Chipmunks in this area rarely are seen at any distance from wooded or brush-covered areas..... They always seem to desire a protective cover and certainly are not at home in the open." Howell (1929) observes that, "....they are partial also to stone walls and rail fences but rarely leave their protecting shelter for any distance to enter adjacent fields."

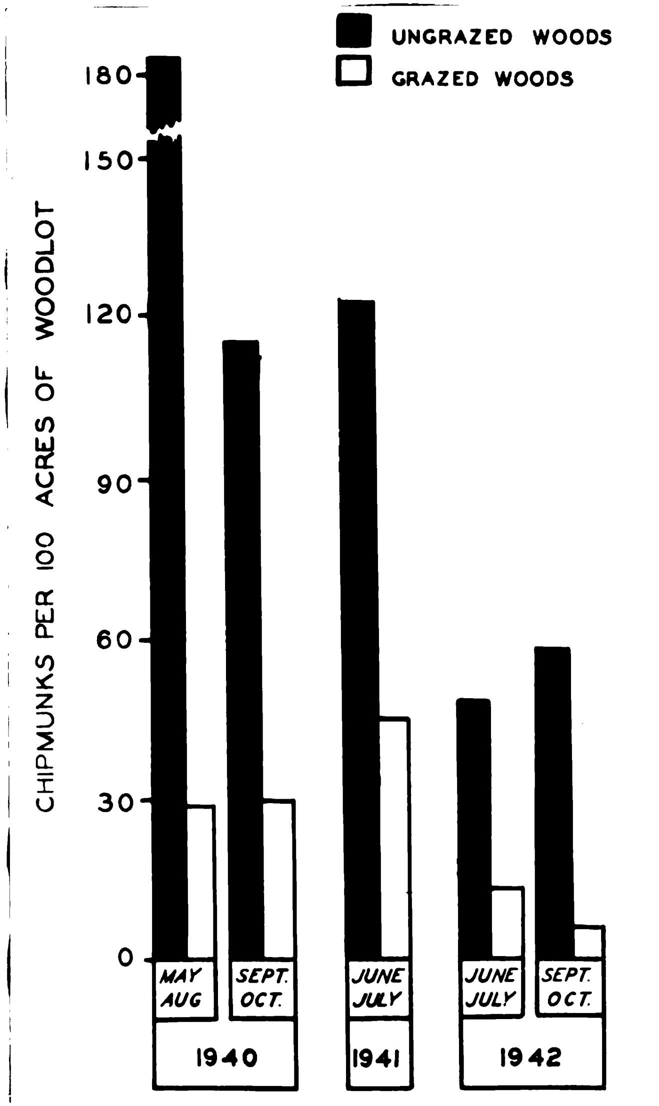

Fig. 58. Comparative numbers of chipmunks trapped in grazed and ungrazed woodlots.

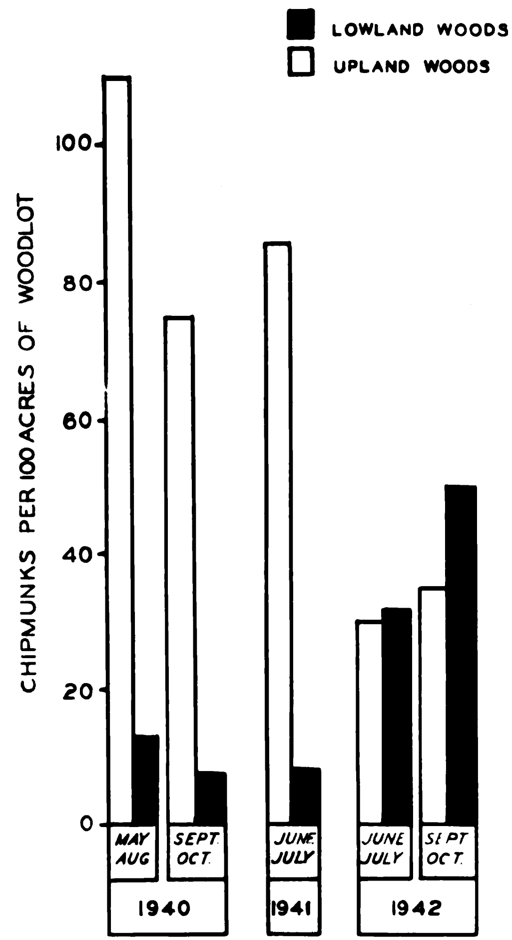

Fig. 59. Comparative numbers of chipmunks trapped in upland and lowland woodlots.

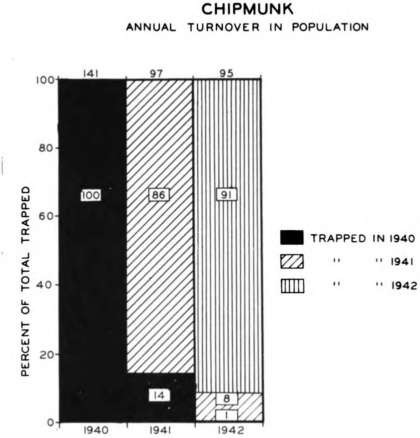

Fig. 60. The numbers of chipmunks remaining in study woodlots from one calendar year to the next.

Biological notes

Population turnover and longevity.- Allen, E. G. (1938) gives accounts of two captive chipmunks, one of which reached the age of 5 years and the other nearly 8 years. It is doubtful that very many experience such a life-span in the wild. In a study extending over 3 years, Burt (1940) marked 106 of these animals and had one individual which he knew to be 3 years old, and three others which were at least 2 years old. In this study, 141 individuals were marked in the first year and of these only one was accounted for 2 years later. This adult female (no. 5845) was first trapped on August 26, 1940, and was last handled on April 15, 1942, at which time it was at least 3 years old. Between these dates it was trapped a total of nine times, six of these captures being in the same trap, and on three other occasions the animal was taken in an adjacent trap.

There was little evidence in this work to indicate extensive distributional movements for chipmunks. Consequently, the marked year-to-year turnover in populations must be credited mainly to a high mortality. Limited information indicated that as many as 90 percent of those reaching an independent age in any one year succumb before the following year. In 1941, only 14 animals were recovered of 141 marked the previous year. In 1942, nine were still present on the area out of a total of 97 handled the previous year (fig. 60).

While no particular effort was given to evaluating mortality factors for woodland mammals, one predator relationship involving the chipmunk and weasel seems worthy of note. While evidence for the importance of this relationship is mostly circumstantial, it is probably no coincidence that woodlots most densely populated with chipmunks also supported the greatest numbers of this small predator.

In summer trapping, 1940, 57 of a total of 87 chipmunks handled in the seven study units were taken in one 23-acre woodlot (no. 5). In this same period, five of eight weasels trapped in woodlands were taken from this same woods. In 1941, woodlot 5 again produced a majority of the chipmunks trapped in summer (44 of a total of 76). During this period two of a total of five weasels caught were taken from this woods, and two others were trapped in the woodlot (no. 1) supporting the second highest number of chipmunks.

The importance of the weasel as a predator on chipmunks apparently has not been investigated. Allen, E. G. (1938) suspected that domestic cats take the highest toll, and added that, "The enemy next most dreaded is, perhaps the weasel ...." Williams (1936) observed cats stalking chipmunks and indicated also that foxes and weasels might be of some importance as predators. Allen, D. L. (1938) reported, "....weasels are most effectively adapted to preying upon small fossorial animals. They are persistent enemies of such mammals as chipmunks, spermophiles, and all species of mice..... All appearances indicate that the weasel may be the most effective check on the numbers of the spermophile on this area." McClelland (1948) on two occasions witnessed a weasel pursuing a chipmunk and commented further that, "The number of chipmunks varied greatly from year to year, and one factor may have been the weasel (<u>Mustela</u>)."

Aside from a concentration of weasels in those woodlots most densely populated by chipmunks, no good evidence was obtained as to the importance of the relationship. When released from traps weasels frequently entered burrows known to be used by chipmunks. On a number of occasions weasels burrowed under box-traps containing chipmunks, and in some unobserved manner were able to chew the feet of these trapped animals. Two or three trapped chipmunks were killed by weasels which apparently had been able to grasp them through the floor of the trap. Also, one instance of a bold attack of a weasel upon a chipmunk was observed. This weasel (no. 5374), when released from a trap, remained within a few yards of the operator while a chipmunk from an adjacent trap was examined. When the chipmunk (no. 5630) was released, the weasel caught and killed the animal before it had progressed more than a few yards from the trap.

Trapability.- In each year of study the repeat catches averaged slightly higher for females than for males (table 25). While the difference is not appreciable, it is hardly what would be expected considering that females probably are more restricted in their movements due to their preoccupation with family duties. In studies on the long-eared chipmunk (Eutamias quadrimaculatus), Holdenried (1940) also recaptured females somewhat more frequently than the males.

Sex ratio.- Blair (1942) in a study of this species in northern Michigan found an even sex ratio (51.3% males and 48.7% females) among 154 live-trapped individuals. In his studies on the George Reserve (Livingston County, Michigan) Burt (1940) took 106 chipmunks in the ratio of 60 percent males to 40 percent females. Among 333 individuals handled at Rose Lake, males were found to constitute only 40 percent of the total and females 60 percent. A similar unbalance of the sexes is noted when the data are considered separately by years (table 26). Whether or not such differences in sex ratio are significant is hard to say. Allen, E. G. (1938), Condrin (1936), and Schooley (1934) have observed that males appear first from hibernation in spring, and Schooley (*op. cit.*) comments further as follows: "Early in the spring the entire catch of animals is likely to be males. This condition changes rapidly so that after about a week of favorable weather the proportion may be three males to one female. The ratio continues to shift until, after a large percentage of the females have ovulated, the balance may have shifted to one male to three females." It is obvious that such differential activity of the sexes would be difficult to evaluate in instances where unbalanced ratios are observed.

Hibernation.- Trapping in early spring and late fall was not of a continuous nature which would allow for determining accurately the dates of entry into, and emergence from, hibernation. However, sight and trapping records testify that this animal is not markedly regular in the matter of hibernation. Individuals occasionally were seen in late November and a few became active on warm days in midwinter. In late December of 1940, two were taken in traps, and another was trapped in mid-January of 1942. In the latter instance the animal emerged during a week when the average temperature was

27 degrees F. with a maximum of 43 degrees. Other investigators have observed that chipmunks may emerge from winter hibernation when weather conditions are favorable (Howell, 1929; Test, 1932; Williams, 1936; Allen, E. G., 1938).

Table 24.
Permanency of residence of 56 chipmunks handled 5 or more times

	Situations Where Caught				
	One woodlot	Two woodlots	Three or more woodlots	Woodlot and field line	Field line only
No. of individuals:	51	1	0	2	2
Percent of total:	91.0	1.8	0	3.6	3.6

Table 25.
Total catches of chipmunks and averages for each sex.

	Males			Females		
	Individuals	Catches	Catches per individual	Individuals	Catches	Catches per individual
1940	51	130	2.55	83	267	3.22
1941	42	98	2.33	49	133	2.71
1942	35	66	1.88	58	114	1.97
Totals	128*	294	2.30	190*	514	2.71

*Includes some duplication of individuals between years.

Table 26.
Sex ratio of chipmunks taken in live-traps.

	Year			
	1940	1941	1942	Total
Total examined:	141	97	95	333
Males:	53	45	36	134
Females:	88	52	59	199
Males/100 females:	60	87	61	67

Southern Flying Squirrel
(*Glaucomys volans volans* Linnaeus)

While most authorities agree that flying squirrels are among the most arboreal of the sciurids, there is little agreement on the extent to which they may move around at ground level. Little ground travel is indicated for the species by Sollberger (1940), and by Howell (1918) who reported that they seldom descend to the ground, ".... apparently never running for any distance on its surface". Other workers are inclined to credit these animals with considerable activity on the ground, and Burt (1940) reported that they may move between woodlots by traveling under the cover of brushy areas. The trapping experiences of Jordan (1948) would also indicate frequent ground travel: "Of all traps which were successful in making captures, only six were located above ground level, a fact that conflicted with the previously accepted techniques of attaching them to the boles of trees." Since flying squirrels are frequently captured by house cats, and are a common source of aggravation to northern fur trappers (Nelson, 1918), an exclusively arboreal existence is hardly indicated.

Populations

While observations in this study suggested frequent terrestrial travel by flying squirrels, it is doubtful if ground trapping was effective in obtaining accurate population figures. The animals entered ground traps readily, but a few comparisons with tree-located traps showed that the former were less effective. During the last three weeks in December, 1941, 10 nest-box traps were paired in location with 10 box-traps and operated concurrently. No flying squirrels were taken in box-traps, whereas the tree-placed traps caught two animals, three times. The same combination was tried in a different woodlot for 14 days in mid-March. Nest-box traps in this case took two animals and box-traps failed to make a catch. Considering these limitations of method, the data are recorded here with a realization that population figures may be low. However, this should not interfere with one of the main uses of the data, that of showing comparative densities and annual trends.

In his studies on the George Reserve, Burt (1940) found that the flying squirrel population on a 3.72-acre plot ranged from 1.6 to 1.34 animals per acre from late June to mid-August. Near Ann Arbor, Michigan, Jordan (1948) took slightly more than one animal per acre on a 28-acre oak-hickory woodlot during July and August. Bole (1939) observed marked variations in the numbers of these squirrels in Ohio woodlands. The largest population noted by him was six per acre in a beech-maple forest during late summer. He estimated that peak populations in 1935 "....were generally in the vicinity of 3 per acre....", and in 1939 animals were so few that

scarcely an individual could be collected. Sollberger (1943) reported taking nearly five per acre from a small Pennsylvania woodland and 2.2 per acre from a 10-acre woods near Ithaca, New York.

While it is doubtful that box-trapping effected a complete catch in this study, July-August trapping in 1940 took 50 individuals on 102 acres. In September-October of the same year 36 were taken, and in December only eight. In 1941, trapping produced 11 individuals in June and July but none in September and October. During 1942, five periods of trapping between January and November never resulted in a catch of more than six of these animals. Obviously flying squirrels underwent a marked decline in numbers from 1940 to 1942. There is no way of knowing whether the 1940 population represented a high density for this area, or if even then it may have been reduced from an earlier "high". In any case, the minimum average population for 102 acres during that summer and fall period was close to one squirrel per two acres.

For several years after 1942, activities of the station were so reduced that intensive box-trapping could not be maintained as a means of following population trends of many species. However, a 10-day interval of trapping from April 21 to May 1, 1944 took 16 flying squirrels from one 15-acre woodlot, which would indicate some recovery of numbers by that year.

As has already been reported for the other sciurids, the flying squirrel population in the seven woodlots was by no means evenly distributed. With the highest population studied in the summer of 1940, one squirrel per acre represented the maximum catch for any of the woodlots. This density was measured in woodlot 6, an ungrazed unit of 12 acres. In the same period, no animals were taken in woodlot 1, a 10-acre woods of similar condition and composition. This woodlot was the only one of seven which evidently was uninhabited by flying squirrels in the summer of 1940. In the fall of the same year, this unit again was the only one in which catches were not made, and it was not until late December that there was evidence of flying squirrels using the area. Two were taken in nest-box traps at that time. No further catches were made in this woodland during the following two years, a rather surprising situation since it contained many mature trees with dens, and appeared well-suited to the needs of this species. It was, however, the most isolated of all the woodlands, and after a total loss of animals, re-establishment of a population in the area conceivably might be a long-delayed event.

Habitat preferences

So few critical population studies have been conducted on this species that it is difficult to estimate what constitutes their optimum habitat. Sollberger (1940) reported that they occur most commonly in climax forests of the beech-maple type. He attributed this to the numerous nesting cavities and the usual abundance of nuts. In his studies of such a woodland (Sollberger, 1943), he found a population of 2.2 squirrels per acre, although the time of year is not indicated. Beech-maple woodlands studied by Bole (1939) in Ohio averaged about three per acre (presumably at the peak annual density) during a "high" period. Oak-hickory types apparently are

less productive of this species, since the figures obtained by Burt (1940), Jordan (1948), and in the present study, show populations of not much over one per acre during late summer.

This study failed to reveal significant differences in the numbers inhabiting upland oak-hickory, and lowland elm-maple types. With reference to the density of ground cover, a slight preference was shown for grazed woodlands (appendix table viii). This would seem to agree with the observations of Jordan (1948), who obtained the greatest number of catches in traps located where ground cover was of sparse to medium density. Both Jordan (1948) and Hanson (1944) observed that severely overgrazed woodlands were avoided by flying squirrels.

It is well-known that flying squirrels will construct outside nests in which they may bring forth young (Landwer, 1935; Cowan, 1936; Burt, 1940; Sollberger, 1943). Whether or not they require the more protective cover of tree-dens in winter apparently is not known. Cowan (op. cit.) indicates that while dens are used in winter in the Transition Zone, the outside type is preferred in summer. Hanson (1944) and Sollberger (1943) have indicated that the frequency of den trees may be important in regulating the numbers of flying squirrels in some areas.

This study afforded an opportunity to observe the use of artificial dens by flying squirrels, and to determine the possible effects of such cover on their populations. In July, 1940, 24 nest boxes were installed, two to the acre, in woodlot 6. These were subsequently examined for signs of occupancy in October and December, 1940, and in

April and May, 1941. Practically all boxes were used, either by arboreal mammals, several species of birds, or bees. Nests of shredded bark, and other signs of use by flying squirrels, were found in five boxes on three examinations and in four boxes on the fourth examination. Three flying squirrels were present in separate nest boxes at the time of the April, 1941, examination. While there were these repeated indications that flying squirrels were making good use of this abundant den cover, the population trend for this woodlot was no different from that noted in other woodlots under study. Just prior to installation of the boxes, 12 animals were taken by trapping. In autumn only two were taken, and in the following two years, trapping never accounted for any more than this number in this particular woodlot.

Biological notes

Population turnover.- Flying squirrels were undergoing a marked decline in numbers during the course of the study, and it is possible that the turnover of individuals was higher than would be the case with a thrifty population. In any event a low year-to-year survival is indicated, just as was found for the other sciurids studied, and as is probably the case for small mammals in general. Of 78 individuals marked in 1940, only four were retaken in the following year when they represented 21 percent of the much-reduced population. None of 14 animals trapped in 1941 was recovered in 1942 (fig. 61). The statement by Sollberger (1943) to the effect that, "Probably five years represents the normal life span of the flying squirrel," could hardly apply to wild populations.

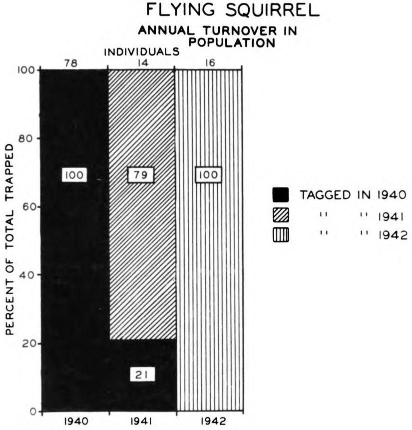

Fig. 61. The numbers of flying squirrels remaining in study woodlots from one calendar year to the next.

Table 27. Permanency of residence of 82 flying squirrels.

	Situations where trapped				
	One woodlot	Two woodlots	Three or more woodlots	Woodlot and field line	Field line only
No. of individuals:	66	14	0	1	1
Percent of total:	80.5	17.1	0	1.2	1.2

Table 28. Sex ratio of flying squirrels taken in live-traps.

	Year			
	1940	1941	1942	Total
Number examined:	78	11	16	105
Males:	39	3	6	48
Females:	39	8	10	57
Males/100 females:	100	38	60	84

Movements.- Considering the apparent ungainliness of these animals on the ground, a rather surprising number were found to have moved between woodlots (table 27). Fourteen of 82 animals were trapped in two woodlots, and in all cases the transfer would appear to have required travel over ground. Under the stimulus of a "homing urge", McCabe (1947) found that one of two marked females returned from a release point at a treeless distance of 1/4 mile, and over a woodland distance of 1-3/4 miles.

For several species of rodents, Evans and Holdenried (1943) have reported the frequent double capture of individuals of a species in single-catch traps. Similar evidence of flying squirrels traveling together has been reported by McCabe (1947). In this study, more than one-fifth (17 of 78) of the flying squirrels taken in 1940 were involved in double captures. This concomitancy in travel may have been related in part to breeding behavior, since 6 of 10 double captures involved opposite sexes. A few of these records are of interest for other behavior notes which they provide:

On July 4, 1940, adult male no. 5531 was taken in a trap in woodlot 4 with adult female no. 5532. On July 20, 1940, the same male was retrapped in woodlot 3 with a second adult female no. 5683. The record of this male might suggest a promiscuous breeding behavior.

Adult male no. 5424, captured in woodlot 5 on July 16, 1940, was retaken 2 days later at a point nearly a quarter mile away in woodlot 6. At the second capture it was accompanied by adult female no. 5425.

Immature male no. 5723 was trapped with immature female no. 5724 on July 31, 1940. One week later, on August 8, this male was recaptured in the same woodlot with an adult male no. 5663.

Trapability.- Recaptures of flying squirrels were considerably lower than for other sciurids, and among 104 individuals, nearly half were captured only once. As was found to be the case with chipmunks and red squirrels, females of this species were retrapped slightly more frequently than were the males.

Sex ratio.- Among 78 individuals caught in 1940, the sexes were equally divided. In the small numbers handled during the two following years, females outnumbered males two to one (table 28). Burt (1940) took 50 percent more males than females in a catch of 45 individuals, and in trapping 32 animals Jordan (1948) found an essentially even distribution of the sexes (15 males and 17 females).

Fig. 62. The white-footed mouse was the commonest small mammal in farm woodlots.

Fig. 63. An agile climber, the white-footed mouse usually took refuge in the nearest tree when released from a live-trap.

Fig. 64. White-footed mice often used nest sites of other species. The grass nest occupied by this animal was made by a red squirrel.

White-footed Mouse
(*Peromyscus leucopus noveboracensis* Fischer)

Trapping for this species was not done with an intensity which would permit an accurate appraisal of its year-to-year status. It is known, however, that these mice are subject to marked changes in numbers (Williams, 1936; Bole, 1939; Lindeborg, 1941). Limited catches in box-traps, together with information from other sources, would indicate that annual levels of the species remained fairly constant during the period of study. Certainly, they did not undergo the pronounced population changes noted for some sciurids.

Populations

Several early studies on this mouse resulted in population estimates as high as 200 or more individuals per acre. In the light of recent work, however, it is obvious that such counts were grossly exaggerated by fallacies in census methods and in calculation of densities. More recent investigations show close agreement in fall counts of 5 to 10 animals per acre for most deciduous woodlands (Burt, 1940; Hanson, 1944; Stickel, 1948). An average density of 29 per acre for upland forests in a known peak year, and a low of 5.2 per acre, were measured by Bole (1939).

In this study, intensive methods were employed to determine the white-footed mouse population of a representative unit of woodland. For this purpose the most isolated of the study woodlots (no. 1, fig. 44) was selected. This ungrazed, 10-acre unit of upland oak-hickory was surrounded by pasture and cropland. The nearest of the other woodlots was at a distance of more than a quarter mile, and the opportunity for any appreciable interchange of individuals appeared negligible. On October 6, 1942, the entire unit was saturated with 204 live-traps set out on a 10-foot grid. These were continued in operation for 7 nights, through October 12, by which date the rate of new captures was so low as to indicate that practically all of the individuals had been captured. The total catch was 76 white-footed mice and 27 individuals of other species. This near-peak annual density of 7.6 white-footed mice per acre is practically identical with that found by Burt (1940) in a similar woodland during early October trapping.

Habitat preferences

Townsend (1935) suspected that this species was "slightly more numerous in dry woods than in wet woods". Stickel (1948) took five to eight times as many in bottomlands as in upland woods. Limited trapping in this study indicated a preference for the lowland type. During the period November 1-3, 1942, traps spaced at 22-foot intervals, and located on single lines running through the center of two lowland and five upland woodlots, were operated for three nights. This involved 50 traps in lowland and 229 in upland units. The catch per 100 trap-nights was 4.2 individuals in the uplands and 11.8 in the lowland woods.

The response of these animals to the effects of grazing of woodlots was not clearly evident from the cursory studies made. Samples of each type of woodland, when trapped in 1940 and 1941, produced nearly equal numbers. In the 1942 trapping described above, 126 traps were located in grazed upland woods and 103 in ungrazed uplands. In this work a catch per 100 trap-nights of 2.9 individuals in grazed units compared with a catch of 5.8 animals in the ungrazed type. Hanson (1944) found these mice were more plentiful in a moderately grazed upland woodlot than in a severely grazed unit of similar type.

A possible further suggestion of habitat preferences of the white-footed mouse was shown by the intensive trapping of woodlot 1. This woodland and the rows of traps are shown diagrammatically in fig. 65. The point at which each of 158 captures of 76 white-footed mice was made is shown by an "X". It would appear from the distribution of these catches that activity over some parts of this woods was considerably greater than in other parts. While several factors might contribute to this apparent irregularity in distribution of the mice, there was a fairly good correlation between density of ground cover and number of catches. Although the woods as a whole is a typical ungrazed type, limited grazing a number of years ago resulted in a reduction of cover along the north and south edges (top and bottom in fig. 65). This permitted the establishment of bluegrass sod that a fairly open canopy had allowed to persist to the time of the study. Burt (1940) has reported that this species avoids such grass areas in woodlots, and the catch records for this study substantiate this observation. Elsewhere in the woodlot, an apparent concentration of individuals was found along the intersection of vertical rows of traps 2 to 5 and horizontal rows D to F. This general vicinity marked one of the low areas in the woods. The shrub and sapling growth was particularly dense and the ground was covered with duff and litter. The greater than average take of mice in this situation is in accord with the observations of Hatfield (1938) who found this and another woodland species of Peromyscus to be most numerous on plots having an understory of shrubs which produced fruits of value as food. Indications of a proportionately large number of animals along the east (right in fig. 65) side of the woods is to be noted, also. The outer row of traps (no. 12) along this margin accounted for 36 captures of white-footed mice, compared, for instance, with only 6 catches in the two center rows (no.'s 6 and 7). Along the entire east edge of this woodland, the canopy was dense, the understory thrifty, and the immediate ground cover consequently sparse (fig. 66). While it may have been this combination which proved attractive to these mice, it is possible that a field of standing corn which bordered the edge that year may have encouraged activity in that area. Nicholson (1941) reported for this species that, "....nearly twice as many mice were captured in boxes near the edge of the woods as were taken in the center....." This tendency also may be reflected in the increased catch of animals on the east and, to a lesser extent, west borders of this woodlot.

While primarily a woodland dweller, the white-footed mouse is known to utilize small patches of brushland and groups of a few trees (Burt, 1940; Hanson, 1944). In this study the animals were taken regularly in shrub fencerows, and on several occasions all their needs appeared to have been provided by a single isolated tree.

Biological notes

Distribution movements.- It is not uncommon for individuals of this species to maintain themselves in shocked corn (Johnson, 1926; Linduska, 1942a; Hanson, 1944), and at times to appear in grassland several hundred yards from woodland cover (Blair, 1940b; Burt, 1940). Probably such appearances in fields can be attributed to population pressure in their preferred habitat. In the "trapping-removal" study (see table 11) a total of 17 of these animals were taken, and the greatest movement through this idle ground habitat coincided with the period (November) of peak annual density for the species.

Sex ratio.- Most sex ratios calculated for this species from trapping returns show a slight preponderance of males (Townsend, 1935: p. 42; Burt, 1940; Nicholson, 1941), a fact which is attributed to more widespread movements of this sex. The numbers handled in the present study were too low for real significance. It is of interest, however, that in the total population trapped in woodlot 1, there was a marked preponderance of females among the adult age class and a slight excess of males in the case of immature animals. In the same autumn period, a small sample obtained from eight woodlots showed similar relationships. For 122 individuals handled at this time, 25 adults included 6 males and 19 females (32 males : 100 females), and 97 young included 54 males and 43 females (126 males : 100 females).

	1	2	3	4	5	6	7	8	9	10	11	12
A			XX		XX					XXX X	XX	
B	X				X	X						
C			XX		0					X	XX	XXX XX
D	XX	0	XXX X	XX 0	X			X		XXX		XXX X
E	XX 0	XX 0	X 0	XXX X	XXX X		X	X 0				XXX 0
F	X	XXX XX	X	XX	XX	X	X	XX				XX
G	XX						0	0	0		X	XXX XX
H	X	X	XX	XXX	X				X		X	XXX
I	X 00		X	X	X						XXX	
J	XX 0		XX						XX	XX		XX
K			X		X			0				X 00
L	X 0	XX										XXX 0
M			X	X		0					X 00	X
N	0	XX					X				X 0	XX
O		0	X	X	X							XX
P	X			X	XXX X			X	X	X		XXX 0
Q	XXX	XXX	XX			X						

Fig. 65. Diagram of woodlot 1 showing location of lines of traps, and points at which 76 white-footed mice (X) were trapped 158 times and 25 short-tailed shrews (0) 26 times.

Fig. 66. This 10-acre unit of upland oak-hickory offered excellent possibilities for studies of an ungrazed woodlot. From October 6-12, 1942, 204 live-traps on a 10-foot grid took 76 white-footed mice and 27 individuals of other species.

Short-tailed Shrew
(Blarina brevicauda kirtlandi Bole and Moulthrop)

Probably most of these animals in woodlot 1 were taken in the intensive trapping of that area. The total of 25 indicated a population (2.5 per acre) considerably lower than that estimated by Bole (1939) and Burt (1940) for similar habitats.

Too few of these shrews were caught in woodlot trapping generally to permit a detailed consideration of habitat preferences. While they were common at times in bluegrass sod bordering croplands, they appeared to avoid such a habitat where it occurred in woodlot 1. Instead, the greatest percentage of the population in this woods was trapped along the east and west margins (right and left in fig. 65), where the layer of duff and litter was heaviest. The two outer rows of traps along these two edges accounted for twice as many catches (17) as was made in the eight intervening rows (9).

In other woodlots limited trapping indicated densities in lowlands similar to those in ungrazed uplands. Grazing appeared to limit numbers strongly. In August, 1941, nine shrews were taken in an ungrazed woods and the same intensity of trapping (170 trap-nights) took only one in a grazed unit. In 1942, trapping for 309 trap-nights in two ungrazed woodlots produced eight of these animals, and concurrent trapping of similar intensity (378 trap-nights) in four grazed units resulted in the capture of only one.

It is understandable that burrowing animals like the short-tailed shrew would find conditions more appropriate to their needs in the mulch layer of ungrazed woodlands than in the exposed hard-packed mineral soils common in many grazed areas. Other results of grazing were mentioned by Dambach (1944) in explanation of population differences similar to those noted here. He observed that invertebrates in an ungrazed tract were two and one-half times as plentiful as in a grazed area and that freezing of the soil is much less severe in ungrazed woodlands.

With reference to the latter point a series of temperatures was taken at various soil depths in two grazed and two ungrazed woodlots in the winter of 1942. This work was accomplished by means of a Leeds-Northrup potentiometer and a number of Constantan-copper thermocouples (fig. 46) loaned through the courtesy of W. U. Garstka of the Soil Conservation Service, U. S. Department of Agriculture.

Under the conditions of the study, no significant differences in soil temperatures were measured in the two types of woodlands. This was to be expected, since a cover of snow of comparable depth was present in all units during the period when records were taken. At other times it was observed that the comparative lack of ground cover in grazed woodlands allowed wind action to remove much or all of the snow. Under such conditions low air temperatures probably would produce lower soil temperatures in grazed than in ungrazed areas. A sample of records obtained for one of the ungrazed woodlands is shown in fig. 68.

Fig. 67. Trilliums are a common early spring flower in the lowland woodlots. This study woods, heavily cut-over in parts but ungrazed, had an excellent duff and litter layer. The short-tailed shrew was abundant here.

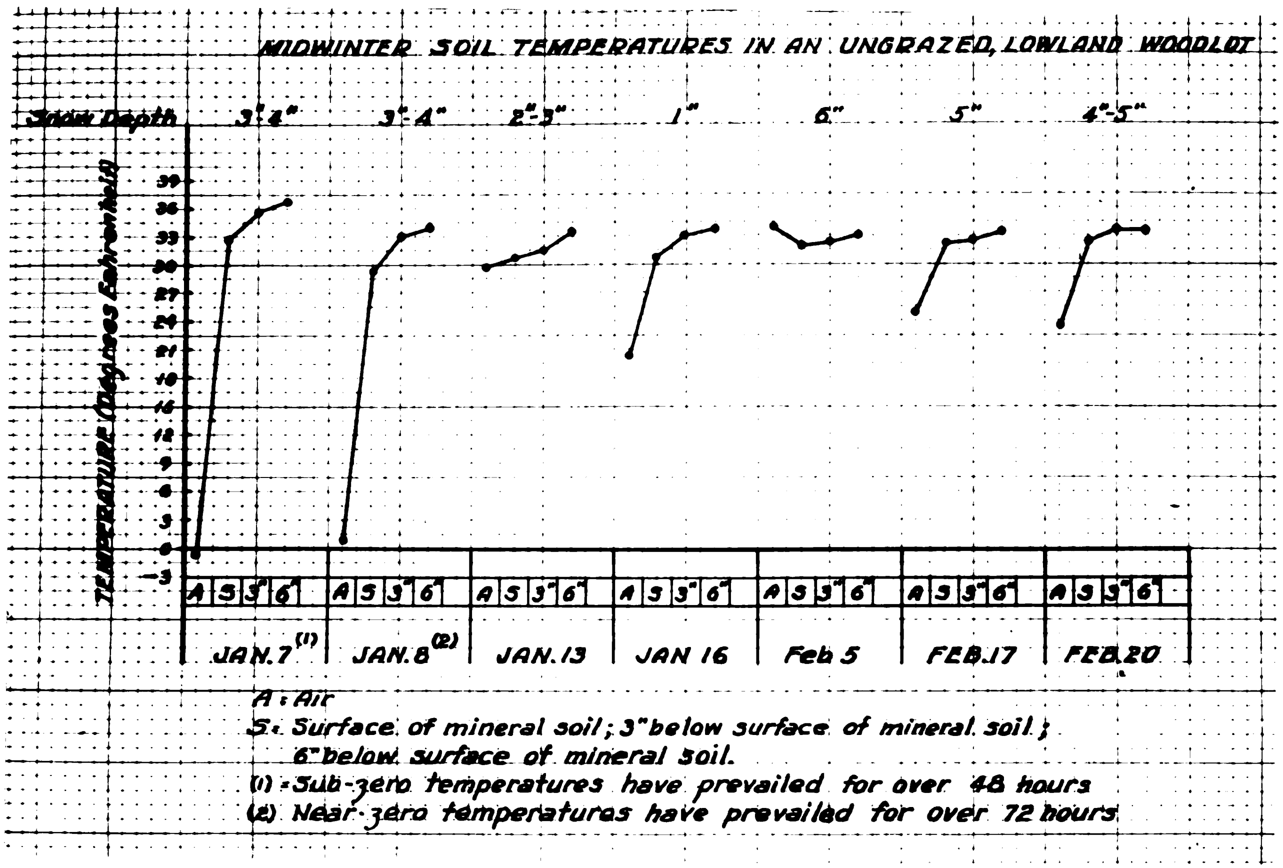

Fig. 68. Burrowing mammals of ungrazed woodlands find a remarkably uniform microclimate in their habitat. The above series of soil temperature records taken in 1942 show little fluctuation even though air temperatures varied widely.

Other Woodland Inhabitants

Several species of small mammals were taken too infrequently in woodlands to provide information on their habits. These were the meadow vole, house mouse, bog lemming, and pine vole. Several species of larger mammals including the cottontail rabbit, opossum, raccoon, skunk, red fox, woodchuck, and long-tailed weasel, also were present in various numbers. The last mentioned is the only one of the group suspected of having an important direct effect on any of the small mammals. This relationship has been discussed under the section on chipmunks.

Acorn weevils

Most woodland rodents depend partly or almost entirely on the annual mast crop for food. A consideration of interrelationships of the woodland fauna would hardly be complete without some mention of what appears to be one of the most serious competitors for this food supply. Korstian (1927) has shown a high loss of acorns to insects generally, and in this study, species of Balaninus, the acorn weevil, were found to be especially important in this regard.

In the fall of 1941, acorns of several species of oaks were examined to determine the incidence of infestation by larvae of Balaninus. The results are summarized in table 29. It will be noted that from 67 to 81 percent of the acorns of white, jack, and black oak were infested. Only seven percent of the red oak acorns had been entered by this insect, a fact of some interest since Baumgras

(1944) found that red oak acorns were poorly accepted by fox squirrels. Apparently both of these mast feeders find the high tannin content (Wainio and Forbes, 1941) and resultant bitterness of the red oak acorn distasteful.

It is doubtful that weevil-infested acorns should be considered entirely a debit in the economy of woodland vertebrates, since many small mammals undoubtedly would utilize the insects (see point 12 in summary of part 1). Gray squirrels are known to relish the larvae of Balaninus (Hatt, 1929), and Petrides (1944) has noted this same squirrel feeding on the larvae of gall insects. However, Dennis (1930) has written of the rejection of "wormy nuts" by the gray squirrel, and Sollberger (1940) probably had reference to insect-infested nuts when, regarding food storage by the flying squirrel, he remarked that, "Worthless nuts are not buried."

Table 29. Infestation of acorns by the acorn weevil (*Balaninus* spp.).

Species	No. of acorns examined	No. of acorns infested	Percent infested
Black oak (*Quercus velutina*)	556	451	81
Jack oak (*Q. ellipsoidalis*)	1,128	881	78
White oak (*Q. alba*)	875	584	67
Red oak (*Q. borealis maxima*)	886	63	7

SUMMARY AND DISCUSSION

1. Scope and methods of study. During the years 1940-42, intensive box-trapping was employed to determine numbers and population dynamics of the Sciuridae of farm woodlots. Studies were conducted principally in seven units totaling 102 acres. Box-trapping during the 3-year period amounted to 29,748 trap-days. Among the principal species discussed (red squirrel, flying squirrel, and chipmunk), a total of 748 individuals were trapped 2,176 times in woodlots. Other records for animals living away from woodlands were obtained from 34,032 trap-days of operation in swales, fencerows, and similar habitats. Limited work with small live-traps resulted in the capture of 194 mice and shrews (mostly white-footed mice) in 3,210 trap-nights.

2. Annual population trends of the Sciuridae. Fox squirrels increased markedly in numbers during the 3 years of study, and the 1942 population probably was nearly double that of 1940. Other sciurids decreased: flying squirrels to the greatest extent (by 75 percent or more); red squirrels to a somewhat lesser degree; and chipmunks the least. Red squirrels in fencerows, swales, and other outlying habitats appeared to maintain fairly uniform population levels in the face of the marked decline among some of the other woodlot dwellers. In the same period there was no evidence among white-footed mice of any marked population changes.

3. Habitat preferences and interrelationships of woodland mammals.

Each of the eight woodlands involved in this study was populated by the white-footed mouse and all four species of sciurids mentioned above. The consistency with which these animals were associated would indicate that no marked incompatibility existed. Nevertheless, all were in direct competition for the same foods and, with the exception of the chipmunk, for the same nest sites. The intensity of such competition may have been mitigated to some extent by differences in daily and seasonal activity rythyms, and further by species preferences for woodlots of a certain type or condition.

(a) Fox squirrel. This animal showed a marked preference for upland oak-hickory woodlots, and it was taken about three times as frequently in this type as in lowland elm-maple. A sparse ground cover appeared favorable to populations of this species, and in uplands they were most abundant in grazed woodlots.

(b) Red squirrel. In contrast with the fox squirrel, this species reached its greatest numbers in lowland woodlots. In this type, and over various seasons, the numbers trapped were 2 to 8 times greater than in uplands. The response of the red squirrel to effects of grazing was not clearly evident. However, a consistent preference was shown for ungrazed situations. In this respect it differed from the fox squirrel.

The red squirrel appeared to be the most adaptable of the arboreal squirrels in the utilization of habitats other than woodlots. Most swales and brushy fencerows were occupied by a few individuals, and others were taken frequently where the only wood cover was one or two isolated trees.

(c) Chipmunk. With high populations in 1940 and 1941, chipmunks were 9 to 12 times more abundant in uplands than they were in lowland woodlots. With a reduced total population in 1942, about equal numbers were taken in the two types. Reasons for this apparent differential rate of decline were not clear. However, a relatively high population of weasels was concentrated in upland woodlots and this may offer a partial explanation of the disproportionate reduction of chipmunks in this situation. During 1940 five weasels inhabited a 23-acre woodlot which at that time was the area most densely populated by chipmunks.

Requirements of this species for a dense ground cover probably account for the greater number taken in ungrazed woodlands. The chipmunk catch in this type was 3 to 6 times greater than in grazed units.

(d) Flying squirrel. No clear-cut preference for a particular kind of woodland habitat was observed among flying squirrels. The numbers taken in upland and lowland units were comparable, but slightly higher catches were made in grazed woodlots where ground cover was sparse.

(e) White-footed mouse and short-tailed shrew. The white-footed mouse was the commonest mammal of these farm woodlots, where it competed directly with the species mentioned above for food and nesting sites. It was taken more commonly in lowland than in upland woods, and in the uplands it appeared to be more plentiful in ungrazed units. An October population of 7.6 individuals per acre was found in an isolated 10-acre woodlot of an ungrazed, upland, oak-hickory type. The local distribution of this population was correlated with the density of ground cover. Sod areas were avoided, and low or edge areas, with a dense understory of shrubs but little immediate ground cover, supported the greatest numbers. In common with the red squirrel, individuals of this species frequently inhabited single trees or small units of wood and brush cover which were entirely isolated from woodlands.

In the herbaceous habitats of farmland, short-tailed shrews were most abundant and widespread in areas of bluegrass sod. This same habitat in woodlots supported few of these animals compared to the much higher numbers in situations where a dense canopy and heavy understory had all but eliminated herbaceous plants, and where a thick mulch layer was present. These requirements probably accounted for its scarcity under conditions resulting from grazing.

A 10-acre woodlot, which by appearances offered optimum conditions for this species, contained a fall population of only 2.5 individuals per acre. This density is well below that reported for similar habitats at other times.

LITERATURE CITED

Aldous, Shaler E. 1931. A fly-eating mouse. Jour. Mamm. 12: 316.

Allen, Durward L. 1938. Ecological studies on the vertebrate fauna of a 500-acre farm in Kalamazoo county, Michigan. Ecol. Monogr. 8: 347-436.

-----1939. Winter habits of Michigan skunks. Jour. Wildlife Mgt. 3: 212-228.

-----1940. Millions of little teeth. Michigan Conservation. September.

------1941. Relationships of winter weather to farmland wildlife in the midwest. Proc. Central Snow Conf. 1: 95-102.

-----1943. Michigan fox squirrel management. Michigan Department of Conservation, Game Division publ. 100, pp. 1-404.

Allen, Durward L., and H. D. McGinley. 1947. A method for the year-to-year measurement of mast yields. Jour. Wildlife Mgt. 11: 184-185.

Allen, Durward L., and Warren W. Shapton. 1942. An ecological study of winter dens, with special reference to the eastern skunk. Ecology 23: 59-68.

Allen, Elsa G. 1938. The habits and life history of the eastern chipmunk, Tamias striatus lysteri. Bull. New York State Mus. no. 314, pp. 1-122.

Bailey, Vernon. 1900. Revision of American voles of the genus Microtus. U. S. Dept. Agr., Div. Biol. Survey, No. Amer. Fauna 17: 1-79.

------1923. Mammals of the District of Columbia. Proc. Biol. Soc. Washington 36: 103-138.

------1924. Breeding, feeding, and other life habits of meadow mice (Microtus). Jour. Agr. Research 28: 523-535.

Baker, J. R. 1930. The breeding season in British wild mice. Proc. Zool. Soc. London. (Part 1): 113-126.

Baker, J. R., and R. M. Ranson. 1932a. Factors affecting the breeding of the field mouse (Microtus agrestis). Part 1. Light. Proc. Royal Soc. London (B) 110: 313-322.

------1932b. Factors affecting the breeding of the field mouse (Microtus agrestis). Part 2. Temperature and food. Proc. Royal Soc. London (B) 112: 39-46.

Balch, R. E. 1936. European spruce sawfly outbreak in 1935. Canadian Entomologist 68: 23-31.

-----1937. The spruce sawfly outbreak in 1936. Pulp and Paper Mag. of Canada. February.

Barrows, W. B., and E. A. Schwarz. 1895. The common crow of the United States. U. S. Dept. Agr., Div. Ornith. and Mamm. Bull. 6: 1-98.

Baumgras, Philip S. 1942a. An unusual clutch of marsh hawk eggs. Wilson Bull. 54: 50.

-----1942b. A technique for confining nestling crows in food-habit studies. Wilson Bull. 54: 251-252.

-----1942c. Population studies and habitat improvement for southern Michigan fox squirrels. Michigan Dept. Cons., Game Div., Unpub. Report :1-112.

-----1943. Winter food productivity of agricultural land for seed-eating birds and mammals. Jour. Wildlife Mgt. 7: 13-18.

-----1944. Experimental feeding of captive fox squirrels. Jour. Wildlife Mgt. 8: 296-300.

Bent, Arthur C. 1937. Life histories of North American birds of prey, Order Falconiformes (Part I). U. S. Nat. Mus. Bull. 167: viii + 409.

Bess, Henry A., Stephen H. Spurr, and E. W. Littlefield. 1947. Forest site conditions and the gypsy moth. Harvard Forest, Bull. 22: 1-56.

Blair, W. Frank. 1938. Ecological relationships of the mammals of the Bird Creek region, northeastern Oklahoma. Amer. Midland Naturalist 20: 473-526.

-----1940a. A study of prairie deer-mouse populations in southern Michigan. Amer. Midland Naturalist 24: 273-305.

-----1940b. Home ranges and populations of the meadow vole in southern Michigan. Jour. Wildlife Mgt. 4: 149-161.

-----1940c. Home ranges and populations of the jumping mouse. Amer. Midland Naturalist 23: 244-250.

-----1940d. Notes on home ranges and populations of the short-tailed shrew. Ecology 21: 284-288.

Blair, W. Frank. 1941. Techniques for the study of mammal populations. Jour. Mamm. 22: 148-157.

-----1942. Size of home range and notes on the life history of the woodland deer-mouse and eastern chipmunk in northern Michigan. Jour. Mamm. 23: 27-36.

------1943. Populations of the deermouse and associated small mammals in the mesquite association of southern New Mexico. Univ. Michigan, Contr. Lab. Vert. Biol. 21: 1-40.

Bole, B. P. 1939. The quadrat method of studying small mammal populations. Sci. Publ. Cleveland Mus. Nat. Hist. 5: 15-77.

Breckenridge, W. J. 1935. An ecological study of some Minnesota marsh hawks. Condor 37: 268-276.

Brown, H. Leo. 1945. Evidence of winter breeding of Peromyscus. Ecology 26: 308-309.

Burt, William H. 1940. Territorial behavior and populations of some small mammals in southern Michigan. Univ. Michigan Press, Misc. Publ. Museum Zool. 45: 1-58.

------1943. Territoriality and home range concepts as applied to mammals. Jour. Mamm. 24: 346-352.

------1946. The mammals of Michigan. The University of Michigan Press, pp. 1-288.

Calhoun, John B. 1941. Distribution and food habits of small mammals in the vicinity of the Reelfoot Lake Biological Station. Jour. Tennessee Acad. Sci. 6: 177-185, 207-225.

Christian, John C. 1936. Mammals caught in post holes. Jour. Mamm. 17: 416.

Condrin, J. M. 1936. Observations on the seasonal and reproductive activities of the eastern chipmunk. Jour. Mamm. 17: 231-234.

Couch, Leo K. 1928. Relationship of predatory mammals and birds to rodent life. Jour. Mamm. 9: 73-74.

Cowan, Ian McT. 1936. Nesting habits of the flying squirrel. Jour. Mamm. 17: 58-60.

Dambach, Charles A. 1940. The effect of land-use adjustments on wildlife populations in the Ohio Valley region. Trans. Fifth No. Amer. Wildlife Conf. : 331-337.

Dambach, Charles A. 1944. A ten-year ecological study of adjoining grazed and ungrazed woodlands in northeastern Ohio. Ecol. Monogr. 14: 255-270.

------1945. A study of the insect ecology and economic value of crop field borders in relation to conservation practices. Ohio State University Press. Abstracts of Doctoral Dissertations, no. 48.

Dambach, Charles A., and E. E. Good. 1940. The effect of certain land use practices on populations of breeding birds in southwestern Ohio. Jour. Wildlife Mgt. 4: 63-76.

Dearborn, Ned. 1932. Foods of some predatory fur-bearing animals in Michigan. Univ. Michigan School Forestry and Cons. Bull. 1: 1-52.

Dennis, Wayne. 1930. Rejection of wormy nuts by squirrels. Jour. Mamm. 11: 195-201.

Dice, Lee R. 1921. Notes on the mammals of Interior Alaska. Jour. Mamm. 2: 20-28.

------1923a. Notes on some mammals of Riley County, Kansas. Jour. Mamm. 4: 107-112.

------1923b. Notes on the communities of vertebrates of Riley County, Kansas, with especial reference to amphibians, reptiles, and mammals. Ecology 4: 40-53.

------1938. Some census methods for mammals. Jour. Wildlife Mgt. 2: 119-130.

------1941. Methods for estimating populations of mammals. Jour. Wildlife Mgt. 5: 398-407.

Eadie, W. Robert. 1944. The short-tailed shrew and field mouse predation. Jour. Mamm. 25: 359-364.

Edgren, Richard A. 1948. Notes on a northern short-tailed shrew. Chicago Acad. Sci., Natural History Miscellanea (25): 1-2.

Elton, Charles. 1942. Voles, mice and lemmings. Oxford Univ. Press. pp. 1-496.

Elton, Charles, E. B. Ford, J. R. Baker, and A. D. Gardner. 1931. The health and parasites of a wild mouse population. Proc. Zool. Soc. London : 657-721.

Elton, Charles, D. H. S. Davis, and G. M. Findlay. 1935. An epidemic among voles (Microtus agrestis) on the Scottish border in the spring of 1934. Jour. Animal Ecol. 4: 277-288.

Erickson, Arnold B. 1938. Parasites of some Minnesota Cricetidae and Zapodidae, and a host catalogue of Helminth parasites of North American mice. Amer. Midland Naturalist 20: 575-589.

Errington, Paul L. 1931. Second winter. American Game, Jul.- Aug. : 56, 60-61.

------1932a. Food habits of southern Wisconsin raptors. Part 1. Owls. Condor 34: 176-186.

------1932b. Technique of raptor food habits study. Condor 34: 75-86.

------1933. Food habits of southern Wisconsin raptors. Part 2. Hawks. Condor 35: 19-29.

------1935. Food habits of mid-west foxes. Jour. Mamm. 16: 192-200.

------1936. Food habits of a weasel family. Jour. Mamm. 17: 406-407.

------1942. On the analysis of productivity in populations of higher vertebrates. Jour. Wildlife Mgt. 6: 165-181.

------1946. Predation and vertebrate populations. Qtly. Review Biol. 21: 144-177, 221-245.

Errington, Paul L., and W. J. Breckenridge. 1936. Food habits of marsh hawks in the glaciated prairie region of north-central United States. Amer. Midland Naturalist 17: 831-848.

Evans, F. C. 1942. Studies of a small mammal population in Bagley Wood, Berkshire. Jour. Animal Ecol. 11: 182-197.

Evans, F. C., and Robert Holdenried. 1943. Double captures of small rodents in California. Jour. Mamm. 24: 401.

Fenyuk, B. K. 1937. The influence of agriculture on the numbers of mouse-like rodents and the biological foundation of rodent control. Rev. Microbiol., Saratov 16: 478-492.

Findlay, G. M., and A. D. Middleton. 1934. Epidemic disease among voles (Microtus) with special reference to Toxoplasma. Jour. Animal Ecol. 3: 150-160.

Fisher, A. K. 1893. The hawks and owls of the United States in their relation to agriculture. U. S. Dept. Agr., Div. Ornith. and Mamm. Bull. 3: 1-201.

Good, E. E., and Charles A. Dambach. 1943. Effect of land use practices on breeding bird populations in Ohio. Jour. Wildlife Mgt. 7: 291-297.

Graham, S. A. 1929. The larch sawfly as an indicator of mouse abundance. Jour. Mamm. 10: 189-196.

Grinell, Joseph. 1914. An account of the mammals and birds of the lower Colorado Valley. Univ. California Publ. Zool. 12: 51-294.

Hamilton, William J. Jr. 1930. The food of the Soricidae. Jour. Mamm. 11: 26-39.

-----1933. The weasels of New York. Their natural history and economic status. Amer. Midland Naturalist 14: 289-344.

-----1937a. The biology of microtine cycles. Jour. Agr. Res. 54: 779-790.

-----1937b. Activity and home range of the field mouse, (Microtus pennsylvanicus pennsylvanicus (Ord). Ecology 18: 255-263.

-----1938a. Life history notes on the northern pine mouse. Jour. Mamm. 19: 163-170.

-----1938b. Small animals as a factor in the control of forest insects. Ecol. Soc. Amer. Bull. 19: 34.

-----1939. Observations on the life history of the red squirrel in New York. Amer. Midland Naturalist 22: 732-745.

-----1940. Life and habits of field mice. Scientific Monthly 50: 425-434.

-----1941a. Reproduction of the field mouse, Microtus pennsylvanicus (Ord). Cornell Univ. Agr. Exp. Sta. Memoir 237: 1-23.

-----1941b. The food of small forest mammals in eastern United States. Jour. Mamm. 22: 250-263.

Hamilton, William J. Jr., and David B. Cook. 1940. Small mammals and the forest. Jour. Forestry 38: 468-473.

Hanson, Harold C. 1939. Ecology in agriculture. Ecology 20: 111-117.

-----1944. Small mammal censuses near Prairie du Sac, Wisconsin. Trans. Wisconsin Acad. Sci., Arts and Letters 36: 105-129.

Harper, Francis. 1929. Notes on mammals of the Adirondacks. New York State Museum Handbook 8: 51-118.

Hatfield, D. M. 1938. Studies on rodent populations in a forested area. Jour. Mamm. 19: 207-211.

Hatt, Robert T. 1929. The red squirrel: its life history and habits, with special reference to the Adirondacks of New York and the Harvard Forest. Roosevelt Wild Life Annals 2: 1-146.

------1930. The biology of the voles of New York. Roosevelt Wild Life Bull. 5(4): 509-623.

Holdenried, Robert. 1940. A population study of the long-eared chipmunk (Eutamias quadrimaculatus) in the central Sierra Nevada. Jour. Mamm. 21: 405-411.

Hooper, Emmet T. 1942. An effect on the Peromyscus maniculatus Rassenkreis of land utilization in Michigan. Jour. Mamm. 23: 193-196.

Hosley, N. W. 1928. Red squirrel damage of coniferous plantations and its relation to changing food habits. Ecology 9: 43-48.

Howell, A. B. 1923. Periodic fluctuations in the numbers of small mammals. Jour. Mamm. 4: 149.

Howell, A. H. 1918. Revision of the American flying squirrels. U. S. Dept. Agr., Bur. Biol. Survey, No. Amer. Fauna 44: 1-64.

------1929. Revision of the American chipmunks (Genera Tamias and Eutamias). U. S. Dept. Agr., Bur. Biol. Survey, No. Amer. Fauna 52: 1-157.

Jacot, Arthur P. 1940. The fauna of the soil. Qtly. Rev. Biol. 15: 28-58.

Jessen, J. Baashuus. 1937. Periodiske vekslinger i småviltbestanden. Norsk Jaeger- og Fisker-Forenings Tidsskrift 66: 12-15.

Johnson, M. S. 1926. Activities and distribution of certain wild mice in relation to biotic communities. Jour. Mamm. 7: 245-275.

Jordon, James S. 1948. A midsummer study of the southern flying squirrel. Jour. Mamm. 29: 44-48.

Kalabukhov, N. I. 1935. ("On the causes of fluctuations in numbers of mouse-like rodents"). Zool. Zhurnal. 14: 209-242.

Kalmbach, E. R. 1918. The crow in its relation to man. U. S. Dept. Agr. Bull. 621: 1-93.

Kendeigh, S. Charles. 1944. Homing of Peromyscus maniculatus gracilis. Jour. Mamm. 25: 405-407.

Klugh, A. Brooker. 1927. Ecology of the red squirrel. Jour. Mamm. 8: 1-32.

Korstian, C. F. 1927. Factors controlling germination and early survival in oaks. Yale Univ. School Forestry, Bull. 19: 1-115.

Landwer, M. F. 1935. An outside nest of a flying squirrel. Jour. Mamm. 16: 67.

Lantz, D. E. 1906. Meadow mice in relation to agriculture and horticulture. U. S. Dept. Agr. Yearbook 1905, pp. 363-376.

-----1907. An economic study of field mice (Genus Microtus). U. S. Dept. Agr., Biol. Survey Bull. 31: 1-64.

-----1918. Field mice as farm and orchard pests. U. S. Dept. Agr., Farmer's Bull. 670: 1-10.

Leedy, Daniel L. 1939. Some land use factors related to pheasant productions. Trans. Fourth No. Amer. Wildlife Conf. :525-533.

Lindeborg, R. G. 1941. Fluctuations in the abundance of small mammals in east-central Illinois, 1936-1939. Ecology 22: 96-99.

Linduska, J. P. 1942a. Winter rodent populations in field-shocked corn. Jour. Wildlife Mgt. 6: 353-363.

-----1942b. Cycles of Virginia voles. Jour. Mamm. 23: 210.

-----1942c. A new technique for marking fox squirrels. Jour. Wildlife Mgt. 6: 92-94.

-----1942d. Insect feeding by the house mouse. Jour. Mamm. 23: 212-213.

-----1943. Cooper hawk carrying a nest of young goldfinches. Auk 60: 597.

-----1946. Edge effect as it applies to small mammals on southern Michigan farmland. Trans. Eleventh No. Amer. Wildlife Conf. : 200-204.

-----1947a. Winter den studies of the cottontail in southern Michigan. Ecology 28: 448-454.

-----1947b. Longevity of some Michigan farm game mammals. Jour. Mamm. 28: 126-129.

Lyon, Marcus W. 1936. Mammals of Indiana. Amer. Midland Naturalist 17: 1-384.

McAtee, W. L. 1935. Food habits of common hawks. U. S. Dept. Agr. Circular no. 370.

McCabe, R. A. 1947. Homing of flying squirrels. Jour. Mamm. 28: 404.

McClelland, E. H. 1948. Notes on the red squirrel in Pittsburgh. Jour. Mamm. 29: 409-412.

McMurray, Frank B., and Charles C. Sperry. 1941. Food of feral house cats in Oklahoma, a progress report. Jour. Mamm. 22: 185-190.

Mayall, K. M. 1938. The natural resources of King Township, Ontario. Toronto, Canada. June 20, 1938.

Mearns, E. A. 1898. Vertebrate fauna of the Hudson Highlands. Bull. Amer. Mus. Nat. Hist. 10: 303-352.

Merriam, C. H. 1884. The mammals of the Adirondack region. Henry Holt and Co., New York, pp. 1-316.

Middleton, A. D. 1930a. Cycles in the numbers of British voles (Microtus). Jour. Ecology 18: 156-165.

------1930b. The ecology of the American grey squirrel (Sciurus carolinensis Gmelin) in the British Isles. Proc. Zool. Soc. London (Part 3): 809-843.

Montgomery, R. D. 1941. Population studies and habitat improvement for southern fox squirrels. Unpub. prog. report, Pittman-Robertson project 8-R, Michigan Dept. Conservation.

Moss, A. E. 1939. Relation between take of upland game and agricultural land use in Connecticut. Jour. Wildlife Mgt. 3: 269-278.

Murie, Adolph. 1936. Following fox trails. Univ. Michigan, Mus. Zool., Misc. Publ. 32: 1-45.

Murie, Olaus J. 1927. The Alaska red squirrel providing for winter. Jour. Mamm. 8: 37-40.

Murie, Olaus J., and Adolph Murie. 1931. Travels of Peromyscus. Jour. Mamm. 12: 200-209.

------1932. Further notes on travels of Peromyscus. Jour. Mamm. 13: 78-79.

Nelson, E. W. 1918. The flying squirrel. National Geographic Mag. 32: 466-468.

Nicholson, Arnold J. 1941. The homes and social habits of the wood-mouse (Peromyscus leucopus noveboracensis) in southern Michigan. Amer. Midland Naturalist 25: 196-223.

Osgood, F. L. 1935. Fluctuation in small mammal population. Jour. Mamm. 16: 156.

Parker, Lansing A. 1941. Factors causing rodent damage to tree plantations in southeastern Minnesota. Jour. Wildlife Mgt. 5: 297-303.

Pearson, Oliver P. 1942. On the cause and nature of a poisonous action produced by the bite of a shrew (Blarina brevicauda). Jour. Mamm. 23: 159-166.

Petrides, George A. 1944. A gall insect food of the gray squirrel. Jour. Mamm. 25: 410.

Piper, S. E. 1909. The Nevada mouse plague of 1907-8. U. S. Dept. Agr. Farmer's Bull. 352: 1-23.

Plummer, John T. 1844. Scraps in natural history (Quadrupeds). Amer. Jour. Sci. Arts 46: 236-249.

Polderboer, Emmett B., Lee W. Kuhn, and George O. Hendrickson. 1941. Winter and spring habits of weasels in central Iowa. Jour. Wildlife Mgt. 5: 115-119.

Preble, Edward A. 1908. A biological investigation of the Athabaska-Mackenzie region. U. S. Dept. Agr., Bur. Biol. Survey, No. Amer. Fauna 27: 1-574.

Quimby, Don C. 1944. A comparison of overwintering populations of small mammals in a northern coniferous forest for two consecutive years. Jour. Mamm. 25: 86-87.

Saunders, Aretas A. 1936. Ecology of the birds of Quaker Run Valley, Allegany State Park, New York. N. Y. State Mus. Handbook 16: 1-174.

Scheffer, T. H. 1924. Notes on the breeding of Peromyscus. Jour. Mamm. 5: 258-260.

Schooley, J. P. 1934. A summer breeding season in the eastern chipmunk, Tamias striatus. Jour. Mamm. 15: 194-196.

Scott, T. G. 1947. Comparative analysis of red fox feeding trends on two central Iowa areas. Iowa State College, Agr. Exp. Sta. Res. Bull. 353: 427-487.

Selle, R. M. 1928. Microtus californicus in captivity. Jour. Mamm. 9: 93-98.

Seton, E. T. 1909. Life-histories of northern animals. Vol. 1, New York.

Shull, A. Franklin. 1907. Habits of the short-tailed shrew, Blarina brevicauda (Say). Amer. Naturalist 41: 495-522.

Siegler, Herbert. 1937. Winter rodent damage to game cover. Jour. Mamm. 18: 57-61.

Smith, Charles C. 1940a. The effect of overgrazing and erosion upon the biota of the mixed grass prairie of Oklahoma. Ecology 21: 381-397.

------1940b. Biotic and physiographic succession on abandoned eroded farmland. Ecol. Monogr. 10: 421-484.

Sollberger, D. E. 1940. Notes on the life history of the small eastern flying squirrel. Jour. Mamm. 21: 282-293.

-----1943. Notes on the breeding habits of the eastern flying squirrel (Glaucomys volans volans). Jour. Mamm. 24: 163-173.

Southern, H. N., and E. M. O. Laurie. 1946. The house-mouse (Mus musculus) in corn ricks. Jour. Animal Ecol. 15: 134-149.

Spencer, D. A. 1941. A small mammal community in the upper Sonoran Desert. Ecology 22: 421-425.

Stickel, Lucille F. 1946a. Experimental analysis of methods for measuring small-mammal populations. Jour. Wildlife Mgt. 10: 150-159.

------1946b. The source of animals moving into a depopulated area. Jour. Mamm. 27: 301-307.

------1948. The trap line as a measure of small mammal populations. Jour. Wildlife Mgt. 12: 153-161.

Stuewer, F. W. 1943. Raccons: their habits and management in Michigan. Ecol. Monogr. 13: 203-258.

Sviridenko, P. A. 1934. Increase and decrease of mouse-like rodents. Bull. Plant Protection (Russia) Ser. 4(3): 1-59.

Taube, Clarence M. 1947. Food habits of Michigan opossums. Jour. Wildlife Mgt. 11: 97-103.

Telford, Horace S. 1943. White-footed mice feeding upon grasshopper eggs. Jour. Mamm. 24: 400-401.

Test, Frederick H. 1932. Winter activities of the eastern chipmunk. Jour. Mamm. 13: 278.

Townsend, Myron T. 1935. Studies on some of the small mammals of central New York. Roosevelt Wildlife Annals 4(1): 1-120.

Van Dersal, William R. 1937. The dependence of soils on animal life. Trans. Second No. Amer. Wildlife Conf. : 458-467.

Venables, L. S. V., and P. H. Leslie. 1942. The rat and mouse populations of corn ricks. Jour. Animal Ecol. 11: 44-68.

Wainio, Walter W., and E. B. Forbes. 1941. The chemical composition of forest fruits and nuts from Pennsylvania. Jour. Agr. Research 62: 627-635.

Walton, M. A. 1903. A hermit's wild friends. pp. 1-304. Boston.

Wayson, N. E. 1927. An epizootic among meadow mice in California, caused by the bacillus of mouse septicemia or of swine erysipelas. U. S. Pub. Health Reports 42: 1489-1493.

Whelan, R. V. 1939. Vole plague at Smoky Falls, Ontario. Canad. Field Naturalist 53: 53-55.

Williams, A. B. 1936. Composition and dynamics of a beech-maple climax community. Ecol. Monogr. 6: 318-408.

Wood, Frank E. 1910. Mammals of Champaign County. Bull. Illinois State Lab. Nat. Hist. 8: 501-613.

APPENDIX

Table 1. Monthly and annual mean temperatures at East Lansing, Michigan, for the years 1940 - 46.

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
1940	18.0	24.6	27.1	42.1	54.8	66.4	71.2	68.5	60.4	50.3	36.0	30.2	45.8
1941	24.8	23.4	28.5	51.8	60.0	68.1	71.7	68.4	64.4	52.9	41.2	34.4	49.1
1942	23.2	20.6	36.8	51.4	58.0	67.0	70.2	67.8	59.4	50.6	38.9	23.6	47.3
1943	19.2	25.6	30.8	41.2	54.8	69.6	70.4	68.6	57.5	48.4	35.2	25.4	45.6
1944	28.2	25.4	28.8	41.8	60.9	68.4	70.4	71.0	62.1	48.7	39.6	21.9	47.3
1945	17.2	25.4	46.4	48.4	50.7	62.6	67.4	67.7	60.8	47.8	39.3	22.9	46.4
1946	25.4	24.0	44.6	46.8	54.3	65.0	70.8	65.8	62.8	55.7	41.6	30.2	48.9
Normal	22.4	22.9	32.2	45.6	56.9	66.4	70.9	68.5	61.4	50.3	37.5	27.2	46.8

Table ii. Monthly and annual precipitation for the years 1940-46 at East Lansing, Michigan.

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
1940	1.35	0.82	2.07	1.42	4.66	5.70	1.84	9.21	1.42	3.58	3.11	2.66	37.84
1941	1.58	0.86	1.67	2.44	3.28	3.70	0.80	2.86	2.96	7.33	2.97	1.83	32.28
1942	2.15	0.84	4.70	0.88	5.25	4.48	4.33	2.36	2.16	3.36	3.45	3.06	37.02
1943	2.99	1.43	3.02	2.81	7.98	3.85	3.87	2.68	3.45	1.80	2.16	0.45	36.49
1944	1.32	2.15	2.99	2.45	4.36	2.50	1.03	2.39	2.50	0.65	1.91	1.61	25.86
1945	0.55	1.34	2.54	3.48	7.42	3.70	2.08	6.31	6.58	2.56	1.11	1.28	38.95
1946	1.65	2.22	2.43	0.82	3.93	2.48	0.25	0.88	1.76	2.14	1.88	3.06	23.50
Normal	1.82	1.90	2.35	2.58	3.42	3.51	3.10	2.82	2.91	2.47	2.48	2.07	31.57

Table iii. Date of first killing frost, after July 15 at East Lansing, Michigan.

Year:	1940	1941	1942	1943	1944	1945	1946
Date:	Oct.16	Oct.27	Sep.29	Oct.20	Oct.15	Oct.3	Oct.1

Table iv. Individual records of prairie deermice which were removed various distances from point of first capture and which returned one or more times to the "evacuation plot."

						First return					Second return				
Ear-tag number	Sex	Age	Date caught and released	Trap No.	1/ Re-lease point	Trap No.	Days to re-catch 2/	Days to re-catch 3/	Distance in yards-release point to trap	Re-lease point	Trap No.	Days to re-catch 2/	Days to re-catch 3/	Distance in yards-release point to trap	Re-lease point
17180	♂	Ad.	8-25	11	1	11	-	1	200	1	12	-	1	200	Dead
17183	♂	Imm.	8-25	15	1	39	-	1	288	Dead					
17185	♀	Ad.	8-25	18	1	19	-	1	200	1	20	-	1	200	Dead
17182	♂	Ad.	8-25	23	1	17	-	1	200	Dead					
17188	♂	Ad.	8-25	30	1	29	-	1	288	Dead					
17153	♀	Imm.	8-26	18	1	22	-	1	200	1	24	-	1	200	2
17154	♂	Ad.	8-26	23	1	22	2	2	200	1	23	2	5	200	2
"	(Cont'd) 3rd return					19	2	2	400	2					
17111	♂	Ad.	8-28	15	2	37	5	11	488	3					
17144	♂	Ad.	9-3	18	2	15	2	5	400	3					
17127	♀	Ad.	9-4	25	2	24	1	4	400	3					
18137	♀	Imm.	10-8	18	4	18	2	5	315	4					
16557	♂	Imm.	10-21	25	4	25	-	1	265	4					
16569	♂	Imm.	10-22	20	4	10	1	5	375	trap 10	20	2	2	-	4
16563	♂	Imm.	11-22	23	4	19	37	134	310	None					
17389	♀	Imm.	11-5	4	4	8	3	5	390	4					
17390	♂	Ad.	11-5	17	4	11	-	1	370	4					
17386	♀	Imm.	11-5	19	4	18	-	1	315	4	16	-	1	330	4
17387	♂	Imm.	11-6	20	4	11	1	4	370	4					
17362	♀	Imm.	11-13	22	4	20	1	6	300	4	22	2	2	285	4
"	(Cont'd) 3rd return					22	-	3	285	4	20	-	1	300	4 (4th return)
"	(Cont'd) 5th return					18	-	1	315	4					

Ear-tag Number	Sex	Age	Date caught and released	Trap No.	1/ Release point	First return: Trap No.	First return: Days to recatch 2/	First return: Days to recatch 3/	First return: Distance in yards-release point to trap	First return: Release point	Second return: Trap No.	Second return: Days to recatch 2/	Second return: Days to recatch 3/	Second return: Distance in yards-release point to trap	Second return: Release point
17384	♂	Imm.	11-17	19	4	23	-	1	280	4					
16511	♀	Imm.	11-17	20	4	24	-	1	275	4					
17364	♂	Imm.	11-17	21	4	25	3	3	265	4					
17375	♂	Imm.	11-17	22	4	19	3	3	310	4	25	-	1	265	4
17372	♂	Imm.	11-17	23	4	2	2	2	435	4	21	2	2	295	4
"	(Cont'd) 3rd return					20	3	5	300	4	16	2	5	330	4 (4th return)
18387	♀	Imm.	11-17	29	4	26	4	7	265	4					
18389	♀	Ad.	11-17	34	4	21	3	3	295	4	36	1	4	340	4
17322	♀	Imm.	11-26	33	4	35	2	5	330	4					
17321	♀	Imm.	3-30	22	4	25	-	1	265	4					
17330	♂	Imm.	3-30	25	4	19	-	1	310	4					
17338	♀	Imm.	3-30	39	4	22	-	1	285	4					

1/ Distances from release points to nearest trap in the plot were: point 1 - 200 yards, 2 - 400 yards, 3 - 600 yards and 4 - 265 yards. Adjusted distances in the table are from release point to the trap in which taken.

2/ Days of trapping.

3/ Total elapsed time in days.

Table v. Summary description of woodlots.

	Management previous to 1938	Principal stand	Understory	Ground Cover
WOODLOT 1. Acreage - 10; Soil -Newaygo loam (smooth). Type -Upland oak-hickory. Ungrazed*	Large timber cut 1910. Pastured lightly for 9 years prior to 1938.	Moderate stocking. Black and jack oaks dominant; white oak, pignut and shagbark hickory, and black cherry secondary.	Dense. Black cherry seeding heavily. Sassafras, soft maple, serviceberry and hickories common. Numerous dense clumps of ground juniper; and raspberry, chokecherry, and gray dogwood frequent.	Fair accumulation of litter. June grass sod still evident in places.
WOODLOT 2. Acreage - 15; Soil -Hillsdale loam and Bellefontaine sandy loam. Type -Upland oak-hickory. Grazed.	Cut-over 1910. Heavily grazed, mostly by sheep for 37 years previous to 1938.	Moderate stocking. Pignut and shagbark hickory dominant; black and white oak secondary.	Sparse. Sassafras common, some reproduction by hickories. Serviceberry, witch hazel, red raspberry and blackberry are common shrubs.	Heavy June grass sod over most of woods. Litter sparse.

Table v. (Cont'd)

	Management previous to 1938	Principal stand	Understory	Ground Cover
WOODLOT 3. Acreage - 14; Soil -Bellefontaine sandy loam. Type -Mostly upland oak-hickory. Lowland elm, and red maple along one margin. Grazed	Cut over (year?). Heavily grazed mostly by sheep for 37 years previous to 1938.	Moderate stocking. Black oak dominant; white oak and red maple second in occurrence.	Sparse. Shagbark hickory seeding in. Serviceberry, blackberry, raspberry and hawthorn scattered. Small lowland portion has red maple and largetooth aspen reproduction with some elderberry and gray-dogwood.	Mostly June grass sod. Slight litter accumulation.
WOODLOT 4. Acreage - 12. Soil -Predominantly Bellefontaine sandy loam. Type -Largely upland oak-hickory with small strip of lowland elm and red maple. Grazed.	Cut over (year?). Heavily grazed by sheep and cattle for 22 years prior to 1938.	Very sparse. Black and jack oaks, and pignut and shagbark hickories are commonest species among larger trees. Soft maple and American elm are dominant in the small lowland strip.	Very sparse. Sassafras and hickory reproduction, and patches of ground juniper furnish most of secondary growth.	Most of upland covered with June grass sod. Litter sparse.

Table v. (Cont'd)

	Management previous to 1938	Principal stand	Understory	Ground Cover
WOODLOT 5. Acreage - 23. Soil -Newaygo loam and Bellefontaine sandy loam. Type -Upland oak-hickory. Ungrazed*	Large timber cut 1910. Grazed very lightly for 17 years between 1910-1938.	Moderate stocking. Pignut hickory dominant. Black oak, shagbark hickory, and white oak occurring in that order.	Dense. Several large, very dense patches of blackberry. Hawthorn and black cherry very common. Sassafras seeding in fairly heavily.	Fair deposition of litter. June grass sod still covers much of woods.
WOODLOT 6. Acreage - 12. Soil -Mostly Bellefontaine sandy loam. Type -Upland oak-hickory. Ungrazed*	Cut over (year?). About one-third of woods fairly heavily grazed, remainder lightly grazed.	Sparse. White oak dominant. Black oak and pignut hickory secondary. A number of decadent white oak trees with numerous dens are present.	Fiarly dense over about two-thirds of woodlot. Sassafras and black cherry are very frequent. Scattered clumps of blackberry, wild rose and ground juniper.	June grass sod on most of area. Slight accumulation of litter.

Table v. (Cont'd)

	Management previous to 1938	Principal stand	Understory	Ground Cover
WOODLOT 7. Acreage - 16. Soil -Rifle peat in lowland portion, Hillsdale loam on higher areas. Type -Lowland, predominantly elm and red maple. Ungrazed.	Cut over recently (year?). Not known to have been grazed.	Fairly heavy stocking. Red maple is dominant and represents nearly 50 percent of stand. Remainder includes a considerable number of species principally white, red and black oaks, pignut hickory, largetooth aspen, and American elm.	Very dense. Red maple is one of principle species in undergrowth. Black cherry and sassafras are seeding in heavily. Dense tangles of wild grape are frequent. Red osier and gray dogwood, dwarf birch, hazelnut, blackberry, witch hazel, and serviceberry are important shrubs.	Heavy accumulation of litter over entire lot. No sod areas present.
WOODLOT 16. Acreage -10. Soil -Hillsdale and Conover loam. Type -Lowland, elm and red maple. Ungrazed*	Cut over (year?). Limited selective cutting 1941. Not recently grazed.	Moderate stocking. Red maple and American elm dominant. Hard maple fairly plentiful. White oak scattered in higher portion.	Fairly dense. Red and hard maple reproduction is conspicuous. Raspberry, blackberry, gray dogwood, and black cherry are other important species.	Good litter layer over most of 'lot. Sod areas sparse.

*With the exception of Woodlot 7 all woodlots were known to have been subjected to grazing at some time. The present classification "Ungrazed" refers to units which have been protected from grazing for such a period as to have again approached an ungrazed condition.

Table vi. Red squirrels taken by live-trapping in six upland and two lowland woodlots, and in three grazed and three ungrazed, upland woodlots.

		Individuals Caught		Individuals per 100 acres		Individuals Caught		Individuals per 100 acres	
		Upland (86 acres)	Lowland (26 acres)	Upland	Lowland	Grazed (41 acres)	Ungrazed (45 acres)	Grazed	Ungrazed
1940:	Feb.-Mar.	15	13*	17.4	81.3	3	12	7.3	26.7
	May-Aug.	70	26*	81.4	162.5	26	44	63.4	97.8
	Sept.-Oct.	52	10*	60.0	62.5	12	40	29.3	88.8
	December	24	20	27.9	76.9	6	18	14.6	40.0
1941:	Mar.-Apr.	31	21	36.1	80.8	12	19	29.3	42.2
	June-July	24	28	27.9	107.7	12	12	29.3	26.7
	Sept.-Oct.	17	27	19.8	103.9	7	10	17.1	22.2
1942:	January	19	19	22.1	73.1	11	8	26.8	17.8
	April	6	9*	7.0	56.3	3	3	7.3	6.7
	June-July	7	18	8.1	69.2	3	4	7.3	8.9
	Sept.-Oct.	6	22	7.0	84.6	2	4	4.9	8.9
	November	1	2	1.2	7.7	0	1	0	0

* Only 16 acres trapped in these periods.

Table vii. Catch of chipmunks in relation to type and grazing of woodlots.

		Individuals Caught		Individuals per 100 acres		Individuals Caught		Individuals per 100 acres	
		Upland (86 acres)	Lowland (26 acres)	Upland	Lowland	Grazed (41 acres)	Ungrazed (45 acres)	Grazed	Ungrazed
1940:	May-Aug.	94	2*	109.3	12.5	11	83	26.8	184.4
	Sept.-Oct.	64	1*	74.4	6.3	12	52	29.3	115.5
1941:	June-July	73	2	84.9	7.7	18	55	43.9	122.2
1942:	June-July	26	8	30.2	30.8	5	21	12.2	46.7
	Sept.-Oct.	29	13	33.7	50.0	3	26	7.3	57.8

* Only 16 acres trapped in these periods.

Table viii. Catch of flying squirrels in relation to type and grazing of woodlots.

		Individuals Caught		Individuals per 100 acres		Individuals Caught		Individuals per 100 acres	
		Upland (86 acres)	Lowland (26 acres)	Upland	Lowland	Grazed (41 acres)	Ungrazed (45 acres)	Grazed	Ungrazed
1940:	Feb.-Mar.	4	1*	4.7	6.3	0	4	0.0	8.9
	May-Aug.	48	10*	55.8	62.5	26	22	63.4	48.8
	Sept.-Oct.	32	4*	37.2	25.0	24	8	58.5	17.8
	December	7	1	8.1	3.9	3	4	7.3	8.9
1941:	Mar.-Apr.	7	0	8.1	0.0	5	2	12.2	4.4
	June-July	8	3	9.3	11.5	4	4	9.8	8.9
	Sept.-Oct.	0	0	0.0	0.0	0	0	0.0	0.0
1942:	January	2	1	2.3	3.9	1	1	2.4	2.2
	April	2	3*	2.3	18.8	1	1	2.4	2.2
	June-July	2	0	2.3	0.0	2	0	4.9	0.0
	Sept.-Oct.	1	0	1.2	0.0	0	0	0.0	0.0
	November	4	2	4.7	7.7	1	3	2.4	6.6

* Only 16 acres trapped in these periods.