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HABITATS OF THREATENED SMALL MAMMALS ON THE ROSE LAKE WILDLIFE RESEARCH AREA, CLINTON COUNTY, MICHIGAN--EARLY FORTIES AND LATE SEVENTIES

presented by

Jacquelyn L. Shier

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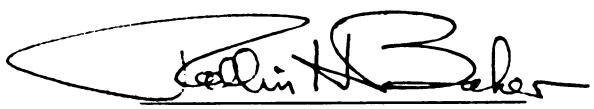

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By

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ABSTRACT

HABITATS OF THREATENED SMALL MAMMALS ON THE ROSE LAKE WILDLIFE RESEARCH AREA, CLINTON COUNTY, MICHIGAN--EARLY FORTIES AND LATE SEVENTIES

By

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In view of succession on the agricultural and forested lands of a game area in southern Michigan a follow-up investigation was conducted to determine the differences in composition and distribution within habitats between current small mammal populations and those obtained in the 1940s, particularly for three threatened species.

Transition from farm-game to wildlife management removed land from agricultural use. Habitat management continues with shrub strip planting, food patches, and brushpiles. Farmed areas have reverted to persistent brome grass (Bromus inermis), oldfield situations.

Introduced grasses, low plant diversity, and inappropriate vegetative structure within the oldfields are cited as responsible for the apparent absence of least shrews (Cryptotis parva) and avoidance by southern bog lemmings (Snyaptomys cooperi). Lemmings persist due to their versatile association with transition habitats. Canopy closure within woodlands reduced the abundance of ground flora such that woodland voles (Microtus pinetorum) apparently no longer inhabit the study area.

ACKNOWLEDGMENTS

I wish to thank Sylvia Taylor, director of the Michigan Endangered Species Program, for making this study possible; and to John Lerg who helped in many ways with administration of the grant that financed this investigation. Other personnel of the Wildlife Division and particularly members of the Rose Lake Staff were helpful in many ways.

Assistance in trapping was given by Kevin Jay in 1978, Pete Verbanac and Brent Danielson in 1979, and Kimberly Rizzo in 1980. I am grateful to have had free access to the results of other small mammal studies conducted on the Rose Lake Wildlife Research Area by Christopher Carmichael in 1978 and by Brent Danielson in 1979. John Johnson of Michigan State University generously loaned traps for predator control during the study.

Special thanks to Rollin H. Baker for conceiving of this project and for encouragement and guidance throughout. Chris Faulkner generously contributed to all facets of this study.

This project was supported by federal aid, the United States Fish and Wildlife Service and the Michigan Department of Natural Resources cooperating through the Federal Endangered Species Act of 1973 and the Michigan Endangered Species Act of 1974.

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INTRODUCTION

Background

A major study of small mammals and their habitats in the mixed agricultural and forested lands at Rose Lake Wildlife Research Area (hereafter called the Rose Lake Area) was conducted in the early 1940s by joint investigators from the Michigan Department of Conservation (DNR) and Michigan State College (MSU), with published results by Joseph Linduska (1950) appearing in bulletin form. These threatened small mammals, the least shrew (Cryptotis parva), the southern bog lemming (Synaptomys cooperi), and woodland vole (Microtus pinetorum), (Jones, et al., 1979), were among the small insectivores and rodents found as members of the local mammalian communities. Periodic observations of small mammals on the Rose Lake Area in the past fifteen years have shown no captures or other evidence of the presence of the least shrew or the woodland vole, and only an occasional record of the bog lemming. There has been no concerted and systematic attempt to appraise or monitor small mammals at Rose Lake since the mid-1940s, especially in view of successional changes in habitats. This project was, therefore, of great importance to the long-term research objectives of the DNR. Evidence concerning the reasons why these small mammals formerly seemingly common and/or widespread are now rare and/or restricted, might be revealed.

Objectives

It was proposed that a survey of small mammals on the Rose Lake Area be conducted systematically to determine (a) the kinds, distributions, habitat preferences, and relative abundance of the small mammals found there currently; (b) the differences in species composition between current mammalian populations and those obtained by the Linduska study in the early 1940s; (c) reasons for the apparent suppressed state or likely disappearance of species on the threatened list; and (d) a plan to monitor small mammals in selected sites at Rose Lake in the future so as to maintain basic ecologic and demographic data on the threatened species.

METHODS OF STUDY

Small Mammal Survey

One objective of this study was to measure the comparative numbers of small mammals in the several habitats at various times of the year, and compare them to species diversity and population levels observed in the 1940s study.

True censuses of small mammals usually require intensive live-trapping on quadrats or assessment lines several acres in size (Dice, 1938; Blair, 1941; Stickel, 1946a; and Smith, et al., 1971). For various reasons, these types of procedures were not adopted in the earlier study by Linduska (1950). Instead, he found it desirable to sample concurrently in more situations than could be trapped conveniently by intensive means. The approach he adopted was one of live-trapping along lines of measured length as suggested by Dice (1938) and used by Blair (1939). For the most meaningful comparison, the same methodology was used in this present follow-up study.

In the earlier fieldwork, trapline placement was systematic and record keeping thorough, making it possible for the subsequent investigators to relocate every trapline. Unless otherwise indicated, all population indices were obtained by using a series of 25 traps spaced at 7-meter (22-foot) intervals along a straight line 170 meters (8 chains) long. Traplines extended from the field border toward the center and were located midway between the field edges

paralleling the line of traps. Fields larger than 10 hectares (25 acres) received two lines of traps, each was placed 40 meters (two chains) in from the field border which the lines paralleled. A few very long hedgerows received 50 traps when it was important to sample along their entire lengths.

When sampling situations demanded the use of more, or less, than 25 traps in a line, the capture results have been standardized to a 25-trap equivalent for their inclusion in Tables 4 and 5.

It was desirable to use the same treadle-operated pressed fiberboard live traps (4.5 x 4.5 x 16 cm) employed by Linduska in the 1940s study. Unfortunately, they had been discarded years ago when they became water damaged. Instead, a treadle-operated galvanized-steel live trap (6 x 9 x 27 cm) made by Leathers and Sons of Athens, Georgia, was used. Treadles could be adjusted to where traps were sufficiently sensitive to capture 8- to 10-gram animals.

A few traplines were established in each habitat type (cropland, perennial grasslands, hedgerow, and woodlot) examined by Linduska in the 1940s. These were used to determine seasonal abundance and habitat preferences of all members of the small mammal community in light of successional changes and present land-use practices. These lines were operated for single three-night sessions in the fall of 1978, spring and fall of 1979, and in the spring of 1980.

Traps were baited in late afternoon and checked and closed the following morning, for each of three successive nights of trapping. Those on shaded lines were also operated during the day to

increase the capture rate for Synaptomys and Microtus. A dry bait combination of peanut butter and rolled oats was used in most situations. The data recorded upon capturing an animal included its toe-clipped number, species, sex, reproductive condition, weight, location on the trapline, and the date. Reproductive condition was assessed in the manner described by Krebs (1966). For males, the position of the testes, whether scrotal or abdominal, was noted. For females, a combination of measures indicated the onset of reproductive activity in subadults and the stage of pregnancy in adults. These include the condition of the vagina, whether perforate or not, the size of the nipples and the surrounding subcutaneous lactation tissue, as well as degree of protrusion of the abdominal area. The degree of separation in the pubic symphysis gave evidence of recent parturition (Hall and Newton, 1946). Although effective for microtines, deermice, and jumping mice, these measures were useful for shrews only in the most advanced stages of pregnancy or lactation.

Since the major objective of this study was to determine the reasons for the apparent suppressed state or likely disappearance of the three "threatened" species of small mammals, the least shrew, the woodland vole, and the southern bog lemming, decidedly different procedures were employed in the search for these species in areas other than those surveyed by Linduska.

Additional study sites having properties similar to those reported in the literature for these three species were selected for trapping using less conventional methods. Removal-trapping with

Museum Special snap traps were employed for the purpose of catching "rarer" species not especially evident until the removal of the more "dominant" mammals which may initially monopolize trap sites. Pitfall can-traps set alone and along drift fences were used to search for all three of the species. These sets were put into operation when low population levels the first year gave the impression that animals might be avoiding the conventional live and snap traps. Both Microtus and Synaptomys are reported to frequently avoid the latter (Bailey, 1929; Jackson, 1961; and Master, 1978). When the trapping success for Synaptomys with both snap and live traps improved in 1979 the can-traps were abandoned, since the yield from these proved to be lower in upland situations than with the standard traps.

Examination of the 1940s trapping records and past literature on Synaptomys suggested that dispersing individuals of this species may be captured almost anywhere with intensive trapping effort. However, concentrations were more often reported from bogs, riparian habitats, and upland in moist-mid-successional stages having monocotyledonous vegetation. In these situations Synaptomys was searched for, initially with snap traps. If an individual was captured within the three- to six-day search period, the snap traps were replaced with live traps for additional investigation. In one pine plantation where a colony of 16 to 20 animals was located, an exhaustive analysis of their use of this habitat was performed to aid in predicting the presence of the lemming at other sites on the Research Area. Runway systems were excavated to locate food caches,

nesting sites, and latrines, and to determine what locations within the grove were most heavily used. Traps for Synaptomys were variously baited with apple and/or grass (after Burt, 1928) and with the peanut butter and rolled oats combination as used for the general trapping.

The woodland vole was searched for by trapping in underground runways located in the humus layer of area woodlots, orchard remnants, and hedgerows of ornamental shrubs. Four woodlots were selected on the basis of herbaceous ground-layer vegetation and humus properties. Those with deep, mor humus (Jameson, 1949) and an abundance of herbs with tuberous root systems that would provide food and cover for the woodland vole (Paul, 1970) were more likely to support breeding populations of the species. Runways were then located and a portion large enough to accommodate a Museum Special snap trap was excavated and set with a trap, as suggested by Paul (1970). Paul also advised that these sets be covered over to block out light. Eadie (1936) and Miller (1964) found that it made little difference in the capture success. Here, initial trapping with the set covered over had little effect on what species were captured, or whether soil excavation by animals during the night covered the traps, so they were left uncovered in subsequent settings.

A special search had to be made for Cryptotis since 3- to 4-gram shrews are too light to consistently trip the treadles of the large live traps and too short to be caught by Museum Special snap traps from the front. The least shrew is frequently reported to have

been found beneath logs, boards, and other debris in fields of herbaceous plants or in pastures (Moseley, 1930; McCarley, 1959). Whenever such items were found on the Rose Lake Area, they were examined carefully for these animals or any leaf nests or runways of pencil diameter that would suggest their presence in the area. Fifty pieces of aluminum sheeting measuring 1 x 2 meters were also laid out in several fields having properties similar to those reported by Howell (1954) and Getz (1962) in the hope of attracting these shrews. Examination of these sheets for nests and runways was made periodically from August 1979 to June 1980. Mouse traps were set around the edge of those sheets where sign suggested the possible presence of the least shrew.

Questionnaire

A questionnaire was mailed to field mammalogists within the range of the southern bog lemming to collect recently gathered information on the species' local habitat use and small mammal associates (see Appendix). A comparison between populations in Michigan and those in other regions where the lemming appears to be thriving will aid in determining why the species is apparently threatened in Michigan.

Vegetation Surveys

Vegetation types on the Rose Lake Area for the years 1941 to 1946 were accurately determined by combining references from several sources. Brief descriptions on the trap cards by Linduska

provided a species list of plants present on the site and a vague idea of habitat fine structure for each of the areas he trapped. A more complete picture of habitat structure for these areas was obtained from camera point photographs periodically taken of the area from 1938 to 1960 by Rose Lake area personnel. Photographs also helped to characterize the earlier vegetative cover present on areas sampled in this study which had not been trapped in the 1940s. Although the latter information was not crucial to this follow-up investigation, it helped to place the results of this recent study in better perspective. In addition, the Rose Lake Station files contained photographs of numerous management activities occurring on the area throughout the years, and of their subsequent effects on the habitat. Finally, personnel employed by the Station over the years were consulted for details not available from the above sources.

Thorough description of the habitat was made for each of the traplines run in this recent survey. Plant species were identified according to Gleason and Cronquist (1963). Photographs were taken of noteworthy situations. In addition, a photographic record was systematically made of those portions of the area where trapping occurred, most of which correspond to regions in which the original study was conducted. Systematically recording the remainder of the Rose Lake Area on film would have been a major undertaking of limited value, as most of it has grown up to a thick tangle of shrub and understory trees. These photographs have been accessioned into the film file located at the Rose Lake Wildlife Research Station, 8562 E. Stoll Road, Bath Township, Clinton County.

Vegetative cover maps for the Rose Lake Wildlife Research Area in 1970 and the central 325 hectares (800 acres) where most of the trapping occurred are shown in Figure 1 and Figure 2, respectively.

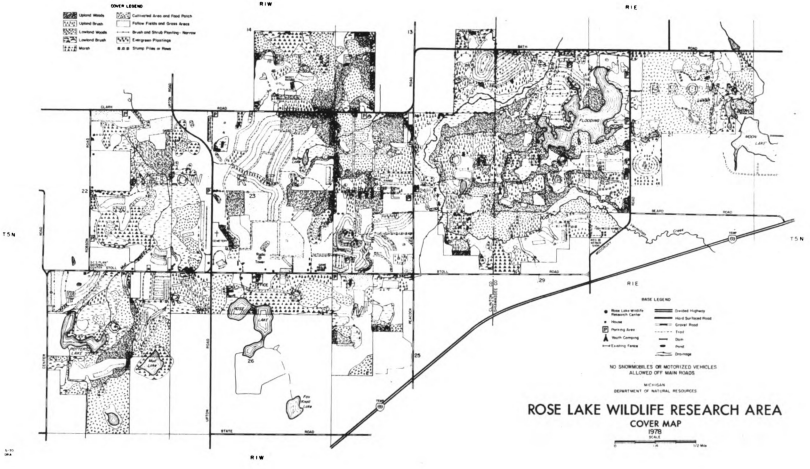
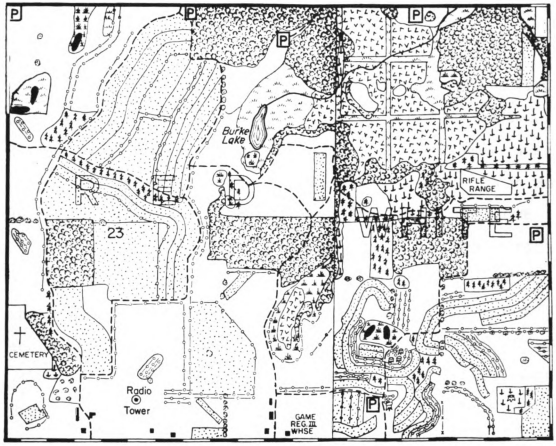


Figure 1.--Vegetative cover map for the Rose Lake Wildlife Research Area in 1970.



COVER LEGEND

Upland Woods	Cultivated Area and Food Patch
Upland Brush	Fallow Fields and Grass Areas
Lowland Woods	Brush and Shrub Planting - Narrow
Lowland Brush	Evergreen Plantings
Marsh	Stump Piles or Rows

Figure 2.--Vegetative cover map for the central 325 hectares.

STUDY AREA

The Rose Lake Wildlife Research Area comprises 1350 ha (3,334 ac) of state-owned mixed agricultural land, forests, and wetlands in Bath Township, Clinton County and Woodhull Township, Shiawassee County, Michigan (see Figure 1). The study area was included in the initial purchase of land for the Research Area by the DNR in 1938.

Topography varies between comparatively level and rolling countryside. The steepest slopes are wooded in most cases, but in the late 1800s early settlers cleared much of the rolling terrain for agriculture; subsequently, it became badly eroded. Early efforts (in the late 1930s) by personnel at the Rose Lake Wildlife Research Station to stabilize those areas prone to erosion with shrub plantings have not only stopped the erosion, but accelerated the return of many areas to a wooded condition. The sandy, less productive soils were removed from production while farming was continued on the better soils (Rose Lake Wildlife Experiment Station, 1941).

The amount of farming activity on the area has continued to decrease. Less than 40 ha (99 ac) are currently farmed by sharecroppers and Rose Lake personnel.

Before the land was cleared, the uplands were covered by beech (Fagus grandifolia), maple (Acer spp.), hickory (Carya spp.), and oak (Quercus spp.) forests with a few scattered white pines

(Pinus strobus). Lowland forests were dominated by maple, ash (Fraxinus spp.), and tamarack (Larix laricina).

The soil pattern is complex as is characteristic of heavily glaciated areas where there is a wide variation in drainage conditions. Twenty-seven soil types were recorded for the Area in the 1940s. In the well-drained uplands were Newaygo loam, Bellefontaine sandy loam, and Coloma loamy sand. The poorly drained soils of kettle-holes, marshes, and lake and stream bottoms were predominantly Rifle and Greenwood peats, and Kerston and Arlisle mucks.

A slightly different soil profile was reported for the 1980s. Well-drained soils include Boyer sandy loam, Marlette loam, and Spinks loamy sand. The poorly drained soils include Adrian muck, Carlisle muck, Gilford sandy loam, Houghton muck, Tawas muck, and Wasepi sandy loam (Threlkeld and Feenstra, 1974; and Pregitzer, 1978).

Mean winter (October-March) temperature is 0.4°C (32.7°F) while mean summer (April-September) temperature is 16.7°C (62.1°F). Periods of extremely hot or cold weather are usually of short duration. Precipitation averages 87.5 cm (34.4 in) per year. The prevailing winds are from the west with an average speed of 16.6 km/hr (10.3 mi/hr) (U.S. Weather Bureau, pers. comm.).

Details of meteorological conditions during both periods of investigation are given in Tables 1 and 2. During the 1940s study period, both snow and rainfall were above normal.

For the recent study period, annual precipitation was 4 to 5 inches below the normal 31.6 inches, despite heavy snowstorms in

TABLE 1.--Monthly and annual mean temperatures recorded at East Lansing, Michigan (°F)

	Jan.	Feb.	March	April	May	June	July	August	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	25.5	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
1978	18.1	14.3	27.3	44.1	58.9	66.1	69.0	69.4	64.9	49.5	39.7	26.5	46.0
1979	17.3	14.1	37.6	44.4	56.5	67.5	68.6	66.5	62.2	49.3	38.4	29.9	46.0
1980	22.6	18.8	27.9	44.4	57.1	62.0							
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

Source: 1940-1946 from Linduska, 1950.

1978-1980 from Climatological Data, Michigan, Monthlies for MSU Horticulture Research Center.

TABLE 2.--Monthly and annual precipitation recorded at East Lansing, Michigan (in inches)

	Jan.	Feb.	March	April	May	June	July	August	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
1978	2.66	0.38	2.17	1.47	2.32	2.26	1.51	2.81	3.79	2.21	1.91	1.88	25.37
1979	1.88	0.42	1.41	2.84	2.12	4.25	1.67	4.37	0.00	2.58	3.27	2.71	27.52
1980	0.61	0.80	1.97	2.76	2.88	3.80							
Normal	1.67	1.12	2.49	2.14	4.41	3.67	2.38	3.76	2.73	2.91	2.42	2.06	31.64

Source: 1940-1946 from Linduska, 1950.

1978-1980 from Climatological Data, Michigan, Monthlies for MSU Horticultural Research Center.

January of both 1978 and 1979. The winter of 1980 had conditions which may have proven detrimental to the local small mammal populations. Of the 9 inches of winter precipitation, 33 percent was in the form of rain. Although the remaining 67 percent was in the form of snow, the accumulation never exceeded more than three inches or lasted longer than 5 days. These snow conditions provided poor insulation of the litter layer from cold winter temperatures. Consequently, frequent freezing and thawing of the water-saturated litter layer probably occurred, critically stressing the more sensitive microtines, including the bog lemmings.

RESULTS AND DISCUSSION

The approach taken here was to determine the more important changes characteristic of plant succession on the area and to take some measurements of their effect on certain of the resident small mammal species.

Direct measurements of the effect of succession were obtained in two ways. One was to determine the effect of the changes in terms of the habitat requirements of each species. This method is closely applicable only when the food and cover requirements have been worked out in detail. This has been done for most of the small mammal species resident on the area, through the use of published ecological accounts, but only to a limited extent for the woodland vole and the least shrew. The other method used was to analyze the cover occupied by each species in the present and in the earlier study and relate this to the more important vegetative changes that have taken place in the meantime.

To determine whether certain habitat conditions have become more or less productive for certain small mammals in the past 35 years, the principles indicated above were applied to the changes in cover which have occurred.

In the early 1940s a farming program was set up under the guidance of the U.S. Soil Conservation Service and Michigan State

College (now Michigan State University). A 280-hectare livestock farm employing new land-use practices was put into operation. Crop rotation, contour farming, level ditching, flooding, fence row development and woodlot management were practiced to enhance productivity of both crops and wildlife.

Management activities on the Area provided a great diversity of habitats for small mammals. Of the 475 hectares (1,172 acres) in ownership by 1940, cropland and pastureland comprised 64 percent of the total area; wetlands constituted 24 percent; and woodlots made up 12 percent (Table 3). In the 325-hectare portion of most intensive study about 71 percent of the land was in pasture and crops; 16 percent in wetlands; and 13 percent was in woodlots. These land-use percentages were typical of the private farms in the immediate area.

The changes that each vegetation type has undergone during the 35 years between observations at Rose Lake are presented in a discussion format. Results of the various trapping operations have been arranged in tabular form and are referred to in the discussion when appropriate. An overall perspective on the fate of the three threatened species of small mammals is presented in the form of species accounts following the general discussion.

Croplands

The adventive vegetation in cultivated fields is sparse and consists chiefly of annuals and biennials. Relatively large areas of bare soil are present between the individual plants.

TABLE 3.--Comparison of percent land use in the central 325-hectare unit under intensive study

	1940s	1970s
Uplands		
Croplands	19.2	5.6
Annual grasses and weeds	9.4	0.6
Perennial grasses and weeds	23.9	43.0
Mixed perennials and shrubs	18.3	1.0
Intolerant trees/shrubs and grass patches	2.9	11.6
Mid-tolerant trees and shrubs	10.2	26.0
Tolerant trees	0.0	0.0
Wetlands		
Grass-sedge marshes	6.5	1.7
Wooded Swamps	4.0	10.5

Forties

Farming of the area was diversified, with fields supporting two crops having different maturation times. Crop rotation occurred on all but the few mucklands. In addition, strip-cropping was used on the largest fields. Corn, oats, and wheat were the principle cash crops grown; and alfalfa and red clover were grown for hay production. Straw was spread over some of the fields planted with crops to reduce erosion of the topsoil. This latter practice no doubt also increased the number of weed seeds in the seed pool in these areas.

Land devoted to the growing of cash crops such as corn, wheat, rye, and oats at this time comprised 19.2 percent of the central study area.

In 1950 the European smooth brome grass (Bromus inermis) was added to hayfields.

During the summer and early fall months the prairie deermouse (Peromyscus maniculatus bairdi) was the dominant small mammal species in cropland habitats (see Table 4). Traplines set in all crop types caught an average of 2.8 individuals per three-day session. The only other small mammal to be taken regularly was the introduced house mouse (Mus musculus), with an average of 0.37 individuals per line.

From December to March the meadow vole (Microtus pennsylvanicus) was the most common associate of the prairie deermouse in cropland. In those situations providing an abundant ground cover it

TABLE 4.--Overall small mammal captures on the Rose Lake Wildlife Research Area from 1940 to 1946. Totals include all methods

		Sorex cinereus	*Blarina brevicauda*	*Microtus pennsylvanicus*	*Synaptomys cooperi*	*Peromyscus leucopus*	*Peromyscus maniculatus*	*Zapus hudsonius*	*Mus musculus*	Percent Land-Use
Uplands										
Cropland (106 lines)	No. of Individuals	0	0	7	0	11	301	0	40	19.2
	No. per Trapline	0	0	0.07	0	0.10	2.8	0	0.37	
Annual grasses and weeds (24 lines)	No. of Individuals	0	0	22	0	0	77	0	17	9.4
	No. of Traplines	0	0	0.90	0	0	3.36	0	0.70	
Perennial grasses and weeds (8 lines)	No. of Individuals	0	2	5	1	0	7	0	1	20.0
	No. of Trapline	0	0.25	0.63	0.13	0	0.88	0	0.13	
Perennial grasses (6 lines)	No. of Individuals	0	1	5	0	0	18	0	2	3.9
	No. of Traplines	0	0.16	0.85	0	0	3.0	0	0.3	
Mixed perennials and shrubs (22 lines)	No. of Individuals	3	17	27	20	7	32	0	6	18.3
	No. of Trapline	0.13	0.76	1.21	0.89	0.31	1.43	0	0.27	
Intolerant Trees/shrubs grass patches (7 lines)	No. of Individuals	0	3	0	0	5	0	0	0	2.9
	No. of Trapline	0	0.43	0	0	0.75	0	0	0	
Mid-tolerant trees/shrubs (44 lines)	No. of Individuals	0	52	0	2	142	0	0	2	10.2
	No. of Traplines	0	1.18	0	0.05	3.22	0	0	1.0	
Wetlands										
Grass-sedge marshes (3 lines)	No. of Individuals	3	0	4	0	0	0	0	0	6.5
	No. per Trapline	1.0	0	1.3	0	0	0	0	0	

greatly outnumbered the deermouse. In contrast, fields where corn was stored as shocks during the winter were favored as winter refuge by most of the local small mammals, including the three species that are presently considered threatened. Linduska (1950) actually found as many individuals of these latter three species in one winter by censusing under corn shocks as he did in all his years of trapping.

Seventies

Of the land previously used for the growing of grains, 70 percent was retired from cultivation by the late 1960s. Since then, these lands have advanced to the perennial grass and weed stage. The 30 percent remaining is planted only with corn on a share crop basis for a program which provides for 25 percent of the crop to be left standing for wildlife food and cover. Annuals and biennials thrive between the rows of corn. When these fields are left fallow, even for one season, the foxtails (Setaria spp.), pokeweed (Phytolacca americana), and Lamb's quarters (Chenopodium album) invade the field en masse.

Today, corn shocking is no longer practiced. Instead, the whole stalk is cut and removed from the field in the fall for silage. In addition, only a small portion of each field of corn is left standing over the winter for wildlife. Such a practice may still allow mice to feed on the fruit in winter, however, its value as cover when standing, compared to when it is in shocks, is greatly reduced. This fact alone probably diminishes the value of cornfields to small mammals in winter compared to what it was in the forties.

In this recent investigation only prairie deermice were captured in croplands during the winter. This evidence, although gathered from a limited amount of winter trapping in January 1979, indicates that cornfields harvested by modern methods may not provide sufficient cover for meadow voles or the rest of the local small mammals as they did in Linduska's day. This also means that winter censusing for any of the threatened small mammals should now be conducted in other suitable cover types, rather than in cornfields.

The principal species in croplands today are still the prairie deermouse and the house mouse (see Table 5). An average catch of 3.8 deermice and 0.77 house mice per trapline was obtained. Since the prairie deermouse is a species which often shows distinct fluctuations in population levels over a period of years (Blair, 1940; Linduska, 1950; and Terman, 1966), this figure in no way indicates the presence of a higher mean population level than existed in the forties. In fact, Linduska observed a marked increase in live trap catches in each succeeding year of study. This trend started with a low of 0.6 individuals per trapline in July 1940 and ended with a high of 4.3 per line in March 1946. Although no data were reported for 1943 to 1945, Station records show that eight lines set in croplands in 1944 caught an average of 3.9 individuals per line. Since this value lies between those found for 1942 and 1946, it gives credibility to the uniform increase inferred by his graph, rather than a crash, during the intervening years.

Trapping during the fall of 1978 in cornfields yielded a catch of 5.6 prairie deermice per line. By the following April a

TABLE 5.--Overall small mammal captures on the Rose Lake Wildlife Research Area from 1978 to 1980. Totals include all methods

		Sorex cinereus	*Blarina brevicauda*	*Microtus pennsylvanicus*	*Synaptomys cooperi*	*Peromyscus leucopus*	*Peromyscus maniculatus*	*Zapus hudsonius*	*Mus musculus*	Percent Land-Use
Uplands										
Cropland (21 lines)	No. of Individuals	0	1	1	0	0	58	0	10	5.6%
	No. per Trapline	0	0.04	0.04	0	0	3.8	0	0.77	
Annual grasses and weeds (sightings*)	No. of Individuals	--	--	--	--	--	*	*	*	0.18%
	No. per Trapline									
Perennial grasses and weeds (36 lines)	No. of Individuals	2	64	391	0	16	26	52	3	14.5%
	No. per Trapline	0.05	4.8	22.4	0	0.44	0.85	3.94	0.07	
Perennial grasses (389 lines)	No. of Individuals	3	273	553	0	101	13	91	1	28.5%
	No. per Trapline	0.05	1.10	6.85	0	0.42	0.37	0.77	0.08	
Mixed perennials and shrubs (4 lines)	No. of Individuals	0	5	5	0	9	4	1	0	1.0%
	No. per Trapline	0	0.87	0.4	0	2.25	0.6	0.25	0	
Intolerant Trees/shrubs grass patches (15 lines)	No. of Individuals	11	71	102	6	73	3	14	0	11.6%
	No. per Trapline	0.42	1.58	2.23	0.21	1.83	0.09	0.59	0	
Mid-tolerant trees/shrubs (50 lines)	No. of Individuals	6	45	7	19	72	5	8	0	26.0%
	No. per Trapline	0.12	0.90	0.14	0.38	1.44	0.10	0.16	0	
Wetlands										
Grass-sedge marshes (28 lines)	No. of Individuals	24	0	129	0	3	0	10	0	12.2%
	No. per Trapline	1.81	0	4.82	0	0.04	0	0.93	0	

catch of 0.82 per line, compared to the 3.6 obtained by Linduska in March of 1944, gave every indication that a crash in their population level had occurred. However, the population in croplands had increased to 6.3 individuals per trapline by June. Apparently, the cornfields are somewhat inhospitable to deermice during the wet spring when the fields are saturated with meltwater. It is probable that the summer population consisted of individuals which had dispersed into the cornfields after they had dried out a bit.

There was no sharecropping on the Rose Lake Area in 1980. Only a few small corn patches were planted by station personnel that spring. Should this trend continue, it will probably have little direct effect on the three threatened species of small mammals under consideration here, since cornfields were of fairly limited value to these species by 1980. Their movements into corn shocks in the winter of 1941 is viewed as having been a preferential act engaged in by these animals, rather than a necessary one stemming from any lack of sufficient cover in their summer range or in alternative ranges.

Annual Grass and Weed Associations

First-year hayfields of alfalfa and red clover, and grain fields in the late fall period (cornfields more than other grains), are similar in many respects to the annual grass and weed stage in succession from plowed ground which Allen (1938) describes. What is bare ground in spring closes in quickly by summer with the maturation of cultivated plants and weed species. Consequently, classification of cover type relative to what is significant to the small

mammal community is complicated by drastic seasonal changes in the habitat. For the purpose of tabulating data in Tables 4 and 5, percent land-use was based exclusively on spring cover maps. However, the assignment of individual traplines to the various seral stages was determined by the condition of existing cover each time the trapline was operated.

Forties

Newly planted hayfields, cornfields in the fall, and retired croplands contributed to the annual grass and weed cover type in the 1940s. At that time, hay production and crop rotation placed an average of 30 hectares per year into this early stage of succession. Most of these autumn cornfields were occupied by common ragweed (Ambrosia artemisifolia), yellow and green foxtails (Setaria glauca and S. viridis), lamb's quarters, knotweed (Polygonum aviculare), and in lesser numbers by other annuals. By the following spring the dominant vegetation in these same cornfields consisted of early-stage perennial grasses and weeds such as quack grass (Agropyron repens), broom sedge (Andropogon virginicus), and wormwood (Artemisia campestris), red sorrel (Rumex Acetosella) and pokeweed.

Seventies

Because of limited tilling or use of herbicides during the present investigation, annual grass and weed associations developed within the cornfields. The plant species diversity closely matched that described by Linduska (1950) for the forties. Sampling for small mammals occurred here in the fall of each year.

Also supporting annual grasses and weeds were strips of land 10 meters wide by 100 to 1000 meters long that were plowed for the planting of shrub hedgerows along the roadways in 1978. Subsequent colonization by annual grass and weed species gradually increased the cover available. By 1980 these strips were being taken over by perennial grasses and weeds.

Now, as in the 1940s, these recently disturbed upland habitats appear to support only the prairie deermouse and the house mouse, and infrequently, the meadow jumping mouse (Zapus hudsonius). In late fall after harvest and in spring before maturation of the planted species only the prairie deermouse inhabitats open farmland. Accompanying the summer transition in abundance of cover there is an influx of the house mouse into croplands when adequate shelter becomes available. Both Linduska (1950) and Whitaker (1967) documented these moves by house mice, and they were observed again in this follow-up survey. In fact, 22 of the 57 house mice captured by Linduska in croplands and annual grass and weed associations were taken after August 1 when the ground cover had matured, and all were captured after July 8. Likewise, the ten house mice captured in the seventies from cornfields were taken after July 24.

Although these annual grass and weed associations support a modest growth of monocotyledonous vegetation and some species of arthropods, they are unlikely fall and winter refugia for either the least shrew, the southern bog lemming, or the woodland vole.

The woodland vole has only been reported from such situations when tuberous root crops are present (Linduska, 1950; Paul, 1970).

There is not enough litter accumulated or high enough stem density for either the bog lemming or the more common meadow vole to establish the runways they usually construct to move, under cover, between foraging sites and nests. Whether they forage here to any extent in the winter was not determined in this present investigation. However, Linduska (1942a) did observe a significant movement of voles into cornfields once appropriate cover existed in the form of field-shocked corn and a moderate accumulation of snow. During the spring, summer, and early fall, he caught only 7 meadow voles from 106 traplines (an average of 0.07 voles per line), and no bog lemmings or woodland voles, in unaltered cornfields. By January a seven-day session of removing rodents from 28 acres of field-shocked corn yielded 166 voles (the equivalent of 0.8 voles per line), several woodland voles, and a few Synaptomys. And there was not enough litter or debris accumulated in these recently disturbed fields for the least shrew to build nests in such "stable" sites as seem to be preferred by this species (Whitaker, 1974).

Perennial Grass and Weed Associations

The transient annual-biennial stage on both cultivated and small grain lands is followed by a longer period in which perennial grasses and weeds predominate. This usually begins about three years after abandonment. Canada bluegrass (Poa compressa) and Kentucky bluegrass (Poa pratensis) are of particular importance in southern Michigan. Either one or both of these species may completely cover the surface of the ground over large areas; Canada bluegrass is

likely to occur on the heavier soil types, whereas Kentucky bluegrass tends to be more common on the lighter upland soils. Many of the weedy associates have long tap roots that allow them to co-exist with the grasses which use mainly the upper soil levels.

Forties

In 1940, 20 percent of the central area was maintained as a perennial grass and weed association for the pasturing of a dairy herd. The dominant grass species were Canada bluegrass and Kentucky bluegrass, the latter was referred to as June grass in notes by Linduska. Considerable variation existed between fields with respect to species diversity and abundance of the herbaceous types mixed with these grasses. Among them were goldenrods (Solidago spp.), milkweeds (Asclepias spp.), yarrow (Achillea Millefolium), common mullein (Verbascum Thapsus), sour dock (Rumex crispus), fleabane (Erigeron annus), flowering spurge (Euforbia corollata), and wormwood.

Second- and third-year hayfields are included in this category because the associated weeds were perennial and the litter layer had developed considerably by this time.

Oldfields of this early seral stage contained a slightly higher diversity of small mammal life than did either the croplands or annual grasslands (see Table 4). However, the overall density of small mammals was substantially lower. Linduska captured only 0.88 prairie deermice and 0.63 meadow voles per trapline. The short-tailed shrew first appears in this seral stage where there is enough ground litter to provide both cover and abundant food of the types

usually selected by the shrew. The diet of the short-tailed shrew in Indiana consists of 36 percent earthworms, 9 percent slugs and snails, 8 percent lepidopterous larvae, crickets, centipedes and beetles (Whitaker, 1972); all of these are more abundant where the ground litter is substantial, or where a moderate diversity of flowering herbaceous plants occur.

Both the meadow vole and the short-tailed shrew were strictly fall and winter residents.

Linduska (1950) observed an annual migration in September by the meadow vole and the southern bog lemming (both from wetlands) and the woodland vole (from the woodlots) into these upland grasslands. Slightly fewer had settled here than had invaded the croplands. Summer trapping failed to take any bog lemmings or woodland voles, and relatively few meadow voles were captured in these areas in summer. Yet, from December to February of 1942, both bog lemmings and meadow voles were common in grasslands. Linduska believed that microtines avoided these areas in summer because most of the vegetation was either severely dehydrated or grazed short by the livestock. When these rodents finally moved upland in the fall, cooler weather had allowed rehydration of the grasses and there was a considerable amount of new fall sprouts for food.

The winter of 1942 was the beginning of an upward population trend for the local bog lemmings which appeared to peak in 1946, although sparse data from 1943 to 1946 during the war makes this conclusion tentative. In December of 1942 lemmings were especially

numerous in a 1.5 hectare opening beside a stream bottom grown up to St. John's wort (Hypericum perforatum), dewberry (Rubus hispidus), wormwood, milkweed, mullein, ragweed, and bluegrass. In this area during mid-day these animals could be seen running along the snow surface as they moved between tunnels. Since winter trapping under snow cover was conducted only within pine hedgerows, cornfields, and along the edges of vernal ponds, it is unknown whether current perennial grass and weed associations serve as winter refugia for either the lemming or the woodland vole.

The only locality, other than field-shocked corn in winter, from which Linduska (1950) reported capturing a least shrew was an old field-bog margin, on 2 October 1941. Although the site bordered on an extensive acreage of old field and pastureland, no additional captures were made during regular trapping operations. Several were taken later in February from beneath corn shocks only 400 meters from the bog margin.

Seventies

The abundance of habitat in the perennial grass and weed association has decreased only slightly, from 20 to 14.5 percent, over the intervening years. However, major differences in successional stage and plant species composition exist, and are probably responsible for the dramatic differences seen in the accompanying small mammal community.

Prior to their abandonment in 1967 when the dairy herd was sold, hay and pasturelands were subject to a major change in principle

grass species. Native bluegrasses were replaced by smooth brome grass imported from Europe for hay production. The lands presently in the perennial grass and weed stage derive from lands abandoned from grain cultivation which were subsequently invaded by brome grass and herbaceous weed species from the pasturelands.

Free from cultivation for a considerable period of time, these tracts have reached a more advanced seral stage than had the perennial grass and weed associations that Linduska had available to sample. While the weeds were dominant on his frequently cultivated hay and pasturelands, long-term abandonment of today's grass and weed fields has allowed a thickening of the sod and the grasses dominate. Consequently, the weedy associates are different and fewer in number. The relative importance values of the grass and weed species found in two abandoned fields in 1979 are shown in Table 6.

When one looks at which oldfields are inhabited by the brome grass, it becomes apparent that some prior clearing of the land was necessary for its successful invasion. Hence, it dominates on the cultivated portion of the Rose Lake Area. Here it established initially by direct seeding onto tilled lands, and later it spread to nearly all lands left fallow.

The more mature perennial grass and weed associations of the seventies appear to support a more stable small mammal community. Shrews and microtines are year-round residents and occur in much greater numbers than in the younger, and drier, grasslands of the forties (see Table 5). The short-tailed shrew has increased from 0.25

TABLE 6.--Importance values of plants in perennial grass and weed associations in the central study area, 1979

Species	Importance Value
Grid A	
Bromus inermis	168.27
Lychnis alba	5.96
Daucus carota	5.88
Berteroa incana	5.82
Solidago canadensis	4.96
Xanthium strumarium	3.18
Agropyron repens	2.92
Solidago graminifolia	1.55
Trifolium pratense	1.46
Grid B	
Bromus inermis	128.92
Daucus Carota	22.54
Medicago sativa	11.57
Taraxacum officianale	6.36
Solidago canadensis	5.92
Solidago graminifolia	5.64
Cirsium arvense	5.63
Bertaroa incana	4.52
Agropyron repens	2.69
Lychnis alba	2.64
Xanthium strumarium	1.84
Convolvulus arvensis	1.74

to 4.8 individuals per trapline and the meadow vole has increased from 0.63 to a phenomenal 22.4 mice per line of 25 traps. The meadow vole still exhibits a multi-annual fluctuation in population density. Since the value of 22.4 was obtained primarily from trapping in the fall of 1980 during a population high, it probably falls well on the high side of the actual average for the entire study period. More realistic as an average value is that of 6.8 per line given for the perennial grasslands.

There has been no significant change in either prairie deermoust or house mouse populations in this habitat type. In addition, the more mature fields of today support a modest 0.44 white-footed mice.

The apparent increase in meadow jumping mice from none to 3.9 per trapline may be, in part, an artifact of the difference in the trap type used in the two studies. Linduska (1950) mentions that, even though only one individual was taken by trapping during the course of his work, at least a dozen were removed from post holes that were dug near a marshy area. His livetraps were much smaller than mine; measuring only 4.5 x 4.5 x 16 cm. It is plausible that a trap this small might be avoided by the jumping mouse, for they readily entered the livetraps used here. They also were caught frequently in snap traps in the present study. However, a comparison of snap-trapping results for the jumping mouse is not possible since Linduska's use of these traps was almost exclusively confined to grain fields where no jumping mice were captured, and to winter grasslands when these mice would be hibernating.

These perennial grass and weed associations are the first stage in the seral development from cropland to forest where conditions supposedly would be suitable for the least shrew. There is a great diversity of broad-leaved herbaceous plants and enough stability of the plant community to support a varied insect diet for the least shrew. Whitaker and Mumford (1972) examined stomach contents which primarily included lepidopterous larvae, earthworms, spiders, orthopterans, and aphids. There also appears to be sufficient stability in the vegetative structure to provide suitable nest sites, and there is lodged grass for winter refuge (Davis and Joeris, 1945). Whether these factors are sufficient to attract the least shrew if it were presently on the area is unknown. The inferences drawn here about potential habitat selection, foraging sites, and trappability mostly derive from publications of minor observations made while the investigators were engaged in research on other species, and some come from incidental encounters with the shrew. This wide range of observations is summarized by Whitaker (1974), but even this large body of literature does not give us a very clear picture of the ecology of this species. Consequently, the previous statements about likelihood of current residency or habitat use by the least shrew on the Rose Lake Area are a "best guess" based on an overall consideration of this body of data.

Perennial Grasslands

Forties

In 1940 only 4 percent of the central area possessed a thick enough sod ground cover to have excluded those weeds that were present in the younger grasslands. These tracts are considered here in the perennial grassland stage as a midpoint in the seral development of plowed ground to woodland. These areas were also used for the pasturing of the dairy herd. Canada bluegrass and Kentucky bluegrass were the dominant grass species, forming dense uniform stands with timothy (Phleum pratense).

The principal species of small mammal captured by Linduska in bluegrass sod were the prairie deermouse, house mouse, and the meadow vole. In all seasons he took a number equal to that collected from adjacent croplands (see Table 4) of both the deermouse (3.0 per line) and the house mouse (0.3 per line). Subsequent to the movement of microtines to upland habitats in the fall, he captured an average of 0.8 meadow voles per trapline.

Pasturelands and other sod areas were attractive to bog lemmings as winter refuge, just as some perennial grass and weed associations sustained winter colonies. In February 1942, 50 snap traps were operated a total of four nights at the edge of a bluegrass pasture and 18 lemmings were taken from less than half an acre.

Seventies

All the grasslands retired from pasturing the dairy herd since the introduction of brome grass onto the Rose Lake Area in 1950

eventually became occupied by brome. In comparison to those grasslands that were abandoned while under cultivation for hay, these pastures have had a longer period of time without disturbance to the sod layer. Hence, today these fields are essentially monotypic, and very stable in this state of succession. Their lack of plant diversity discourages seed-eating birds and mammals from inhabiting these fields, and consequently the introduction of propagules from other plant species is slow. The few associates found with brome grass in these mature fields were goldenrods and soapwort (Saponaria officinalis).

The transition of perennial grasslands to a woody condition is further curtailed by the apparent resistence the growth form of brome grass has to the germination of other species. Colonization by woody species occurred in one field only, where the grade was sufficiently steep to have allowed a mild erosion of the topsoil and a thinning of the grasses there. Although the sod areas have been undisturbed by man for at least 15 years, they can be expected to remain this open for another 15 years, and probably longer (Bump, 1950). In a study similar to this one Bump found that, even though open fields were located a short distance from existing seed sources, colonization was much less rapid on sites that supported a particularly lush growth of grass and other herbs. In his study area, several such sites remained quite open even though untouched by man for 30 years or more.

The perennial grass association now occupies 28.5 percent of the central 325 hectare study area (see Table 5) and was the

predominant habitat type during the present investigation. Even more importantly, the overwhelming success of smooth brome grass has significantly altered the patterns of seasonal distribution and abundance in the grassland small-mammal assemblage.

The widespread establishment of monotypic brome grass cover has substantially reduced the amount of grassland habitat that will support the prairie deermouse. In the forties, Linduska caught an average of 3.0 deermice per trapline in bluegrass sod, whereas in the seventies only 0.37 per line were taken. Closer examination of the seventies data reveals that captures of deermice within brome grasslands occurred only in early seral stage grasslands directly adjacent to croplands. Here food was readily available from both the mature crop plants and from weeds that grew among the rows, and abundant cover could be had within the grasslands. The discovery of several occupied deermouse nests within the adjacent brome field verified the use of grassland for cover in these situations.

While reduced in value to the prairie deermouse, mature perennial grasslands were more attractive to the meadow vole and the short-tailed shrew. Linduska obtained an average of only 0.85 meadow voles in the few sod fields that there were to examine, whereas extensive trapping in the seventies netted an average of 6.8 voles per trapline. With the dramatic population fluctuations exhibited by this species, trapping results varied from an average of 1-2 per trapline during a population low to a high of 22 or more per line. More significant is the fact that mature brome grass

fields support populations of voles even in the driest years. Granted, populations also became higher in wetlands when grasslands were very dry in 1978, but the upland fields always had viable breeding populations, numbering about 20 per hectare. There was no noticeable evidence of an annual upland migration of microtines in the fall like those that Linduska observed. Or if they did occur, then the grasslands are now extensive enough to absorb these individuals into widespread resident population with little effect on local numbers. Whatever the case may be, the grasslands were not completely abandoned during the hot summer. That moisture retention by brome grass fields is probably greater than in the bluegrass fields in summer, and therefore, has less affect on annual movements by meadow voles, was discussed in the section on perennial grass and weed associations.

The greater moisture retention of brome grass cover seems to have had a different, but equally significant, affect on the short-tailed shrew. In both brome and weed fields, and in brome alone, Blarina reached densities far greater (4.8 and 1.1 shrews per trapline, respectively) than what had been observed by Linduska for bluegrass fields (0.25 and 0.16). It is likely that the greater moisture content of brome sod has enhanced the soil environment of earthworms and other arthropods on which the short-tailed shrew feeds.

All of the other local small mammal species were secured from brome habitat type except for the southern bog lemming.

Although mature grasslands are not a habitat frequented by the house mouse, it occasionally appears in these situations. This

may depend more on the nature of the surrounding habitat than on characteristics of the grassland through which it is probably passing to reach more favorable areas. Whitaker (1967) suggests that the combination of its foraging behavior and its desire for cover restrict it to mature cultivated locations. Since these locations usually prevail for only a short period of time, the house mouse leads a nomadic existence in search of suitable habitat. Given this, the decline from 0.3 individuals per trapline in the forties to 0.08 in the seventies probably reflects the reduction in cultivated and annual grass and weed associations that these animals would be moving between. Undoubtedly the same situation pertains for the woody hedgerows and forest margins from which house mice were captured in the forties, but not in the recent surveys (see Tables 4 and 5).

The seed-eating meadow jumping mouse was much less abundant in the monotypic grass associations than in those having both grass and weeds. It was captured at the rates of 0.77 and 3.94 per trapline, respectively. This difference may, in part, be due to reduced seed abundance. However, for the other seed-eaters, the insignificant difference in captures of the white-footed mouse and house mouse, and the small reduction in capture rate for prairie deermice suggests that another habitat requirement of the jumping mouse may not have been met. A higher stem density in the perennial grasslands was an obvious situation that may make travel in these fields difficult for the jumping mouse.

Probable reason for why the meadow jumping mouse was not caught in the 1940s investigation was discussed in the section on perennial grasses and weeds.

The white-footed mouse is a seed-eater of late oldfield succession and of woody habitats. Yet trapping in both perennial grass and weed associations and perennial grasslands yielded a modest catch of 0.4 mice per trapline. The distribution of captures with respect to trapline placement revealed that these captures were confined to traps in close proximity to bordering hedgerows. Grasslands should, therefore, be considered marginal habitat for the white-footed mouse, and the extent of their utilization of these habitats be considered dependent on the management of directly adjacent tracts.

Smooth brome grass fields in various stages of succession now cover 43 percent of the 325-hectare study area. Such dominance attests to the success this grass species has had in establishing in the more fertile lands abandoned following farming operations. The brome grass has not, however, spread into the bluegrass-weed fields that developed on the infertile sandy soils before the introduction of brome grass. There is apparently little threat of this grass spreading into the native grasslands that developed as a seral stage following the lumbering in southern Lower Michigan. However, its dominance in abandoned farmland and on highway rights-of-way (where it has spread following construction or been sodded in) seems to have been of great consequence to the grassland small mammal community in Lower Michigan.

Mixed Perennials and Shrub Association

Perennial forbs are replaced by a number of woody plants that gradually become of increasingly greater importance in the vegetation. Shrubs seldom completely occupy an area to the exclusion of all other types of plants. Usually they are present in aggregations, with perennial grasses and forbs in the open spaces between and a number of trees scattered over the area. However, group plantings for wildlife management result in more discrete, monotypic stands or rows of shrubs.

Forties

In his study of field borders in relation to farming practices, Linduska (1950) examined eight sod fencerows for comparison with brush-tree borders. These sod borders were grown up principally to stands of bluegrass (Poa pratensis and P. compressa) with a variety of vines and shrubs providing a secondary vegetative structure absent from the open grasslands. Numerous shrub plantings for wildlife food cover and for erosion control placed scattered patches directly into this advanced oldfield seral stage.

Small mammal populations in these transition type communities had lower densities than did those in adjacent croplands during the same period. These two habitat types showed parallel seasonal variation in the relative abundance of the resident species. During early August of 1942, four of these sod borders yielded 11 individuals including 6 prairie deermice, 2 meadow voles, 2 bog lemmings and 1 short-tailed shrew. In late October and early November of that year

four sod borders, including two examined before and two new ones off the area, were trapped again. Of 77 small mammals captured in this period, 50 were meadow voles, 19 were short-tailed shrews, 3 were bog lemmings, 3 were prairie deermice and 2 were 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. During April 1946, a few border habitats were sampled once more. In this trapping ten lines took a total of 58 individuals, which included 21 meadow voles, 17 bog lemmings, 8 short-tailed shrews, 6 house mice, 3 prairie deermice, and 3 masked shrews. Several of these lines also appear to have been operated off the area in nearby farmland.

Considering only results from traplines operated on the central research area, these semi-open oldfields and border strips supported the most diverse small mammal assemblage of all cover types examined. The observed small mammal species also were present in more nearly equal numbers than in other habitats (see Table 4).

In general, transition areas like grass-shrub fields support a mix of vegetation types and structural profiles. By this very fact one would expect that some individuals of species normally found within areas supporting the various components of the mix might venture into this border habitat, with some taking up permanent residence. In addition, lands with border vegetation frequently act as dispersal routes between major habitats. Both of the above circumstances would promote greater species diversity than that found in the surrounding major cover types, as was found in this study. However, more frequent and long term trapping would have been necessary to determine the

real extent to which any such dispersing non-residents may have contributed to the net catch here.

The predominance of grass cover over shrubs in these units still favors the prairie deermouse. The capture rate for the prairie deermouse was 1.43 individuals per trapline and for the white-footed mouse was 0.31 per line. This disparity existed whether in semi-open oldfields, (1.41 and 0.08 mice, respectively) or in sod strips bordering croplands (1.75 and 0.43).

The mixed perennial and shrub association was the only upland cover type from which the masked shrew was secured in the forties. Only three individuals were captured in regular trapping. However, six other of these shrews were trapped in November and December and two additional ones in March during an eight-month study on the homing ability of prairie deermice in oldfields over the winter of 1942-43. The short-tailed shrew was also more abundant in bluegrass sod borders than in the more open grasslands or croplands. The overall distribution of the short-tailed shrew was found by both Linduska (1950) and Dambach (1944) to parallel the location of thick ground litter and loose soil. Populations were much higher in ungrazed woodlands and in field border situation than they were in similar unites where grazing occurred. In explanation of these population differences Dambach stated 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 this point, a comparison of short-tailed shrew

abundance in perennial grass and weed associations, in perennial grasslands, and in intolerant tree, shrub and grass patch regions upholds this conclusion.

Perennial grass and weed fields of the forties were young hayfields where the soil had been tilled in the last three to four years. Trapping here averaged 0.25 shrews per line compared to 4.8 in grasslands that had been fallow for up to ten years.

Perennial grasslands in the forties were grazed or recently grazed pasturelands. Only 0.16 shrews were captured per trapline compared to 1.10 obtained from grasslands retired from grazing for nearly 15 years.

In the brushy roadside and fencerow borders supporting vegetation in the intolerant tree and shrub stage, the vegetation had closed in to such a degree that little or no herbaceous undergrowth was present. However, most of the border vegetation from this category examined in the seventies supported a light growth of grasses and herbs amidst a thick accumulation of litter. Trapping in these two situations yielded 0.43 shrews per line in the forties compared with 1.58 in the present investigation.

In contrast, although fields supporting mixed perennials and shrubs were of somewhat different seral stages in the two time periods, both were undisturbed areas with a substantial accumulation of litter. Here the relative catch was more nearly equal, with 0.76 shrews per trapline in the forties and 0.87 in the seventies.

The differences in number per trapline may not seem that great compared to differences seen for other species. However,

considering that captures of shrews are relatively rare events and that individuals are rarely recaptured in subsequent efforts due to high mortality when confined in a trap, the numbers are rather convincing.

In Linduska's survey, the southern bog lemming was most often captured in early-stage transition habitats. He obtained an average of 0.89 lemmings per trapline. As was the case with other grassland habitats, there were seasonal differences in residency. Lemmings and voles avoided these areas in the hot summer months, preferring the wetland habitats instead.

Bluegrass sod hedgerows and border strips were the first to contain bog lemmings at the onset of the fall upland migration. From there they appeared to move out into shrubby oldfields (0.25 per line, 24 lines), stream borders (observed 18 on a winter day at noon), and isolated grass and weed patches having shrubby borders (7.5 per line, 0.4 lines). However, the hedgerows still maintained relatively high, (0.78 per line, 16 lines) and widespread (12 out of 16 traplines caught lemmings) populations.

Linduska's survey of transition habitat concentrated on areas with young shrub and conifer plantings from two to four years old that were recently planted for wildlife, and on borderlands with young shrubs or vines. The recent survey was not to replicate the earlier study, but to examine how the maturation of these same lands has influenced small mammal species diversity and relative abundance. Consequently, trapping efforts on lands supporting mixed perennials

and shrubs were kept to a minimum, both by design and by scarcity of qualifying habitats (less than 1 percent).

Seventies

The hedgerows surveyed in the recent investigation were not very comparable to those just discussed above. They contained relatively fewer seed- and fruit-bearing species and the shrubs were more mature (8 to 10 years old). Red cedar (Juniperus virginiana), white cedar (Thuja occidentalis), apple (Pyrus Malus), staghorn sumac (Rhus typhina) and numerous oak saplings (Quercus spp.) were among the common woody plants and either brome grass or bluegrass was the principle ground cover. Hence, the white-footed mouse was more abundant than the prairie deermouse, with relative densities per trapline of 2.25 and 0.6, respectively. When this trapping occurred in the spring of 1980, the prairie deermouse was at a low in its population fluctuation, as well.

The southern bog lemming population was also at a low in the spring of 1980 (see Table 8). There was abundant sign in the form of characteristic droppings and runways from the previous fall. However, prebaiting for one week and trapping for another in two separate locations where they occurred before failed to catch any lemmings. Even so, it appears that these hedgerows do sustain lemmings in years when their populations are high enough to fill most appropriate habitats.

Intolerant Trees, Shrubs, and Grass Patches

This stage is composed of trees that are relatively intolerant, that is, they require considerable amounts of light, they are able to tolerate only moderate root competition, and their seedlings are unable to grow under their own shade.

Forties

Vegetative cover composed of tolerant trees, shrubs, and grass patches occurred in two different forms, isolated shrub or tree patches (wasteland or plantings) and hedgerows, and comprised only 2.9 percent of all cover types.

Uncommon were dry upland areas with scatterings of small intolerant trees (average dbh 5 cm) including American elm (Ulmus americana), black cherry (Prunus serotina), and black locust (Robinia Psuedoacacia). The ground cover consisted of a thick leaf litter, sparse grasses, and several species of bramble (Rubus spp.) including dewberry, blackberry, and raspberry.

The only small mammal species associated with these predominantly woody cover types was the short-tailed shrew (0.87 per line). The significance of thick leaf litter to the presence of short-tailed shrews was discussed in the previous section on mixed perennials and shrubs.

In a comparative study Linduska (1950) examined fencerows to determine the potential of hedgerow vegetation to form reservoirs of cropland pests that could invade cultivated tracts at opportune times. The wide variety of species found in the common bluegrass sod

borders was discussed in the previous section. Less common, and only occasionally continuous with the bluegrass-shrub fencerows, were the brush roadside fencerow representing the other extreme. In some of these, woody vegetation had closed in to such a degree that little or no herbaceous undergrowth was present. The principle trees and shrubs in these situations included white and black oak (Quercus alba and Q. velutina), shagbark and pignut hickory (Carya ovata and C. glabra), choke cherry (Prunus virginiana) and black cherry, red maple (Acer rubrum), hawthorn (Crataegus), staghorn sumac (Sambucus canadensis), wild grape (Vitis), and others.

Hedgerows with primarily woody vegetation attract relatively few small mammals. In early August of 1942, trapping in four wooded borders secured only five individuals; four were prairie deermice and one a white-footed mouse (Linduska, 1950; not included in Table 4). In April 1946, two traplines in wooded borders caught only one white-footed mouse. An analysis of Linduska's raw data (see Table 4) shows that the only two small mammal species associated with these woody fencerows were the white-footed mouse (0.75 individuals per trapping, 4 lines) and the short-tailed shrew (0.23 per line). At this stage of woody plant succession the white-footed mouse is now obviously the predominant resident deermouse. The scarcity of leaf litter in these hedgerows, in conjunction with a low shrew population may corroborate earlier statements about what are acceptable burrowing conditions.

Seventies

From what can be determined, these woody hedgerows have not changed much from photos taken of the area in 1940. Sumac and the other woody plants have increased in diameter and height. The larger trees have also grown and spread into areas previously occupied by the sumac. Thickness of the leaf litter has increased to the extent that most of the grasses have been smothered out. Oak and hickory seedlings are sprouting through the leaf litter in places where significant seed pools exist. In addition to these border strips, several of the wildlife plantings may now be categorized with the intolerant trees and shrubs.

Transition to a game area program called for extensive wildlife plantings in the form of food patches and cover plants. Woody plants were placed in hedgerows and plantations crisscrossing the study area, connecting many of the previously separated habitat types with a common transition zone providing a network of dispersal routes for small mammals. The many species planted include red and scotch pine (Pinus resinosa and P. sylvestris), black locust, silver buffalo berry (Sheperdia argentea), autumn olive (Elaeagnus umbellata), honeysuckles (Lonicera spp.), multiflora rose (Rosa multiflora), hawthorn, apple, and others. Woody plants associated with these plantings, but not restricted to them, were staghorn sumac, grey-stemmed dogwood (Cornus racemosa), the blackberry and the raspberry. Maturation of these plantings by the late seventies has placed a considerable portion of the land into the intolerant tree and shrub stage with brome grass sod frequently beneath in patches.

Since a variety of different aged plantings are included in this category, their combined capture results reflect a much more diverse small mammal assemblage than what occurred in the more mature woody hedgerows that Linduska examined (see Tables 4 and 5). His objective was to obtain a clear contrast between sod fencerows and those with woody vegetation and little ground cover. However, my objective was to find the southern bog lemming. Since some of the most productive cover types for lemmings in the forties were fencerows with grass sod and shrubs, this recent survey concentrated on these trasition-stage border strips from the available range in maturity of the wildlife plantings.

Only 0.09 prairie deermice and no house mice were captured in these moderately-woody hedgerows, which are probably too woody for these species (see earlier sections of more thorough discussions of habitat use by these species). On the other hand, most of the other local small mammal species were moderately abundant relative to their other more preferred habitats.

Mark and recapture analysis indicated that three of the species had individuals that were predominantly residents in their habitat. These were the white-footed mouse, short-tailed shrew, and masked shrew, whereas individuals of the other three species, the meadow vole, bog lemming, and meadow jumping mouse, were largely transients passing along these borders.

Mid-Tolerant Woodlands

In this stage an assortment of mid-tolerant trees, principally oaks and hickories, predominate. It is generally believed that a mixture of beech, basswood, and sugar maple is the most tolerant, and therefore climax, vegetative type in Clinton County under present conditions. The beech-maple-basswood stage will thus slowly replace the intermediately tolerant oak-hickory type, although the rate of succession will be extremely slow.

Forties

Of the central 225-hectare study area, 22 hectares were in the woodland condition in the 1940s. The great diversity in soil, litter, vegetation structure, and plant species diversity among the area woodlots (see Table 16) allowed for a broad examination of how woodland type might affect small mammal abundance and species diversity.

Seven woodlots, 4 to 10 hectares in size, were present in this unit. Six were of the typical upland oak-hickory type, the principle species being black oak, jack-oak (Quercus ellipsoidalis), white oak, pignut and shagbark hickory, with an average dbh of 15 to 25 cm. Most had little or no middle story. The sparse understories contained seedlings of the principle tree species along with black cherry, sassafras (Sassafras albidum), ground juniper (Juniperis communis depressa), various brambles (Rubus spp.) and occasionally other woody plants.

One woodlot was a lowland type in which maple dominated. The principle species here was red maple, mixed with white, red, and

black oaks, pignut hickory, large-toothed aspen (Populus grandidentata) and American elm. This woodlot has a very dense understory of red maple seedlings and a tangle of grape (Vitis spp.), dogwood (Cornus spp.), hazel-nut (Corylus sp.), witch hazel (Hamamelis virginiana) and service-berry (Amelanchier sp.). No sod areas were present in this woodlot.

Their past history showed that all were cut over for large timber sometime within the 50 years prior to 1940.

In the recently grazed upland woodlots the soil tended to be compacted and bluegrass sod was a predominant ground cover. This provided a contrast to the more typical woodland conditions present in those lots which had nearly recovered from light grazing. Even then, most of the woodlots were young enough in 1940 that breaks in the canopy allowed substantial patches of sod to develop.

The diversity of small mammal species captured in the mid-tolerant tree and shrub stage for woodlands probably reflects the great abundance of ground-layer vegetation and sod patches. Not only were the white-footed mouse and short-tailed shrew captured, but also the southern bog lemming, house mouse, and the woodland vole (see Table 4). Previous investigations have stressed how important soil and ground cover properties appear to be for the short-tailed shrew (Linduska, 1950) and the woodland vole (Hamilton, 1938; Jameson, 1949; Benton, 1955). The latter usually requires loose, sandy soils and deep humus suitable for burrowing, as well as an abundance of root plants (grasses, shrubs, etc.) and tubers (woodland herbs) for food. Young, open woodlots of the uplands provided these conditions.

The more mature lowland woodlots supporting tolerant tree species still had open canopies and lush understories, but there were no sod patches and few woodland herbs. Consequently, even these woodlots should be considered in the mid-tolerant stage with respect to small mammal habitat.

The heavy accumulation of litter over the entirety of the lowland woodlots still attracted short-tailed shrews, but there were no bog lemmings or woodland voles captured in these woodlands during Linduska's survey.

Seventies

Since the early 1940s, additional cutting has occurred in only one of the central-area woodlots and all have been protected from grazing by domestic animals. With the cessation of these activities the woodlots have matured following the pattern of succession typical of most upland deciduous woodlots.

The canopy has closed in above with the aid of maturing second-story trees. This closure has reduced the amount of available light for understory herbs and shrubs, allowing only spring woodland perennials and shade-tolerant shrubs and saplings to persist. Sod patches no longer prevail in the ground story except at the margins of the woodlands where light penetrates from the side. Woodlots with these characteristics were placed in the mid-tolerant tree category in the present investigation because the ground story still supports more vegetation than one would expect in a tolerant woodland.

The small mammal communities for woodlands now in the mid-tolerant seral stage are more diverse than those present in the forties (see Table 5). Although more diverse, the substantial reduction in the density of understory shrubs and saplings may have caused a two-fold reduction in the population of white-footed mice, from 3.22 to 1.44 individuals per trapline. Considering the relative abundance of white-footed mice in all the sampled habitats in the 1940s versus the 1970s, the above conclusion is preferred over the alternatives of (1) an overall low in population levels on the area; or (2) it having been an artifact of more limited sampling in this seral stage. For example, ample increases occurred in cropland (0 to 0.1), grass and weed associations (0 to 0.4), grasslands (0 to 0.4), grass and shrub areas (0.3 to 2.3), and in intolerant tree and shrub stands (0.8 to 1.8).

The amount of land supporting woodland vegetation has more than doubled since the 1940s and now totals 81 hectares (200 acres). The majority of this land is in the mid-tolerant tree and shrub category.

Some of these areas result from the maturation of oldfields and very young woodlands; the rest is from tree and shrub plantings. Several younger stands are open enough to support brome grass sod.

The greater diversity of small mammal species associated with this seral stage in the seventies can mostly be attributed to the fact that, in addition to trapping Linduska's lines, some trapping was conducted nearer the woodland borders in search for the woodland vole and the bog lemming.

Included here are the pine plantations that have reached a stage of maturity where the litter layer, sod patches, and sparse shrub associates resemble that present in the mid-tolerant deciduous woodlands. Small, relatively stable bog lemming colonies were found in these upland pine plantations throughout the summer of 1979. Their only small mammal associates within these groves were white-footed mice and short-tailed shrews. In the shrub hedgerows bordering one such grove, these three species were joined by meadow voles, jumping mice, and masked shrews. In another, more open, grove individuals of all five species were captured in neighboring traps.

Wetlands

Linduska operated a few traplines in wetland habitats in conjunction with his farmland study. Since no vegetation descriptions were made of these sites, photographs taken during the study period were relied upon for some basic information.

Areas on or bordering wet lowlands were primarily covered with sedges. Reed canary grass (Philaria arundinacea) occupied stream banks and formed patches around shallow ponds and lakes.

The few photographs available to characterize the willow-maple-dogwood association showed shrubs approximately 1 to 2 meters tall with a ground cover of sedges and mixed herbaceous plants. Shrubs were fairly thick within a few feet of the water's edge and thinned out farther from the edge. The principle shrub species were red osier and grey-stemmed dogwood (Cornus stolonifera and C. racemosa), black willow (Salix nigra) and a variety of shrubby willows.

Also present were posion ivy (Rhus radicans), poison-sumac (Rhus Vernix), water-hemlock (Cicuta maculata), marsh ash (Fraxinus pennsylvanica), and some small red maples. In the very wet areas, most sedges and reeds grew on hummocks of soil and organic matter emergent from the surface of the water.

Linduska captured only three masked shrews and four meadow voles on three lines operated each for one three-day period. In such moist situations the masked shrew predominates over the short-tailed shrew; the latter rarely ever is captured in wetlands.

Although the only bog lemmings Linduska ever actually captured in the vicinity of wetlands were taken from an adjacent lowland woodlet, he makes several references to their association with wetlands. Linduska (1950) observed an upland migration from the bogs and marshes by Synaptomys in the fall. These movements coincided with the invasion of meadow voles into upland sod areas that neither species of mouse occupied during the summer months. He speculated that both microtines were moving into the grasslands, which in summer were dry and inhospitable, but by fall were moist and suitable refuge from the seasonally colder and eventually frozen wetlands. He also observed several lemmings in a grass-weed opening beside a stream bank in winter.

By the 1970s, lowland areas have acquired a new growth of mid-tolerant trees. Box elder (Acer Negundo), black willow and black locust have grown to an average dbh of 5 cm. multiflora rose, honeysuckle, willow and dogwoods have matured, with stems approximately 3 cm in diameter. Vegetation is very thick around water edges and

new sprouts, 10 to 15 cm tall, appear further out from the shore in the sedge, canary grass, and brome patches.

Much more extensive trapping was conducted in wetlands for the present survey. This was primarily to assess whether upland populations of the bog lemming were higher or lower than those that occurred simultaneously in the wetlands, or whether there were seasonal migrations between the two regions.

On the solid boggy borders of lakes an equal mix of short-tailed shrews, meadow voles, and meadow jumping mice was obtained. At both Burke Lake and Moon Lake these species each averaged 3 individuals per trapline.

Tamarack stands yielded no captures of small mammals on any of three occasions.

Of greatest significance to this study was the total absence of bog lemming captures in wetland habitats even though a variety of trap types were used, including Museum Special snaps, pitfall-can traps, and livetraps. Microtine sign was abundant in many of these locations. It had qualities similar to that described for bog lemmings by numerous authors, namely a light green color and blunt-ended fecal pellets. But these qualities may be just as dependent on the nature of the vegetation eaten as on the microtine's intestinal tract. Evidence supporting this possibility was observed in the upland pine plantations. Here, fecal pellets that could unquestionably be attributed to the bog lemming appeared very dark green and blunt when formed from brome grass and yet were small and tapered, much like that of

deermice, when taken from a trap from which the animal had eaten oats. Hence, it is conceivable that a blunt, light green pellet could just as likely be formed by meadow voles feeding on light green sedges as by bog lemmings. If this is the case, then much of this sign may be attributed to meadow voles. This is indeed a ripe area for further investigation.

SPECIES ACCOUNTS

Cryptotis parva

In the northeastern United States, the least shrew is found predominantly in open grasslands (Blossum, 1931; Burt, 1946; and Barbour and Davis, 1974) and abandoned oldfields (Getz, 1962; Gottschang, 1965; and Choate and Fleharty, 1973). Although this species has occasionally been found in forest- or marsh-edge situations in the northeast (Hoffmeister and Mohr, 1957), it is more often reported from grassy or weedy fields in close proximity to wetlands.

What these weedy fields may provide is a diversity of broad-leaved herbaceous plant species necessary to support a varied enough insect diet for the least shrew. In a survey by Whitaker and Mumford (1972) the five commonest foods of *Cryptotis parva* were found to be lepodopterous larvae (18 percent), earthworms (11 percent), spiders (7 percent), orthopteran internal organs (7 percent), and aphids (4 percent). They also derived significant portions of their diet from centipedes, crickets, and mast. Such a variety of prey items might only be supported by a large variety of leafy herbaceous plants. Howell (1954) saw evidence of habitat selection highly correlated with cover vegetation within old-fields during a live-trapping study where he captured *Cryptotis* in only three of seven cover types examined. He caught four individuals in open growths of bush-clover (*Lespedeza*), 17 in goldenrod (*Solidago*) and sassafras, and three in

honeysuckle (Lonicera). None were caught in dense bluegrass stands (Poa pratensis) with sparse goldenrod, in Johnson grass (Sorgum halepense), left fallow or in dewberry or blackberry stands.

Oldfield habitat supposedly suitable for the shrew was available in great abundance on the Rose Lake Area as both annual and perennial grass and weed associations in the forties. This cover type constituted 34 percent of all major habitat types present on the area. Even though 15 percent of the land supported this same cover type in the seventies, trapping efforts in excess of 2000 trap nights for each study period captured so few animals as to suggest that this species was, and still is, very rare on the Research Area.

Many of the oldfields on land more recently acquired by the State were never planted to hay, and were retired from cultivation before the introduction of brome grass. They, therefore, support a greater diversity of weed species, and they support the native bluegrasses. It is more likely that the least shrew will be found in these oldfields, since there is a great diversity of braod-leaved herbaceous plants and enough stability of the plant community to support a varied insect diet for the least shrew. There would also be a greater amount of debris in these older fields that might provide suitable nest sites for the shrew (Whitaker, 1974).

Whether these factors are sufficient to attract the least shrew if it were presently on the area is unknown. The inferences drawn here about potential habitat selection, foraging sites, and trappability mostly derive from publications of minor observations

made while the investigators were engaged in research on other species, and some come from incidental encounters with the shrew. This wide range of observations is summarized by Whitaker (1974), but even this large body of literature does not give us a very clear picture of the ecology of this species. Consequently, to say that the least shrew is probably absent from the central study area, but potentially present on the out-lying oldfields more typical of southern Michigan, is a "best guess" based on an overall consideration of literature published on the shrew.

Linduska (1950) reports of snap-trapping only two individuals on the study area during the six-year period. A third individual was found on 2 October 1941, apparently left by a predator beneath an oak tree at an oldfield-bog margin. In addition, one was collected during the examination of field-shocked corn in January, 1941 (Linduska, 1942a; and Aldrich, 1978).

Four additional specimens were obtained from activities on the Area over the years since Linduska's work. One was reported killed by a fox in 1946 (Gordinier, 1946), one was trapped in 1957 and two in 1960 (Aldrich, 1978).

In my own trapping in all seasons and with various trap types (pitfall, snap, live) not a single least shrew was taken.

There is independent verification of this scarcity of least shrews if one looks at the owl pellets collected on the Area during both periods. In 681 items taken in all seasons from five species of hawks and three species of owls, Linduska (1950) found no least shrews. I also found no least shrews in the 90 pellets I identified

from three species of owls (see Table 7). These items were all from winter collections. Should the species be extinct from the Rose Lake Area at the present time (it probably is not), there is abundant habitat to support viable populations should a re-invasion or population increase occur.

Despite the fact that this species readily builds nests just below ground in open fields (Hamilton, 1944; and Davis and Joeris, 1945), it has been most frequently collected during incidental discoveries from above-ground nests beneath logs, rocks, sheet metal, and boards (see Table 8). Davis and Joeris (1945) state that this shrew is difficult to catch from March to November, which happens to coincide with its reproductive season in the northern parts of its range (Hamilton, 1944). Consequently, it is the information gleaned from incidental discoveries, along with several captive studies (Hamilton, 1944; Conaway, 1958; and Pheiffer and Gass, 1963), which comprises the bulk of our knowledge about the least shrew. The examination of debris occasionally used for nesting by the shrew may be a useful way to locate and capture these animals (Barbour and Davis, 1974). However, one should not consider these objects to be a necessary component of the least shrew's habitat.

Careful examination of the literature published on this species suggests that there is a strong seasonal aspect to their activity. It is interesting to note that in 90 percent of the reported instances where this animal has been taken by trapping, the captures have been made during the winter months from November

TABLE 7.--Prey items identified from owl pellets collected on the Rose Lake Wildlife Research Area from February 24 to April 1, 1980

	No. of Pellets Examined	*Sorex cinereus*	*Blarina brevicauda*	*Microtus pennsylvanicus*	*Peromyscus* spp.	*Rattus norvegicus*	*Sylvilagus floridanus*	*Sciurus* spp.	Songbirds
Screech Owl (*Otus asio*)	63	4	8	29	9	--	--	--	3
Long-eared Owl (*Asio otus*)	12	2	4	5	1	--	--	--	--
Great Horned Owl (*Bubo virginianus*)	23	--	--	7	3	3	1	1	9

TABLE 8.--Dates of collection by hand of Cryptotis parva. Entries are taken from the literature

State	Habitat	No.	Nest Location	Date	Investigator
Florida	Dry bamboo, brush pile	1	Under brush pile	31 Dec. 1935	Springer, 1937
Florida	Fort Myers	2		25 March 1940	Hamilton, 1944
Georgia	Okefinokee Swamp	1		26 August 1922	Hamilton, 1944
Illinois		1 ad, 4 yg		March 1961	Pfeiffer & Gass, 1963
Kentucky	Oldfield--pasture	1 ad, 6 yg	Below rock	16 April 1938	Welter & Sollberger, 1939
New Jersey	Tidal meadows	4	Under boards	8-22 July 1951	Connor, 1953
New York	Half-cleared field	1		1 November 1927	Hamilton, 1928
New York		5	Under rock	30 November	Hamilton, 1934
	Oldfield	3	Underground	17 March 1933	
	Oldfield	1	Underground	5 April 1933	
New York	Dog uprooted nest	1 ad, 5 yg		2 Nov. 1034	Hamilton, 1944
New York	Buildings and Vicinity	6	Various	4 Nov. - 3 Feb.	Peterson, 1936
N. Carolina		3		Feb, May, Sept.	Brimley, 1923
Ohio	Old pasture	2	Under log	17 Oct., 1930	Moseley, 1930
Ontario	Drift line on beach	7	Driftwood	June-July 1927	Snyder, 1929
Texas	Pasture by creek	2 ad, 3 yg	Under sheet metal	10 February	Broadbrooks, 1952
Texas	Grass pasture	3 yg.	Underground	26 September	Davis & Joeris, 1945
		12	Underground	6 December	
Texas	Grassy bank near river	2 ad, 4 yg	Under tin sheet	25 February	Hunt, 1951
Texas	Oldfield	25	Old log	7 January 1958	McCarley, 1959
Virginia		25	Underlog	5 April 1925	Jackson, 1961

to March (see Table 9). Davis and Joeris (1945) noticed this as far south as Texas: "We observed that shrews rarely entered our live traps as long as the weather was mild and natural food was present in great quantity in the area, but after the first cold spell or the fall, which came in early November in 1941, seldom did we fail to catch at least one shrew each time our traps were set." Jackson (1961) also mentions that in Pontiac, Michigan, several least shrews were captured in window wells in successive evenings "just as the first cold weather set in that fall." There is an indication that winter may also be when predatory birds and mammals have their best luck catching this species (see Table 10). Nearly all the reports of the least shrew in owl pellets are from collections made at winter roosts. Although the ease of collection at these roosts may bias such reports in favor of the winter months, there are also reports of abundant captures in winter by hawks (Cope, 1949) and red fox (Jackson, 1961). Incidental captures of least shrews from beneath nesting materials, although reported throughout the year (see Table 8), are also slightly more frequent from the winter season. However, these captures cannot be thought of as voluntary above-ground activity on the part of the shrews. This evidence lends support to the notion that winter may be the best time to look for these shrews.

Davis and Joeris (1945) suggest that their increased capture of least shrews in winter may be the result of concentration by these animals into areas of lodged grass favored in winter. These same animals would then undergo wide dispersal in spring and summer.

TABLE 9.--Dates of trap capture of Cryptotis parva. Entries are taken from the literature

State	Habitat	No.	Trap Type	Date	Investigator
Florida	mesic (old dune)	16	Sherman live	Jan. 1969	Kale, 1972
	Costal hammock	180	Museum sp.; mouse snap	Feb. 1969	
	same				(none caught 1966-68)
Illinois	Sparse grass field	1		Dec. 1934	Mohr, 1935
Indiana	Oldfields	108	"Trap"	Winter 1971	Whitaker, 1972
Kansas	Shrubby oldfield	1	Snap	8 Apr. 1923	Linsdale, 1928
	Weedy oldfield	1	same	28 Nov. 1923	
Michigan	Open grassy hill near marsh	1		16 Nov. 1929	Blossum, 1931
Michigan	Country farm house	many	Window Well	10 Nov. 1937	Hatt, 1938
Michigan	Oldfield	19	Multiple catch	2-6 Dec., 1957	Getz, 1962
	Same	4	Live-trap	31 Dec. - Jan. 1958	(None caught September to November 1957
Michigan	E. S. George Reserve	1		Sept. 1960	Master, 1978
Missouri			Pitfall	Sept. 1956	Conaway, 1958
New Jersey	Grassy edge of pine woods	1	Snap	July 1951	Conoway, 1953
	Tidal meadow	1	Snap	July 1951	
New York	Open field	1	"Trap"	18 March	Hamilton, 1934
Ohio	Old	39	Mouse snap	4 Nov. - 20 March	Gottschang, 1965
Tennessee	Hayfield	24	Live traps	28 July - 25 August 1951	Howell, 1954
Texas	Grass pasture	2	Live trap	20-24 Oct. 1941	Davis & Joeris, 1945
	Same	3	Live trap	12 Dec. 1941	
Virginia	Salt marsh	4	Live trap	Sept. 1940	Hamiton, 1944
	Same	1	Live Trap	July 1941	

TABLE 10.--Dates of collection of pellets containing Cryptotis parva. Period of accumulation is provided instead when available. Entries are taken from the literature.

Indiana	Rough-legged Hawk	27	13 Jan.	Cope, 1949
Kansas	Short-eared Owl	99		Linsdale, 1928
Michigan	Barn Owl	1	Oct.	Wallace, 1950
		1	Dec.	(all seasons sampled)
Michigan	Long-eared Owl	12	Winter 1954	Master, 1978
Michigan	Long-eared Owl	2	Sept. 1932-May, 1933	Wilson, 1936
	Screech Owl	5		
	Barred Owl	8		
	Barred Owl	7		
New York	Great Horned Owl	1	6 April 1935	Jones, 1937
Ohio	Great Horned Owl 3	18	April, 1939	Price, 1942
	Barred Owl 7	30	March, 1939	
	Barn Owl 27	14	May, 1939	
	Barn Owl 17	28	May, 1939	
Oklahoma	Feral house cat 3	10	Jan., 1943	McMurry, 1945
Texas	Long-eared Owl 171	Old--undated		Davis, 1938
	Barn Owl 102	Undated--before 11 May		Davis, 1940
Wisconsin	Great Horned Owl 1	31	Jan., 1932	Nelson, 1934
	1	21	Feb., 1932	
Wisconsin	Red Fox 1	15	Dec., 1942	Jackson, 1961

This behavior may be a significant aspect of their history since many authors report of sudden large concentrations of least shrews in areas where there were none previously (Peterson, 1936; Getz, 1962; and Kale, 1972).

Microtus pinetorum

The woodland vole is most often associated with mature hardwood forests where there are loose, sandy soils and deep humus suitable for burrowing (Hamilton, 1938; Jameson, 1949; Benton, 1955). Other habitats with similar soil and ground cover properties occasionally support populations of this vole. Fitch (1958) collected several voles from runway systems that were situated along the line of contact between woodland and pasture within a 300-meter strip of woodland edge in Kansas. Paul (1970) frequently found woodland voles in similar border situations in North Carolina, but these usually bordered woodlands that supported larger populations within the forest. Of the 90 specimens recorded for Michigan, most were taken in deciduous woodlands with a well-developed ground cover of thick litter or woodland herbs (Dice, 1920; Burt, 1940; and Linduska, 1950).

Linduska (1950) conducted fall trapping in seven woodlots (6 upland, 1 lowland) at various intensities during his survey of small mammals. This set of woodlands encompassed a great diverstiy of soil and litter types, vegetation structure, and plant species diversity. In preliminary trapping in one of the ungrazed woodlots (Woodlot 1) he collected four woodland voles in only 240 trapnights

from 9 to 11 August 1940. These were simply caught in livetraps set atop the litter using raw peanuts as bait; they were released after examination. Three of these were captured in adjacent traps (two within the same trap) and the fourth was taken an unknown distance away. Where these voles were localized within the woodlot could not be determined from his earlier records. A total of 240 trapnights in one other woodlot that fall yielded no woodland voles. Additional trapping in all woodland types included 2,503 trap nights in the fall of 1942 and 1946 and 150 trapnights in the early summer of 1946. More than half of these trapnights were logged for the same woodlot that had contained woodland voles in 1940. This sampling effort involved a 204-trap grid run for seven days in October of 1942. Despite this extensive effort, no additional woodland voles were taken by trapping in his investigation. Woodland voles were reported to be "abundant" (7 individuals) in field-shocked corn adjacent to woodlot 1 where the August captures were made in the winter of 1940-1941 (Rose Lake Wildlife Experiment Station, 1941), although none were taken from shocks in any subsequent years.

In the intervening years between Linduska's study and this late 1970s survey, four additional woodland voles were captured on the Area. One each year in 1953, 1955, 1956, and 1966 was obtained from the same woodlot as before (Aldrich, 1978).

These observations attest to the fact that populations of the woodland vole may be local and highly variable showing marked fluctuations over time (Benton, 1955).

In the present investigation, I logged a total of 4,800 trap-nights in and bordering woodland situations from 1978 to 1980. Nearly half of this effort was devoted to surveying Woodlot 1 and adjacent habitats. In trapping directed at capturing the woodland vole, several procedures were utilized including livetraps, snap traps placed both above and below ground level, and pitfalls with drift fences. These were operated mostly in late summer and fall of 1978 and 1979. In spite of these pointed efforts, no woodland voles were taken by any method in any season on the Rose Lake Area. I cannot at this time offer conclusive evidence for or against the existence of this species on the Area. Some woodland habitat appears favorable for this vole. Many of the woodlots are continuous with grasslands, providing an ecotonal margin supporting grasses mixed with woodland perennials. Both Fitch (1958) and Paul (1970) found populations that were localized within similar situations. The lowland maple woodlot (W-No. 7) shows great potential for this species. There are extensive small mammal burrow systems covering most of the woodlot, no doubt due to the thick ground vegetation and deep humus layer. Limited trapping in 1978 revealed only the white-footed mouse (Peromyscus leucopus) and the short-tailed shrew. Unfortunately, no trapping was conducted in this woodlot in 1979 when populations of the meadow vole and the southern bog lemming were at a high level. Hamilton (1934), Burt (1940) and Linduska (1950) found woodland voles to be syncronous in their population fluctuations with the other local microtines. This would probably have been the best time to find woodland voles active in the woodlots, were there any to be found. With more land slowly

reverting to the mature woodland condition in association with grassland border, the potential for the woodland vole to establish more stable, viable populations will increase with time.

Review of the literature on the woodland vole gives several indications of how future investigators might implement censusing efforts with the best timing and effectiveness:

1. Voles tended to be confined along the line of contact between woodland and pasture (Fitch, 1958) and along edges and openings within the forest proper (Paul, 1960), usually in association with a deep humus layer, heavy litter, or a thick covering of ground-layer perennials (Paul, 1970; and Goertz, 1971).

2. Most of the evidence suggested a loose colonial association. Even though habitat may be extensive and fairly uniform, woodland voles appeared to be clustered in scattered local colonies (Hamilton, 1938; Benton, 1955; Fitch, 1958; Miller and Getz, 1969; and Paul, 1970).

3. Since marked animals have been observed to be restricted to localized runway systems, one should concentrate on burrow systems when trapping (Fitch, 1958). These should include active or abandoned burrows of moles because these are often taken over and incorporated into a runway system of the voles (Eadie, 1936; Jameson, 1949; Fitch, 1958; and Miller, 1964).

4. In woodlands where the same burrows are used by various species of small mammals, the only sure way of establishing the presence of woodland voles is by trapping them. This can be accomplished using snaptraps or livetraps set to one side of a runway, or

pitfalls set across a runway, but all should be set below ground level within the burrow system to maximize trapping success.

5. Equal captures of voles during daytime and nightime periods may be obtained during cooler months of the year. During warm periods, these voles may restrict their activities to the lower portions of their burrow system (Benton, 1955; Miller and Getz, 1969; Paul, 1970; and Gettle, 1975).

6. Study periods could be selected short-term to coincide with high population levels of the other local microtines, with which the woodland voles are often syncronous (Hamilton, 1934; Burt, 1940; and Linduska, 1950).

Synaptomys cooperi

Throughout its range the southern bog lemming is most often caught in spagnum-sedge-heath bogs devoid of standing water and in abandoned upland fields, but are not restricted to those habitats (see summaries by Connor, 1959, and Master, 1978). It is frequently described as "uncommon." Lemmings may be locally abundant one year and absent the next.

Linduska (1950) captured a total of 41 Synaptomys over a period of six years at Rose Lake. These were taken in various habitats including sod hedgerows, brushy old fields, winter corn shocks, and open grassy woodlots.

Presently, the bog lemming is as uncommon on the Rose Lake Area as it was in the 1940s. In both live- and snap-trapping only 20 Synaptomys were captured a total of 45 times over a two-year period.

These were taken exclusively from pine hedgerows or plantations still open enough to sustain a modest grassy understory (see Tables 11-15). Under such conditions, the lower branches contact the ground and create a thick litter layer around the base of each tree; a condition which favors the presence of Synaptomys. Within the pine areas the bog lemming feeds almost exclusively on brome grass. The content of fecal pellets from latrines, and of from stomachs removed from those lemmings that were captured by snap-trapping in these groves, consisted of a uniform dark green mash with few insects and no conifer needles. Yet, a total of 425 traplines operated for 31,876 trapnights in perennial grasslands (where the dominant plant species also was brome grass, see Table 6) yielded no captures of Synaptomys. Also canopy closure in the maturing woodlots has eliminated what sod cover once supported lemmings.

The introduction of brome grass to the Rose Lake Area may have reduced the cover available at ground level, since brome grass occurs at a lower stem density and appears to lodge less than the native bluegrasses. In the pine groves and hedgerows lemming surface runways had been constructed in areas where the lodged grasses combined with a thick needle litter to form a dense mat from 2 to 4 cm deep in open areas, and up to 10 to 12 cm deep around the bases of trees. Subterranean burrows had been constructed 3 cm below the soil surface beneath areas where only a sparse litter had accumulated. These subsurface burrows existed as singular routes traversing the bare regions between grass patches.

Subsistence on brome grass does not appear to have influenced the reproductive capacity of Synaptomys. All females captured during this study period were reproductively active, either pregnant or lactating. Two juvenals (8 and 9 grams) were also captured (see Tables 11-15).

Connor (1959) correctly stated that the "chief requirement of Synaptomys seems to be the presence of green, succulent, monocotyledonous plants, primarily sedges and grasses, which are its primary source of food." However, the presence of proper vegetation for food may only be a necessary criterium for habitat selection, and not a sufficient one. This factor may explain why "large areas of apparently suitable habitat often contain only a single, small local colony of lemmings" (Barbour and Davis, 1974). Careful scrutiny of their distribution within those habitats occupied at Rose Lake and of the many reports in the literature on lemmings in both upland and wetland habitats, shows that, within areas having favorable types of food, physical factors greatly influence distribution. In most studies moisture was the physical factor that exerted noticeable influence on lemming distribution. The apparently necessary high moisture level was most often mediated by the presence of overhead cover in the form of a highly structured ground litter or flora (Hill and Hibbard, 1943; Miller, 1955; Mumford and Handley, 1956; Lindsay, 1960; and Gottschang, 1965). In open grasslands lemmings often localize where depressions or ravines expose a shallow water table (Linsdale, 1927; Stegeman, 1930; Walter and Sollberger, 1939; and Barbour, 1951). Of several bog habitats examined in Michigan,

TABLE 11.--*Synaptomys cooperi* captured on the Rose Lake Wildlife Research Area, Clinton County, Michigan, for the years 1979 to 1980--Planted Conifer Stand-A

Date	Status--First Capture	Captures	Comments
	Females		
7-11-79	Lact.; 19.5g MSU 28905	1-snaptrap	106-14-16-10
7-11-79	Juvenal; 8g MSU 28607	1-snaptrap	81-15-15-7
7-12-79	Pregnant; 24g MSU 28608	1-snaptrap	117-17-18-11
7-20-79	Juvenal; 13.5g	1-livetrap	
8- 7-79	Subadult; 16-31g	7-snaptrap	Pregnant 10-17-79
8-23-79	Adult, nonreprod,; 20-23g	4-snaptrap	Pregnant 8-29-79
8-21-79	Adult, nonreprod.; 20-23g	9-snaptrap	Pregnant 8-28-79
10-17-79	Juvenal; 9g	1-snaptrap	
7-21-79	Adult, early preg.; 22g	1-snaptrap	Medium nipples, imperforate vagina
	Males		
7-20-79	Adult; 20g abdominal MSU 28606	1-snaptrap	Hypothermic--died later that night
7-31-79	Adult; 17-26.5g abdominal	7-snaptrap	Scrotal later
8- 5-79	Adult; 25g scrotal	1-snaptrap	
11-31-79	Adult; ca, 25g	1-snaptrap	Dehydrated--trap had been set by someone while trapline was closed down
	Associates		
Sorex cinereus; *Blarina brevicauda*; *Peromyscus leucopus*; *Tamias striatus*; *Tamiasciurus hudsonicus*			

NOTE: Planted Conifer Stand--4-5 meters in height, 15 x 350 meters planted, with hedgerows radiating from it; *Bromus* beneath, sparse and patchy (40-500 stems/m^2) vegetation; *Pinus sylvestris* is the predominant tree; Trapped 6/28/77-10/17-79; 4/30/80-5/9/80. T5N, R1W, Sec. 23, NW¼, SE¼, NE¼; T5N, R1W, Sec. 23, NE¼, SW¼, SW¼.

TABLE 12.--*Synaptomys cooperi* captured on the Rose Lake Wildlife Research Area, Clinton County, Michigan, for the years 1979 to 1980--Planted Conifer Stand-B

Date	Status--First Capture	Captures	Comments
	Female		
10-18-79	Lactating; 25g	1-livetrap	In 4 days trapping
	Associates		
Peromyscus leucopus; *Blarina brevicauda*; *Tamiasciurus hudsonicus*; *Microtus pennsylvanicus*; *Tamias striatus*			

NOTE: Planted Conifer Stand--4-5 meters in height, 100 x 350 meters planted; mixed forbs and grasses beneath, patchy; bordered by old-field; Jack Pine (*Pinus banksiai*), Scotch Pine (*Pinus sylvestris*), and Red Pine; Trapped 10/17/79 - 11/8/79, 5/7/80 - 5-9-80*; T5N, R1W, Sec. 14, SE¼, NW¼, SE¼, S½.

(*Disturbance by raccoons prevented any small mammal captures here in 1980.)

TABLE 13.--*Synaptomys cooperi* captured on the Rose Lake Wildlife Research Area, Clinton County, Michigan, for the years 1979 to 1980--Planted Conifer Stand-C

Date	Status--First Capture	Captures
	Female	
4/29/80	Pregnant; 25g	2-livetrap
	Male	
5/7/80	Subadult; 19g	2-livetrap
	Associates	
Sorex cinereus; *Blarina brevicauda*; *Peromyscus maniculatus bairdi*; *Tamiasciurus hudsonicus*		

NOTE: Planted Conifer Stand--4-5 meters in height, 70 x 130 meters planted; *Bromus* beneath in only two 10 x 20 meter portions on the perimeter, sparse (50-500 stems/m^2); bordered by shrubby old-field and coniferous hedgerows; Red Pine is the planted tree; Trapped 4/16/80-5/9/80; T5N, R1W, Sec. 23, NW¼, NW¼, NE¼

TABLE 14.--*Synaptomys cooperi* captured on the Rose Lake Wildlife Research Area, Clinton County, Michigan, for the years 1979 to 1980--Conifer Hedgerow A

Date	Status--First Capture	Captures	Comments
	Female		
9-14-78	Lactating; 23.5g 28438 MSU	1-snaptrap	Emb. 1L x 1R RC = 3mm
	Male		
1- 5-79	Subadult; 20g	1-livetrap	
	Associates		
Peromyscus leucopus; *Blarina brevicauda*; *Tamiasciurus hudsonicus*; *Microtus pennsylvanicus*; *Tamias striatus*			

NOTE: None have been captured in this hedgerow since, even with intensive trapping occurring during all of 1979.

Conifer Hedgerow A- 3-4 meters in height, 5 x 100 meters planted; *Bromus* beneath, thick (500-1000 stems/m^2); bordered by olive (*Olea*) and devoid of ground vegetation in this area; Red Pine is the planted tree; Trapped 8/1/78-10/15/79; T5N, R1W, Sec. 23, SW¼, SE¼, SW¼, E½.

TABLE 15.--Synaptomys cooperi captured on the Rose Lake Wildlife Research Area, Clinton County, Michigan, for the years 1979 to 1980--Conifer Hedgerow B

Date	Status--First Capture	Captures	Comments
	Female		
7-4-79	Lactating; 23 g MSU 28439	1-snaptrap	97-15-17-12
	Associates		
Peromyscus leucopus; Blarina brevicauda; Tamiasciurus hudsonicus; Microtus pennsylvanicus; Tamias striatus			

NOTE: Conifer Hedgerow--3-4 meters in height, 5 x 100 meters planted; Bromus beneath, thick (500-1000 stems/m^2); bordered by olive (Olea) and devoid of ground vegetation in this area; Red Pine is the planted tree; Trapped 6/25-8/29/79; T5N, R1W, Sec. 23, NW¼, SE¼, NW¼, SE¼.

Synaptomys were most commonly found in wet bogs characterized by numerous hummocks (Wilkinson, 1980) or low-growing shrubs (Getz, 1961) and on absence of standing water. Further substantiation for this information can be found in additional references too lengthy to list here.

In his 1940s survey, Linduska (1950) observed an upland migration from the bogs and marshes by Synaptomys in the fall. These movements coincided with the invasion of Microtus pennsylvanicus into upland sod areas that neither species of mouse occupied during the summer months. He speculated that both microtines were moving into grasslands which in summer were dry and inhospitable, but by fall were moist and suitable refuge from the seasonally colder and eventually frozen wetlands. These seasonal movements were also documented by Connor (1959) for Synaptomys within the New Jersey Pine Barrens. It is possible that both species have a high evaporative loss of moisture so that water loss becomes too great in the drier situations to maintain a proper water balance (Lindeborg, 1952). In Linduska's study, Synaptomys appeared first in upland sod borders and hedgerows between cultivated fields. Later in the winter from December to February, concentrations of the lemming were located in numerous situations. One colony located in an aspen stand undergrown by perennial weeds and bluegrass. A second one appeared in a sparsely vegetated area on Coloma sand which supported oak saplings whose lower branches were in contact with the ground and covered with lodged grasses. A third was found in a shrubby wildlife planting on a

grassy hillside. Several lemmings also moved into corn shocks assembled in the fields each fall. In all cases, there was abundant vegetative cover at ground level. This cover was there in addition to what the local grasses provided.

During the present study, Synaptomys also underwent dispersal movements with the approach of winter. However, one need not assume that these animals originated from the wetlands, since the upland pine plantations supported lemmings throughout the summer. One of the three pine plantations in which Synaptomus was found was monitored during the summer of 1979 (see Table 11). The 13 resident lemmings captured there were localized in three places within the woodland where openings in the canopy made possible a moderate growth of brome grass and retention of lower branches on the trees. Beneath where the grass had lodged over these branches, Snyaptomys built nests and established feeding places and latrines. The majority of movement by the lemmings was most probably confined to an underground burrow system which ran within and between grass patches.

Apparently only those animals which were dispersing at the time of capture were taken by trapping in pine hedgerows (see Tables 14 and 15). These animals were collected during periods of high movement by all the local small mammals (September, January, and May) which was in evidence by the high turnover in the meadow vole populations in adjacent grasslands. No additional lemmings were captured in these two hedgerows despite continuous trapping during

summers of 1978 and 1979 and frequently in other seasons. These lemmings may undergo short excursions down a hedgerow system and back. These movements were revealed by a mark-recapture study. Marked animals from the pine grove were captured in traplines set along these rows, while no lemmings were captured out in the adjacent grasslands. These observations further support the notion that a moderate amount of vegetative structure overhead is important to this species.

Synaptomys in upland habitats behaves as a typical microtine, having multi-annual population fluctuations. Although Linduska (1950) observed annual fall irruptions of this species into the uplands, a longer cycle was apparent. Over the duration of his study, he observed an upward trend in lemming population density that paralled that of the meadow vole, both peaking at the same time. The crash was not monitored, but it was apparent that it would occur. One complete cycle of the microtine population changes occurred over the 3 year duration of the recent investigation (see Table 16). Here, again, the meadow vole and the bog lemming were syncronized in their cycle. Other investigations in Michigan (see Table 17) verify that cycling is a frequent occurrence and major aspect of Synaptomys populations in this state. Likewise, Synaptomys cycles in unison with the local microtines in other parts of its range (Beaseley, 1978; and Gaines et al., 1977). This suggests that any significant competitive interactions between Synaptomys and Microtus are probably worked out in the area of habitat segregation. If there was any direct interference competition occurring, then any numerical effect

TABLE 16.--Population changes for resident microtines over three years

	1978	1979	1980	
	Summer	Summer	Spring	Summer
Microtus pennsylvanicus in perennial grasslands				
Average no. of animals/grid	32 (15-45)	108 (72-140)	31	3
No. of grids (trap/grid)	4 (100)	3 (100)	1 (100)	1 (100)
Trapnights/grid	800	800	600	600
	1978	1979	1980	
	Fall	Summer	Spring	Summer
Synaptomys cooperi in planted pine stands				
Average no. of animals/line	0.3 (0-1)	3.3 (0-15)	0.3 (0-2)	
No. of lines (traps/line)	3 (25)	7 (25)	7 (25)	
Trapnights/line	150	550	70	

TABLE 17.--Population levels in Synaptomys cooperi in two Michigan Counties

Year	Livingston County		Clinton County	
	Burt, 1940	Blair, 1948	Linduska, 1950	Shier in 1980
1936	(abundant) in many upland habitats			
1937	(low) None captured even where sign abundant from before			
1938		(abundant) 5 taken in 7.6 acre plot		
1939		(low) only one taken		
1940		(low) none taken	(low) none captured	
1941		(low) none taken	(low) some in January none in summer	
1942		(common) 3 taken	(common) some in summer in upland sod, common in winter	
1943			(common) 18 in ½ acre sod in February	
---			---	
1946			(abundant) 14 taken in February	
1978				(low) 1 animal in Oct.
1979				(abundant) 15 taken in 8 acres
1980				(low) 2 taken in spring

on either species' populations caused by the other would probably be swamped out by the "overriding" effect of the cycles.

Other evidence for or against competition between the two local microtine species is weak. Getz (1961) observed a strong avoidance by Microtus pennsylvanicus for a shrubby section of the marsh that Synaptomys preferred. In contrast, the lemming would readily enter the habitat preferred by Microtus. Alicia Linzey at Virginia Polytech is presently investigating this interaction to determine the nature of their cohabitation of grassland habitats.

Just as with Master (1978), the data from owl pellets at Rose Lake may suggest a real decline in Synaptomys populations since the 1940s. Linduska (1950) found 44 bog lemmings in a collection of 681 prey items in the pellets of several hawks and owls, 284 were Microtus. In the collection of pellets from the Area in winter and spring of 1979, no Synaptomys were found among 98 prey items taken from three species of owls, of which 41 were Microtus. Likewise, in a collection of pellets that C. T. Black obtained from a Great Horned Owl roost in Meridian Township, Ingham County, only one bog lemming was found in 43 prey items, of which 23 were Microtus pennsylvanicus.

SUMMARY

The Rose Lake Wildlife Experiment Station was established in 1938 to provide information for the management of small game on farmlands. 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 conservative farming. This systematic appraisal of small mammals on the Rose Lake Area, the first since the mid-forties, was in line with the long-term apsects of research at the Station and the broad scope of their objectives.

In the early 1940s a farming program was set up under the guidance of the U.S. Soil Conservation Service and Michigan State College (now Michigan State University). A 700-acre livestock farm employing new land-use practices was put into operation. Crop rotation, contour farming, level ditching, flooding, fence row development, and woodlot management were practiced to enhance productivity of both crops and wildlife.

The economic importance of farm rodents and their significance as key organisms in the wildlife complex justified their inclusion in the program. Hence, a major ecological study was performed over several years, from 1941 to 1946, to investigate the status of small mammals on this representative unit of Michigan farmland. The study sought to determine (1) the comparative population levels of

associated species in the various cropland, field, and woodland habitats; (2) the effects of various land-use and farming practices on population densities; (3) the interrelationships within the group of small mammals and with other wildlife species; and (4) the biological information which might contribute to a better understanding of farm wildlife in general.

Management activities on the Area provided a great diversity of habitats for small mammals. Of the 1,172 acres in ownership by 1940, cropland and pasture constituted 64 percent of the total area; wetlands comprised 24 percent; and woodlots made up 12 percent (Table 3). In the 800-acre portion of most intensive study about 71 percent of the land was in pasture and crops; 16 percent in wetlands; and 13 percent was in woodlots. These land use percentages were typical of the private farms in the immediate area.

Farming of the area was diversified, with fields supporting two crops having different maturation times. Crop rotation occurred on all but the few muck lands. Strip-cropping was also used on the largest fields. Corn, oats, and wheat were the principle cash crops grown, and alfalfa and red clover were grown for hay production. The prairie deermouse inhabited cultivated areas early on when there was little to no herbaceous ground cover. The introduced house mouse later joined the deermouse when adequate ground cover in the form of mature crop plants and weeds became available. In 1950 the European smooth brome grass was added to the hayfields.

Pasturelands, grown up principally with bluegrass and various weed species, were maintained for livestock. Meadow voles occupied

the pasturelands, accompanied by prairie deermice at one-half the density found in croplands.

The transition from livestock farm to a game area program was initiated in 1962. Grain farming was continued on a share crop basis. This program provided for 25 percent of the crop to be left standing for wildlife. Today, corn is the only crop which continues to be planted by sharecroppers and Area personnel. Even this limited sharecropping is in jeopardy of ceasing for lack of interest by area farmers.

All the grasslands retired from cultivation since the introduction of brome grass onto the Rose Lake Area eventually became occupied by this grass species. Today, these fields are essentially monotypic, and very stable in this state. Their lack of plant diversity discourages seed-eating birds and mammals from inhabiting these fields, and consequently the introduction of propagules from other plant species is slow. The transition of these fields to a woody condition is further curtailed by the apparent resistence the growth form of this grass has to the germination of other species. This general cover type occupies 43 percent of the study area, and its success has significantly altered the patterns of seasonal distribution and abundance in the grassland small mammal assemblage of meadow voles and short-tailed shrews.

In the forties, meadow voles occupied upland bluegrass-weed fields only during the fall and winter when moisture levels were high.

Populations averaged 0.85 per line and showed fluctuations of an annual nature.

In contrast, brome fields in the seventies usually retained sufficient moisture to support meadow voles year-round. Population levels are much higher, averaging 6.8 voles per trapline and fluctuating from 1.5 to 15.1 per line of twenty-five traps over a two-year period. The absence of weedy plant species from these fields excluded the prairie deermouse from this seral stage that it had inhabited in the forties. Although the least shrew was taken in small numbers from this seral stage in the past, its presence on the central study area at this time is questionable.

The transition to a game area program called for extensive wildlife plantings in the form of food patches and cover plants. Woody plants of all types were planted in hedgerows and plantations crisscrossing the study area; connecting many of the previously separated habitat types. The maturation of these plantings by 1980 has placed a considerable portion of the land into the intolerant tree and shrub stage with brome grass sod beneath. The earliest plantings and retired oldfields have now advanced to the mid-tolerant tree stage, with grass patches interspersed throughout the woodland. This range of woody cover types with grass patches beneath is favored by the southern bog lemming (now considered a threatened species in Michigan). White-footed mice, and an occasional short-tailed shrew, occupy these sites. However, there is a distinct absence of meadow voles from these shrub-grass-tree areas. Maturation of these tracts

since the 1940s has more than doubled the amount of land supporting woody vegetation. It now totals 200 acres (81 hectares). Hedgerows continue to be planted along roadways surrounding the property.

The upland oak-hickory and lowland maple woodlots were all cut over for large timber sometime within the 50 years prior to 1938, creating substantial breaks in their canopies. Grazing also occurred in many of the woodlots on the herbaceous ground cover and understory shrubs prior to the Linduska study. Together, these activities had allowed substantial patches of sod to develop on many of the woodland floors. One woodlot supported a population of the woodland vole, and an occasional bog lemming was captured in several of these timber stands. Since the early 1940s, additional cutting has occurred in only one of the central area woodlots and all have been protected from pasturing. With cessation of these activities, the woodlots have been allowed to mature, following a pattern of succession typical of most upland woodlots. The canopy has closed in above, aided by maturation of the second story trees. Hence, only spring woodland perennials and shade tolerant shrubs and saplings persist in the interior, and sod patches have been eliminated from all but the margins.

The effect of canopy closure and concomitant thinning of the ground story vegetation has been the reduction of white-footed mouse populations to half of what they were in mid-tolerant woodlands in the forties, from 3.2 to 1.4 individuals per trapline. For this same reason the woodlots are no longer appropriate for either the

southern bog lemming or the woodland vole. However, much of the 81 hectares now in woodland condition is in an early mid-tolerant tree and shrub category that, at this point along with intolerant wooded areas, seems favorable to both species.

Wetlands on the central study area, which in the forties were surrounded by grasses, sedges, reeds, and a few woody associates in an early seral stage, are now surrounded by thick zones of more mature trees and shrubs. In addition to masked shrews and meadow voles, which were caught in limited trapping in the forties, white-footed and meadow jumping mice were captured within these habitats in the seventies.

RECOMMENDATIONS

It is apparent from this study that major modifications in both censusing methodology and habitat preservation be made for three of our threatened or rare small mammal species, the least shrew (Cryptotis parva), the southern bog lemming (Synaptomys cooperi), and the woodland vole (Microtus pinetorum).

The suggested changes in our routine search for these species are carefully outlined in the Methods and in the Species Accounts sections of this text.

It is highly recommended that several diverse mid-successional upland habitats ranging from oldfields supporting native grass and weed associations to early mid-tolerant woodlands be maintained in patchy interspersion. Such arrangements are similar to what commonly occurred in Lower Michigan when natural disasters, such as fire and flood, went unaverted.

All three small mammal species are widely reported to have scattered, loosely colonial associations during most of the year, even though habitat may be extensive and fairly uniform. This behavior is considered by this investigator to be reflective of their association with rapidly changing transition habitats. For example, the least shrew is often found in a nesting situation with several other individuals, and often inhabits grassy or weedy fields in close

proximity to wetlands (see summary by Whitaker, 1974). The woodland vole is frequently found in colonies within ecotonal margins supporting grasses mixed with woodland perennials (Dice, 1920; Linduska, 1950; Fitch, 1958; and Paul, 1970). The most versatile in its association with transition habitats is the southern bog lemming. This species can be found in a wide range of both wetland and upland habitats wherever there is monocotyledonous vegetation contiguous with overhead cover in the form of highly structured ground litter or flora (Hill and Hibbard, 1943; Linduska, 1950; Miller, 1955; Mumford and Handley, 1956; Lindsay, 1960; Getz, 1961, Gottschang, 1965; and Wilkinson, 1980). Its reported scarcity probably stems from both its colonial nature and from what are apparently frequent relocations by these colonies. Hence, an interspersion of smaller patches in various stages of succession is seen as more desirable than extensive tracts of uniform cover type.

In the past, it was considered good management practice to conceal fragile wetland habitats within thick zones of woody vegetation that might reduce human traffic. It is advisable that, at least for the less fragile wetlands, a portion of wetland margins be maintained in early seral stages having native grasses, sedges, spagnums, or reeds, mixed lightly with woody vegetation for the least shrew, and the winter needs of the southern bog lemming.

APPENDIX

MICHIGAN STATE UNIVERSITY

THE MUSEUM EAST LANSING · MICHIGAN · 48824

To: Field biologists

Re: Local population status of Synaptomys cooperi

There is a lack of published information regarding the population status and habitats of several of the less conspicuous small mammal species. Although these species occur in such low numbers as to be unlikely research subjects, valuable information on their habitat selection, life history, and population dynamics may be collected incidental to investigations of the more common species. In light of this, we are conducting a survey of the current populational status of the southern bog lemming (Synaptomys cooperi) in various parts of its range.

Past records from Michigan document marked fluctuations in the bog lemming populations, and presently we are both finding these rodents on the increase in our study areas, Clinton county in southern Michigan and Gogebic and Iron counties in the Upper Peninsula. This questionnarie is being submitted to mammalogists with the distributional range of this species to inquire specifically about 1) present numbers of the southern bog lemming in their areas, and 2) if increasing, what habitats are being used, and 3) if meadow voles (or prairie voles as the case may be) and other small mammals are being influenced by this density buildup. Also it would be useful if the person could determine the timing of probable subsequent population declines in their areas. Information derived from your mammalogy class' field studies is welcomed.

We are mainly trying to establish:

1) whether the population buildup in Michigan is strictly a local phenomenon, or whether it has some common basis for occurance over the entire range of the species;

2) whether any interactions between Synaptomys and associated species, particularly with Microtus spp., are responsible for the population changes observed;

3) what the refuge habitats for Synaptomys are in periods of low numbers, and which ones they expand into in peak periods

Attached is the questionnaire and return envelope. Feel free to contribute any additional observations you think may be useful regarding other aspects of this species' biology.

Cordially,

Tony Wilkinson
Graduate Research Assistant
Michigan Technological University

Jacquelyn L. Shier
Graduate Research Assistant
Michigan State University

QUESTIONNAIRE ON THE POPULATION STATUS OF *Synaptomys cooperi*

In the course of your recent field studies, have you located any southern bog lemmings?

____ Yes ____ No If no, and you have recently performed a field study of small mammals, please briefly describe the study area and observational methods in the appropriate sections. If yes, please complete all sections.

HABITAT: Describe in detail.*

Well drained _____ Describe:

Poorly Drained _____

Successional stage:

Vegetation description:

Small mammal associates:

LOCAL STATUS: Indicate whether high, low, scarce or absent.

	Synaptomys cooperi	*Microtus* spp.
Summer 1978		
Winter 1978-79		
Summer 1979		
Winter 1979-80		

Did you observe any interspecific interactions which would indicate that the species are directly affecting each others' population levels or local distributions?

OBSERVATION METHODS: Indicate trap type, duration, and season, etc. (or whether specimens were brought in without data).

COMMENTS: Comments on any of the above questions or additional information on other aspects of *Synaptomys* biology in your area (attach additional sheet if necessary).

*If you have information regarding more than one local population of *Synaptomys*, please photocopy the questionnaire and record the information separately.

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