

THE LIFE HISTORY AND ECOLOGY OF THE BOG LEMMING, SYNAPTOMYS COOPERI,
IN SOUTHERN NEW JERSEY

By

Paul F. Connor

A THESIS

Submitted to the College of Advanced Graduate Studies of Michigan
State University of Agriculture and Applied Science
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Department of Zoology

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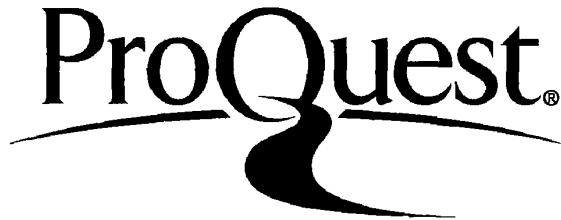
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Don W. Hayne

ABSTRACT

A study of the bog lemming, Synaptomys cooperi, was undertaken during parts of 1953, 1954, and 1955 in the bogs of the New Jersey pine barren region. Methods of study included snap-trapping, live-trapping, field observations, and observations of animals in confinement.

Average and range of weights and external measurements are given for 52 adult males and 31 adult females. Counts of plantar pads and mammae were made and general characteristics of hip glands and pelages were noted.

One hundred and forty bog lemmings were trapped in 20 sphagnum bogs, in pine woods adjacent to several of the bogs, and in one dry field. In the bogs, wherever there was a stand of sedge and shrubs Synaptomys was likely to be present; in several such areas Synaptomys was the most numerous microtine trapped. The habitats of the study areas are described, including the physical environment, plant species, small mammal associates, and other animals present. In several areas during the colder months most lemming activity shifted from the bogs to adjoining pine woods.

Thirty-eight of the bog lemmings were taken in live traps, with a total of 190 captures and recaptures of these individuals. Two areas which were live-trapped gave information relating to home range. Centers of activity were computed and apparent home ranges were mapped.

Approximate trap-revealed "minimum home range" and maximum distance between captures are given for 10 individuals. Some home ranges included both wet and dry habitat at the same time. Territoriality and population density is discussed. In trapping, considerably more males than females were taken. Three of the animals marked in the fall were re-taken the next spring. Abundance of sign was estimated and recorded for 20 areas at different seasons.

Two principle methods used in studying food habits were analyses of the contents of digestive tracts and observations of cuttings and other signs. Eighty-six stomachs were examined. A list of 27 plant species and parts consumed is presented. Stomach contents are given in frequency occurrence, per cent frequency occurrence, and per cent of total bulk. Field observations of cuttings and chewings of various plants are discussed in detail. Observations were made of certain habits associated with feeding.

Fifteen nests are described, including nests containing young at time of discovery. Surface runways, subsurface tunnels, and chambers were studied and measured. Detailed description of sign is given. The sign was believed to be distinctive and usually separable from that of Microtus pennsylvanicus in southern New Jersey.

Observations of caged animals were useful in obtaining information relating to reproduction, development, and behavior. Individuals lived up to a year in captivity.

Synaptomys was bred for the first time in captivity so far as I know. Six litters (22 young) were born in captivity to one female

during a five-month period. The gestation period was 23 days in one case and was believed to be 23 days in another.

Information relating to number of young per litter was obtained from embryo counts, placental scar counts, and litters born in the wild and in captivity. Three nests containing a total of 10 young were found in the wild. Breeding season based on trapped animals is discussed. Parental care, including building and repair of nests, is described.

The growth and development of 28 young were studied in the laboratory. Condition at birth, and weights, measurements, pelages, molts, external features, and behavior at various stages of growth are given.

Observations are reported on the behavior of bog lemmings in the field and laboratory, including times of activity, movements, voice, sanitation, and temperament.

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INTRODUCTION

Bog lemmings of the genus Synaptomys (Tribe Lemini; Subfamily Microtinae) are widely distributed over northern North America. Synaptomys borealis, the northern bog lemming, ranges throughout much of Alaska and Canada. Synaptomys cooperi, the southern species, occurs from Canada south to Kansas, Arkansas, and North Carolina. Within this vast area it inhabits a large variety of habitats. However, it is apparently very irregular in its geographic distribution and has been captured in numbers only on a few occasions in a few localities. Perhaps for this reason, much remains to be said concerning the habits of members of this genus.

Richardson, in 1828, described borealis but he assigned it to the genus Arvicola (= Microtus). Baird named and described the genus Synaptomys in 1857, at which time he also described the species cooperi. Rhoads in 1893 described stonei from New Jersey, and designated it as a race of cooperi in 1897. Howell (1927) revised the genus and listed most of the important references to Synaptomys published up to that time. Recently, an important review by Wetzel (1955) presented new data on speciation and dispersal in Synaptomys cooperi. Among the more important contributors to our knowledge of the natural history of this species may be mentioned Quick and Butler (1885), Linsdale (1927), Burt (1928), Stegeman (1930), Oehler (1942), Fichter and Hansen (1947), and the authors of the Pennsylvania Mammal Survey (1949-52). Among the various common names that have been applied to this species are southern bog lemming, lemming mouse, bog mouse, Cooper's bog lemming, Cooper's lemming,

Cooper's lemming vole, etc. The race stonei has been called Stone's lemming or Stone's lemming mouse.

In the summer of 1951 the present writer made a survey of small mammals in different habitats in the pine barrens of southern New Jersey (Connor, 1952, 1953). Several bog lemmings, Synaptomys cooperi stonei Rhoads, were trapped in a small sphagnum bog, and sign, believed to be of this species, was seen in many other bogs. In this region Synaptomys seemed to be regular enough in its occurrence to present an unusual opportunity for field study. An investigation was subsequently carried out as a doctoral research problem.

AREA AND GENERAL METHODS

The field study was carried out entirely in southern Burlington County and adjacent parts of Atlantic and Ocean counties, within the pine barren region of the coastal plain of southern New Jersey. Many of the trapping and study areas were located in Penn State Forest, Green Bank State Forest and Bass River State Forest. All of the areas were located 6-25 miles north of May's Landing (central Atlantic County), the type locality of stonei. Headquarters during the study were maintained at Lower Bank on the Mullica River near Green Bank State Forest.

Methods of study included 1) snap-trapping, 2) live-trapping (mark, release, and recapture), 3) field observations, and 4) observations of captive animals. One-hundred^{and two}/bog lemmings were snap-trapped in 19 different bogs and 1 dry field, and yielded information relating to food habits, reproduction, weights and measurements, and other topics. Thirty-eight individuals were live-trapped (190 captures and recaptures), giving information relating to home range and other habits, chiefly on a three-acre quadrat in October, 1954 and May, 1955, and on a smaller area in November-December, 1954. A few animals were taken alive for study in the laboratory. Three nests containing a total of 10 young were found in the wild. Field observations were of several kinds, including that of recording the plant and animal environment, studying nests, runways, and sign, and rarely, watching individuals feeding. The sign, especially cuttings and droppings, was useful in detecting the presence of this species, in estimating relative abundance, and as an aid in

determining food habits. Observations of captive animals were helpful in studying reproduction and development and in obtaining other information difficult to obtain in the wild, such as behavior and call notes. Twenty-two young (6 litters) were born in captivity.

A total of about 10 months time was spent in the field during 1953 (July 22-September 19), 1954 (March 25-26; June 28-December 12) and 1955 (April 1-June 17). Caged animals were brought to the campus of Michigan State University in June, 1955 and kept until May, 1956. Twenty-three study skins, 32 skulls, 36 whole alcoholic specimens, and parasites (tapeworms, ticks, mites, fleas and lice) at present are in the author's possession.

DESCRIPTION OF ADULTS

General Description

"The characters whereby the genus Synaptomys may be most readily distinguished from all other Microtinae are its grooved upper incisors and the extreme shortness of the rostrum (about 25 per cent of the total length of the skull). . . . Externally there is little or nothing by which the genus may invariably be distinguished, but the shortness of the tail is sufficient to separate it from all but a very few species of American Microtus. In appearance its members are robust, with massive heads, in this respect somewhat resembling the other lemmings, but in the main the superficial appearance is that of voles and meadow mice." (Howell, 1927). The facial features of living specimens of Synaptomys differ from those of Microtus pennsylvanicus in several respects. Among these may be mentioned the broader and less pointed nose, slightly smaller eyes, and more exposed ear pinnae in the former.

There are two recent species of Synaptomys, the southern bog lemming, S. cooperi (subgenus Synaptomys), the species reported upon here, and the northern bog lemming, S. borealis (subgenus Mictomys). Hall and Cockrum (1953) give the following key characters in separating these two species, characters which are also included in subgeneric diagnosis by Howell (1927). Synaptomys cooperi: No hairs at base of ears appreciably brighter than remainder of pelage; mammae 6; mandibular molars with triangles on outer side; palate with broad, blunt median projection. Synaptomys borealis: A few hairs at base of ears distinctly brighter

(with bright rusty tinge) than remainder of pelage; mammae 8; mandibular molars without triangles on outer side; palate with sharply pointed median projection pointed backward.

The features chiefly used in differentiating the subspecies of S. cooperi are various skull characters, the pelage differences being relatively minor (Howell, 1927; Wetzel, 1955). The same authors have given detailed descriptions of the skull characters and also pelages of the various races.

Weights and Measurements

Weights and external measurements are given here for individuals collected which were not nestlings or in juvenile pelage (for these groups see Growth and Development). Juvenile and adult were the two main age classes recognized during trapping; all of the former which I collected were quite small and none was in breeding condition. However, within the adult group, younger or subadult animals may frequently be recognized; these are generally darker or duller than the older animals, they average somewhat smaller, and many of them probably have not bred. Ten lemmings trapped which overlapped the juvenile range in weight (3 individuals) or total length (8 individuals) probably belong in this subadult category; however, half of these were breeding and one was in bright pelage characteristic of older adults. Because of lack of suitable data for setting up age standards on the specimens, I have included these individuals within the adult group in these calculations.

The following table summarizes measurements in millimeters and weights in grams of 52 adult males and 31 adult females (except ear from notch: 39 males and 19 females; and ear from crown: 25 males and 15 females) trapped at various seasons in 1953, 1954, and 1955 in southern Ocean and Burlington counties and northern Atlantic County. Body length was obtained by subtracting tail length from total length. All measurements were made by the writer.

	Males		Females		Total
	Mean and SE	Range	Mean and SE	Range	Mean and SE
Total length	124.7 $\pm$.82	112-139	124.5 $\pm$ 1.26	112-139	124.6 $\pm$.69
Body length	104.0 $\pm$.70	93-117	104.5 $\pm$ 1.13	92-117	104.2 $\pm$.61
Tail length	20.7 $\pm$.28	14-24	19.9 $\pm$.34	16-24	20.4 $\pm$.21
Hind foot	19.1 $\pm$.10	17.0-20.5	18.9 $\pm$.17	18.0-20.5	19.0 $\pm$.09
Ear (notch)	11.8 $\pm$.11	11.0-13.5	12.0 $\pm$.18	11.0-14.0	11.9 $\pm$.11
Ear (crown)	9.9 $\pm$.20	8.5-12.0	9.7 $\pm$.23	8.5-11.0	9.8 $\pm$.15
Weight	28.4 $\pm$.58	20.0-39.6	28.0 $\pm$.89	18.7-38.9	28.3 $\pm$.49

Howell (1927) stated that the sexes do not differ with respect to external size. Wetzel (1955) found skull measurements of sexes in this species to differ little in certain large samples from one area. Similarly, the above table indicates that the sexes are closely alike in both weights and measurements. Only tail length differs more than half a millimeter between the means.

Wetzel (1955), using a conservative treatment of the adult category based on skull characters, obtained a mean total length of $126.6 \pm .91$ mm. for 46 bog lemmings of both sexes of stonei from Massachusetts to North Carolina. For six of these specimens from New Jersey alone, he obtained a mean of $125.2 \pm .6$ mm. His figures for mean total length do not differ greatly from those I obtained.

Plantar Pads

Plantar pads, or tubercles, number six. Howell (1927) examined 11 alcoholic specimens representing three races of S. cooperi and one of S. borealis, and found six well-developed pads on each hind foot. In my collection of 34 alcoholic specimens of S. c. stonei from southern New Jersey 30 have six well-developed pads. Of the remaining four specimens, the pads on two cannot be counted because of damage by ants while still in the trap. The last two animals have five pads on each hind foot but it was not definitely established that the sixth pad was not destroyed by ants or broken off. On the fore-feet I counted four pads on each foot, not counting the one on the thumb.

Mammae

All females examined had six mammae, two pairs pectoral and one pair inguinal. This is the number now usually reported to be present in the species cooperi. Eight are sometimes given in reference books for cooperi, but Howell (1927) states that 6 seems to be the maximum in

this species. Quick and Butler (1885) said all individuals they saw apparently had 4 mammae, 1 pair pectoral and 1 pair inguinal; Linsdale (1927) reported one individual with just 2 pairs, but two other females he collected had the normal complement. Harper (1929) diagramed the position of the mammae in a specimen of Synaptomys cooperi. In lactating females certain mammae may be more prominent than others. The most anterior pair are frequently the most prominent, but the inguinal pair is occasionally so.

Hip Glands

According to Howell (1927) old males may be distinguished from females and from other genera by the dingy white hairs growing from the center of the hip glands. These glands are located on the sides immediately anterior to the hind limbs. It may be that the white color of the hairs is derived from the glandular secretions. In study skins with the most conspicuous gland hairs, the hairs are white to the tip, but in other specimens the hairs are white only at the base. In nearly all cases, however, the fur must be ruffled slightly to see them. In one laboratory-raised specimen the whiteness of the hairs was gradually lost after the animal had been made into a study skin, and after about two weeks time the location of the glandular area was scarcely distinguishable. However, this was not observed to occur in wild-caught specimens. Internally the glands in 6 alcoholic specimens of adult males appear as an oval, dark or fairly light spot 3-8 mm. in length. These spots were not found in several females examined.

Pelage

Color variation in animals which appeared to be adults commonly ranged from a rather dark grayish-brown to a light, bright pelage. Actually, the dark individuals were usually the younger animals which had not yet attained the fully adult pelage, and thus these colors represent age differences and cannot be considered true variations (see Growth and Development). Three adults collected (one each in August, September, and October) were very reddish (caused by unusually bright tips to the hairs) in contrast to normally bright adults. These reddish or chestnut individuals may be the same as specimens of a rich chestnut color mentioned by Wetzel (1955) as occurring in varying proportions in the different subspecies of Synaptomys cooperi. It is possible that these individuals attained the unusually reddish color by having recently come into fresh pelage. Manville (1955) gave the first report of an albino bog lemming; it was completely white. I know of no other color aberrations reported in this species.

Adults apparently have a definite fall molt, and in addition there is apparently a certain amount of molting at other times of the year. In younger animals the juvenile molt, and also probably the post-juvenile or subadult molt, occur at more or less definite stages of development (see Growth and Development). Most of the older animals trapped, those already in bright pelage, which had new hair coming in were taken during the fall. Fourteen of 21 adults taken from October to December showed evidence of pronounced molting, with new hair coming in all over the

back in some of them. In spring only one (a pregnant female) out of 12 adults examined showed evidence of molting. During summer no adults were molting of 10 or more examined externally, although several sub-adults were undergoing the molt to adult pelage. One individual born in the wild in May, 1955, and taken into captivity molted during the following October. Another adult in captivity (an old female) was observed molting in February. In both of these captive mice as well as in many trapped specimens the new short hair was observed to be located in scattered patches. So far as I can tell, while the hair has a regular sequence of growth in the juvenile and apparently in the post juvenile molts, the progress of molt in adults is without pattern. In these respects Synaptomys may not differ essentially from Microtus californicus, in which the molt was worked out by Hatfield, 1935.

Bole and Moulthrop (1942) describe seasonal molt and pelage characteristics for the race cooperi in Ohio based on over 70 museum specimens. Besides a fall molt (October to first week in November) they discerned a summer molt from the end of June to mid-August. They observed the fresh winter pelage to be relatively pale and gray; by late May or early June the race assumed a bright ochraceous tawny cast due to wear of dark hair tips; during July, with molt in progress specimens were dark and seedy; by mid-August all specimens were in the dark brown pelage of summer. Aside from the fall molt, I am unable to describe such a sequence in my specimens of stonei from New Jersey. Perhaps with a larger series of skins from all times of the year such seasonal changes could be observed. I have both relatively pale and bright specimens

from each season (spring, summer, and fall). The very light yellowish (faded?) color of the hair tips, instead of a bright or rich yellow, is chiefly if not entirely responsible for the color of the pale individuals. However, all of my specimens were much darker and richer brown in coloration than three adult cooperi from Michigan with which they were compared. Howell (1927) states that the winter coat differs from the summer one in that it is longer and denser, but I have made no observations on this point.

ECOLOGY

Geographical Distribution

Synaptomys cooperi ranges from the southeastern corner of Manitoba east across Ontario and Quebec to Saguenay County on the northern shore of the Gulf of St. Lawrence, Cape Briton Isle, Nova Scotia and New Brunswick south to Kansas, north-eastern Arkansas, the mountains of Tennessee and North Carolina and on the coast to the Dismal Swamp area of Virginia and North Carolina. The most recent map showing the subspecies of cooperi is given by Wetzel (1955) who recognized three main groups, cooperi, stonei, and gossii and two lesser groups, helaletes and paludis. S. c. stonei, the form studied here, extends from Massachusetts to Maryland and southwest through the Appalachians of West Virginia, Virginia, eastern Kentucky, eastern Tennessee, and North Carolina to within 10 miles of the Georgia line (Odum, 1948). The population in southern New Jersey, where this study was carried out, seems to be a more or less isolated center of abundance along the coast, probably because of the numerous sphagnum bogs remaining in this area. Wetzel (1955) described an apparent reduction in range which produced helaletes in the Dismal Swamp south of the main stonei group. Only two specimens of Synaptomys have been taken on the Del-Mar-Va peninsula, (Poole, 1943, and Poole in personal letter to author, 1956). Northwards in New Jersey, to my knowledge it has not been taken between the southern part of the state (stonei) and the northern tier of counties (cooperi); stonei is again recorded in Connecticut and Massachusetts. Westward, in

southeastern Pennsylvania, across the Delaware River from southern New Jersey, Roberts and Early (1952) did not record Synaptomys although S. cooperi was taken fairly commonly further west in the state. Although additional collecting will probably turn up the species from localities around the pine barrens, it is possible that the same trend in reduction of range which produced helaletes is taking place in relation to the population in southern New Jersey.

General Habitat Preference

Synaptomys cooperi has been found in a large variety of habitates in different parts of its geographical range. Many of the references are mentioned below. It is often thought of as an inhabitant of the sphagnum, and it has been trapped in this habitat in many places, especially in the eastern part of its range. Thus, it has been recorded from sphagnum bogs in Nova Scotia (Sheldon, 1936); New Jersey (Rhoads, 1903); eastern shore of Maryland (Poole, 1943); Highlands Plateau of North Carolina (Odum, 1948, 1949); Michigan (Green, 1925); Minnesota (Bailey, 1929); and elsewhere.

Most of the records of the occurrence of Synaptomys in dry or damp fields and pastures are from the mid-western states. It has been taken in areas of bluegrass in Minnesota (Bailey, 1929); Ohio (Preble, 1942); Indiana (Quick and Butler, 1885; Mumford and Handley, 1956); Iowa (Miller, 1955); Nebraska (Fichter and Hansen, 1947); Kansas (Linsdale, 1927; Burt, 1928; Hall, 1955); Missouri (Fisher, 1945); and probably other states. It was trapped in tall grass in Nebraska (Fichter and Hansen, 1947);

tall native prairie grass in Kansas (Linsdale, 1927); hillside meadows overgrown with blackberry and crab grass in Ohio (Oehler, 1942); small clearing with weeds and bluegrass and alfalfa-bluegrass pasture in Michigan (Linduska, 1950); and sandy fields with June-grass in Michigan (Stegeman, 1930). Synaptomys has been recorded from grassland near Lake Drummond, Virginia (according to Howell, 1927) and grassland including abandoned clearing and pasture in Kentucky (Barbour, 1951, 1956). It has been found in shocked corn in Michigan (Linduska, 1950) and Pennsylvania (Grimm and Roberts, 1950). The several authors of the Pennsylvania Mammal Survey (1949-1952) found Synaptomys occupying various grassland and old field habitats.

Bog lemmings also inhabit forests, especially in the north. They have been taken in forests in Ontario (Coventry, 1942); New York (Hamilton, 1941b); New Hampshire (Eadie, 1937); Connecticut, where dense shade and sphagnum and other moss on ground (Goodwin, 1932); Pennsylvania (Pennsylvania Mammal Survey, 1949-1952); Michigan, in oak-hickory woods in times of high population (Burt, 1949); northern Michigan in various types of woods as well as bogs (Dice and Sherman, 1922; Dice, 1925).

Preliminary trapping of small mammal habitats in the New Jersey pine barrens was made by the author in the summer of 1951. A variety of habitats, from dry pitch pine plains to wet bogs, were trapped. Bog lemmings were taken in two bogs (7 in leatherleaf-sedge-sphagnum; 1 on edge of wet sedge bog), and sign, believed to be of this species, was found in a stand of Andropogon virginicus in an abandoned orchard. In the present study there was no trapping at random in different

habitats. The presence of sign was the criterion for judging if Synaptomys was present in an area, and usually trapping was carried out only where there seemed to be enough sign to indicate a satisfactory catch.

The chief requirement of Synaptomys seems to be the presence of green, succulent monocotyledonous plants which are the chief source of food for these mice. All of the areas where bog lemmings were found in this study had a good stand of some kind of monocotyledon. Broadly speaking, the habitats in which bog lemmings were trapped may be classified into two major categories, 1.-Bogs (generally shrub-sedge-sphagnum complex, not mature cedar bogs) and adjacent areas, and 2.-Dry fields (chiefly grasses). Areas adjacent to bogs were chiefly pine woods with monocotyledonous ground cover, occupied seasonally by Synaptomys in several of the areas studied.

Bogs are the principle habitat of Synaptomys in the pine barrens. Small sphagnum bogs are scattered liberally throughout the region. Here, wherever there is a good stand of sedge combined with the sphagnum and shrubs, Synaptomys is likely to be present. In this habitat Synaptomys was the most numerous microtine trapped. The presence of shrubs and sedge seemed to be important. In two sedge meadows which lacked the typical moss and shrub cover only one Synaptomys was taken and Microtus was the most common species to judge from trapping results and sign. In addition, within bogs, most of the sign is typically located in the sedge along the fringes of clumps of shrubs. Sign believed to be of Synaptomys was found in forty-one bogs; of these thirty were trapped,

with twenty-six yielding bog lemmings. The few fields which occur in the pine barrens are dry, sandy, and usually only sparsely covered with grass, appearing to support very few Synaptomys and Microtus. However, four bog lemmings were taken in one field and old sign, believed to be that of Synaptomys, was found in two other fields. To my knowledge Synaptomys on the New Jersey coastal plain has not previously been reported outside of sphagnum bogs.

Seasonal Variation in Habitat

Burt (1940) reported Synaptomys from oak-hickory woods as well as low moist places with heavy matted grass in a year when the population was high in southern Michigan. When the population went back to a low, it was found only in the favored grassland habitat. Barbour (1956) found Synaptomys confined to tall grass of fencerows, swampy areas, and a few waste fields in Kentucky during January, February, and March; with the spring growth of grasses, these mice spread into other areas and became more difficult to locate. With Microtus, a fall and winter movement into upland areas and subsequent population buildup has been reported by workers in different parts of the country (Linduska, 1950; Roberts and Early, 1952).

In the present study it was found that Synaptomys showed a pronounced seasonal shift in fall and winter from many of the bogs into adjoining pine woods. Both trapping and observation of fresh sign gave information on this phenomenon. There may also have been breeding in the pine woods following the shift, with a subsequent increase in

population, but no information was obtained concerning this. In three bogs with adjoining pine areas this seasonal movement was observed over a three-year period (three summers in bog, two winters in woods).

Fresh sign in the woodland turkeybeard (Xerophyllum asphodeloides) usually appeared during late October or November. By March a great amount of sign had accumulated in such areas and it seemed to reach a maximum at this time (Figs. 18-21). In the winter the bogs nearby seemed to be unfavorable habitat and contained little or no sign. During April, with the beginning of spring growth, fresh cuttings began to increase out in the bogs and to decrease in the woods. In the hot, dry pine woods in summer it was not usually possible to find anything except old sign from the previous winter, although the old runways, droppings, large piles of cuttings, and eat-outs remained conspicuous. Lines of snap traps in such situations in summer failed to procure specimens of Synaptomys.

Patches of a grass (Stipa avenacea?) were occasionally found in pine lowland near bogs. On two such areas old sign was present, without evidence as to season when occupied. On a third area, the Bear Swamp quadrat, this vegetation was frequented in fall, before it turned brown. After that, bog lemming activity was entirely in the turkeybeard.

The mice apparently did not move far from the wet bogs during this seasonal shift. One hundred and sixty feet was the maximum distance from bog edge of a trap taking Synaptomys. No sign was found farther than this, although a number of more distant areas were closely examined. In most areas sign was concentrated within fifty feet of the edge.

In the Bear Swamp quadrat live-trapped in October, 1954 and May, 1955, individual bog lemmings were taken in both habitats (See Home Range). The location of fresh sign in this area in summer was confined to the bog and in winter almost all of it was in the dry areas. During December a small quadrat of live traps in another area showed day-to-day forays of a few individuals back and forth from the wet sedge bog to certain scattered clumps of turkeybeard on a dry sandy slope which had little ground cover otherwise.

This back and forth movement occurred irrespective of precipitation factors in the bogs. Temporary flood conditions, which followed heavy rains at different seasons, probably caused movements of mice, but no shift so extensive as the seasonal one was detected during flood. Snow cover, which would allow greater movement in winter must be ruled out as a factor in this region, for snow cover is practically nonexistent in southern New Jersey. However, during winter the ground under the pine litter is much cooler and more moist than it is in summer, and this may be a factor in permitting the movement.

This shift in centers of activity appeared to be primarily for reasons of food supply, probably in conjunction with the fall build-up of mouse numbers. The areas on which it occurred were those in which the sedge growth turned almost completely brown in the bogs and where the evergreen turkeybeard (Xerophyllum asphodeloides) grew in the adjoining pine woods. In contrast, bog lemmings remained in areas where the sedge in the bogs grew densely and retained much green succulence all winter as was true with many of the Carex stands in

leatherleaf-sphagnum bogs. During summer the turkeybeard was not eaten in places where it grew along the edges of the bogs, mingled with Carex and other sedges. Here the lemmings showed a preference for the scattered blades of sedges. The turkeybeard was eaten later, after the sedge died down. The evidence, then, seemed to indicate that the winter shift into turkeybeard areas was a direct response to the deterioration of the favorite food supply in the bogs (Also see Food Habits).

Description of Habitat

Physical Environment

Climate. Temperatures in southern New Jersey are rather high compared to much of the range inhabited by the genus Synaptomys. The summers are rather hot and the winters are moderate, with much freezing and thawing but with very little snow. The total annual precipitation in the pine barrens area ranges from 42 to 45 inches (Barksdale, 1952).

Hurricanes are a factor in the ecology of the pine region. Along the edge of lumbering operations in a cedar swamp adjacent to a trapping area a "blow" was observed to create a large area of dead-falls. On the live-trap quadrat in Bear Swamp a hurricane in mid-October blew down numerous dead cedars, shredded the bark from others, and even snapped off green pines in the middle of the woods. The most spectacular alteration of the bog environment by hurricanes was the sudden, drastic, but temporary raising of the water level.

The tree-less bogs inhabited by lemming mice were a much less stable environment in regard to temperature and wind movement than the dense cedar bogs. Water and moss in the open bogs were seen to freeze and thaw repeatedly before the same materials froze under the cedars. Within a cedar bog in the midst of a hurricane very little air movement was felt, although the tops of the trees were whipped back and forth overhead.

Soil. The southern three-fifths of New Jersey lies on the coastal plain, which is composed of loose Cretaceous, Tertiary, and Quaternary sediments of gravel, sand, and clay. In southern New Jersey this plain dips gently to the southeast and over half of it is less than 100 feet in elevation, (Kummel, 1940). The pine barrens, the largest of the floral districts* in southern New Jersey, occur on various sands and gravels, mainly the Cohansy formation of Tertiary sands (Lutz, 1934). The region includes some lenses of clay (Barksdale, 1952). The soil is a true podzol, which is characterized by strong acid leaching; the pH ranges from 3.7 to 4.5 and this high acidity limits herbaceous food plants (Moore, 1940). Peat forms in the bogs, especially in the white cedar bogs.

The vegetation of the pine barrens shows little relationship to that of the rest of New Jersey. Tedrow (1952) stated that "The pine-barren area in New Jersey owes its existence primarily to the character

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Stone (1911) and Harshberger (1916) discussed the floral districts or divisions of southern New Jersey.

of the geologic materials from which the soil was derived. Soil type, poor moisture conditions, lack of nutrients, acidity, aluminum toxicity, and repeated fires appear to be traceable to the nature of the materials." Others, however, place greater importance on fires, which will be discussed later.

Water. It is of interest and significance that the pine barrens contain a large store of unpolluted water surrounded by heavily populated areas. According to Barksdale (1952) the pine barrens contain the last great essentially untapped source of good water within the state of New Jersey.

In bogs and swamps water level is an important ecological factor in determining the amount of territory available to terrestrial organisms. During this study, records were made of the relative amount of water on the different areas. At each visit to a bog, rough notes such as the following were made: Completely dry (shoes dry); standing water in low depressions and ditches only; water covering about half of the area and about ankle deep; over half the area submerged; most of the area submerged and most sign covered, only the tops of higher hummocks emergent. An examination of the notes showed that in general the summer was the driest season. For other seasons there is insufficient data to state when the highest waters occurred; perhaps it varies from year to year.

Hurricanes during summer and heavy storms at any season caused temporarily deep water. Bogs associated with streams and cedar bogs

seemed to be relatively immune from major fluctuations in water level. One such bog visited at 8 a.m. following a heavy storm at night had considerable water on it, but the excess ran off during the day and by nightfall the bog had returned to a condition approximating that of the previous day. However, the depression basins fluctuated wildly. "Bone dry" one day, they were often transformed into virtual lakes overnight, and required days or even weeks to drain off. Depression basins contain a layer of clay below, which holds the water above normal ground level.

I have little information as to what happens to the populations of small mammals under such conditions. Live-trapping of the bog lemmings was successfully carried out only on two areas which did not flood during the study. Frequently a decrease in signs of activity was noted following a flood, with no apparently suitable nearby areas to which the animals could repair. On two areas during protracted periods of deep water, sign of Synaptomys was concentrated in narrow linear fashion along the edge of higher ground, in one case an overgrown road-fill.

Sometimes during deep water much sign was found on small peninsulas and islands of higher bushy areas. Food areas of sedge in the low spots are the first to be covered by water, and sometimes new sign was found in situations where the animals must have had to stand in shallow water. One lactating female was snap-trapped on a small island (6 x 3 feet) of Carex around the foot of a red maple, a location attainable only by swimming a short distance. Most nests found were located in elevated

hummocks of sphagnum. These are probably above most high water levels, but may occasionally be covered, as discussed elsewhere.

The depression basins, filled deepest after rain, also dried out more than other bogs during the summer. At this season the sphagnum dried out, losing its green color and becoming crusty in consistency. Bog lemmings were still present and were trapped at holes or in slightly damp runways under the dried sphagnum. During drought, the mouse activity seemed to occur primarily in the subterranean passages, with scarcely any sign on the surface. At the same time mice must have made frequent surface forays to obtain leaves, for in some areas cuttings were found just inside of holes opening on the surface.

Drought affects the vegetation directly and also increases fire hazard. For example, the spring and summer of 1954 were unusually dry, and many blueberry farms on upland sites suffered loss of bushes from the drought. At the same time fires were more frequent than usual in the pine region.

Fire. Fire plays an important part in the ecology of the pine barrens. Many modern investigators (Lutz, 1934; Moore, 1939; Little, 1946; Little and Moore, 1949) credit fire with the role of maintaining the dominance of pine and preventing the successional trend toward a hardwood forest. Many workers attribute these fires chiefly to man's activities, going as far back as Indian times. Chapman (1952) states that lightning has operated frequently enough to place fire among the determining ecological factors that have influenced development,

modification, and survival of species, especially pines. Pollen profile analyses of bogs in southern New Jersey (Potzger, 1952) indicates that the importance of pine was little changed as far back as the pollen record goes.

Signs of past fires were frequently seen on the trapping areas. Some of the bog shrub-sedge habitats occupied by Synaptomys had apparently been created by fire and would eventually revert to cedar swamp (scattered fired trunks; young trees coming in). In May, 1955, near Weymouth, three recently burned depression basin bogs were examined. Dr. Jack McCormick (In Charge of Vegetation Studies, American Museum of Natural History) visited the area with me and pointed out the two years growth on the leatherleaf, which indicated the fire had occurred two winters previously. Two of these bogs bore little indication of mouse activity, but the third, which was mostly under water, and with a good stand of Carex, exhibited considerable bog lemming sign in a relatively narrow zone along the edge. The uncovered and conspicuous position of the cuttings showed that the animals had fed in unusually exposed situations along the edge of the available Carex. Most of the Carex was further out, under water, and the fire had produced very poor cover conditions. The shrubs were dead, blackened, and leafless, although new shoots were coming in. The sphagnum had apparently been killed off by the fire, and only a small amount of it remained, rotten and soggy. One nest with four young bog lemmings was found in a low mound of dead moss, earth, and roots under a charred branch of a pine which stood on the edge of the bog. Trapping took two other bog

lemmings, as well as meadow voles and jumping mice. This bog was not inspected before the fire; thus nothing can be said of the previous history of small mammals on the area.

Microclimate of the runways. The temperatures in runways under the water-retentive sphagnum are probably much cooler in summer than those at the surface or than temperatures under a grass mat or pine-oak leaf litter. The moss always feels cool to the touch on the hottest summer days. The coolness of the sphagnum bogs may be an important factor in maintaining Synaptomys in the southern parts of its range, although it has been found living in dry as well as moist grassland in Virginia, Missouri, and Indiana (Howell, 1927). Temperature recordings in a sphagnum bog were made only once during the study; between 1:30 and 2 p.m. on September 2, 1954, a relatively warm day. A thermometer set on the surface beneath the shade of a leatherleaf bush fluctuated between 82° and 88° F; when set in a runway 4 to 5 inches beneath the surface of the moss under the same bush it registered a steady 73° F.

Plant Environment

Species of Plants. Although lemming mice were trapped in a fairly large variety of wet habitats, most of the areas in which these animals were taken can be classified as either depression basins or areas adjacent to streams and cedar bogs. Depression basins (Fig. 1) are typically oval or round in shape and bordered by dry pine barrens. A relatively small number of plant species occur in such a basin and leatherleaf (Chamaedaphne calyculata), Carex (probably C. bullata most

commonly), and sphagnum were generally dominant in the areas studied. Other plants frequently present were the Virginia chain fern (Woodwardia virginica), Carolina red maple (Acer rubrum var. trilobum), sheep laurel (Kalmia angustifolia), cranberry (Vaccinium macrocarpon), and high-bush blueberry (Vaccinium corymbosum). The blueberry grew chiefly along the edges of these bogs (said to grow about where the clay ends).

The most favorable places for lemmings in the depression bogs seemed to be where shrubs as well as sedge and sphagnum were present. Although the sedge furnished the food, activity in most bogs seemed centered around or near the clumps of leatherleaf. Perhaps factors involved were the greater cover afforded by the shrubs and the moss (which grew over the roots and reclining stems of the shrubs) and the drier, more elevated, nature of the shrub areas. Synaptomys was trapped in seven bogs of the depression basin type and sign was seen in eight others.

The other common type of shrub-sedge-sphagnum bog was associated with streams and cedar bogs. (Figs. 3, 11). Seen from the air, the cark cedar bogs are observed to form a branching network, following as they do the course of streams through the pine barrens. The Synaptomys areas are frequently narrow linear bogs (Fig. 3), a transitional zone where pine woods drop off into cedar bogs. These areas contained a greater variety of plants than did the depressions (Figs. 4, 5). The sphagnum was generally quite thick and luxuriant, forming large hummocks on the surface. A large variety of low shrubs occurred, chiefly dwarf huckleberry (Gaylussacia dumosa), blue huckleberry (Gaylussacia frondosa),

leatherleaf, sheep laurel, bayberry (Myrica pennsylvanica), and shining holly (Ilex glabra). The dwarf huckleberry was dominant in some of the bogs. The shrubs were often sufficiently low and scattered so that a good stand of sedge was mixed in. Sedges were of a much greater variety than in the depressions, although without dense stands of Carex often characteristic of the latter. Sedge often died down completely in winter. Carex spp., Rhynchospora spp., Cladium mariscoides, Andropogon glomeratus, and other sedges, grasses, and rushes occurred. Rhynchospora was very frequent and sometimes dominant in areas in which bog lemmings were trapped. Xerophyllum was sometimes common along the edge, mingling with bog plants in the moss. Other plants included scattered trees (Chamaecyparis thyoides, Pinus rigida, Acer rubrum var. trilobum, Nyssa sylvatica), high-bush blueberry, and cranberry, and a variety of herbaceous forms, such as pitcher plant (Sarracenia purpurea), sundew (Drosera spp.), several species of orchids, and other flowers. Bog lemmings were trapped in nine bogs of this type and sign was located in three others.

Synaptomys was present in a variety of other areas, some of which seemed to me difficult to classify. Two pine bogs had signs of these mice and several were caught in one such area. These areas had an open stand of pine (Pinus rigida) over a sphagnum bog with a fairly large variety of shrubs, sedges, and herbs. Several bog lemmings were trapped in a roadside ditch a few feet wide containing Carex and some sphagnum. A Carex meadow without sphagnum and with few shrubs yielded one bog lemming along with several Microtus. Lemmings were trapped in a

Fig. 1. Depression basin sphagnum bog habitat with Carex bullata and leatherleaf (Chamaedaphne calyculata) dominant. Dry pitch pine woods in background. Three specimens of Synaptomys were trapped along edge of the leatherleaf area in center and sign of cut Carex leaves and leatherleaf twigs (December) was heavy here. Near Bass River State Forest. June 17, 1955.

Fig. 2. Another bog dominated by Carex and leatherleaf. Here, the leatherleaf occurs as scattered clumps or islands. Pitch pine, red maple, and southern white cedar in background. The following were collected here in July and April: Sorex cinereus, 24; Blarina brevicauda, 1; Synaptomys cooperi, 6; Microtus pennsylvanicus, 1; and Clethrionomys gapperi, 8. All specimens of Synaptomys were taken along the edges of the clumps of leatherleaf; the Clethrionomys were trapped near the trees. Near Harrisville, September 19, 1953.



Fig. 3. Long, narrow type of bog habitat, with cedar bog and stream on left and dry pine woods on right (just right of deciduous trees shown here). Low shrubs, chiefly huckleberry (Gaylussacia dumosa), mingle with sedges (Carex, Rhynchospora) on thick sphagnum mat. During August, ten specimens of Synaptomys were trapped here, and in November twelve more were taken. Other specimens collected included Sorex cinereus, 15; Blarina brevicauda, 8; Microtus pennsylvanicus, 6; Clethrionomys gapperi, 14; and Zapus hudsonius, 2. Sedge cuttings were abundant. Bass River State Forest, September 18, 1953.

Fig. 4. Close-up of dense cover of shrubs of several species and Carex, adjacent to cedar bog, with heavy sign of Synaptomys beneath (chiefly cuttings of Carex leaves). The shrubs are growing on a sphagnum hummock in which a nest (probably of Synaptomys) was found. June 13, 1955.



Fig. 5. Close-up of Synaptomys habitat on Bear Swamp quadrat showing continuous thick mat of sphagnum on ground. Cuttings were on the surface and burrows led beneath the moss. Base of a large southern white cedar is visible in upper right corner. Penn State Forest, June 17, 1955.

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Fig. 6. Close-up of Carex bullata and leatherleaf in area shown in Fig. 1. Tunnels ran beneath the sphagnum among roots of the leatherleaf. Synaptomys was the most numerous microtine trapped in leatherleaf-Carex-sphagnum areas. June 17, 1955.



Fig. 7. Typical stand of pitch pine, huckleberry, and blueberry in dry sandy habitat. Here much old (previous winter) sign of Synaptomys was found in turkeybeard (Xerophyllum asphodeloides) growing beneath the shrubs. Bass River State Forest, August 23, 1953.

Fig. 8. Zone A of Bear Swamp quadrat showing grass mat and shrubs in small opening in pines. Numerous live captures of bog lemmings were made in this habitat during the second half of October. June 10, 1955.



Fig. 9. Dry field habitat (next to buildings shown below) in which specimens of Synaptomys were trapped in June and December. Bluegrass and dewberry in foreground, broom-sedge in left background, and switchgrass and red-top in right background. Near Lower Bank, June 17, 1955.

Fig. 10. Dense growth of bluegrass with heavy sign of Synaptomys, adjacent to abandoned house and outbuildings. Three specimens were trapped here in December. June 17, 1955.



burned-off cedar swamp, in a stage with shrubs and sedge but with many small cedars coming in. Scattered Synaptomys sign was found in two second-growth cedar bogs, in which the trees were about fifteen feet in height and beginning to close overhead, giving much shade; scattered Carex was still present. Also sign was seen in what appeared to be an overgrown cranberry bog, where the vines were fairly thick, but grown up to sedge. Four bogs in which Synaptomys were trapped did not seem to fit any of the above categories; one of these was at the foot of a dam and contained an unusually rich assortment of plants.

Dry pine areas adjacent to bogs (Fig. 7, 8) where bog lemmings were trapped in spring and fall but not in summer contained pitch pine (Pinus rigida), various ericaceous shrubs including huckleberry, turkey-beard (Xerophyllum asphodeloides), and locally an unidentified grass (Stipa arundinaceum?). Specimens were trapped in four such pine areas and sign was seen elsewhere.

In the one example of dry field habitat where bog lemmings were taken (Figs. 9, 10), heavy sign was in a thick mat of bluegrass (Poa compressa) near a house. Three lemmings were taken in this bluegrass and one in nearby switch-grass (Panicum virgatum). Low black cherry (Prunus serotina), trailing blackberry or dewberry (Rubus sp.), red-top (Tridens flava), and patches of Bromus tectorium were mixed in. In another sandy field area nearby Synaptomys sign was recorded in broomsedge (Andropogon virginicus).

Effects of animals' activity on plant environment

Activities of these mice are probably in general beneficial to plant growth. The burrows in the bogs may aid in drainage and aeration of the soil, and the soil is probably enriched by the vegetation and other organic material incorporated into the tunnels.

A remarkable case of spreading of a plant by cuttings was observed with the rush, Juncus pelocarpus. On several occasions cuttings of this rush at the entrance to holes in the moss were observed to sprout and take root, resulting in several new plants a foot or two from the plant from which the cuttings had been taken.

Little evidence was obtained concerning serious direct damage to vegetation by the food-getting activities of Synaptomys. The most extensive damage observed concerned turkeybeard, in which series of clumps were killed in several areas ("eat-outs").

Animal Environment

Small Mammal Associates. A variety of small mammals are found in the company of bog lemmings in the sphagnum bog areas. In this habitat there were taken, using snap traps and live traps, 135 bog lemmings (Synaptomys cooperi), 102 masked shrews (Sorex cinereus), 94 red-backed mice (Clethrionomys gapperi rhoadsi), 85 meadow mice (Microtus pennsylvanicus), 40 jumping mice (Zapus hudsonius), 23 short-tailed shrews (Blarina brevicauda), 10 white-footed mice (Peromyscus leucopus), 3 pine mice (Pitymys pinetorum), 2 weasels (Mustela frenata), 2 star-nosed moles (Condylura cristata), and 1 common mole (Scalopus aquaticus).*

*Biological data regarding certain of these species may be assembled and published at a later date.

The species and numbers cited pertain only to animals caught in areas where Synaptomys was also taken. Almost all the traps in these areas were set at likely-looking spots where there was sign of Synaptomys. Thus the other species mentioned were taken in the same runways or in closely adjacent spots in the same habitat.

In the single small dry field area in which four bog lemmings were trapped, 6 Microtus, 4 Pitymys, 3 Sorex, and 1 Blarina were also taken in the same location.

Sorex and Blarina make liberal use of Synaptomys holes and runways and these shrews were repeatedly taken in the same traps in which Synaptomys were taken.

Synaptomys has been taken in the tunnels of Parascalops, the hairy-tailed mole (Eadie, 1937; Hamilton, 1939), star-nosed mole (Palmer, 1954; Roselund, 1951). In the present study two star-nosed moles were taken in one bog in surface traps set for Synaptomys. Large runways and holes, oval in cross-section, were seen in mucky soil here and in four other bogs. Cuttings and droppings, probably of Microtus and Synaptomys, were found in the tunnels. Occasionally holes which seemed to be the work of Condylura led straight down into water from the floor of subsurface runways of Synaptomys and other mice. One of these holes was about 18 inches from a nest believed to have been that of Synaptomys.

Synaptomys may occasionally enter the tunnels of the common mole and of the pine mouse but little trapping was carried out (no Synaptomys

were collected) in these situations. Scalopus and Pitymys are forms which occur commonly on upland sites in the pine barrens and Pitymys is perhaps the most common microtine in the pine region as a whole, but they were rarely encountered in the bog environment. One common mole was taken in a snap trap set at a hole in the sphagnum. If this mole occurs regularly in the bogs, it does not make typical tunnels there. Three Pitymys along with two Synaptomys and two Clethrionomys, were taken in close association in a small, but wet, streamside bog, not the usual situation for Pitymys. This was the only place aside from the dry field in which pine mice were taken in association with bog lemmings. Since many traps were set in sub-surface situations, it seems quite certain that pine mice would have been taken more frequently in the bogs if they were common in this habitat. Holes believed to be the work of pine mice were seen in some of the turkeybeard areas, although no pine mice were trapped there.

The microtines most commonly associated with Synaptomys were Clethrionomys and Microtus. In live-trapping, all three were often taken in the same trap at different times, and their home ranges broadly over-lapped (not shown on maps). In the pine barrens, Clethrionomys was found in almost every damp location, but this species seemed to prefer the vicinity of trees as opposed to sedge or grass. In several bogs, the red-backed mice were taken along the edge, under the trees, whereas the bog lemmings occurred further out in the shrubs and sedge.

The animal with requirements which seem to most closely approximate those of Synaptomys is Microtus. Other workers in different parts of the country have also found the two genera closely associated or using the same runways. Thus, Microtus ochrogaster and Synaptomys cooperi have been reported together by Linsdale, 1927; Burt, 1928; Fisher, 1945; Fichter and Hansen, 1947; and others. Microtus pennsylvanicus and Synaptomys cooperi by Bailey, 1929; Eadie, 1937; Odum, 1949; Preble, 1942; Linduska, 1950; and others. Stegeman (1930) reported that in one field he studied, there were certain runways in which only Microtus was taken, while in other runways only Synaptomys was found, with both species together in still different runways.

However, within the overlapping geographical range of both, Microtus occurs in many situations where Synaptomys does not, the bog lemming being much more local in distribution. Conversely, Synaptomys has been reported in areas or habitats in which Microtus was not found (Goodwin, 1932; Harper, 1929; and others).

Richmond and Rosland (1949) stated "In those localities where both Microtus and Synaptomys occurred, they appeared to be occupying different portions of the field or other habitat. Only rarely did we find them using the same runways. This segregation of the colonies was not determined by minor variations in the habitat, nor was it constant as the same area that at one time would be occupied by Synaptomys might later contain only Microtus."

In southern New Jersey, Microtus is much more abundant in the tidal brackish meadows which border the pine barrens on the east than

it is anywhere within the pine barrens. Their runways are everywhere in the march hay. In casual trapping of this habitat at different times during the present study 58 Microtus pennsylvanicus, 1 Blarina brevicauda, and 5 Cryptotis parva were taken. There was no records in the literature of the occurrence of Synaptomys in this habitat.

Inland, in the dry, sandy, fields Microtus is probably more prevalent than Synaptomys. In short trap lines in four fields 3 Sorex, 1 Cryptotis, 10 Blarina, 23 Microtus, 9 Pitymys, and 4 Synaptomys were collected. Three of the four bog lemmings were taken in the unusually dense grass mat near a house, as described previously.

In this region it is only in the sphagnum bogs containing sedge and shrubs that Synaptomys appears to occur in numbers approximating those of Microtus. More bog lemmings than Microtus were taken in this habitat, but special efforts were made to obtain the former. Several small bogs of this type yielded Synaptomys only. Sign also seemed to indicate that Synaptomys was the dominant microtine in this habitat. In bogs lacking the shrub-sphagnum cover and in parts of bogs without these constituents, Microtus seemed to be dominant.

A possible factor in the ecological distribution and abundance of Synaptomys may be competition with Microtus. Most of the evidence indicates, however, that although either may dwell in an area exclusive of the other, there are many places where Synaptomys seems able to dwell successfully alongside Microtus. In some habitats, and locally, as in the sphagnum bogs of southern New Jersey, the bog lemming may even be better adapted to the environment than the meadow vole. From

the over-all viewpoint, however, it would seem that Synaptomys is less successful in a wide variety of habitats than is Microtus.

Predators. According to Hamilton (1943) owls, hawks, predatory mammals, and snakes all prey on Synaptomys. The following records were gleaned from a partial search of the literature. Preble (1942) reported the remains of Synaptomys in raccoon (Procyon lotor) scats in Ohio; Murie (1936) found this mouse in high frequency in red fox (Vulpes fulva) droppings in southern Michigan (in 127 out of 535 droppings, with Microtus in approximately equal frequency); Scott (1943) and Scott and Klimstra (1955) reported the remains in red fox droppings in Iowa; Cook (1939) in New York found a dead Synaptomys which had apparently been killed by a weasel. Allen (1937) reported a Synaptomys in a cat stomach in Michigan; Smyth (1956-personal communication) reported Synaptomys from the stomach of a rattlesnake (Crotalus horridus) in Virginia; Peterson (1956) recorded a probable Synaptomys in stomach of trout (Salvelinus fontinalis) in Ontario; Uhler, Cottam, and Clark (1939) reported Synaptomys as being eaten by the copperhead (Agkistrodon mokasen) in Virginia. Synaptomys has been found in pellets of several species of owls: barred owl (Strix varia), on the eastern shore of Maryland (Poole, 1943); barn owl (Tyto alba), in Michigan (Wallace, 1948) and in Pennsylvania (Richmond and Rosland, 1949); long-eared owl (Asio otus), (Fisher, 1893) and in Michigan (Wallace, 1948; Linduska, 1950; William H. Armstrong, personal communication, 1956); great horned owl (Bufo virginianus), in Michigan (Linduska, 1950).

In the present study no direct evidence concerning predation upon Synaptomys was obtained. The following list of vertebrates known to eat mice were recorded one or more times on the areas on which Synaptomys were trapped. The number following each name represents the number of Synaptomys areas on which it was recorded. Opossum (Didelphis virginiana), 1; short-tailed shrew (Blarina brevicauda), 12; raccoon (Procyon lotor), 8; gray fox (Urocyon cinereoargenteus), 5; long-tailed weasel (Mustela frenata), 4; striped skunk (Mephitis mephitis), 1; red-tailed hawk (Buteo jamaicensis), 7; broad-winged hawk (Buteo platypterus), 2; marsh hawk (Circus cyaneus), 2; horned owl (Bubo virginianus), 1; barred owl (Strix varia), 2; crow (Corvus brachyrhynchos), 10; blacksnake (Coluber constrictor constrictor), 4; king snake (Lampropeltis getulus getulus), 5; water snake (Natrix sipedon sipedon), 4; pine snake (Pituophis melanoleucus melanoleucus), 1.

Among mammalian Carnivora, the raccoon, the gray fox, and the long-tailed weasel are probably the most numerous in this region, and are probably important predators of small mammals in the bogs. On the quadrat in October a weasel kill of one of the marked Microtus was found. Raccoons disturbed my live-traps so frequently as to seriously interfere with the study. They reached into the traps and took the shelled corn used as bait, and perhaps they took the mice as well; often they removed the traps. Gray foxes regularly traversed some of the bogs. Bodies of bog lemmings and other mice in snap traps were often partially eaten; this was judged to be the work of Blarina. A live trap contained a half-eaten Clethrionomys and a live Blarina.

A general impression was gained that there are relatively few hawks and owls existing in much of the pine region. Red-tailed hawks were seen occasionally throughout the year. Wintering individuals were sometimes seen in November and December, hunting over the bogs.

Barred owls and great horned owls were heard at night, especially in the vicinity of large cedar swamps and in richer woods near tidal water. A barred owl pellet found in a sphagnum bog contained remains of Clethrionomys. A barn owl roost, within two miles of three of my bog areas, yielded 28 pellets containing 60 Microtus pennsylvanicus, 2 Blarina brevicauda, 1 Cryptotis parva, parts of a crustacean, and 2 or 3 pieces of three-square (Scirpus) stems. The contents of the pellets indicated that these owls were doing their hunting out in the tidal meadows, about $1\frac{1}{2}$ -2 miles away.

Large snakes are common in the New Jersey pine barrens. King snakes were seen more frequently during the study than any other species and were active day and night in wet and dry habitats. They were recorded five times in Synaptomys areas. In three of these instances they were associated with mouse sign, and although perhaps merely sunning themselves, were strategically placed to seize any passing prey. In two of the three cases they were disposed with their heads at runways. One of these snakes used a runway for travel when I disturbed it and disappeared into a small mammal hole. Two king snake stomachs were examined. One contained the feet and tail of newborn mice (Peromyscus leucopus?), the other, that of a small king

snake injured by a mouse trap, contained two red-bellied snakes (Storeria occipitomaculata). Black snakes were probably important predators of small mammals in the bogs. Frequently large shed skins of this species were found in subsurface runways and at holes, where they had apparently used the intricacies of the tunnels to help work off their skin. During live-trapping in May, 1955, a large blacksnake was observed attempting to remove a bog lemming from a trap. It wrapped itself around the trap and tried to work its head inside; it worked at the task for many minutes until another blacksnake came by and then both snakes left together. Pine snakes were usually encountered in dry pine areas, although one was seen beside a bog. One stomach examined (DOR) contained the remains of a pine vole. Rattlesnakes (Crotalus horridus) were not encountered in the study, but according to natives these snakes were present in some of the bogs which I trapped. In 1951 I found a road-killed rattlesnake with two Clethrionomys in the stomach.

Other animals recorded on study areas. Red squirrels (Tamiasciurus hudsonicus) were the most conspicuous and frequently seen mammal, and were recorded in nearly every bog trapped. Their nests were frequent in white cedars bordering the open bogs. Shredded cedar bark, and also sedge and sphagnum were used in the construction of nests. One nest was found on the ground, in the cover of a clump of Xerophyllum. Deer (Odocoileus virginianus), or signs of deer, were recorded in every area. A new-born fawn was found on the live-trap quadrat in May, 1955. Deer ate sedges and other plants, but no excessive damage was noted.

The animals sought out Xerophyllum flower heads, however, and for this reason in some areas it was not easy to find this plant in bloom.

Cottontails (Sylvilagus floridanus) were recorded in or near most of the bog areas. Muskrats (Ondatra zibethica) were recorded in three sphagnum bogs, but were usually uncommon in this habitat to judge from sign. Only one typical muskrat house was seen in this habitat during the study. Otter tracks were seen in one bog and a den and heavy sign were seen by a lake near another area. Beaver were not encountered on the areas, although old sign was seen on two streams during the course of the work.

Large numbers of frogs inhabited all bogs, and Anderson's tree frog (Hyla andersonii), swamp cricket frog (Pseudacris nigrita feriarum), spring peeper (Hyla crucifer), wood frog (Rana sylvatica), carpenter frog (Rana virgatipes), green frog (Rana clamitans), and leopard frog (Rana pipiens) were commonly encountered. Few species of salamanders occur in these bogs, however, and red salamanders (Pseudotriton ruber) and four-toed salamanders (Hemidactylium scutatum) were the only kinds met with. Ribbon snakes (Thamnophis sauritus) were frequently seen. Turtles common in the bogs were the painted turtle (Chrysemys picta), box turtle (Terrapene carolina), and spotted turtle (Clemmys guttata).

Few typical marsh birds are associated with these acid bogs. Characteristic of the bushes and sedges in summer were catbirds (Dumetella carolinensis), yellowthroats (Geothlypis trichas), redwings (Agelaius phoeniceus), field sparrows (Spizella pusilla), swamp

sparrows (Melospiza georgiana), and song sparrows (Melospiza melodia). Song sparrows wintered in the same spots. Woodcock (Philohela minor) bred locally. Whip-poor-wills (Caprimulgus vociferus), blue jays (Cyanocitta cristata), and pine warblers (Dendroica pinus) usually were abundant in the vicinity of the bogs. Other species recorded on or around the bogs in the breeding season were osprey (Pandion haliaetus), black-billed cuckoo (Coccyzus erythrophthalmus), nighthawk (Chordeiles minor), ruby-throated hummingbird (Archilochus colubris), flicker (Colaptes auratus), hairy woodpecker (Dendrocopus villosus), kingbird (Tyrannus tyrannus), wood pewee (Contopus virens), barn swallow (Riparia riparia), purple martin (Progne subis), crow (Corvus brachyrhynchos), Carolina chickadee (Parus carolinensis), robin (Turdus migratorius), wood thrush (Hylocichla mustelina), blue-winged warbler (Vermivora pinus), prairie warbler (Dendroica discolor), and towhee (Pipilo erythrophthalmus).

Among invertebrates, ants of two or more species (including the genus Tapinoma) were conspicuous, frequently taking over large hummocks of moss for nesting sites. Spiders seemed to be unusually numerous in this habitat; small ones were active even in winter. A very large wolf spider (family Lycosidae) was observed on several occasions in the bogs. It may carry enough poison in its large fangs to kill a mouse. One of these spiders was found with a dead juvenile Microtus in a live trap. On the face of the mouse was a small, but apparently fresh wound.

Parasites and Diseases. Parasites were collected and await identification at a later date. The digestive tracts of 21 lemming

mice were examined macroscopically for parasites. Four contained tapeworms (Cestoda) in the cecum and in the intestine near the cecum. Two of the mice had 2 tapeworms each and two had 3 each.

Ticks were collected from six individuals in April (2), August (3), and November (1). In two cases they were seed ticks. Of the other four mice, one had a tick on the cheek, another had two on the outer surface of the ear pinna, and the last had a large swollen tick at the base of the neck.

Fleas were more numerous on the lemming mice during October, November, and December than in spring and summer. Six or more individuals were recorded as having fleas during live-trapping in October. Seven of the specimens snap-trapped in November and December carried fleas. From April through September, only two snap-trapped animals had fleas. During the warmer months, fleas probably leave the carcasses faster; even so, several which were examined at death or in live traps were without fleas.

Lice of three or more species were collected during all seasons, though spring seemed to be the season of greatest abundance. Several animals trapped in April were very heavily infested.

Reddish-brown mites, as yet unidentified, were collected at all seasons and occurred on all or nearly all individuals. On some a brilliant red mite occurred on the inside of the ear pinnae; these were associated with scabs. Of eleven animals with these ear mites, nine were from the same bog. Of the eleven individuals, eight were taken in July, two in August, one in October, and one in December. Less often

a white mite was present in the ear, also associated with scabs. In mid-December an arched, dry warm nest, believed to be inhabited by Synaptomys, contained numerous small mites (a species of Collembola was also in the nest).

During October, two individuals had patches of hairless skin, one with the condition on the nape and the other, a sickly animal, with it on the rump. Both recovered and regained the hair. Occasionally an animal was taken with a hairless or nearly hairless tail. One animal showing this condition (December) also had swellings, or nodules, on the tail and feet. One of the individuals heavily infested with lice in spring had a bad ear condition at the same time, with scabs present and also most of one ear pinna missing. Diseases observed with captive specimens are described under sections on Development and Behavior.

Relationships with Man

Present and former status of bog lemming habitat. One of the few industries of the pine barrens today is the growing of cranberries. This has involved the destruction of natural streamside and bog habitats. The open and savannah-like bogs are preferred to the wooded swamps because of the greater ease of clearing, and for this reason almost all of the large bog areas of this type have been destroyed. Thus it seems certain that territory available to bog lemmings here has been greatly reduced. Nevertheless, the region still contains many scattered small bogs which are important in aggregate.

Economic importance. There seem to be no references in the literature to economic loss caused by bog lemmings. From the present study little information can be added on this point. Small spots of native vegetation were sometimes found to be damaged by Synaptomys; this included "eat-outs" of grass-like plants (Fig. 19). Woody plant parts were also eaten. Synaptomys has been found in corn-shocks in southwestern Pennsylvania (Grimm and Roberts, 1950) and in southern Michigan (Linduska, 1950). Perhaps Synaptomys contributes in a minor way to the financial losses blamed on meadow voles and other species where corn is still allowed to remain shocked.

POPULATIONS

Sex Ratios and Age Classes

Sex ratios

A large preponderance of males seems to be characteristic in a series of bog lemmings from any one locality. Stegeman (1930) in Washtenaw County, Michigan, collected 9 females and 33 males, a ratio of 1 female to 3.66 males. Oehler (1942) in Ohio collected 5 females and 32 males, a ratio of 1 female to 6.40 males. In my study in southern New Jersey, of 130 snap-trapped and live-trapped bog lemmings in which sex was recorded, there were 46 females and 84 males, a ratio of 1 female to 1.83 males, or expressed in another way 65.1% were males and 34.9% were females. Males were taken considerably in excess of females both by snap-trapping and live-trapping. Statistically, the difference from the expected hypothetical "50-50" sex ratio is highly significant.

The table given below shows the numbers of males and females captured arranged according to years and seasons into five periods. More males than females were taken at each of these periods. The differences are significant for the summers of 1953 and 1954; the differences are not significant for fall, 1954, and spring, 1955. The numbers most closely approach the 50-50 ratio in the spring of 1955.

Season	Year	Number of Females Trapped	Number of Males Trapped
Summer (July-Sept.)	1951	2	4
Summer (July-Sept.)	1953	4	14
Summer (July-Sept.)	1954	8	20
Fall (Oct.-Dec.)	1954	19	30
Spring (April-May)	1955	13	16

This unbalanced sex ratio may not exist at birth, although males outnumbered females in 27 individuals whose sex at birth was known; there were 11 females and 16 males. However, this difference is not statistically significant.

The numbers of each sex born in 8 different litters are listed below. The first two litters listed were found in nests, the others were born in the laboratory.

- | | |
|-----------------------|-----------------------|
| 1. 0 females, 2 males | 5. 1 female, 2 males |
| 2. 1 female, 3 males | 6. 1 female, 2 males |
| 3. 1 female, 4 males | 7. 3 females, 1 male |
| 4. 1 female, 2 males | 8. 3 females, 0 males |

An excess of males trapped in a species is generally attributed to the greater proclivity of the males to wander, permitting them to come into contact with more traps. Live-trapping indicated that male Synaptomys do travel farther than females, and thus this could very well be the cause for the greater catch of males in this species.

Age classes

Age classes recognized during the field work were nest young, juvenile, and adult. Juveniles were small young animals in grayish pelage; none of these was found to be in breeding condition. The table under Dates of Breeding (Juveniles) shows the proportion of trappable young to adults at different seasons. The high proportion of adults to juveniles does not mean that they are long-lived, since the juveniles are available to traps for only a short period, that is, about two weeks as indicated by litters raised in captivity.

Longevity and Mortality

Longevity

Two individuals, a male, and a female which produced six litters, were kept for a year in captivity. The male was found in a nest on May 15, 1955 (estimated date of birth May 12) and was raised in captivity with a Microtus litter. The female was captured as an adult (estimated age a month or more) on May 2, 1955. Both of these animals might have lived much longer in captivity but were killed and preserved on May 15, 1956. Thus the male lived in captivity to the approximate age of 1 year; the female lived 50 weeks in captivity to the estimated age of 54 weeks or more.

In the wild probably few individuals of this species survive to the age of one year. On the area in Penn State Forest which was live-trapped during October, 1954, 12 Synaptomys (not including trap mortalities) had been marked. Of this number three were retaken when

the area was next trapped during May, 1955. Thus one-fourth of those marked in October had overwintered and were still present on the area in May. One of the three was a juvenile male (estimated age 2 weeks or older) when first trapped on October 2; it was retaken on May 7, and thus lived at least 7 months and 3 weeks in the wild. Another one was an adult male (estimated age one month or older) when first taken on October 9; it was recaptured on May 13, and thus lived in the wild for 8 months or longer. The third, an adult female when first captured on October 2, was recaptured five times between May 3 and 5 and also had lived at least 8 months in the wild. This female was not taken after May 5, although her area was trapped continuously until May 15. As she was a "repeater," when she ceased coming to the traps after May 5 it was assumed that she either had left the area, or more likely, had died. With an indicated survival rate of about 0.82 per month, there would probably be little chance of recapturing any of these individuals after a full year (calculated annual survival rate about 0.10).

Causes of mortality

Predation is perhaps the principle direct cause of death in this species; the predators are discussed elsewhere. On the Synaptomys areas where live-trapping was carried out, the natural fate of only one marked animal, a Microtus, was known; it was found lying on the ground where it had been killed by a weasel. Another animal, a marked Clethrionomys, was killed and partly eaten by a short-tailed shrew (Blarina) which

had apparently chased or followed it into a single-catch type of live trap.

Floods, which were frequently observed during the study, may be important as an indirect cause of mortality by forcing animals to move into more exposed marginal areas where there would be crowding, less food, and probably more chance of being caught by predators. During the study there was no evidence of any serious disease among wild lemming mice.

Home Range

Materials and methods used in studying home range

Areas trapped. Although bog lemmings were snap-trapped in many different places, they were less easily taken alive. Twenty-three live traps set during early September, 1953, in an area of heavy fresh sign yielded no *Synaptomys* nor any other microtines. Thirty live-traps operated for ten days during July 1954 in an area of heavy fresh sign yielded only two *Synaptomys* among other mice and shrews. To judge from the sign in these instances, either the bog lemmings were not entering the traps or they had recently left the areas. On two other occasions live traps were set without success in areas of heavy sign, in one instance using 12 traps set one night and on the other using 9 traps set for several nights. At other times small numbers of live traps were set out in different places to obtain animals for study in captivity; a few bog lemmings were taken in this way. Bole (1939) stated that *Synaptomys* is difficult to capture in live traps.

Two areas afforded information on home range. On the large area a line running through the peripheral traps enclosed 2.95 acres; here 22 Synaptomys were live-trapped a total of 145 times in the periods October 1-November 1, 1954 and May 1-15, 1955. On the other area, a little less than 2 acres in size, 5 Synaptomys were trapped 30 times in the period November 22-December 3, 1954. The first area was located in Burlington County, Penn State Forest, in Bear Swamp within a mile of Bear Swamp Hill; the other area was located in Burlington County in Bass River State Forest. Both quadrats spanned narrow bogs 100-160 feet in width and included dry pine woods on either side. Figures 8, 11, 12 (photos), Figures 13-15 (Maps), and key to vegetation zones on maps at end of this section show the zones of vegetation included in the Bear Swamp trapping area.

Arrangement of traps. In Bear Swamp 143 traps were set in 11 lines, roughly in grid fashion, covering the principle vegetational zones which lay parallel to the bog; individual traps were generally set according to abundance of sign. Intervals between traps ranged from about 20 feet to 60 feet. Watery areas in the middle of the bog accounted for spaces without traps. The entire area was not trapped at one time. In the fall, the center of the area was trapped first; in the spring alternate lines were trapped first. Each trap was set for one week or slightly longer. When a trap continued to catch an individual over and over again the trap was unset for a time. Occasionally an additional trap was set at a station. In Bass River State Forest 44 traps were set in a rough grid, at 40 foot intervals.

Fig. 11. View of Bear Swamp quadrat. Sedges and cedars in foreground and right background (zone E), shrubs left and center (zones B, D) and pitch pines (zone A) left background. Penn State Forest, June 10, 1955.

Fig. 12. Stand of Carex in zone D of Bear Swamp quadrat. High-bush blueberries in middle background (zone C), with shrubs of zone B beyond them, and pines (zone A) in distance. June 10, 1955.



Description of traps. Most of the live-trapping was carried out with single-catch metal traps, the design resembling that of Blair (1941). In size, captured animals ranged from shrews (Sorex cinereus) to long-tailed weasels (Mustela frenata). No bedding material was used. Traps were covered with roofing material or bark during cold weather.

Bait. Early in the study rolled oats was the chief bait used. Following a number of mortalities on frosty nights in early October, a switch was made to shelled corn, following the suggestion of Llewellyn (1950). By providing the traps with high-energy corn, and covers, there was very little mortality in the cold weather. Microtus, Clethrionomys, Peromyscus, and Zapus all seemed to eat more corn in the traps than did Synaptomys. A few of the latter never ate the corn; perhaps for this reason a few died on cold nights. However others, especially those with the "trap habit" regularly ate a certain amount of corn.

The entrances to the traps were baited with rolled oats, and diced apple was often provided. Apple is apparently a good bait for Synaptomys. They always ate it in the live traps and it was a useful bait in snap-trapping. Burt (1928) also found apple an effective bait for Synaptomys.

Method of marking. Marking was by toe clipping, according to a scheme in which the toes of the front feet are numbered 1 to 8 and those of the hind feet 10 to 100. In this way 143 animals can be marked without removing more than 3 toes and never more than one toe

from a foot. As no more than 80 animals were trapped on any area this method was satisfactory.

Discussion of home range

Home range is that area about the home site which is traversed by an animal in its normal activity (Burt, 1940). There is very little published data concerning live-trapping Synaptomys. The only reference I could find which gave home range data was that of Burt (1940). He stated, "I have records which are sufficient to indicate extent of the home range of but one lemming, an adult female. The animal was taken seven times in the period August 25-September 23, 1936, within an area forty yards in greatest diameter. She then moved about 115 yards, where she was last taken October 11."

Most small mammal home ranges have been studied by capturing and recapturing the animals in live traps set in grid pattern and then plotting the points of capture on a map. From the information thus obtained various methods have been used by different workers in calculating home range or the extent of territory covered by the animals. Hayne (1949a, 1950) demonstrated a correlation between apparent size of home range and distance between traps, made clear the limitations involved in each method of calculation of home range, and pointed out that the relationship between the trap-revealed home range and the true home range is in need of further investigation. Hayne (1949a) proposed a method of stating results in terms of distribution of the points of capture about a center of activity, and showed how to calculate the

center of activity, which takes into consideration the greater frequency of capture toward the center of the area traversed by an animal.

In the present study, centers of activity have been computed for each individual. Where an individual was captured both spring and fall, two centers of activity have been calculated. The apparent home ranges of individuals have been located on the map according to the "minimum home range" method recommended by Mohr (1947) in which extreme points of capture are connected with straight lines (except for individuals which were captured at only one or two traps) and the enclosed area used in calculating the home range. However, as these polygons are merely the trap-revealed home ranges, and subject to error, their areas are not emphasized and are not given in decimal fractions. Home ranges are best thought of as shading off according to probability of capture, instead of having definite boundaries (Hayne, 1949a). The areas of the polygons are given in approximate fractions of an acre for comparative purposes. In addition, for each individual for which there are a substantial number of captures the greatest distance between points of capture is given.

The maps on the succeeding pages show the points of capture, number of captures, apparent home ranges, and centers of activity for adult male, adult female, and juvenile Synaptomys on the quadrat in Bear Swamp during October, 1954, and May, 1955. The maps also show the different habitats included within the areas occupied by the individuals of the species. Maps are not given for the Bass River State Forest area trapped in November-December.

Fig. 13. Map of Bear Swamp live-trapping area, indicating location of traps, number of captures, trap-revealed home ranges, and computed centers of activity (male and female symbols) of 6 adult females, and of 7 adult males taken at one or two traps. Closed symbols and Arabic numerals are for October, 1954; open symbols and Roman numerals are for May, 1955. A- Pine woods; B- Shrubs; C- High-bush blueberries; D- Low shrubs, Carex, thick sphagnum; E- Wet meadow and scattered trees; F- Shrubs; G- Pines and shrubs. The various zones of vegetation are described in greater detail at end of this section.



Fig. 14. Map of Bear Swamp live-trapping area, indicating location of traps, number of captures, trap-revealed home ranges, and computed centers of activity (male symbols) of 3 adult males. Closed symbols and Arabic numerals are for October, 1954; open symbols and Roman numerals are for May, 1955. A- Pine woods; B- Shrubs; C- High-bush blueberries; D- Low shrubs, Carex, thick sphagnum; E- Wet meadow and scattered trees; F- Shrubs; G- Pines and shrubs. The various zones of vegetation are described in greater detail at end of this section.

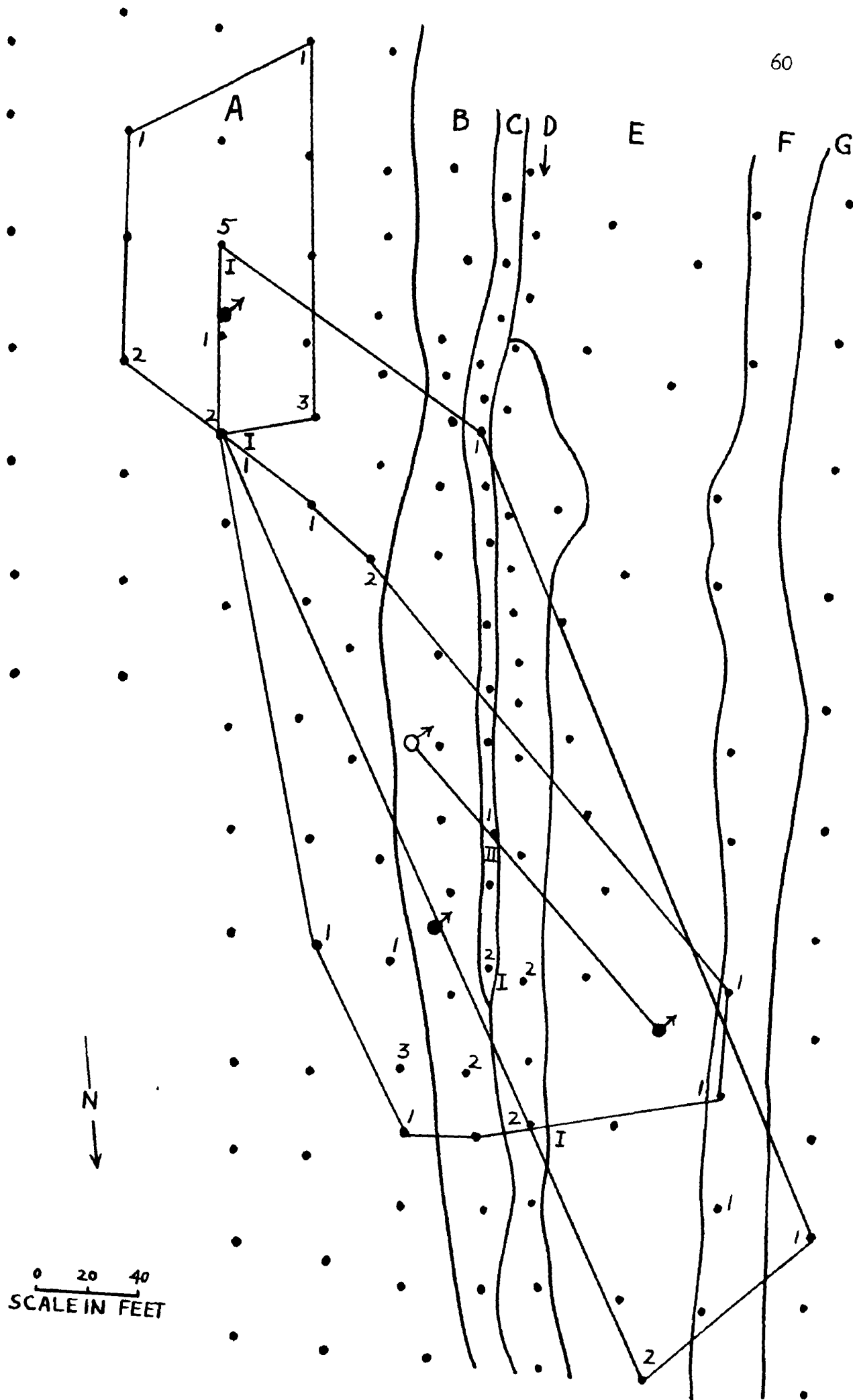
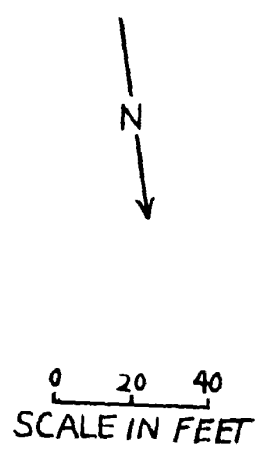


Fig. 15. Map of Bear Swamp live-trapping area, indicating location of traps, number of captures, trap-revealed home ranges, and computed centers of activity (male and female symbols) of 7 juveniles. Closed symbols and Arabic numerals are for October, 1954; open symbols and Roman numerals are for May, 1955. A- Pine woods; B- Shrubs; C- High-bush blueberries; D- Low shrubs, Carex, thick sphagnum; E- Wet meadow and scattered trees; F- Shrubs; G- Pines and shrubs. The various zones of vegetation are described in greater detail at end of this section.



Age	Sex	Date	Approx. trap-revealed "minimum home range"	Max. distance between captures
1. Ad.	female	Oct.	1/2 acre	160 feet
2. Ad.	female	Oct.	Less than 1/10 acre	120 feet
3. Ad.	female	Nov.-Dec.	Between 1/10 and 1/5 acre	160 feet

4. Ad.	male	Oct.	Over 1/2 acre	320 feet
5. Ad.	male	Oct.	1/5 acre	150 feet
6. Ad.	male	Oct.		330 feet
7. Ad.	male	Oct.	Between 1/10 and 1/5 acre	370 feet
		May	1/4 acre	360 feet
8. Ad.	male	Nov.-Dec.	1/5 acre	190 feet

9. Juv.	male	Oct.	1/5 acre	135 feet
10. Juv.	male	May		175 feet

During October and May combined, the No. 7 adult male ranged over an area 460 feet in greatest length and encompassing 2/3 of an acre.

Data presented here indicate that adult females may regularly range over areas at least 160 feet in greatest diameter, while adult males probably cover much more territory, perhaps ranging over areas 300 feet or more across. The size of home range may be expected to vary according to habitat, season, population pressure and other factors.

Home ranges of an adult male and an adult female in Bass River State Forest in November-December were split by a swift-flowing stream 8-10 feet wide flowing through their areas. Apparently these individuals, as well as several red-backed mice were crossing the stream along a very narrow shoulder of a road-fill which crossed the stream

at right angles and paralleled the edge of the home ranges (they were not taken on the other side of the road). A trail (tracks and bright green droppings) of a bog lemming was followed across this route in snow in December, and one individual was trapped three times at the cross-over point. Unless these animals were also crossing the stream at other points, their home ranges were extremely "dumb-bell" shaped.

On the Bass River area in November-December certain bog lemmings were observed to range back and forth daily between Carex stands in the bog and clumps of turkeybeard in adjacent pine woods on either side. Two individuals must have climbed a fairly steep, sandy slope on one side of the bog to reach isolated clumps of turkeybeard, for upon release from the live traps these animals ran down the surface of the slope to the bog. This area was examined during two other years and fresh sign in turkeybeard was found during winters but not in the summers, while in summer there was much sign out in the wet bog.

It was anticipated that live-trapping in Bear Swamp might demonstrate a seasonal shift in centers of activity between bog and dry land habitats. A comparison for October and May, of centers of activity of the three individuals taken in both seasons, was inconclusive. An adult female showed a small shift towards the bog in spring and a juvenile, which had its fall center of activity on dry land, was taken in the bog in spring, although it was captured only once at this season. On the other hand, an adult male was centered in the bog in fall and in dry habitat in spring.

A comparison of centers of activity for all individuals (Figs. 13-15) does show a seasonal trend. During May all centers of activity were in or near zones C and D, the favorite Carex area. However, in the fall when the population was higher, many centers of activity were well-removed from this area, many then being in the upland. In October, 12 individuals were captured 84 times in the woods, whereas in May only 2 individuals, captured four times, were taken in this habitat. As there were about as many centers of activity in the bog in fall as in spring, it seems that this spreading out in fall may be a response to greater population as well as exploitation of available food at that season. Food appeared important in their seasonal shift on most areas, since the winter increase in sign in the woods was usually accompanied by a sharp decline of fresh sign in the bogs, in areas where the vegetation was turning brown.

Live-trapping demonstrated an individual day-to-day movement back and forth between habitats for certain animals in spring and fall. Information obtained from sign in this area (no fresh sign found in woods by mid-June) and from sign and trapping elsewhere, indicated that Synaptomys did not commonly occur in the dry woods during summers, but were chiefly confined to the bogs at that season. The less-favored nature of food in the woods compared with that in the dense summer growth of nearby bogs, and the high ground temperatures under the pines could be factors operating at this season. Had the live-trapping been conducted during summer and winter, instead of spring and fall, it is possible that more pronounced shifts in centers of activity could have been shown.

Territoriality

The territory is that part of the home range which is protected from other individuals of the same species, and territory is important in preventing overpopulation in a favorite habitat by forcing excess individuals into marginal areas (Burt, 1943, 1949). The size of territory in most mammals is unknown. Burt (1940) found that the area occupied by each adult female Peromyscus leucopus is separate, that is with little overlap of adjoining areas. He interpreted this finding as showing an active defence of territory and believed that home range approximately equals the territory in size in this species. The same author (1949) considered the bog lemming to be a territorial species.

Habitat, season, abundance of food, sex, age and other factors probably play a part in determining size of territory as well as home range. In addition, trap interference with the normal behavior of animals should be considered where territory is defined in terms of trapping results.

Results of live-trapping in the present study seemed to indicate that the adult females of Synaptomys may have territories. During October, 1954, four non-breeding females occupied closely adjacent, but apparently non-overlapping areas in grassy pine woods. Adult males had home ranges which overlapped one another as well as those of other individuals; this also seemed to be true of juveniles. This observation does not mean that males and juveniles do not possess territories.

In view of the above, and considering the fact that adult females may range over an area 160 feet or more in length, I was surprised to find two nests, which contained young at the same time, situated only 14 feet from one another. In addition, a Microtus nest with young was located only 10 feet from one of the Synaptomys nests. No live-trapping was carried out on this area; thus the areas traversed by the females is not known. It is possible that in this situation a limited number of elevated nesting spots in relation to large food supply enforced such short distances between home sites.

Population Density

Estimated density figures

Literature. Estimated population densities of bog lemmings have been given by Stegeman (1930) and Bole (1939). Stegeman concluded after trapping an area with snap-traps that there were about 14 lemming mice per acre in the area in which they were taken in southern Michigan. Bole presented data for different years in Ohio based on large quadrats which were trapped intensively with snap-traps; evidence indicated a high in 1935 of 4 per acre and another high in 1938 of 6 per acre.

Mark and release trapping. During mark and release trapping on Bear Swamp in October, 15 bog lemmings were taken in a three acre area. Those taken in peripheral traps are not included, except those which were taken a sufficient number of times to indicate the home range was chiefly within the quadrat. The long sides (east and west boundaries)

of the quadrat were not Synaptomys habitat. Assuming that all individuals residing on the area were trapped, which I do not think is likely, this would give us an estimated figure of 5 per acre. On the same basis, spring figures for the same area are 2.3 per acre. In Bass River State Forest in November-December 4 adults were live-trapped on a one-acre square delimited by unlikely habitat on three sides. This would indicate a figure of about 4 per acre.

Removal trapping. In order to collect specimens, lines of 30 to 150 snap-traps were frequently established. Usually only a small number of bog lemmings, ten or a dozen at the most, was taken on any one trap line. The heaviest catch of Synaptomys in three nights totalled nine captured on a 250 foot trap line of 50 traps in July, 1954. According to the method described by Hayne (1949b), in which the population is estimated by following the decrease in the rate of capture as animals are removed, a population estimate for the animals in contact with this trap line is 10. By the same method, another trap line (500 feet long, 120 traps) which removed 8 animals, gives a population estimate of 9. This method was not applicable to some of the other trap lines, where there was not a progressive decrease in new captures.

Occasionally a small isolated area of habitat was encountered in which it seemed to be possible to trap out entirely the resident population. One such area, a small oval bog about one acre in extent was trapped intensively from September 18-22, 1954. Four were removed the first two days of trapping and none was captured during the remainder of the trapping period.

An isolated roadside ditch contained heavy sign in a small patch of Carex totaling about 1/10 of an acre. A 250 foot trap line through the length of this area in April removed 4 Synaptomys (lactating female, adult male, 2 small juveniles) in two days. After this no more were taken and the sign dried up, no new sign appearing during the following month. These animals probably ranged somewhat into adjacent wooded swamp, but the best cover and food was confined to the ditch.

Variations in density

Annual and seasonal variation. Synaptomys is known to fluctuate in numbers, being fairly common in some years and rare in others. Burt (1940) found 1936 to be a peak year in an area in Livingston County, Michigan, when these animals occurred in upland woods as well as low moist places; in 1937 they had apparently disappeared from the entire area and not one was caught. Murie (1936) studied a pair of red foxes in the same area in 1934 and found a high frequency of bog lemmings in the diet (23.7% of 535 droppings gathered away from den). Blair (1948) in a southern Michigan bluegrass area found that high population levels were indicated for 1938 and 1942, years in which Microtus was also at peak abundance. Bole (1939) found evidence of population peaks in Ohio in 1935 and again in 1939. Grimm and Roberts (1950) found Synaptomys to be scarce and localized in southwestern Pennsylvania in 1948-49 but they stated that it had apparently been more numerous in years previous. Hall (1955) reported that at Lawrence, Kansas, in the 60 year period 1892-1952, Synaptomys seems to have been abundant only in the five year period 1924-1928.

I have obtained little information concerning annual fluctuations in Synaptomys in the New Jersey pine barrens as a whole. However, I was always able to trap them there during my visits in four different years, 1951 (summer), 1953 (summer), 1954 (early spring, summer, fall), 1955 (spring). Populations of individual localities within this region seemed to fluctuate independently; that is, in some years (or seasons) these mice were obtainable in certain areas and at other times were seemingly rare in these same places, but were then present in numbers somewhere else, where there had been little indication of them previously. On only two areas was relative abundance of sign checked over the five year period (omitting 1952). In the first of these areas heavy sign was present in the summer of 1951. After that (December, 1951; summer, 1953; summer and fall, 1954) the population was apparently low as little sign was seen. There was a slight increase in sign in the fall of 1954; in April, 1955, nearly four years from the 1951 abundance, heavy sign was present. In the other area there seemed to be less fluctuation. In 1951 there was a moderate amount of sign. In late summer, 1953, and spring, 1954, there was fairly heavy sign. During the summer of 1954 the sign was low but increased considerably in fall and continued heavy to at least June of 1955.

Abundance of sign of Synaptomys was estimated and recorded according to a system devised for Microtus areas in Michigan (Hayne, 1950). Criteria used in judging and recording abundance of sign were placed in a series from 1 (no trace of activity or signs) to 10 (maximum condition of signs of activity). In each area 25 likely-looking spots

were checked for presence of fresh sign; after examining all the spots, the area was assigned a grade in the numerical scale. The same areas were visited at different seasons in order to obtain information on relative trends in numbers. The study was not conducted long enough to give yearly trends.

In the period from June 1954 to April 1955 certain Synaptomys areas were examined several times. The table on page 71 has been assembled from these data. The areas included are those which were rated three or more times. In each period 12 to 19 areas were examined. At present the numerical abundance of mice cannot be related to the sign seen; however, median grades for each season seem to show a seasonal trend much as we would expect for a small mammal. In fall, 1954, there are indications of a population increase over the summer, followed by a decrease in numbers again by next April. Most of the individual areas demonstrate this increase and decrease. Live-trapping results on a three-acre area in Bear Swamp reveal the same trend, with 18 taken in October and only 7 in May.

Variation in density within an area of habitat. Many workers have found Synaptomys occurring in local groups or "colonies" within a given area of habitat. Hamilton (1943) stated that Synaptomys usually occurs in colonies of a few to several dozen individuals and that of a large area of similar habitat a small part will be occupied by a little colony and the rest of the area will be unoccupied. The same author (1941) found that they colonize in forest areas in New York. Oehler

TABLE I

ABUNDANCE OF SIGN ON 20 SYMPTOMYS AREAS IN SOUTHERN NEW JERSEY,
BASED ON A NUMERICAL SCALE FROM 1 TO 10

Area	June 1954	Late July- Early August 1954	September 1954	November 1954	April 1955
1	1	3	7	5	7
2A	4	2	7	5	4
2B	4	3	5	5	1
2C	-	8	9	6	3
2D	-	7	2	6	1
3	1	-	1	1	-
5B	3	3	3	7	3
6	3	1	-	4	8
7	6	4	-	3	1
8	6	9	-	7	7
9A	8	8.	8	3	3
9B	1	-	7	4	3
10	1	-	4	1	-
11	8	-	5	-	6
13	-	3	4	5	1
14	-	6	6	8	8
15	-	3	-	7	6
16	-	3	6	6	1
17	-	7	4	5	5
19	-	1	6	3	-
<u>Medians</u>	3.5	3.3	5.5	5.0	3.4

(1942) in Ohio found small isolated colonies around the roots of bushes and fence posts. Richmond and Rosland (1949) wrote that if Synaptomys was present in a locality in northwestern Pennsylvania it occurred in small, more or less definite colonies, and not generally distributed even in favorable habitats. Grimm and Roberts (1950) wrote that this species in southwestern Pennsylvania was never evenly distributed

throughout a habitat, although the authors could detect no obvious differences between occupied and unoccupied areas. Barbour (1951) took five adults from three restricted areas in a single large clearing. Palmer (1954) stated that Synaptomys is often local, and absent from seemingly identical nearby areas. Stegeman (1930) in southern Michigan found Synaptomys to be colonial and, in the territory studied, to be located in three small areas, which measured 100 feet square, 50 feet by 200 feet, and approximately one acre, respectively.

In the bog habitat in the pine barrens Synaptomys did not appear to me to be especially colonial, at least not more so than Microtus and Zapus. Bog lemmings were not evenly spread throughout the bogs, yet their abundance seemed to be very much correlated with variations of the habitat. Synaptomys was present in almost all areas trapped which contained a good stand of sedge combined with shrubs and sphagnum. Perhaps the conditions in the New Jersey pine barrens are favorable to this species, enabling it to spread throughout areas of favorable habitat.

The maps (Figs. 13-15) which show home ranges illustrate distribution of bog lemmings in a three-acre area of habitat. During fall the individuals were spread throughout the quadrat, except for the southern part of zone E, which was under water, and some of the peripheral areas which were without herbaceous vegetation. Individuals also occurred beyond the northern and southern limits of the quadrat. In may most centers of activity were in or near the dense stands of Carex (zone D).

In another bog, Synaptomys sign was concentrated in a small area, and this area of sign did not shift appreciably over a period of several months observation in summer and early fall. An examination of the area revealed that the area of sign closely corresponded to territory occupied by Carex. In addition, shrub cover was thicker and moisture conditions more moderate (not too dry or too watery) than much of the surrounding area. If the population built up sufficiently in this spot I believe the surrounding area of coarser sedges would have been occupied also. In December I could find no sign anywhere in the bog (Carex withered), but in a small area of green turkeybeard nearby there was heavy sign.

Scattered sign and captures of these mice between or beyond areas of concentrations in favorable parts of the habitats indicated considerable movement or that a few individuals lived in less suitable parts of the habitat.

Frequently I observed a small area of concentrated sign within a larger area of sign. Upon trapping such an area, a lactating female, often some small juveniles, and sometimes a male or two would be taken. Heavy sign in these cases had apparently accumulated in the vicinity of a nest.

Key to Zones of Vegetation A to G on Maps of Bear Swamp Trapping Area

(A, B, and G are dry areas; C, D, E, and F are in the bog)

A -- Pine woods. Characterized by low pitch pines (Pinus rigida) which range from 5 to 25 feet in height, but most about 8 feet to 10 feet high.

Ericaceous shrubs chiefly sheep laurel (Kalmia angustifolia), blue huckleberry (Gaylussacia frondosa), black huckleberry (Gaylussacia baccata), form low cover throughout most of the area. Chief herbaceous cover is a grass (Stipa arundinaceum?), and turkeybeard (Xerophyllum asphodeloides), the former growing thickly in small openings among pines and shrubs in upper part of zone. The zone becomes progressively drier toward eastern border of quadrat, and just outside of the boundary herbaceous cover completely disappears and dense scrub oak begins.

B -- Shrubs. Shining holly (Ilex glabra), high-bush blueberry (Vaccinium corymbosum), blue huckleberry (Gaylussacia frondosa), and dwarf huckleberry (Gaylussacia dumosa) growing taller than in the pines, form a strip between pines and wet bog, with herbaceous cover chiefly the grasses Andropogon glomeratus and Stipa arundinaceum (?).

C -- High-bush blueberries. Vaccinium corymbosum, mostly over six feet in height, grows in narrow strip sometimes only one or two bushes wide, with scattered Carex and sphagnum moss under these bushes.

D -- Low shrubs-Carex-sphagnum. Characterized by low-growing leather-leaf (Chamaedaphne calyculata), blue huckleberry, dwarf huckleberry, bayberry (Myrica pennsylvanica), and others. Carex fairly dense in most of the zone, growing among the bushes or in separate small patches. Sphagnum mat present everywhere and cranberry (Vaccinium macrocarpon) characteristic.

E -- Wet meadow with scattered islands and trees. Here, most of the traps were set on small islands containing southern white cedars (Chamaecyparis thyoides), shrubs, bushy beard-grass (Andropogon glomeratus), and other sedges and grasses, and sphagnum moss. Water or bare muck with scattered sedges and other plants stand among the islands. Deep watery holes make the zone impassable to man along upper edge of quadrat.

F -- Shrubs. This zone corresponds to D on opposite side of bog, but with very little Carex present, and scattered dead cedars common.

G -- Pine woods and shrubs. This resembles both A and B zones, with low to tall pitch pines, blue huckleberry, high-bush blueberry typical and herbaceous ground cover chiefly of Andropogon glomeratus.

REPRODUCTION

Courting, Mating, and Associated Habits

Four adult females were captured and kept in captivity and ten females were raised from birth; all of these were placed in the presence of males, but only one female was successfully bred in captivity. One male was believed to be the father of all five litters born in captivity.

When the female was near the time of giving birth, the male was placed in the cage with her for the purpose of mating immediately following the birth of the litter. Before the arrival of the young, the male usually acted wary and nervous and remained in an opposite corner of the cage from the female. After parturition the male roamed about more freely. Successful copulation was not observed. However, mating behavior was noted one afternoon following birth of young the previous morning or night. Both male and female were out in plain view and one was seen to quietly and slowly follow the other about on two or three occasions. In at least one instance it was the female that followed the male. Later in the afternoon the female was observed licking her genital region. Conception occurred on this date (the male was removed the same day and a litter was born later).

On other occasions the same adult male repeatedly attempted to mate with unwilling young adult females. The male weighed about 40 grams, and the young females, which recently had lost the juvenile coat, weighed 25-27 grams. The male was the aggressor and would pursue a female about the cage. Frequently the pursued would turn to face the

male. This was generally followed by sniffing at each other's face and harsh, grating, quarrelsome calling by the female. But the male often continued the action by sniffing along the side of the head and neck of the female. The female usually ran again after "threatening" the male, with the male following closely. He was observed several times ~~trying~~ to mount a female, but appeared to be unsuccessful in all his attempts and no pregnancies followed.

Calls associated with mating behavior are discussed in the section on voice under Behavior.

Period of Gestation

So far as I know members of this genus have not previously been bred in captivity and the gestation period is unknown. As observed in the laboratory during this study, females may come into heat immediately following or within a few hours of the birth of the litter. The procedure used to determine the gestation period was to place a male in breeding condition with a female about to give birth. The female or nest was examined twice a day to determine if parturition had occurred. The male was left in the cage not more than twelve hours following the discovery of young; thus the male was in the cage no more than 24 hours following the birth of young. The time elapsing between the discovery of young and the birth of the next litter was taken as the length of the gestation period.

Actually, this procedure was not successfully carried out until the 5th litter of the breeding female was born. An early attempt, in

which the male was not placed with the female until the discovery of young, did not result in pregnancy. In another try the male was left in for four days to insure pregnancy; here the length of gestation was not definitely established. Data obtained relating to length of gestation is shown in the following table, the birth of litter 5 giving a figure accurate to within 24 hours.

<u>Female Number 1</u>			
Litter Number	Date of Birth	Length of Gestation	Lactating or Not
3	Dec. 5 or 6, 1955	Not over 26 days	Not lactating
4	Dec. 29, 1955	23? (20-24) days	Lactating
5	Jan. 21, 1956	23 days	Lactating
6	Mar. 8, 1956	Not over 26 days	Not lactating

Number of Young

Number of young per litter

Embryo and placental scar counts of snap-trapped females and litters born in the field and laboratory indicated relatively small litters, as has been previously reported for Synaptomys. Howell (1927) stated that Bureau of Biological Survey collectors trapped females containing from 4 to 6 embryos. Linsdale (1927) reported two females containing 4 and 5 embryos. Burt (1928) stated that 1 to 7 young are brought forth, and that indications are that the litter size is smaller in cold than in warm seasons. Stegeman (1930) reported litter sizes

of from 1 to 4 young (4, 3, 3, 3, 2). Coventry (1937) reported 9 pregnant uteri averaged 3.20 young (range 2-5). Fichter and Hansen (1947) captured 3 pregnant females containing 4, 4, and 6 embryos. Linduska (1950) reported 4 pregnant females with embryo counts of 3, 3, 3, and 2. The next three publications are reports of the Pennsylvania Mammal Survey: Richmond and Rosland (1949) reported embryo counts of 1, 2, 3, and 3; Roslund (1951) reported 3 pregnant females with 2, 3, and 4 embryos; Gifford and Whitebread (1951) trapped 13 pregnant females containing 2 to 6 embryos (2, 3, 3, 3, 3, 3, 3, 3, 4, 4, 4, 5, 6). Hall and Cockrum (1953) stated that 9 females had an average of 3.5 (1-7) embryos, with a mode of 3. Barbour (1956) reported 8 pregnant females with an average of 2.6 embryos (2-4). Information in this study was obtained from 16 snap-trapped females, three litters in nests in the field, and six litters born in captivity, as follows.

Embryo counts--	1, 2, 2, 2, 2, 3, 3, 3, 5
Placental scars--	2, 2, 2, 3, 3, 3, 4
Nest litters (born in wild)	2, 4, 4
Laboratory litters (of one female)	3, 3, 3, 4, 4, 5

The mean is 2.96 (range 1-5). Three is the most frequent number.

Number of young per year

Females are in heat immediately following parturition, that is, on the same day. In less than 4 months, one female in captivity produced five litters totaling 18 young. Of six pregnant females trapped

in spring, three were both pregnant and lactating, indicating that litters may be born in rapid succession in the field. However, breeding probably does not occur at such a high rate throughout the year. The data, though meager, suggest that during the spring, and summer, adult females have a litter every 67 days on the average (9 of 26 adult females pregnant).

Dates of Breeding

Breeding may occur throughout the year, at least in some areas. Quick and Butler (1885) reported breeding from February to December. Burt (1928) reported pregnant females of this genus have been taken every month of the year. Hamilton (1943) stated that half-grown young have been secured every month of the year.

Adult females

Forty females in non-juvenile pelage (adult and subadult categories) were taken, almost equally distributed among spring, summer, and fall (no trapping was done during January, February, and March). Eight were taken in live traps and 32 in snap traps. The table below shows the number in breeding condition at each season.

	Number of Females Trapped (Adults and Subadults)	Number Breeding (Pregnant or Lactating)
Spring, 1955 (April and May)	14	7 (6 pregnant, 3 both pregnant and lactat- ing, 1 lactating)
Summer, 1953-54 (July, August, September)	12	4 (3 pregnant, 1 lac- tating)
Fall, 1954 (October)	14	2 (both lactating)

In addition, three nests with young were found during spring (May).

Months in which juveniles were taken

Animals in juvenile pelage were considered to be no more than a month old, since juvenile molt occurred at about that age in captive animals. It is doubtful that many juveniles under two weeks of age were active enough to enter traps, thus the following data cannot be accepted as age ratios without correction.

	Month	Total Number of Animals Trapped	Juveniles
Spring	April 1955	20	2
	May 1955	10	4
	June 1955	1	0
Summer	July 1953-54	14	2
	August 1953-54	35	3
	September 1953-54	6	3
Fall and Early	October 1954	20	7
Winter	November 1954	19	6
	December 1954	13	3

Adult males

For those snap-trapped males which were examined internally, notes were taken concerning the size, position, and appearance of the testes, and relative size and appearance of some of the accessory genital structures. A correlation was found between the season, the size and position of the testes, and the development of seminal vesicles, although according to Jameson (1950), position of testes is a poor criterion of fecundity in male small mammals. These seasonal differences are shown in the following table in which, for purposes of comparison, only adult males weighing 25 grams or more are considered, except October, when only two males were dissected.

Season	Wt. of Males Examined	Length of Testes	Position	Seminal Vesicles
Spring (April, 1955)	26.3-33.4 gms.	3 examined: 5.5-7.0 mm. Av. 6.1 mm.	4 examined: All descended	5 examined: 4 conspicuous
Summer (July, Aug., Sept, 1953, 1954)	25.0-34.8 gms.	22 examined: 6.0-8.0 mm. Av. 6.6 mm.	12 examined: 10 descended	Several examined: All conspicuous
Early Fall (Oct., 1954)	21.5, 23.0 gms.	Both 7 mm.	---	---
Late Fall (Nov. 11-Dec. 11 1954)	25.0-36.1 gms.	10 examined: 3.0-5.5 mm. Av. 3.9 mm.	7 examined: None descended	7 examined: All inconspicuous

Thus, in spring and summer the testes were relatively large, 5.5-8.0 mm. in length,* and were descended in position, and the seminal vesicles were conspicuous and turgid. While two animals had large testes in October, by late fall the testes observed were 3.0-5.5 mm. long, were undescended in position, and the seminal vesicles had shrunk. Thus regression of male reproductive system may have occurred in late October or early November.

Summary

The breeding condition of the trapped adult females indicates a spring peak in the breeding cycle. Breeding also occurs during summer and fall and half of the juveniles trapped were taken in the fall. Three small juveniles were taken in early December, and some breeding may take place in mid-winter in New Jersey, although no trapping was carried out then (in the laboratory breeding occurred in December and January). In spring the first juveniles were trapped on April 22. The adult males were in breeding condition during spring and throughout the summer but showed regressed condition of the reproductive organs by mid-November. When the trapping was resumed in early April the males were already in reproductive condition.

Family Life

Building and care of nest by mother

In captivity a pregnant female will usually build a large, deep

*The testes were never observed to attain the large size commonly found in microtines such as Microtus and Clethrionomys, and thus were much less conspicuous externally.

nest for the young if plenty of grass is provided. This nest is usually built very shortly before the birth of the young. In two cases the nests were built no more than 24 hours before parturition and in another case no more than 48 hours.

After a nest has been broken into for purposes of examining the young, the degree of response on the part of the female parent varies. On one occasion the mother was observed to work vigorously for ten minutes or more in cutting grass and carrying pieces to the nest and in reshaping the nest. She made a good repair job, after which the nest was as good as new. With her next litter, however, the same female did very little in the way of repair, although a big nest had been built originally. If overly excited on being returned to the nest cage, the mother will carry the young about in her mouth and may even build a new nest for them somewhere else in the cage.

In general, the most nest-tending activities were noted during the first few days after birth of the litter. On one occasion, a pronounced drop in temperature was accompanied by a reinforcing of the nest by the mother.

Field observations on repair of nest

On May 18, a nest of dry shredded sedge leaves containing 4 small, naked young was found under the surface of the moss in a sphagnum bog. In order to examine it, the moss cover was pulled back and the roof of the nest was partly opened. After several minutes the mother returned and as she did not seem excited it was surmised she had been away when the nest was first disturbed. She came in over the young and for

several minutes looked up at the hole and once stuck her head out. Although my head and shoulders were only about two feet away, she did not appear alarmed so long as I remained motionless. Next she began to repair the damage, and by shifting and rotating her body she pushed pieces of sedge up into place. The roundness of her back created a perfectly new, dome-shaped roof. Once or twice she chewed up some pieces of sedge. She was still faintly visible through the lattice work of the new roof and was observed to spend much time quietly on the nest, perhaps nursing the young. Once a gust of wind blew the bushes and she bolted but returned shortly. Before I departed, I replaced the moss over the nest. The next day the nest was still occupied.

Relationship of parents to young

Carrying and removal of young. Individual young were observed to be carried by the mother, her mouth grasping the ventral surface of the young in the usual method of small rodents. This was witnessed among caged animals when the mother appeared to be nervous after I had examined the young and returned her to the cage. Upon numerous occasions, I startled the mother from nests containing young but never saw her leave with young attached to the teats, as has been reported for a number of other small mammals (Hamilton, 1939; and others).

As is reported for Microtus, it is probably true that if one finds a nest of young in the wild, even the slightest disturbance will usually be sufficient for the mother to move the young elsewhere. Burt (1928) described a nest with young which he found; he visited the nest the following day and the young were still present, but on the third day

they were gone. I had a similar experience. The young of the family described previously, in which the mother repaired the nest, were still present the next (second) day. When one of the young was lifted out of the nest on the second day it called loudly and the mother appeared a few seconds thereafter. She appeared very nervous, and although I returned the young one and patched up the hole in the roof of the nest, the young were gone on the third day. It was assumed that the mother had removed them.

Nursing and weaning. In captivity the young were nursed until sometime during the third week. Weaning seems to be gradual and young apparently associate with the female for a short time after leaving the nest. In the wild a lactating female and young with milk and green vegetation in their digestive tracts were trapped in runways a few feet apart.

Stegeman (1930) reported that baby lemming mice would not nurse from a lactating house mouse foster mother. In the present study two small naked young about four or five days old were successfully raised by a Microtus foster mother along with two of her own young of about the same age.

General activity of the mother. In captivity, activity of the female seems to be greatly curtailed during the first few days following the birth of the young. Very little food is eaten, she is seen less often, and is more difficult to capture with a live trap set in the cage. Most of the time seems to be spent quietly on the nest with

the young. Hamilton (1953) stated that the female woodrat seems to sleep away the time during suckling.

Relationship of the father to mother and young. When the father was present in the nest cage, very little friction was noted between him and the mother or the young. Occasionally the female "threatened" the male if he wandered too near the nest, but otherwise no fighting was observed.

GROWTH AND DEVELOPMENT OF YOUNG

The following account is based primarily on 28 young observed in the laboratory, and for this reason may not represent normal growth and development. Six young (2 litters) were obtained from nests in the wild at about 2 and 5 days of age during May, 1955, and 22 young (6 litters) were born in captivity to a single female in the period September, 1955, to March, 1956. All the young were raised by their own mothers from birth, except one wild-born litter of 2 young which was raised by a lactating meadow vole. One young taken in the wild lived over a year in captivity; young born in captivity were studied for various lengths of time up to 6 months of age. Several young were killed at various ages for study purposes. As far as I know, there is only one previous study of development in this species, that of Stegeman (1930). He recorded the time of hair covering, color above and below, weight, opening of eyes, and appearance of the mammae to the age of 12 days in a litter of 2 born in captivity to a wild-caught female.

Because of an unidentified malady, I was unable to keep many of the young alive in the adult stage and none of the laboratory-born mice bred. During the early and juvenile stages of development, the young seemed perfectly normal in every way and developed rapidly. However, most of them died when 4-13 weeks old. Of 22 young (6 litters) born in captivity, 14 died of this condition, 6 were preserved at different ages, 1 escaped, and 1 was killed at birth by an adult. Some of the

young which were preserved (including one which attained 6 months and 10 days of age) had begun to lose weight and I believe all the young born in captivity would have died. One litter found in the wild (age 2-3 days) died in captivity apparently of the same affliction. But the other litter (estimated at 5 days old when caught), which was raised by a meadow vole, seemed normal and one of these, a male, bred and lived over a year in captivity. None of the older animals obtained by live-trapping showed this disease

The symptoms of the disease included loss of weight (first symptom, and beginning as much as 6 weeks before death), sluggishness, greatly increased consumption of water, and finally weakness and partial closing of eyes. The malady seemed to strike at a rather definite stage of development, in that all individuals completed the first, or juvenile molt, but the first weight loss in most individuals began shortly after the molt was completed. The mice attained weights of 24.0 to 38.1 grams before losing weight. Young isolated from weaning developed symptoms and adults in contact with diseased young did not. Dr. Lawrence D. Fay (Game Pathologist, Michigan Department of Conservation) found no gross inflammation and obtained no reaction in white mice injected with tissue from the afflicted lemmings. The possibility of a dietary deficiency must also be considered.

Condition of Young at Birth

Twelve young of four litters were examined on the first day, usually within a few hours of birth (all had nursed). The skin of the

new-born is wrinkled, and pinkish in color except for light grayish pigmentation on the dorsum, indicating the presence of developing hair follicles. The general appearance is quite naked, and yet mystacial vibrissae are 3 mm. long, and in good light minute, fuzzy hairs on top of the head, and sometimes on the rest of the dorsum, are barely visible to the unaided eye. Under the dissecting microscope the erupted, short, dark-based dorsal guard hairs are readily seen. The skin is semi-transparent and on the ventral surface the ribs, viscera, and milk in the stomach are visible.

The eyes are closed, but faint grooves which mark the future separation of the eye-lids are present. The pinna of the ear is folded down over the lower portion of the ear. Claws are present on the toes, which are held together by interdigital membranes for their entire length. Movement of the young when handled consists chiefly of uncoordinated waving of limbs and feeble turning motions. At least some individuals can crawl weakly, using the front limbs; some of these mice were so vigorous at first that they were able to crawl off the weighing pan, but they soon tired. Voice consists of a series of weak (sometimes louder) squeaks or cheeps in which the mouth is opened widely.

Average weights and measurements of 11 young at birth are: weight, 3.9 grams (range 3.1 grams to 4.3 grams); tail length, 5.7 mm. (range 5.0 mm. to 6.5 mm.); hind foot length, 7.9 mm. (range 7.5 mm. to 8.5 mm.). Weights within litters varied considerably, but were independent of sex. Three litters of 3 young each ranged from 3.6 to 4.3 grams,

3.6 to 4.1 grams, and 3.1 to 4.1 grams respectively; two young measured in a litter of five weighed 3.7 grams and 4.1 grams.

The two young observed by Stegeman (1930) weighed 2.7 grams and 2.4 grams at birth, less than the weights reported here. Racial difference may account at least in part for this discrepancy. Wetzel (1955) relates that Synaptomys cooperi cooperi (the form studied by Stegeman) is smaller in all dimensions of body and skull than the other races, whereas Synaptomys cooperi stonei is comparatively large in body and skull. In addition, the young examined by Stegeman may have been less developed at birth than those I studied. On the first day his specimens were pink above and did not attain the slightly gray color dorsally until the second day, whereas those I observed were dorsally pigmented within 8 hours of birth. However, by the ninth day the weights of Stegeman's animals were about the same as those in this study.

Weights and Measurements

Increase in weight of 21 young in captivity was fairly constant, with a small amount of variation between litters (Fig. 16, Table 2). During the first three weeks they increased rapidly in size, followed by a gradual leveling off at the upper plateau of the growth curve (Fig. 16). In about 8 weeks the laboratory-reared mice attained a weight equal to that of many of the relatively large adult animals trapped (30 to 34 grams). Increase in weight continued at a reduced rate. One male of litter number 1 was observed until one year of age (not shown on graph) at which time it had attained a weight of 42.7 grams.

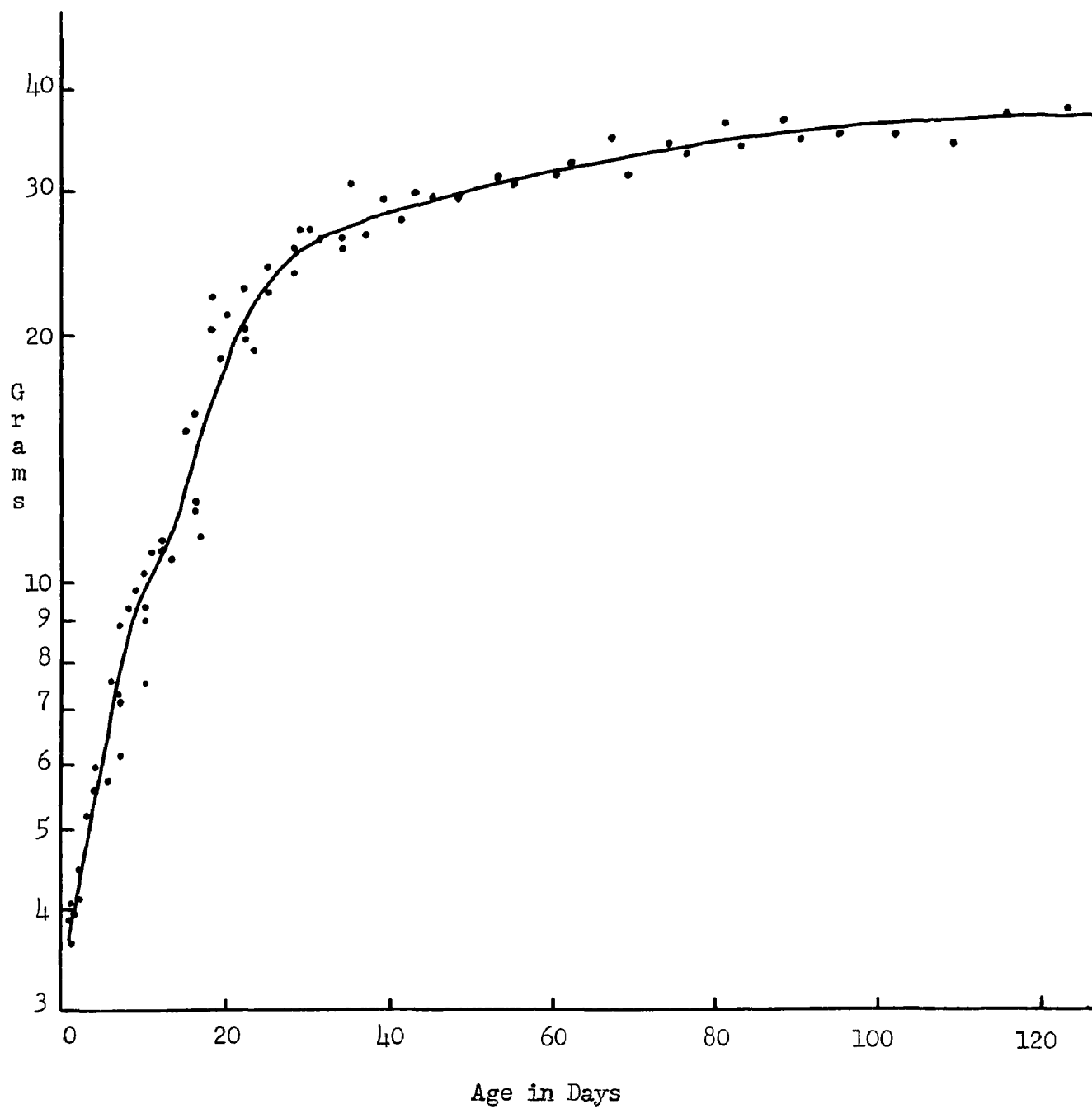


Fig. 16. Average weights of young of six litters of bog lemmings.

TABLE 2

AVERAGE WEIGHTS IN GRAMS OF SIX LITTERS OF SYNAPTOMYS. ALL LITTERS
EXCEPT #1, BORN IN CAPTIVITY. DATES OF BIRTH ESTIMATED
FOR LITTERS #1 AND 6

(Numbers in parentheses refer to number of young weighed)

Age in Days	Litter #1 2♂♂ 0♀♀	Litter #5 4♂♂ 1♀	Litter #6 1♂ 3♀♀	Litter #7 2♂♂ 1♀	Litter #8 4♂♂ 1♀	Litter #9 2♂♂ 0♀♀
1		3.9 (2)		4.0 (3)	3.9 (3)	3.6 (2)
2					4.4 (3)	4.1 (2)
3					5.2 (3)	
4			6.0 (4)	5.9 (3)		5.6 (2)
5	5.7 (2)				7.6 (3)	
7	6.1 (1)	7.2 (5)	7.3 (4)	8.7 (3)		
8						9.6 (2)
9					9.8 (3)	
10	7.5 (1)	9.3 (5)	9.2 (4)	10.4 (3)		
11						11.8 (2)
12				11.7 (3)	12.6 (3)	
13		11.4 (5)	11.2 (4)			
15				15.6 (3)		
16		15.0 (5)	14.5 (4)		17.0 (3)	
17	12.7 (1)					
18				19.2 (3)		22.2 (2)
19		17.8 (5)	17.3 (4)			
20				21.0 (3)		
22		19.9 (5)	20.4 (4)		23.0 (3)	
23	18.3 (2)					
25		22.8 (5)	24.2 (4)	24.1 (3)		
28		23.9 (5)	25.8 (4)			
29				26.9 (3)		
30					27.1 (3)	
31		28.2 (5)	26.5 (4)			
34		25.5 (3)	26.3 (1)			
35				30.8 (2)		
37		26.4 (3)	26.6 (1)			
39				29.3 (1)		
41		27.8 (3)				
43			30.0 (1)			
45				29.4 (1)		
48		29.8 (3)				
53				31.3 (1)		
55		30.9 (2)				
60				31.7 (1)		

Continued next page

TABLE 2 - Continued

Age in Days	Litter #1 2♂♂ 0♀♀	Litter #5 4♂♂ 1♀	Litter #6 1♂ 3♀♀	Litter #7 2♂♂ 1♀	Litter #8 4♂♂ 1♀	Litter #9 2♂♂ 0♀♀
62		32.8 (2)				
67				35.0 (1)		
69		31.7 (1)				
74				34.7 (1)		
76		33.6 (1)				
81				36.8 (1)		
83		34.3 (1)				
88				37.1 (1)		
90		35.0 (1)				
95		35.4 (1)				
102		35.3 (1)				
109		34.8 (1)				
115		37.2 (1)				
123		38.1 (1)				
240	41.0 (1)					
281	41.5 (1)					
356	42.7 (1)					

Most old adults in captivity weighed about 40 grams, with 46.6 grams for a non-pregnant female being the maximum weight recorded. The heaviest individual trapped in the field was a male weighing 39.6 grams.

In wild animals, increase in weight may proceed more slowly, by comparison to linear measurements, than in laboratory animals. The two young of litter number 1, which was found in a nest in the wild, weighed 5.6 and 5.8 grams. If this litter is compared with those raised from birth on the basis of weight alone, the age would be estimated at 3-4 days. However, the field-born litter was already furred above, and those born in captivity did not become furred until about

6 days. Only four juveniles weighing less than 13 grams were trapped. Of these, two (probably litter mates) weighed 8.8 and 8.9 grams. They had already been weaned; the digestive tract containing only green vegetation. Their weights, however, were equal to lab young 7-9 days old which were still in the nest being nursed, with eyes not yet open and still furred in first, light brown pelage. However, length of hind feet and tail in the two wild-caught young approximated laboratory young of 16-19 days, which were running about and being weaned, and these measurements seem a more valid age criterion than weight.

The next largest young trapped (also probably litter mates) weighed 11.3 grams and 11.9 grams. These contained milk as well as green vegetation in their digestive tracts and were thus being weaned. However, linear measurements were very close to those of the young described above (length-89.5 mm.; tail -17.5 mm.; hind foot-17.8 mm. for the lighter; length-88.5 mm.; tail-18.3 mm.; hind foot-18.0 mm. for the heavier). The weights of this heavier litter were equal to those in captive young of 11-13 days although these animals were more advanced in other characteristics. Perhaps the relatively uniform conditions in the laboratory tend to produce more regular growth while variable conditions in the field may cause greater differences in weights. Furthermore, all young born in captivity were the offspring of the same mother.

Weights of 21 specimens (14 males, 7 females) of Synaptomys in juvenile pelage (2 to 6 weeks of age to judge from captives) which were

TABLE 3

AVERAGE LENGTHS IN MILLIMETERS OF TAIL AND HIND FOOT OF FOUR
LITTERS OF SYNAPTOMYS BORN IN CAPTIVITY

Age in Days	Litter #5 4♂♂ 1♀		Litter #6 1♂ 3♀♀		Litter #7 2♂♂ 1♀		Litter #8 4♂♂ 1♀	
	Tail	Hind foot	Tail	Hind foot	Tail	Hind foot	Tail	Hind foot
1	5.5	8.0			6.2	7.8	5.3	8.2
3							6.8	9.3
4			8.0	9.9	9.3	10.5		
6							9.0	13.0
7	8.7	13.2	9.9	12.1	11.3	14.5		
9							10.5	16.3
10	11.8	15.8	14.0	16.2	14.3	17.0		
12					15.3	17.3	14.5	17.5
13	16.4	17.2	15.5	17.2				
15					17.3	19.0		
16	17.4	18.9	18.2	19.5				
18					19.7	20.5		
19	18.6	19.3	18.5	19.7				
20					21.3	20.7		
22	20.2	20.0	20.3	20.5			19.0	20.3 ^a
25			21.8	20.5				
28			21.3	20.3				
30							19.0	21.0 ^b
31			22.3	20.3				
34			22.8	20.5				
37	21.3	20.3 ^a						
53			23.0	21.0 ^b				
76	22.0	21.0 ^b						
83	23.5	21.0 ^b						

^a 3 young measured.

^b 2 young measured.

trapped at different seasons averaged 16.2 grams, with a range from 8.8 grams to 21.9 grams.

Measurements of tail and hind feet were recorded from birth to 83 days of age (Table 3). Although the tail in adults is usually somewhat longer than the hind foot, at birth the tail is considerably shorter. The tail surpassed the hind foot in length at about 20-25 days in three out of four litters studied. Measurements of the live animals are rough approximations only, particularly after they became active. Measurement of total length was not attempted.

Average measurements of 21 (14 males, 7 females) specimens of Synaptomys in juvenile pelage trapped at various seasons were as follows: total length, 103.0 mm. (range 88 mm.-117 mm.); tail, 18.1 mm. (range 14 mm.-22 mm.); hind foot 18.6 mm. (range 17.0 mm.-22.0 mm.).

External Features

Eyes. The eyes opened on about the tenth day of age in five litters of bog lemmings born in captivity, as shown in the following table. The eyes opened on the twelfth day in the litter observed by Stegeman (1938).

Litter Number	No. of Young	9 days	10 days	11 days	12 days	13 days
5	5	-	closed	-	-	open
6	4	-	opening ^a	-	-	open
7	3	-	opening ^b	-	open	-
8	3	closed	opening ^c	newly opened	-	-
9	4	-	-	newly opened	-	-

^a 2, eyes closed; 1, eyes open; 1, left eye closed, right eye open.

^b 1 with left eye partly open; all others with eyes closed.

^c 1, closed; 1, both eyes partly open; 1, left eye closed, right eye open.

Ears. In two litters observed the ear pinnae (external ears) unfolded on the second day. In one of these litters the pinnae were unfolding at about 24 hours of age (18-26 hours after birth). In one young both pinnae were folded; in another young, one pinna was folded and the other unfolding; in the third, one pinna was unfolding and the other was unfolded. Two young of the second litter were examined at 16-40 hours after birth. In one of the young, both pinnae were folded; in the other, both were unfolded. The auditory canal opened at 8-9 days in four litters which I examined. The external ears appeared more prominent in juveniles than in adults, perhaps because of the shorter hair in the younger pelage.

Incisor teeth. The incisors are visible through the jaw tissue on the fourth day or earlier, and usually erupt at about 6-8 days. The lower incisors develop slightly faster than the uppers. In 1 litter small white lower incisors had erupted by the sixth day; in 2 other litters lowers and very small uppers were out at 7 days; in 1 litter the lower teeth only were erupted at 8 days; in 1 litter no teeth were out at 7 days (erupted at 8-9 days). The newly-erupted incisors are white; they become yellow at 10-12 days.

Feet. In at least one litter the toes were joined by interdigital membranes up to the fifth day. By the tenth day (7 days in one individual) all toes were free. The three central toes of the hind feet were the last to become separated.

The plantar pads are light in color during the first two weeks or so after birth. Later the pads become dark gray or blackish, and this color may be retained for a month. Although I did not study them closely, the pads seem to be darkest during the period the pelage is juvenile gray. By the time the animals are fully adult the pads are light in color again.

Mammae. At birth the mammae are not visible on the females, thus sex at birth cannot be told by this character. Usually the three pairs of mammae are faintly visible on the third day and become more prominent during the next 2 or 3 days, and remain conspicuous until the growing hair obscures them. This agrees essentially with the findings of Stegeman (1930).

Testes. Length of testes of 14 specimens of Synaptomys in juvenile pelage taken at various seasons averaged 3.0 mm. in length and ranged from 2.0 mm. to 5.5 mm. One male in each of 2 caged litters was observed to have testes descended or scrotal by 35 and 55 days respectively, shortly after completion of the juvenile molt. The testes of their litter mates were not yet descended in position.

Pelage

During the second and third days the young become dark gray on the dorsum, including tops of feet and tail; the developing guard hairs seem to be responsible for this color, although light brown regular hairs, light to the base, are also present. The hair itself becomes

increasingly visible to the unaided eye, but the essentially naked appearance, and pink ventral color is retained through the fourth day. Individual variation exists; in a 4-day old litter one young was tinged with brown above from the developing fur, while the other two still appeared chiefly gray and wrinkled.

Usually by the sixth day, no later than the seventh in the young I observed, the young become well-furred above, and the skin is then hidden. The pelage at this stage is compact, and light, even, yellowish-brown in color, with a lustrous sheen. The light color is due to the relatively long bright yellowish tips to the regular hairs and the dark basal portions have not as yet grown out to their full length. Vibrissae are about 7 mm. long at this age. At about the same time, whitish hairs are apparent ventrally, sparsely covering the gray skin. The ventral hair comes in anteriorly first and proceeds caudad. The inguinal region and inner portions of the hind legs are still naked at 7 days. By 9-10 days, at the time the eyes open, the mice are well furred everywhere, although mammae are usually still visible in the females, and the fur is thin on the inner portions of the hind legs, the last area to be covered. The color below is a light, or whitish gray at this time.

By 10-12 days the dorsal pelage begins to turn from a light brown to a darker, grayish brown. Probably between 12 and 18 days, or at roughly 2 weeks of age, about the time the mice become active, the regular juvenile appearance is attained. They are now much darker than previously, being a dark brownish-gray, and are grayest on the rump,

browner anteriorly. The darker color seems to be due to the increased length of the dark gray bases of the hairs, duller color and perhaps shorter length of the light tips of the hairs (wear), and growth of the black guard hairs which now considerably overlap the fur. On the rump in particular the guard hairs project, giving a gray "fuzzy" appearance.

In the laboratory the juvenile pelage was replaced by an extensive growth of new hair which began during the fourth week. In all individuals of 4 litters observed, the new, short hairs were first seen coming in on the dorsum at 24-28 days. Most young required about two weeks to complete the molt, but with a range of individual variation of about 1-3 weeks. Dorsally, the new incoming hair first appeared along the sides and on the rump. From these two areas the new growth spread up over the back and shoulders, although there seemed to be some variation in that it spread more evenly in some individuals than in others. The hair along the mid-line of the back (except the rump) always seemed to be the last replaced. Four individuals were recorded as having lost the juvenile appearance by 34, 35, 37, and 48 (or fewer) days.

After the first, or juvenile molt, the animals were more of an even dark brown, with less gray on the rump and with guard hairs less prominent. The mice now had a rather adult appearance, and yet compared with old adults in captivity, they were usually darker and duller in color. One of the young had an extensive molt again during the fourth month (at about 86-104 days), apparently resembling the

juvenile molt in pattern, when the animal attained the lighter, brighter coat typical of the older adults. Also at this time the white tufts of hair on the hip glands became noticeable and were easily seen by slightly ruffling the fur. Most of the young died or were preserved before passing into the fully adult pelage. The lighter color of the old adults seems to be due chiefly to the more conspicuous yellowish tips of the hairs.

In summarizing the different pelage conditions according to age as I observed them in captive animals, five classes may tentatively be listed. 1) Appearance is naked from birth to about 5 days. 2) Juvenile pelage. This includes the compact, light brown or yellowish glossy appearance (6 days to two weeks of age and none were trapped at this stage) and the regular juvenile grayish pelage (about 2-6 weeks of age). 3) Post-juvenile or subadult pelage. The animals are dark in color. 4) Adult pelage. Adult pelage is lighter and brighter than preceding pelage. Two regular molts were observed, first from the juvenile to post-juvenile pelage and second from the post-juvenile to adult pelage.

In the field, molting may quite likely occur at different ages than in the laboratory, depending upon health and environmental factors. Most of my trapped specimens may be placed in one or the other of the last three categories listed above. However, there is considerable overlap in size between the last two groups, some fairly small individuals being bright in color, and also there is some individual variation within each of the groups. While trapping, I did not distinguish between the last two groups, and simply listed them all as adults.

Comparison With Microtus Young

A combined litter of 2 Synaptomys young about 5 days old and 2 Microtus young of about the same age, which were removed from nests in the field in May, 1955, and raised in captivity by the mother Microtus, afforded comparisons at early stages of growth. The table below gives weights in grams and measurements in millimeters of these young at ages at which pelage and other conditions are described in the following paragraphs.

Estimated Age in Days	<u>Microtus</u>			<u>Synaptomys</u>		
	Weight	Tail	Hind Foot	Weight	Tail	Hind Foot
5	6.5	14.5, 14.0	11.0	5.8, 5.6	8.0	
7	7.6	16.0		6.1	11.0	
10	9.4	22.0	17.0	7.5	10.0	15.5
17	17.3, 16.4			12.7		
23				17.9, 18.7		

5 days -- The most obvious difference in the specimens of the two genera was in color, the bog lemmings being of a much lighter, yellowish color (as described previously) in contrast to the dark gray cast of the young field mice. The tail and feet were much lighter in the lemmings, and the tail noticeably shorter. They also appeared to have larger heads with wider snouts, and to be more vocal than the young Microtus.

7 days -- Lighter color in Synaptomys persists. Microtus are strongly tinged with blackish on feet, tail, and back. Microtus seem

more active.

10 days -- The same difference in color prevails. Eyes are open in Microtus, closed in Synaptomys.

17 days -- Both are active and running around. Synaptomys are eating grass (Microtus noted doing so on 15th day). Pelage of the two are beginning to look more alike, but there is still considerable contrast. Short hairs on snout are pale in Synaptomys, dark gray in Microtus. Differences which also persist in adults are readily noted: naked rim of ears shows in Synaptomys (rims not covered with fur as in Microtus); eyes smaller in Synaptomys; nose shorter, "puffier" in Synaptomys.

Behavior

In contrast to the first day, the young on the second day were more vigorous in their uncoordinated movements and they called more loudly (insistent, piping calls). By the fourth and fifth days many individuals called incessantly when handled. Occasionally an entire litter would call at once, sounding remarkably like a chorus of spring peepers. When the mother was separated from the young and heard these calls, she acted as though very excited. A Microtus nest (previously described) was found near a Synaptomys nest because of the calls of the young. When the Synaptomys nest was uncovered, the young called loudly in long, rapid, high-pitched series of squeaks; seemingly in answer a similar series of notes emanated from a hummock a few feet away. A check of

the spot revealed a Microtus nest with young. Apparently it was the calls of the baby lemmings that stimulated the young meadow mice to call, for to my knowledge they had not been disturbed. Activity at 5 days still consisted chiefly in waving the limbs about, although some could crawl feebly on a flat surface. At 7 days most still called loudly when handled; also a low note was heard at this time, as if the young were communicating among themselves.

By 9-10 days the young had developed considerably. At this age when the nests were opened one or more young ran out onto the floor of the cage, even though the eyes in most of them had not yet opened. They blundered into tangled grass or corners of the cage, sometimes calling, and I believe they remained there until the mother rounded them up. When placed in a large hat, a little of five showed an inquisitive, explorative disposition, but they kept bunched together and slumbered in a pile when they tired. On a flat surface they walked with the feet splayed out at right angles to the body and with rump flat. If turned over on a flat surface, they usually were unable to right themselves, although they thrashed limbs violently. Eleven days was the earliest at which an individual entered a live trap set in the cage. Some individuals were much more aggressive and advanced in their activities than others. Young in one litter were noted to have several kinds of calls at 10 days: 1) typical baby calls--loud, high-pitched series of notes, 2) loud, harsh chatter resembling typical call of adult when handled, 3) low, not loud, short notes. Sometimes calls were given which sounded intermediate between calls 1 and 2.

By 12-13 days (or immediately after the eyes opened) the young began to run about the cage and eat solid food (including grass and rolled oats). They even chewed on metal parts of the cage. The mice now walked well, and the hind feet were usually kept under the body, but on a flat surface the hind feet sometimes suddenly went out of control, and they still had difficulty in righting themselves if turned over.

The young were never observed clinging to the nipples of the female when she was disturbed from the nest or at any other time.

Weaning apparently occurs during the third week, although the young may continue to get milk for a longer time. The young were definitely known to nurse at least until 16 days; by three weeks, they were getting little or no milk. Twenty days was the earliest a litter was separated from the mother but I believe they could survive at 15 days.

By three weeks the mice were active in running about and repeatedly entered live traps set in the cage (much more frequently than the adults). They were more difficult to handle now, as they were quite agile and coordinated in their movements. The young rarely bit however, and could be handled at 2-3 months of age with bare hands. Baby-like calls ceased at about three weeks, although they voiced noisy adult-sounding calls upon handling. Two females 6 weeks old built a fairly good nest for themselves.

FOOD HABITS

Review of Literature of Food Habits

Much remains to be learned concerning the food habits of Symaptomys, as few stomachs have been examined. The following items have been previously reported:

Endogone (fungus). Hyphae, spores. C. C. Sperry, reported by Burt, 1928; Hamilton, 1941b.

Fleshy fungi. Martin, Zim, and Nelson, 1951.

Mosses. Oehler, 1942; Richmond and Rosland, 1949; Martin, Zim, and Nelson, 1951.

Liverworts, including Conocephalum and Marchantia. Richmond and Rosland, 1949.

Lycopodium complanatum (ground pine). Green portions, ripe heads. Richmond and Rosland, 1949.

Aspidium (fern). Richmond and Rosland, 1949.

Grasses. Linsdale, 1927; Stegeman, 1930; Eadie, 1937 (blades, stems); Grimm and Roberts, 1950; Martin, Zim, and Nelson, 1951 (9/10 of the food in 23 specimens examined).

Bluegrass. Quick and Butler, 1885; Burt, 1928 (chief food; leaves, stems); Hamilton, 1941b; Oehler, 1942; Fisher, 1945.

Poa pratensis (Kentucky bluegrass). Stems, leaves. Richmond and Rosland, 1949.

Poa compressa (Canada bluegrass). Basal stems, leaves. Richmond and Rosland, 1949.

Danthonia (poverty grass). Basal portions of leaves, seed heads.

Richmond and Rosland, 1949.

Timothy. Seed heads. Richmond and Rosland, 1949.

Danthonia spicata. Crowns. Roslund, 1951.

Sawgrass. Goodwin, 1932.

Sedges. Hamilton, 1941b; Richmond and Rosland, 1949 (seed heads);

Grimm and Roberts, 1950.

Carex. Leaves. Connor, 1953.

Scirpus lineatus. Green, 1925.

Beech. Twigs, seedlings. Hamilton, 1941b.

Hackberry. Bark. Oehler, 1942.

Buttercups. Martin, Zim, and Nelson, 1951.

Ranunculus acris. Petioles. Harper, 1929.

White clover. Quick and Butler, 1885; Martin, Zim, and Nelson, 1951.

Raspberry. Seeds. Hamilton, 1943.

Helianthus (sunflower, wild artichoke). Tubers. Quick and Butler,
1885; Martin, Zim, and Nelson, 1951.

Delicate plant roots. Eadie, 1937.

Foliage leaves. Epidermal cells. Eadie, 1937.

Apple, as bait. Burt, 1928.

Beetles. C. C. Sperry, reported by Burt, 1928 (Haliplidae); Stegeman,
1930 (piece of elytra); Hamilton, 1941b (including larvae);
Oehler, 1942.

Methods Used in Studying Food Habits

Two principle methods were used in determining what the bog lemmings were eating. These were analyses of the contents of the digestive tracts and observations of cuttings and other sign in the field. Eighty-six stomachs were examined. The contents were usually examined with a binocular dissecting microscope, occasionally with a compound microscope, and the general nature of the material determined. Twenty-three of those animals whose stomachs were examined also contained large, easily-recognized, fragments of food in the mouth. Considerable time was spent in observing workings in the field at different seasons and recording the nature of the cuttings or chewings and species of plants utilized.

Two methods less used were direct observations in the field, and information obtained from animals in captivity. On a few occasions in the field individuals were observed eating, and the behavior of the animal and the kind of plant were noted. No specific feeding experiments were carried out with the animals in captivity, although general preferences were noted and feeding behavior was observed.

Discussion of Foods Eaten

List of food species and parts consumed

Table 4 lists plants and plant parts recorded in this study as food of Synaptomys, based on stomach contents and field signs. All species in this list were recorded more than once. Their degree of

utilization is discussed in the next section. No animal remains were found in any of the 86 stomachs examined.

In addition, an unidentified species each of grass and sedge were recorded. Additional species of Carex and Vaccinium may have been represented besides those listed. A small, low-running swamp blackberry (Rubus), fruit, and Polygala sp., flowers, were noted as probably eaten by Synaptomys.

Food preferences and foods at different seasons

Analyses of stomach contents and other parts of the digestive tract. Table 5 summarizes the contents of 86 Synaptomys stomachs examined. All of the stomachs were from individuals trapped in the bog habitat, except for two taken in a dry field in December. Bright green matter that signified sedge or grass was correlated with cuttings observed in the locality where the trapping was done. Blueberries and huckleberries were readily recognized by the blue stain, seeds, and bits of skin. White, starchy material was usually succulent bases or root-stocks of plants; occasionally the reddish sheathing at the base of Carex was identified in this material. Sphagnum was readily recognized in the stomach by the consistency, grayish-green color, and the small, whole, leaves. Some material was not identified as to type.

The percentages-of-bulk measurements are rough approximations. In examining individual stomachs the percentages of the various items were estimated to the nearest 10 per cent. Sometimes the items were mixed in the stomach and percentages were then rather arbitrarily

TABLE 4

SPECIES OF PLANTS AND PARTS EATEN RECORDED AS FOOD OF
SYNAPTOMYS IN SOUTHERN NEW JERSEY, 1953-1955

List of Species	Parts Eaten
<u>Sphagnum</u> spp.	vegetative parts (leafy shoots)
<u>Poa compressa</u> L. (Canada bluegrass)	leaves
<u>Tridens flavus</u> (L.) Hitchc. (Tall red-top)	
<u>Stipa avenacea</u> L. (Needlegrass) ?	leaves
<u>Andropogon virginicus</u> L. (Broomsedge)	leaves
<u>Andropogon glomeratus</u> (Walt.) (Bushy beardgrass)	leaves
<u>Panicum mattamuskeetense</u> Ashe (Panic grass)	
<u>Panicum virgatum</u> L. (Switchgrass)	leaves
<u>Dulichium arundinaceum</u> (L.)	
<u>Rhynchospora alba</u> (L.) (Beak-rush)	leaves; stems
<u>Rhynchospora</u> spp. (Prob. <u>R. glomerata</u> , <u>R. gracilienta</u> ; also <u>R. pallida</u> ?)	
<u>Cladium mariscoides</u> (Muhl.) Torr.	leaves; prob. basal parts
<u>Carex atlantica</u> Bailey	leaves
<u>Carex bullata</u> Schkuhr.	leaves, succulent white bases, rootstocks, shoots
<u>Carex walteriana</u> Bailey	prob. same as for <u>C. bullata</u>
<u>Xyris</u> sp. (Yellow-eyed grass)	heads
<u>Juncus canadensis</u> J. Gay (Rush)	
<u>Juncus pelocarpus</u> Meyer (Rush)	leaves; stems
<u>Juncus</u> spp. (including <u>J. militaris</u> and <u>J. aristulatus</u> ?)	
<u>Xerophyllum asphodeloides</u> (L.) Nutt. (Turkeybeard)	leaves; white bases of leaves; stalks?
<u>Iris prismatica</u> Pursh. (Slender blue flag)	leaves (at least basal parts)
<u>Ilex glabra</u> (L.) (Inkberry)	twigs
<u>Chamaedaphne calyculata</u> (L.) Moensch. (Leatherleaf)	twigs; prob. roots
<u>Gaylussacia dumosa</u> (Andr.) T. and G. (Huckleberry)	fruit
<u>Gaylussacia frondosa</u> (L.) T. and G. (Huckleberry)	fruit
<u>Vaccinium corymbosum</u> L. (High-bush blueberry)	fruit; prob. roots
<u>Vaccinium macrocarpon</u> Ait (Cranberry)	stems; fruit?

determined. No distinction was made in the size of the stomachs, except that a few very small ones were eliminated.

Twenty-three mouths contained large, identifiable particles. Thirteen of these contained Carex leaves (8-spring, 3-summer, 2-late fall); three contained Rhynchospora leaves (2-summer, 1-December); one contained bluegrass leaves (December); one contained sphagnum (December); one contained huckleberry fruit (summer); and five contained apple used as bait (November-December).

The color of the intestinal contents was usually a bright to light green. In spring intestines of three individuals were of different colors, one a very pale color, presumably from white starchy plant parts, another was blackish-green, and a third partially light brown (leatherleaf twigs?). In several animals in summer the intestinal contents were all or partially blue to bluish-gray from the berries. Occasionally, other dull colors were represented in summer.

The prominence of blueberries and huckleberries in the summer diet is of interest in view of the fact that there seems to be no record in the literature of these items being eaten by Synaptomys. Apparently the only fruit which has been previously reported in the diet is raspberry seeds (Hamilton, 1943). Blueberries and huckleberries (Fig. 23) were especially prominent in 1953, and my field notes indicate there was a much bigger berry crop that year than in 1954. In the sample of 15 stomachs from the summer of 1953 alone, the fruit actually surpassed the green vegetation in percentage bulk. The frequency of occurrence was 13 (87 per cent) for both green vegetation

(A) FREQUENCY OF OCCURRENCE, (B) PER CENT FREQUENCY OF OCCURRENCE,
AND (C) PER CENT BY BULK OF FOOD ITEMS IN 86 SYNAPTOMYS STOMACHS
EXAMINED IN 1953, 1954, AND 1955 IN SOUTHERN NEW JERSEY

Number of specimens	Spring*			Summer*			Late Fall*			Combined		
	20			39			27			86		
	A	B	C	A	B	C	A	B	C	A	B	C
Green vegetation (chiefly sedge, grass)	16	80	66.0	33	85	52.6	24	89	86.7	73	85	66.4
Sphagnum moss				1	3	1.0	1	4	3.7	2	2	1.6
Huckleberries, blueberries				20	51	31.8				20	23	14.4
White, starchy plant parts (chiefly rootstocks and basal parts)	3	15	8.5	3	8	3.6				6	7	3.6
Slender iris (base)				2	5	.8				2	2	.3
Leatherleaf? (woody)	2	10	8.5							2	2	2.0
Dried sedge leaves	2	10	2.5							2	2	.6
Cranberries? (fruit)				1	3	.5				1	1	.2
Fungus?				2	5	.8				2	2	.3
Bark?	1	5	1.5							1	1	.3
Unidentified materials (several types)	2	10	7.5	7	18	8.5	1	4	1.1	10	12	5.9
Apple (bait)							4	15	8.5	4	4	2.7
Milk (in small juveniles)	2	10	5.5							2	2	1.3

*

Spring (April 7-May 17, 1955); Summer (July 12-September 17, 1954, 1954); Late fall
(October 23-December 11, 1954).

Under the category of green vegetation in summer, Rhynchospora was identified in three stomachs;
under white starchy material, base of Carex shoots identified in one stomach in spring and base
of Carex plants in one stomach in summer; 2 species of huckleberry (Gaylussacia dumosa, G.
frondosa) and one of blueberry (Vaccinium corymbosum) were identified in summer stomach contents.

and berries, while the percentage of bulk was 44 per cent for green vegetation and 53 per cent for the berries.

Field observations of sign. The finely ground up plant materials in the stomachs were usually difficult to identify beyond the general types of food. This was especially true in the case of green vegetation, the chief type of food eaten by Synaptomys. Thus it was necessary to observe the cuttings and other workings in the field and to identify the plants involved.

Microtus pennsylvanicus left cuttings of the same general type as that of the bog lemmings. Often, however, the cuttings of the two could be separated and certain operations of Synaptomys seemed to be distinctive (see section on sign). Also in the 17 areas in which most of the food observations were made 126 Synaptomys were trapped as against only 48 Microtus. In eight of these bogs no Microtus were taken, and in the other bogs the two species seemed to be partially segregated. Thus the following discussion has been based on field recordings of sign assumed to be that of Synaptomys.

The most obvious signs were cuttings of sedges and grasses and sometimes of shrubs. Sub-surface workings on succulent bases of plants were harder to see, but sometimes were encountered on a large scale (Figs. 19, 20). There was not a great deal of field evidence of eating fallen berries in summer, yet stomach analyses revealed them as a choice food for lemming mice and other species.

The plants were thought of as falling into three categories, based on their degree of utilization on the areas as a whole: Primary foods, Secondary foods, and Other foods.

A. Primary Foods

1. Carex, mainly the large species Carex bullata,* is the most important food of Synaptomys in the bogs of the New Jersey pine barrens. It was very common in nearly every bog trapped. In some bogs, such as the leatherleaf-Carex type, it grows in solid stands and is almost the only herbaceous plant present.

Fresh Carex cuttings (Fig. 24) were recorded on almost every day that I was in the field: this period covered the seasons from March 25 to December 12. Frequent observations were made of seeming preference by bog lemmings for Carex even where it grew quite scattered among other grass-like species. Also a common observation was to find a pile of green Carex cuttings under the dense, arching shelter of a turkeybeard plant, some distance from where the leaves had been cut off, indicating use of turkeybeard only as cover where Carex was available. It was undoubtedly eaten throughout the year, forming a staple even in winter and early spring in areas where it formed dense stands. In other areas however, where the plants were more scattered, they died down

*

Two large species, C. bullata and C. walteriana, were identified on the areas, and perhaps even other large species of this genus may have been present. Dr. J. McCormick informs me that C. bullata is regarded as the common one of the bogs.

considerably, leaving very little green foliage in the bogs, and signs of activity typically shifted to nearby areas of turkeybeard.

All vegetative parts of the Carex plants were eaten. Generally, piles of sections of the stout, green leaves were found as sign. Frequently, areas were found with the runways actually paved solid with vast numbers of cuttings. In winter and early spring (observed November, December, March, and early April) the basal half or so of the inner leaves of old plants remained green and these leaves were picked out and cut. The shoots also formed a good food of the "off season." Cut-off shoots, or parts of them, often gathered in little piles, were frequently found in April, and also recorded in November, December, and March. The shoots were often available on the floor of runways under the moss as well as on the surface. Another type of feeding, eat-outs of the succulent white bases of Carex from below the surface, was less often encountered, but probably was more common than observed. On August 28, September 2 (old), and November 9 eat-outs were encountered on a large scale in three different bogs. The eat-outs were discovered by tugging on plants; those that had been eaten out came up in the hand with the slightest exertion. Closer examination revealed that the plants had been chewed out at the base in runways that wound about the plants under the sphagnum. Cut sections of rootstocks were also sometimes found; they were highly relished by lemming mice in captivity.

Carex, then, was important in being common, palatable in all parts, and often available throughout the year.

2. Rhynchospora, a slender-leaved sedge, ran a fairly close second to Carex. At least two species were commonly eaten, and R. alba, which grows in tufts or clumps, was frequently identified and was believed to be the species most often involved. Rhynchospora was not encountered in the depression basins but was common elsewhere and was the dominant sedge in two or three of the areas near streams. Fresh cuttings were observed from spring to winter (April 5-December 12) but were most frequently seen in summer. This sedge probably furnishes green food in some areas throughout most of the year, but it dies down considerably in winter. Sometimes the bog lemmings "graze off" a clump of Rhynchospora, leaving a mass of stubble and a pile of cuttings frequently numbering several hundred pieces. Such sign is very conspicuous.

3. Turkeybeard, Xerophyllum asphodeloides, a member of the Liliaceae and in the same genus as the "bear grass" of our West, must be ranked high among the important foods in the pine barrens, although it is not a preferred food. (Figs. 17-21). It is a seasonal item, eaten only during winter and early spring when the more succulent species have died down. It seemed to be relied on heavily at these seasons around many of the bogs. The grass-like, but tough, dry, and wiry leaves are evergreen and in winter furnish bright green tufts along the margins of sphagnum bogs or in dry woods nearby. In several areas a very distinct shift in seasonal activity was noted. As the sedges turned brown in the bogs, green sign appeared in the turkeybeard, often well up into dry, sandy pine woods. Fresh sign in turkeybeard was seen

from early November to April in some areas. Preference for light green blades of new growth was noted several times.

Sometimes in a small area of turkeybeard very heavy workings took place; these were the most concentrated and striking sign of Synaptomys observed during the study. In such cases, large pyramidal piles of hundreds of green cuttings of the leaves appeared (700 pieces counted in one pile). In addition, everywhere the plants were riddled from beneath and the large clumps came up easily in the hand. Closer examinations revealed shallow sub-litter tunnelings around and under the clumps, and eat-outs of the white basal parts of the leaves. Often all, or almost all, of a clump was found to be sheared off from below (Figs. 19, 20). Large piles of cut sections of white bases were found everywhere in the tunnels. Also large piles of green cuttings were in the tunnels, representing leaves cut from below and pulled through. Tunnels sometimes ended at a turkeybeard plant or clump. Sometimes little pits were dug from the surface of the ground to get at the basal parts. Eat-outs were easily recognized the following summer and fall by the areas of brown, dead plants.

However, Xerophyllum was not sought out in summer. Between May and October only a few clippings of doubtful origin were recorded on five or six occasions, although the areas were closely checked. But it was believed to be an important green food during the winter months.

4. Blueberries and huckleberries of three swamp species furnished fruit popular in summer to judge from stomach contents. These plants are strikingly common throughout the pine barrens, other species

occurring on the upland, and furnish food for many kinds of animals. Dwarf huckleberry (Gaylussacia dumosa) (Fig. 23) and blue huckleberry (Gaylussacia frondosa) were usually very abundant in the bogs, although less common in the leatherleaf-Carex type. High-bush blueberry (Vaccinium corymbosum) was present on most of the areas. Fruit is probably not as important as other foods, as it occurs only in summer and varies in amount available from year to year.

In 1954 the berries began to ripen in late July. During August and September on several occasions signs of mice eating the berries were recorded. Fallen berries were numerous nearly everywhere and no doubt constitute the kind generally eaten, although dwarf huckleberry fruit sometimes hangs low enough for mice to reach it.

5. Other plants than those mentioned above probably furnish food of importance locally. In the acid bogs of the pine barrens there is a lack of the grasses commonly encountered by microtines elsewhere. In the single dry field in which *Synaptomys* were trapped, most were taken in a small area of bluegrass in which much sign had accumulated. Locally in dry fields in this region broomsedge or switchgrass may furnish chief foods.

B. Secondary Foods

Some of these were utilized fairly heavily seasonally or locally, others occurred in many areas but were not common enough to furnish a great deal of food.

Fig. 17. Old cuttings at foot of turkeybeard plant (Xerophyllum
asphodeloides). Bass River State Forest, August 18, 1953.

Fig. 18. Fresh workings of Synaptomys in stand of turkeybeard. Four clumps on left and foreground were cut off an inch or two from ground. In center, under shelter of reclining leaves, are green cuttings. Runways extend into dense growth in background. Bass River State Forest, March 26, 1954.



Fig. 19. Large clump of turkeybeard which recently had been completely cut off at the base from subsurface runways (eat-out). This clump grew along edge of bog in Bass River State Forest. March 26, 1954.

Fig. 20. Basal subsurface workings in turkeybeard showing the white cuttings in place. To take this photo, the surface cover was removed and the top of the clump pushed back. In pine woods near bog, Bass River State Forest, March 26, 1954.



Fig. 21. Bog lemming runway and large pile of cuttings along edge of turkeybeard growth. Bass River State Forest, March 26, 1954.

Fig. 22. Low pitch pines and huckleberry (G. dumosa) beneath which were located the cuttings illustrated in Fig. 21. Cedar bog in background. Bass River State Forest, March 26, 1954.



Fig. 23. Dwarf huckleberry (Gaylussacia dumosa), in some areas a common shrub which made up a large part of summer diet of Synaptomys and other small mammals. Bass River State Forest, September 9, 1953.

Fig. 24. Cuttings of Carex leaves in subsurface situation just inside tunnel entrance under roots of southern white cedar. The whole leaves had been cut off on the surface nearby and carried inside for cutting and eating. To take this photo, the burrow was opened up and earth and small roots pushed back. June 13, 1955.



1. Needlegrass, Stipa avenacea?, occurred in patches in low pine woods adjacent to a few of the bogs studied. Like the more common Xerophyllum, it was temporarily used by Synaptomys near the bogs. Several heavy concentrations of old sign were found. It was not definitely determined in which season it was most often utilized, although on the Bear Swamp quadrat it seemed to be used chiefly in the fall. This grass dies down completely in winter. Flowering heads needed for identification, were not found.

2. Leatherleaf, Chamaedaphne calyculata (Fig. 6), which occurred in every bog trapped, furnished green woody food during winter and spring. Piles of clipped, small, new green twigs were found in bog lemming areas, often in conjunction with Carex cuttings and green droppings, in December, April and May. This kind of sign was not found in summer and fall. The green tender wood of newly-sprouted twigs near the ground was the part eaten. Cut twigs ranged up to about 2.5 mm. in diameter. The leaves on the cut sections were not touched, and small strips of outer bark were often accumulated in small piles.

3. Cladium mariscoides, a sedge closely related to the "sawgrass" of the South, occurred in most of the bogs and green cuttings were found throughout summer and fall.

4. Bushy beard grass, Andropogon glomeratus, was not highly favored, although quite common and occurring on most of the areas. Frequently it seemed to be avoided for other species close at hand. On occasion, however, piles of cuttings and sometimes fairly heavy concentrations of sign were found. Most of the recordings were in mid-summer.

5. Rushes, Juncus spp., were scattered throughout the areas, and cuttings of several species were recorded. J. pelocarpus, a slender, branching species, was recorded on three of the trapping areas. J. canadensis and probably J. militaris and others were also cut up. Recordings of green cuttings are from April 1 to December 1, with most seen in August and September.

C. Other Foods Recorded

The following species were noted as sign a few times: Dulichium arundinaceum; Carex atlantica (a small Carex), leaves; Xyris, sp. (yellow-eyed grass), heads; Iris prismatica, base of leaves, also in stomachs; Ilex glabra (inkberry), twigs cut in manner of leatherleaf cuttings; Vaccinium macrocarpon (cranberry), stems. Also one or two unidentified slender sedges and bog grass were noted.

In the dry field (in or near the bluegrass), cuttings of Panicum virgatum (switchgrass), leaves; and Tridens flavus (red-top) were recorded. Old sign found in Andropogon virginicus (broomsedge) in two dry fields was believed to be that of Synaptomys.

Woody roots and stems were observed to be chewed on in runways under sphagnum moss. Usually the species of mouse responsible was unknown, but Synaptomys was frequently suspected. In November, 1954, heavy chewings on large roots of high-bush blueberry were unearthed in shallow subsurface runways winding about the base of a large bush, in conjunction with a great abundance of typical Synaptomys sign (green Carex cuttings and bright green scats all through the tunnels).

The roots, about 1/2 inch in diameter, were cut in two or had long chewed areas 2 1/2 to 3 inches long. Several bog lemmings were the only mice trapped here. Several times in bog lemming areas leatherleaf roots and stems were found to be attacked or small sections cut. Most of these records were for spring, but were recorded also in other seasons.

Sphagnum was underfoot everywhere in the bogs, and was found in the digestive tracts of three bog lemmings.

Perhaps every plant in the habitat is nibbled on now and then. The following were noted as probably eaten by Synaptomys to judge from sign: Polygala, flowers; low running bog blackberry (Rubus), fruit.

Cranberries were characteristic of the bogs, but not much evidence was found that Synaptomys feeds on them although other animals eat them or open them for the seeds. Small mushrooms were frequently present in the tunnels under the moss and seemed likely food, but no direct evidence that the mice eat them was obtained.

Wild foods eaten in captivity. Animals in captivity were not fed many different items from the habitat at one time. But frequently two to several kinds of food were presented at one time and any selection was observed. A few impressions were gained; frequently these were consistent with field observations. Because of the highly artificial environment in captivity little importance has been attached to these results in this study, but they are perhaps helpful in corroborating evidence from the field work.

Within limits, variety was appreciated by the mice. Samples of many foods were tried and a familiar item which was withheld for a while and then returned seemed to be more valued than previously.

A great many kinds of sedges and grasses were eaten to a greater or lesser degree. All parts of the Carex plants were relished (rootstocks, succulent bases, leaves, and shoots). The slender tips were very often the favorite part of the leaves. The leaves of this genus appeared to be preferred over Rhynchospora and Cladium, although the slender leaves of Rhynchospora did not keep well after being cut. But all of these, including the heavy stems of Cladium, Andropogon glomeratus and Andropogon virginicus (leaves and stems) were readily cut up and eaten. Heads and heavy tough stems of bushy beardgrass were not attacked, nor the heavy stems of Eriophorum, although the heads were chewed up.

Xerophyllum was definitely low on the list, when sedge and grass leaves were provided. Occasionally some was eaten after other things were cleaned up. The white bases seemed to be preferred over the green part of the leaves. Andropogon glomeratus (broomsedge) was noted as eaten in preference to Xerophyllum.

Leaves and stems of Juncus canadensis (a rush) were twice observed to be cut up but apparently not eaten.

The most striking preference observed in captivity was for the rootstocks of Carex. Repeated observations were made in which Carex rootstocks were eagerly taken before anything else, and consumed by the mice in large quantities. In nature, these rootstocks may often be

too deep to be available. The succulent white bases of the leaves of Carex and Cladium were also highly favored. Roots of leatherleaf were rarely eaten.

Huckleberries and blueberries were always enjoyed (except over-ripe and green ones). Blackberries and cranberries were eaten much less.

A limited amount of insect food was presented. Sometimes this food was ignored by the lemming mice or they failed to catch it. On one occasion two mice ate part of a large cricket.

Summary. Green vegetation, chiefly the blades and stems of sedges, grasses, and other grass-like plants, was the principle food throughout the year. This kind of material occurred in 85 per cent of 86 stomachs examined and made up roughly 66 per cent of the total bulk. Although lemming mice elsewhere may find the blades of grasses their chief food, here in the acid bogs of the pine barrens sedges are the main group represented. Carex bullata was the most important food on the areas as a whole. Other foliage commonly eaten was that of Rhynchospora, Cladium, Xerophyllum, Stipa, Andropogon, and Juncus. Other sedges and grasses and Iris were also eaten. Even sphagnum moss was eaten to some extent.

Xerophyllum (turkeybeard) and Stipa? (needlegrass), unlike the others mentioned, usually do not occur in the bogs proper but in low pine woods nearby. Evergreen turkeybeard is eaten in winter and early spring.

In a dry field, the food was grasses, and a patch of bluegrass contained a number of bog lemmings. Cuttings were also recorded in switchgrass, red-top, and broomsedge.

Green woody twigs, especially of leatherleaf, were eaten in winter and early spring. Similarly, inkberry twigs and cranberry stems were also accumulated in little piles of cuttings.

Starchy succulent plant parts were believed to be eaten quite regularly. Sign in the field included bases of Carex leaves and shoots, Carex rootstocks, bases of turkeybeard leaves. Such material was found to some degree in the stomachs. A strong predilection was shown for this kind of food in captivity.

Woody roots possibly furnish some food.

Based on stomach analyses, fruits of blueberry and huckleberry furnish a high proportion of summer food and in season may rival green leaves in popularity.

Although green foliage is the chief food, even when this material is available in abundance other items are also included in the diet, as for example, blueberries and basal parts of Carex in summer.

No animal remains were found in any of the 86 specimens examined.

Substitute Foods Eaten in Captivity

Staple foods furnished to bog lemmings in captivity were rolled oats, apples (including seeds), lettuce, and carrots; shelled corn, sunflower seeds, and grapes were occasionally given. These were found to be preferred among a large variety of household foods offered.

The mice took longer to learn to eat the lettuce, carrots, and corn than the other items, but eventually came to relish these foods. Lettuce was consumed in large quantities. Apples (sectioned), as well as blueberries, were effective bait in trapping.

Habits Associated with Feeding

Manner of eating

Direct field observations. Three or four field observations were made of lemmings feeding on sedge (Carex). Two fairly good observations were made at distances no greater than five feet. An account of one of these observations is presented below, taken nearly verbatim from my field notes.

November 23, 1954, a dark, quiet, over-cast day with the temperature in the mid-40's. At 1:30 p.m. I was standing in a bog in Bass River State Forest when I heard a rustling in the sedge very close at hand. Quiet observation finally revealed a Carex leaf slowly disappearing into a hole in the sphagnum, accompanied by audible munching of teeth from within. In a few moments a bog lemming came out into plain view from where I stood. He went to a sedge plant nearby, reached up, standing on his hind legs, and twisting rapidly sideways (exposing light-colored underparts), cut off a leaf 3 inches to 4 inches from the ground. Then he ran back into the hole, trailing the long leaf behind. Just inside the entrance he turned around to eat the leaf. The upper part of the leaf was brown, but the basal part where he began eating was bright green. He chewed for a while, then drew the leaf in, making

cuttings in the process, took some bites in a new place, and so on. After disposing of it, he came out of the hole and walked about two feet away, then turned around and went back in. After a period of silence, he began chewing again on the cuttings or parts of leaves within.

Suddenly, both of us were surprised by an unidentified fairly large animal (weasel?) approaching rapidly down a nearby small mammal runway. It passed through the mossy mound directly behind the bog lemming, out the other side, and kept on going. But it startled the mouse, and he left in a hurry.

Then I went up and examined more closely the hole leading into the moss. Within were five long leaves lying side by side, with the ends sticking out, and about twenty very even-lengthed cuttings and a quantity of bright green droppings. Visits to the spot at 4:30 p.m. and early next morning revealed new signs at each of these times.

Sign as a clue to manner of eating. The nature and position of cuttings and other sign in the field were often clues to feeding behavior. Among mice, Synaptomys is one of the heaviest feeders on green blades of sedge and grass. Leaves and stems are sectioned not to reach seed heads, but in order to sample different parts of the greenery. Often the upper ends or tips of the sedge leaves are preferred. Occasional measurements of newly-cut stubs of Carex plants (leaves) showed they are often cut 3- 3 1/2 inches from the ground, indicating the animals stand up on their hind legs to cut off a leaf. This may

be to avoid the basal sheath. The exact manner of handling food is recorded in the next section, as observed in captivity.

It is often apparent in the field that a bog lemming has fed for a long time in one spot, either all at one time or returning at intervals. Often a great pile, a low pyramid of hundreds of cuttings, will accumulate in one spot, with a small area of stubble around it. Frequently such a pile is all of the same age, at other times it appears to be of different ages.

Where the sedge or grass is thick, providing good cover, the animals will feed on the spot. Very frequently in the bogs however, the plants are rather scattered, and in this case the leaves, often being cut off near the base, are often carried into nearby openings of runways under the mossy mounds. Usually the leaves are sectioned just inside the entrance and partly eaten, perhaps as was recorded in the direct observation. These holes, occurring as they do at the bases of mossy mounds, allow an animal to enter the tunnels directly on a level. Other kinds of cover where leaves were carried and cut up, were anything close at hand; cranberry vines, tufts of Andropogon, Xerophyllum, or dead Carex, holes under pine needle litter, fallen cedar poles, old boards, and even large, rusty tin cans were noted. Usually the cut plants could be found a few inches or feet away. Occasionally in contrast, no trace of the food species was found close at hand.

In some bogs, especially in summer, no sign could be found anywhere on the surface, yet by raising the moss many piles of green cuttings

would be discovered. In two or three areas the sedge was cut at the base from beneath the surface and pulled down into the runway.

Sometimes the leaves are carried into holes and accumulated but not cut up, or only a few cuttings are made. Apparently the animal makes many trips to accomplish this. One of the most conspicuous signs of Synaptomys in these bogs are the lengths of large Carex blades laid side by side and protruding from holes, often in bundles of 40 or more, each stout leaf being over a foot long (see Sign).

The bog habitat, particularly in the depression basins, is an unstable environment characterized by fluctuating water levels. Under these conditions the bog lemmings may have to enter water occasionally to get to areas of food. On several occasions new cuttings were found on the water where the animals apparently had to wade in shallow water in order to reach the plants. In April one individual (lactating female) was trapped on a small island of Carex, where there were new cuttings, at the base of a tree. The island measured only 6 x 4 feet; to reach it required a swim across at least two feet of water.

Handling of food as observed in captivity. Carex plants were placed upright in the cages, being passed through the roof wiring, in order to observe the animals' handling of food. The following method was observed many times. The animal cuts at the base directly, or stands on its hind legs reaching as high as it can, and then cuts into one of the leaves. Usually only one leaf is cut at a time and this is pulled down with the two forefeet. When the animal is working rapidly

the leaf is brought down the length of one cutting and then a cut is made between the two paws. The lower piece is then dropped into place. The animal next reaches up with the front feet, pulls down another similar length, and cuts it off. The length of the cuttings seems to be governed by the height reached. Usually without shifting from the spot the mouse pulls down and cuts several such pieces, and very often drops them in place in nearly perfectly parallel alignment, either side by side or on top of one another. Frequently the animal does not stop until the upper end of the leaf is reached and as the last cutting is dropped in place the animal eats up most of the tip end. At other times, after making a cut, it holds the cutting in one paw and the main blade in the other and eats from the end of either. Then it pulls down the blade, makes a cutting or two and samples some more. Usually the lower, heavier, compressed part of the blade is not eaten.

At other times a mouse merely cut off a leaf at the base and ran to cover with it, as was noted in the field. In captivity this seemed to occur chiefly by day, whereas at night feeding was frequently in the open, perhaps because of less disturbance at that time.

One individual was never observed to make the typical cuttings, but she ate the tips of bent-over leaves. She often grasped one of these and ran with it, but of course the other end was attached, so she had a difficult time.

In eating blueberries and huckleberries, a bog lemming sits on the hindquarters, somewhat squirrel-like but less upright, and holds a berry much as a squirrel would an acorn, rotating it with the forepaws

as it feeds. With huckleberries it eats around the central mass of large seeds and connecting flesh, which is dropped, as are pieces of skin. This avoiding of the seeds is reflected in the stomach analyses for only occasionally did a stomach contain more than one or two of huckleberry seeds. When blueberries, with their smaller seeds, have been eaten many of the seeds are included.

Capacity for carrying food; storage; fighting over food

The carrying of whole leaves or parts of plants to cover has been mentioned. In captivity fruit and other food was carried briefly in the mouth. It was common to find snap-trapped bog lemmings with unswallowed food in the mouths. One individual had 14 pieces of Carex leaf arranged in bundle fashion across the tongue. The pieces were each 5-7 mm. long and about 2 mm. wide.

Quick and Butler (1885) reported that Synaptomys sometimes stores large quantities of the tubers of the wild artichoke (Helianthus). In this study, no evidence was obtained in the field of any storage of food in the usual sense of the word. Close observation of sign showed that they will chew on and remove leaves previously carried into burrows. Occasional individuals in captivity had great capacity for hoarding all kinds of food items in one part of the cage.

Occasionally individuals in captivity had short fights over food items, involving angry-sounding "churr" notes, narrowing of eyes, and one chasing the other.

Cannibalism

The only instance of cannibalism observed was the partial eating of one of the young of the sixth litter of a captive female. Both the mother and an adult male were in the cage at the time. The other young in the litter were raised successfully.

Dead animals in cages were not touched. In the field, some individuals were eaten in snap traps, probably the work of Blarina.

Dependence on water

In the bog environment standing water is very often present. Succulence alone, however, satisfied the animals' needs in captivity. Several individuals were kept through the summer months and bred, on succulence alone (grass, lettuce, apple). When water tubes were furnished most of the mice drank from them.

Times of feeding

Based on trapping results and times of full stomachs, feeding apparently occurs both day and night. Captives were most active in feeding after dark, but this could have been because of greater quiet at that time in the artificial environment.

NESTS, RUNWAYS, AND SIGN

Nests

General Description of Nests

Bog lemming nests, usually described as balls of dried grass, have been reported as occurring both above and below ground. Quick and Butler (1885), as quoted by Rhoads (1903), described the nest as "always under cover, generally in a hollow log or stump and composed of fine grass. It is not so securely built as the nests of some of the other species of this family." Hahn (1909a) stated that a large round nest of moss and dry grass or sticks is made; also, he said (1909b) that the nests are not always under cover, as he found one quite exposed. Burt (1928) said that the nests, which are six to eight inches in diameter, are built of dry grass (sometimes lined with fur) and are located both above and below the surface of the ground. He states further that they usually have three to four exits, but sometimes only two. Stegeman (1930) observed that the nests were made entirely of dried grass and resembled the nests of Microtus; the nests were usually placed in a slight depression in the ground alongside the main runways, and usually had a single entrance, although two had two entrances. Oehler (1942) referred to the nests as being globular and made of leaves and grass, similar to the nests of Microtus, and constructed either above or below ground with surface nests located at the bases of shrubs or grass clumps. Richmond and Rosland (1949) reported

a nest containing young which was found in a shallow depression and which was indistinguishable from that of Microtus. A nest found by Barbour (1951) which was presumably that of Synaptomys, was globular, about eight inches in diameter and constructed solely of grass.

Most of the nests found during the present study were located just under the surface in the tops of hummocks of moss or other elevated material in bogs, but were completely concealed from view. Most nests were balls of dried shredded sedge or grass, but some were made of other kinds of leaves. The majority of the nests had two entrances; a few had only one. The diameters of four nests which were measured were 3 1/2 inches, 4 1/2 inches, 4 1/2 inches and 6 inches. The hollow space within the nests measured about 2 1/2 inches in diameter.

Nests which contained young

During May, 1955, three nests were found which contained young bog lemmings (other nests, probably build by Synaptomys, are described in the next section). Two nests which contained young at the same time were situated only fourteen feet apart, and were located in elevated hummocks of sphagnum. Both nests had two entrances, were globular, and were made entirely of dried blades of finely-shredded Carex with some intact pieces on the outside of the nest. One of the nests had an outside diameter of about 4 1/2 inches and an inside space diameter of about 2 1/2 inches (the other nest was approximately the same size). The nest fitted snugly into a cavity near the top of the hummock and was about 1 1/2 inches below the surface. The floor of the nest cavity

was about five inches above water level. There was much sign near both nests, at holes where runways emerged from the hummocks containing the nests.

A Microtus nest, also containing young, was located only ten feet away from one of the two Synaptomys nests described above. The Microtus nest was similarly situated, was 3 1/2 inches in diameter, had two entrances, and was constructed of dried Carex. This particular Microtus nest was not as substantially built as the two nearby Synaptomys nests, although poorly and well-built nests belonging to both species were found during the study. A striking difference involving these three nests was the relatively few cuttings in the vicinity of the Microtus nest in comparison with the large number found in the vicinity of the Synaptomys nests. Most Synaptomys nests did have a great abundance of cuttings adjacent to them, but too few nests believed to be of Microtus were studied in the same habitats to make any definite conclusions.

The hummocks in which these nests were located were a foot or less in height and stood among channels of water one to two feet wide. Surface runways were very ill-defined in the thick moss. The hummocks contained a growth of scattered Woodwardia virginica (chain fern), Carex, and leatherleaf. Denser, green Carex grew several yards from the nests, away from the elevated mounds.

A third Synaptomys nest containing young, which was located in a bog which had burned two years previously, differed from those described above. This nest was very poorly constructed of dried leaves of shrubs,

needles of pitch pine, and some dried Carex. There was very little in the way of a roof and the nest material was somewhat damp. The floor of the nest cavity was three inches above water level. The nest was situated in a low mound of humus, roots, and dead sphagnum containing charred stubs of shrubs, and located just above the watery edge of the bog. Pine needle litter was present on the dry edge of the nesting site. The Carex bed and heavy sign began five feet out from the nest. The nearest available material seems to be used in nest construction, and in this bog, sites for nesting were along the edge of the bog where leaves and pine needles were the nearest dry material.

On June 12 several of the nesting sites, all now unoccupied, were checked to observe the effects of heavy rains of the previous day. Two of the Synaptomys nests and also a nest unoccupied when found were dry, but one of the first two Synaptomys nests described contained standing water in the cavity, and in this case the mice would have had to move. The water just reached the floor of the cavity in the Microtus site. In the vicinity of the third Synaptomys nest all the Carex feeding areas, where the sign was, were covered with water.

Nests not containing young when discovered

A dozen nests were found in elevated spots in boggy areas where Synaptomys was common, and were constructed chiefly of shredded Carex leaves. Most of these nests were probably built by Synaptomys.

In April, a lactating female and two very small juveniles were taken three to six feet away from a dry, recently used nest. Six feet

away from this nest was another similar but older nest. After trapping these animals and an adult male, no other mice were taken in the vicinity, so the nests were assumed to belong to Synaptomys. Both nests were on slightly elevated points of ground under trees bordering a roadside ditch grown up to Carex, in which the mice were trapped. Although located on top of the soil, which was black muck containing fine rootlets, the nests were perfectly concealed under the leaf litter. The newer nest was 6 inches in diameter across the outside, and the inside diameter was 2 1/2 inches. Each nest seemed to have only one entrance, on the side, which led into a runway in the soil which in turn connected with surface runways in the Carex.

Another probable Synaptomys nest, which was 3 1/2 inches in diameter and made of Carex leaves, was in the top of a small mossy hummock containing low shrubs, and was surrounded by a wet area of sedges. Much Synaptomys sign was present in tunnels around the nest and three Synaptomys were trapped within five feet of it. Another nest in the same bog was constructed of sedges and turkeybeard leaves.

In November and December two thick, well-constructed nests were found which may have been used only by adults. These nests were located in high mossy hummocks where heavy sign of Synaptomys was present. On November 9 both of these nests were quite new. On November 12 one felt distinctly warm inside, indicating that the occupant had just left. On December 4 and 11 this nest showed signs of disuse, but the other was still arched and dry within. However, by April 4, the next visit,

this nest had also long been out of use. These nests were made of Carex leaves (inner pieces shredded) and their inside diameters, or lumens measured about 2 1/2 inches. One of the nests had two entrances and was situated three inches below the surface of the moss.

In mid-November two other recently-built nests were found in turkeybeard (Xerophyllum) and sphagnum along the edge of a bog where twelve Synaptomys and one Microtus were trapped. Heavy sign was present in the immediate vicinity of these nests and a bog lemming was trapped next to one of them. One nest was on the surface of the ground between two clumps of turkeybeard, the reclining leaves of which protected and hid the nest. The nest was made chiefly of dried, shredded sedge leaves, with some reclining leaves of the turkeybeard incorporated into the outside of it. There were two entrances, but one seemed to be more heavily used than the other. The second nest which was under sphagnum adjacent to a clump of turkeybeard was made of dried sedge leaves and small dried leaves of shrubs, and had only one entrance.

Besides the nest in turkeybeard described above, there were only two other surface nests found in Synaptomys areas. One, in dense Carex, was composed entirely of dried leaves of this plant; the other was in a patch of bluegrass and built of dried grass. In a bog where Microtus and Synaptomys were both common, four large, globular, surface nests were located in tussocks of sedge and grass.

Two nests, one in a sphagnum hummock and one under leaf litter, were made chiefly of finely shredded reddish bark of southern white cedar. However, the species of the maker is unknown. The nest in

Fig. 25. Two Synaptomys nests with young were found in this bog in May, 1955. One nest was located just to right of the small lone pine, the other several feet further to right. Carex, leatherleaf, and fern (Woodwardia virginica), above hummocks of sphagnum. Near Weymouth, June 12, 1955.

Fig. 26. Nest of unknown species showing typical situation in which nests of Synaptomys were found. The surface of the sphagnum has been rolled back, exposing the nest in its chamber. Near top of picture is a tunnel in the moss leading away from the nest. September 18, 1953.



sphagnum was an especially beautiful, dry, globular affair, the bark for which may have been taken from roots near the nest. It was 3 1/2 inches in overall diameter and located only an inch or two under the surface. Synaptomys sign was nearby. Red-backed mice were taken next to the other nest. Another nest by an unknown builder was made entirely of dry sphagnum moss.

Elevated hummocks (such as those where most of the nests were found) probably contained the majority of nests in the bog areas. Because of the high water levels, nests would not usually be located underground, and surface situations in dense sedge usually seemed to be too wet. However in many bogs of the leatherleaf-Carex type I was unable to find any nests, even where sign was heavy. The only apparent sites for nests in these places were in slightly elevated areas of dense leatherleaf, where thick tangles of roots and reclining stems prevented me from doing much excavating.

For information relating to care and repair of nests in the field and in captivity refer to Reproduction.

Runways, Tunnels, and Chambers

Synaptomys makes runways in a variety of substrates, both on the surface and underground, much as Microtus does. Howell (1927) stated that well-defined runways are maintained and that burrows are constructed in the ground or through beds of sphagnum. Hamilton (1943) stated that in fields of bluegrass, runways are constructed above ground and that on the forest floor these mice tunnel just beneath the leaf mold.

Burt (1948) said that surface runways and underground burrows are made or appropriated from Microtus.

Surface Runways

Surface runways about an inch and a half in width formed networks in beds of Carex in the bogs. These runways were sometimes so heavily paved with cuttings that the ground was not visible. Runways over the sphagnum generally registered only as faint traces from hole to hole. Low mucky depressions between hummocks and tussocks in the bogs were utilized as surface highways. In the woods Synaptomys probably traveled on the surface as well as beneath it. Short surface trails in the vicinity of turkeybeard plants and little pits dug from the surface to the base of these plants were associated with Synaptomys sign.

Tunnels

In the bogs the subsurface runways, usually called burrows or tunnels, occurred most commonly under the sphagnum and in the humus among the roots of shrubs. Frequently there were several levels of these tunnels in large hummocks. Tunnels through the hummocks of sphagnum and other elevated mounds connected with the surface runways in the lower spots. During live-trapping, released individuals were sometimes observed to run through these routes, popping in and out of holes with remarkable speed. The holes seemed to be the easiest and most productive spots for trapping.

In the pine woods Synaptomys frequently pushed shallow tunnels just beneath the litter of leaves and pine needles. These tunnels were

traceable from the bogs and ran to areas of turkeybeard, circling around and under tussocks and containing an abundance of cuttings. Tunnels often ended at individual tussocks or clumps. Animals released during live-trapping ran with seemingly great familiarity through these tunnels.

Short tunnels which went deeper, into the mineral soil, were also believed to have been made by Synaptomys. These were often found in higher ground along the edges of bogs, connecting directly with surface runways out in the wet ground. These tunnels entered sandy banks, were sometimes inclined upwards at a steep angle, and usually ended blindly.

Synaptomys tunnels were usually about $1 \frac{1}{8}$ inches to $1 \frac{1}{2}$ inches in diameter.

Chambers

Chambers which were apparently used for feeding and resting were located in a variety of situations. They were most frequently found just inside of holes entering the hummocks. The chambers were small enlargements in the tunnels and contained both cuttings and droppings. Frequently they were conspicuously marked by long blades of sedge projecting from the holes. The blades had been cut on the surface and carried to the shelter within the hole to be eaten in leisure. Some of the chambers seemed to be used chiefly for the deposition of droppings, although droppings were also scattered along the runways. Six chambers which were measured ranged from $2 \frac{1}{2}$ inches to 6 inches in maximum

diameter. Behavior of a bog lemming observed feeding and resting at one of the chambers is described elsewhere.

In the beds of dense Carex, sites of heavy feeding were at junctions where three or more surface runways radiated out from a common center. These enlarged feeding spots were about 3 inches in diameter, and cuttings and droppings were accumulated here. Long leaves in bundles frequently radiated out from the spot along the runways.

In turkeybeard, the reclining leaves often made sheltered little spots next to the plants where lemming mice fed and perhaps rested.

Stegeman (1930) mapped surface runways in a dry field, in which he showed the positions of side chambers which seemed to be used as feeding and resting places and which contained accumulations of cut grass stems and green droppings.

Sign

In the literature of Synaptomys cooperi mention is frequently made of the sign, especially the cuttings and bright green droppings, often with comments as to whether or not it is recognizably distinctive. Linsdale (1927) said the stomachs and intestines of bog lemmings were usually of a uniform bright green, brighter than in meadow mice occurring in the same place. Burt (1928) referred to the small slender green droppings in small piles (in contrast to the large black or brown droppings of Microtus scattered along the runways) and bundles of blue-grass blades in the runways as being distinctive of Synaptomys.

Goodwin (1932) ascertained their presence by the cuttings of saw-grass, chopped off in lengths of about 1 1/2 inches, heaped up under the edges of large tussocks and mentioned other full-length grasses which were cut off at the base and dragged under cover. Odum (1948) mentioned the characteristic sign of green droppings and cuttings; Miller (1955) mentioned the characteristic bright green droppings. Richmond and Rosland (1949) stated that the presence of Synaptomys in an area is rather easily determined; the littered condition of the runways, the narrower runways, and frequent holes opening into underground runways were mentioned in contrast with Microtus. Barbour (1956) stated that the runways resemble those of Microtus but are generally not so well worn. Mumford and Handley (1956) stated that the runways observed were not bare, as those of Microtus usually are, but were lined with living bluegrass. However, Hall (1955) said that the runways alone are not distinctive but that the fresh droppings are light green if from Synaptomys but are brown or blackish if from Microtus. Others have found the sign not particularly distinctive in any way. Stegeman (1930) reported no distinguishing features in the runways used by Synaptomys and found no difference in the color of the droppings, although those of Microtus appeared to be somewhat larger. Palmer (1954) stated that the runways and cuttings are like those of Microtus and that Synaptomys is perhaps never detected for certain except by trapping. Murie (1954) briefly mentioned the droppings as not being distinctive and made no reference to the cuttings.

From the outset of my study I devoted considerable time to this question of the recognition of sign, to determine whether the presence of Synaptomys in southern New Jersey habitats could be ascertained by this means. The sign (cuttings and droppings) was found to be generally separable from that of Microtus. Once developed, this field technique was found to be quite reliable in the region in which this study was made, a fact tested on a number of areas by recording in advance the suspected status of Synaptomys and comparing trapping results with this record. The ability to recognize the sign aided in determining whether areas and habitats were inhabited by Synaptomys, in placing of traps, in estimating relative abundance in different places and seasons, and in studying food habits.

In places where the population was very low, with only a few scattered, light signs in evidence, it was not always possible to state with certainty the species involved, although a good guess could frequently be made. Where the sign was moderate or heavy, a combination of characteristics occurred which was quite distinctive for Synaptomys and differed from sign on Microtus areas. Sign was compared on areas where only Synaptomys and where only Microtus were taken.

The cuttings of Synaptomys were usually of an even length, that is, almost all pieces were about 1 1/2 to 2 1/4 inches in length, and in any given pile of cuttings only a few pieces, if any, were longer or shorter. Microtus, on the other hand, tended to make cuttings with a much greater variation in length, including an abundance of very short and long pieces of irregular lengths.

The cuttings of Synaptomys tended to be accumulated into large piles whereas Microtus cuttings were in smaller piles or the pieces more scattered. It was not uncommon to find hundreds of Synaptomys cuttings in one pyramidal pile. A large pile of turkeybeard cuttings was counted and found to contain 700 pieces; one of Rhynchospora cuttings contained 450 pieces. The two piles mentioned were composed of pieces all of the same age, indicating the animal may feed for a long time in one place. Other piles contained pieces of different ages, indicating feeding at the same spot at different times. Droppings were mixed in with the cuttings.

Another distinctive sign was the bundles of full-length leaves of sedges or grasses cut off at the base, apparently resembling those mentioned by Burt (1928), Goodwin (1932), and Enders (1930).^{*} These leaves lay parallel in the runways or protruded from holes in the moss to which they had been carried piece by piece. The stout sedge leaves were generally 1 to 1 1/2 feet in length and frequently laid side by side in groups or bundles of one to several dozen pieces, a very conspicuous type of sign. One bundle contained 124 full-length blades of two different ages.

Other characteristics of the cuttings may be distinctive. The individual cuttings are frequently laid down in remarkably parallel alignment, with the pieces side by side and parallel, instead of criss-cross. Where the population is high and runways frequently are paved

*

Enders found grass stems cut and piled in bundles of 10 or more stems where a specimen of Synaptomys but no Microtus or Zapus were taken in intensive trapping.

with cuttings so that the ground is no longer visible. Sometimes regular platforms of cuttings are built up over reclining stems of leatherleaf in the bogs.

The evidence pertaining to cuttings was supported by observations of animals in captivity. Synaptomys seemed to make more cuttings and the cuttings appeared to be more regular in length compared with those of Microtus.

The droppings were usually, though not always, a very bright, light green, whereas those of Microtus tended to be darker green, gray, brown, or black. On the other hand, the droppings of Synaptomys occasionally were light brown and often those of Microtus were bright green, but not as light a shade as those of Synaptomys. Thus there was overlap in color, but in general the usually brighter and lighter green of Synaptomys scats was distinctive. These observations on the color were gathered from scats associated with other distinctive sign in the field, from droppings in live traps, and from examination of intestines of freshly killed animals.

Another character found to be promising but not uniformly dependable was the size and shape of the scats. Those of Synaptomys tended to be smaller and more blunt on the ends than those of Microtus.

No definite information was obtained concerning differences in the runways of the two genera. The few measurements taken did not indicate any difference in the width of runways on Microtus and Synaptomys areas. On the other hand, an impression was gained that the runways of the lemming are not so clean cut nor so distinct as trails of Microtus.

Testing the reliability of field judgment of signs was carried out on 39 areas. Before trapping, written notations were made regarding the presence of Microtus and Synaptomys, and usually these guesses were supported by the trapping returns. The characters chiefly used in recognizing Synaptomys sign were the even-length cuttings in large piles, the large groups of full-length leaves, and the bright, light green droppings. Specimens of Synaptomys were trapped on 27 of 33 areas believed to contain numerous signs of Synaptomys before trapping. On some or all of the remaining six areas it is possible that they were present but escaped the traps. Of the seven areas thought to have no or very few Synaptomys (sign being that of Microtus), on only one area were any Synaptomys caught. The incidence of correct field appraisal was well above any level attributable to chance.

BEHAVIOR

In the following paragraphs several aspects of behavior are covered which are not discussed elsewhere. In other sections of this report, such as those dealing with food habits, reproduction, and development, descriptions of various types of behavior are given which are directly related to those particular phases of life history.

Times of Activity

I did not obtain information concerning daily peaks of activity, but did observe that bog lemmings were active both day and night and that they probably run about at all hours. During marking and releasing, traps were checked at dusk and usually within an hour after daylight, thus the results are probably a good indication of actual day and night activity. In Bear Swamp during October there were 63 day and 47 night captures and in May on the same area 7 day and 11 night captures; in Bass River State Forest in November-December there were 50 day and 36 night captures. It seems, therefore, that there is considerable activity both day and night. In captivity the mice were most active after dark. Burt (1928) stated that Synaptomys is chiefly nocturnal, but that it is also about during the day, both in the field and in captivity. Oehler (1942) visited snap traps three times a day and found greatest activity during the afternoon and night, with relatively few captures before noon.

Impressions were gained that the patterns of activity differed somewhat during the summer, although I have little definite data to support this idea. Records of known day or night captures during summer consist of only 25 snap trap captures; 18 were by night and 7 by day. But these data are probably not indicative of the true situation, because for any trap line the first visit, when traps usually held the most animals, was made in the morning after the first night's catch. Another impression was that there was less surface activity in the summer, especially in bogs which dried out at this season. In such situations there frequently was little sign of mice on the surface, but heavy sign was present beneath the moss. The animals seemed easier to trap in cold weather, especially with live traps.

There appeared to be considerable activity quite late in the day, at least in the summer. At this time, when the temperature begins to fall, stirrings and rustlings and occasionally glimpses of small forms were sometimes noted while I was setting traps. Five captures of bog lemmings were made at this time; the mice were heard to set off traps while I was setting others. The times of capture were approximately 5 p.m., 5:15 p.m., 6:15 p.m., 7:30 p.m., and 7:45 p.m. As far as I can recall, there was only one other capture recorded while setting snap traps and that was at noon (summer). On the other hand, I may have put in more hours in setting traps later in the day than earlier in the day.

On several dark, overcast, quiet days in late November an unusual amount of mid-day activity was observed. An individual was watched feeding from 1:30-2 p.m. and I saw and heard others (see Food Habits).

Oehler (1942) said that temperature seems to have little influence on amount of activity, except that he trapped none below 20° F. Burt (1928) observed that bog lemmings in Kansas were active during the most severe weather and were trapped at temperatures as low as -4° F. I observed that individuals in captivity on very hot days were inactive and seemed to eat less.

Movements and Locomotion

In activities such as running, leaping, climbing, and swimming, this lemming probably does not differ essentially from many other microtines. They run rapidly through runways in the area with which they are familiar. When held at a height above the ground, they are reluctant to jump down, and often climb about on a person's arms and shoulders instead. They climb up screening in cages; during live trapping I found that "repeaters" will get into a trap standing on end with the top open. Bog lemmings swim well, and at times probably have occasion to do so in their habitat. One was released in a pond; it swam rapidly, with its back out of water, to the nearest land several yards away. A pine mouse released at the same place swam equally well.

Although bog lemmings also appropriate tunnels of other small mammals, they are efficient diggers themselves. Palmer (1954) states that the powerful jaw muscles undoubtedly are useful in cutting through tangles of roots and soil or moss. I have seen tunnels, apparently the work of this species, which penetrated hard-packed coarse sand, and soil compacted of fine tough rootlets. Comparatively large roots and bases of tussocks were cut through in the course of these tunnels. With the forepaws they have considerable dexterity in handling food (see Food Habits).

As far as I know, there are no specialized defense or escape mechanisms in this species. Use of cover and rapid flight by running are undoubtedly the principle means of avoiding danger. When cornered, they will turn and bite if they have the opportunity. On one occasion I found an individual in a mouse trap caught merely by a scruff of hair; my approach gave it the stimulus necessary to twist itself free. At that moment I closed my hand upon it, but it suddenly lunged and inflicted a painful bite, which so startled me that the mouse made good its escape. Probably this action would rarely be effective against an efficient predator.

Voice and Other Means of Communication

Voice

The voice of the bog lemming has not been adequately described. I believe this species is one of the most vocal of our native eastern

mice. When handled during live trapping, and while in cages, they were observed to be more vocal than meadow voles, pine voles, and red-backed mice.

Descriptions of the calls given in the following paragraphs are from notes which I made on the spot. As far as my limited ability goes in interpreting them, I believe the calls of the adults may be placed in three main categories: 1) threatening, anger, or fear, 2) courting (or when male and female are together), and 3) maternal (mother to young). Probably calls were also given to express other meanings. In general, the voice may be described as a series of notes run together; rarely, a single short note is uttered.

The most commonly heard type of call was associated with quarreling and threatening among caged animals and was given by animals being handled. Usually it could be described as a harsh, grating series of notes, with high and low elements, but rarely squeaky, and characterized by the distinct burr, grating, or rasping sound. It was often harsh, strident, and annoyed or angry sounding. This call might be termed a rapid chatter or "churr." The call varied in duration, loudness, and pitch in different situations, perhaps corresponding with different intensities of emotion. On one occasion I recorded it as a rapid "tzit-tzit-tzit-tzit-tzit" (2-6 notes) lasting a few seconds.

These notes were given among caged animals, especially when a new individual was introduced, by unwilling females in response to advances by males, by a mother when a male was too near the nest, and by animals fighting over food. Once when a male and female were newly placed

together this call was given for over five minutes without interruption. When handled, the calls are somewhat similar (a chatter-like series of notes) and are perhaps an expression of alarm or fear. On one occasion a "repeater," on being released from the trap, moved just a few feet away and gave the harsh chatter continuously for over two minutes, after which I tired of listening to it and departed.

In the wild I heard this call at least once while setting traps. It came quite loudly and distinctly from a hummock, where I may have disturbed an individual in its retreat.

Meadow mice have calls of the same general pattern, but the calls are higher pitched, thinner, and more "squeaky," with less "burr" to the voice. I had frequent opportunity to compare the voice of individuals of both species located in adjacent cages. In handling, the same difference was noted; Microtus called less frequently, but when it did the sound was a high-pitched squeaking.

The most pleasant sounding calls were those apparently associated with courting or mating. Both sexes may give it, but only the male was definitely known to; a male gave it even in the presence of females which did not desire to mate. This note sometimes alternated with quarreling notes when an adult male and female were together. The courting voice was mellow, soft, fairly high-pitched (but not squeaky), and slowly given. Also noted was a "sweet" and subdued voice. These calls varied in duration, though all had the same mellow quality. Once I recorded it as a "tew-tew-tew-tew."

Another call, unlike any other heard, was given only by a certain adult male, usually when in the presence of a female. It was a peculiar "ticking" or "clicking" note given slowly and deliberately but not loudly. It reminded me of a person clicking his tongue against the back of his upper teeth.

Low, brief, not unpleasant notes were given by the mother when young were in the nestling state. These were heard when the mother was rounding up small young which scattered through the cage after I had weighed them.

Short squeaks, and probably other notes which I failed to record, were occasionally heard. Rarely a short "erk" or "eek" seemed to be expressed in annoyance when a cage was moved or lights turned on at night.

Touch

Physical contact observed between individuals in captivity was chiefly the usual contact of mating or attempted mating, between mother and young, when sleeping together in nests, and probably when fighting. However, occasionally individuals were seen to touch noses briefly and once one seemed to lick the face of another.

Glands

Although I have made no observations on this point, Palmer (1954) states that each sex of this species undoubtedly makes its presence known by the secretion from the large glands in the groin (preputial glands), and that the small hip glands of the males are more developed in the breeding season.

Cleanliness (Sanitation)

Condition of nests and runways

Nests in the wild were usually clean, and without droppings in them or in tunnels immediately adjacent. In the runways and tunnels droppings were accumulated in piles at frequent intervals, but also spread through the runways and mixed with cuttings at the feeding stations. Piles of droppings were often located an inch or a few inches outside of a burrow; apparently the animals came out of their retreats to deposit the droppings there.

Grooming

In captivity the lemmings were sometimes observed cleaning and grooming themselves. The belly and feet (including toes) were carefully licked with the tongue. At other times the forefeet were passed over the face and head. Rapid scratching, using the hind feet, was observed.

Sunning

At times, early morning sunlight shone through the screening of the cages and the mice were seen out in it, apparently enjoying it. In September, 1955, an individual (I believe the same one each time, an adult female) was observed several times lying down in the sunlight with the body extended out straight at full length, a position not observed at other times.

Sociability

For a brief time after the young venture from the nest they continue to be closely associated with the mother (see Reproduction). I have some information which may indicate that litter mates continue to keep company for longer periods. On December 3, 1954, two adult males were killed in a single snap trap; apparently they were traveling the same direction in the runway. Their dimensions were remarkably alike, and each weighed about 30 grams. At another time two small, non-breeding adult females, both 116 mm. long and weighing 24 grams each, were caught between 3 p.m. and 5 p.m. in two snap traps located 6 inches apart. There is a possibility, strengthened by the close resemblances in size, that in both these cases litter mates were involved.

General Temperament Observed in Confinement

Nervousness or shock resulting in death

Several writers have commented on the difficulty of keeping Synaptomys in captivity or of getting them to breed (Burt, 1928; Stegeman, 1930; Fisher, 1945; Fichter and Hansen, 1947). Burt (1928) and Fichter and Hansen (1947) described an extremely nervous temperament in captivity which often ended in the death of the mice. Fichter and Hansen told of an individual which repeatedly climbed to the top of the cage and then dropped to the floor. On the next day (morning following capture) the mouse was dead, the skull showing a fracture

of the zygomatic arch. Burt observed that lemming mice often seem to worry themselves to death in the laboratory.

Four adult lemming mice which I caught (one, summer, 1951; three, summer, 1954) died seemingly of a nervous condition. Two died on the third, and one on the sixth day of captivity. With each of these three, the symptoms were identical, being characterized by extreme nervousness and overactivity, and excessive desire for food, resulting in almost continual activity, chewing, and eating until shortly before death. They were abnormally tame and one could be stroked on the first day of capture. One individual was seen at the time of death, when it became weak, staggered, fell on its side, and soon expired. The fourth, a female, became over-active after about two weeks of captivity, and then died within four days. It is not easy to suggest an explanation for such deaths as those observed here. The impression would seem to be that in confinement they "wear themselves out" or "eat themselves to death," which may literally be true. The symptoms resemble those cited by Christian (1950) for the exhaustion of the pituitary system subsequent to high population stresses, the so-called "shock disease," which involves a hypoglycemia preceding death. Christian quoted Best and Taylor's (1939) descriptions of the first signs of hypoglycemia (produced by any means) in the rabbit as being hyperexcitability and desire for food. The symptoms I observed were suggestive but I have no further evidence that "shock disease" was involved.

Tractability

Burt (1928, 1948) stated that bog lemmings are docile in captivity and do not bite when handled, unless they are mistreated. I agree, and believe that they may differ from the ordinary meadow vole in this respect. Newly captured animals were inclined to bite, but usually those that had been in captivity for some time and especially those which were born and raised in captivity could be picked up at any time with bare hands.

Certain individuals responded to my visits to the cages with food, especially when I fed them at frequent intervals, by coming to the screen, and even taking food from my hand. One individual stood up on its hind legs each time I opened the cage, and looking up, immediately grasped whatever item of food I held near it.

Strife

Among themselves, these mice seemed to show a moderately mild disposition, although fighting occurred. Those born in captivity continued to nest together as adults without friction, regardless of sex. When a new individual was put into a cage fighting usually resulted until the new animal found its place in the group. One young female which was introduced into a cage with two other females and an adult male, died shortly thereafter and showed an old wound or injury to the shoulder. It was also affected by the disease of the young described elsewhere so I am not certain of the cause of death. Aside from this case, no wounds were observed among these mice in captivity. However,

Burt (1928) found evidence of cannibalism in captivity, with one animal being partly eaten. In this study, the only cannibalism encountered was that of one newborn young partly eaten by an adult. Several other litters were raised with one or two adult males present in the same cages without the young being hurt.

Little data was obtained concerning strife in the wild. No major injuries were seen and a relatively few individuals had very minor damage to ears or tail, such as may have resulted from fighting.

SUMMARY

A study of the bog lemming, Synaptomys cooperi, was carried out during parts of 1953, 1954, and 1955 in the bogs of the pine barren region of southern New Jersey. In addition to numerous hours of field and laboratory observations, 102 bog lemmings were snap-trapped, 38 were live-trapped (190 captures and recaptures), three nests containing a total of 10 young were found in the wild, and 22 young (six litters) were born and raised in captivity.

Mean and range in weights and external measurements were determined for 52 adult males and 31 adult females. The sexes were closely similar in size and only tail length differed more than half a millimeter between the means. Plantar pads numbered 6 on the hind foot and 4 on the front. All females examined had 6 mammae. A definite fall molt in adults was observed; adult molt, unlike the juvenile and apparently post-juvenile pelage changes, appears to be patchy and without pattern.

Bog lemmings were trapped in 20 sphagnum bogs, in pine woods adjacent to several of the bogs, and in one dry field. In the cool sphagnum bogs, wherever there was a stand of sedge (usually Carex) combined with shrubs it was usually possible to trap Synaptomys. A short-distance seasonal shift in habitat was noted. In areas where the evergreen Xerophyllum grew in pine woods adjoining the bogs, signs of activity during the colder months ceased or were appreciably reduced in the wet bogs and spread into the nearby pine woods. Apparently few,

if any, bog lemmings occurred in the hot, dry pine woods in summer. Depression basins (chiefly Carex and Chamaedaphne), where Synaptomys was often the most numerous microtine trapped, were characterized by strongly fluctuating water levels depending on the amount of precipitation. Numerous species of shrubs, sedges, and other herbaceous plants occurred in some of the bog habitats, such as areas transitional from pine woods to cedar swamps.

Ten other species of small mammals were also taken in traps set for Synaptomys. The most frequently captured associates, occurring in the same runways, tunnels, and feeding spots, were Sorex cinereus, Blarina brevicauda, Clethrionomys gapperi rhoadsi, Microtus pennsylvanicus, and Zapus hudsonius. Certain predators which habitually prey on mice, such as the red fox, small species of weasels, and several hawks and owls, are scarce or absent in the pine barren region; others, such as the long-tailed weasel, gray fox, and several large species of snakes are common and undoubtedly prey on Synaptomys as well as other small mammals.

Of 130 trapped bog lemmings, there were 46 females and 84 males, a ratio of 1 female to 1.83 males, probably a reflection of greater exposure of males to traps. Of 27 individuals whose sex at birth was known, there were 11 females and 16 males.

In the wild 3 individuals were known to have lived about 8 months or longer. Two lemmings, a male and a female, lived for a full year in confinement before being killed and preserved.

A three acre area live-trapped in November and December gave information relating to home range. Centers of activity were computed and apparent home ranges were mapped. Apparent home range (minimum home range method) in October varied from less than $1/10$ to about $1/4$ of an acre. Maximum distances between captures for three adult females were 120 to 160 feet; males ranged farther and five had maximum distances of 150 to 370 feet. Some home ranges included both wet bogs and dry woods at the same time. Trapping results indicated bog lemmings were about equally active both day and night.

Trap-revealed home ranges of 4 adult females in one area were closely adjacent but not overlapping. This may indicate a territorial sense. On the other hand, in another area two nests containing young at the same time were situated no more than 14 feet from one another.

Mark and release trapping gave estimated densities of 2.3 (spring), 4 (fall), and 5 (fall) per acre. Abundance of sign of Synaptomys was estimated for 20 areas at different seasons according to a system devised by Dr. Don W. Hayne for Microtus areas in Michigan. A fall buildup in population followed by a loss by spring was indicated for most areas, as might be expected; the study was not conducted long enough to show yearly trends.

In southern New Jersey Synaptomys does not appear to be as colonial as reported by workers elsewhere. The abundance of Synaptomys here seemed to be correlated with variations within the habitat and these mice apparently occurred throughout areas of suitable habitat.

Individuals of Synaptomys were bred for the first time in captivity so far as I know. Six litters (22 young) were born to one female during a five month period. She came into heat immediately following parturition on at least one occasion. The gestation period was 23 days in one case, and was believed to be 23 days in another.

Nine embryo counts, 7 placental scar counts, and 9 wild and laboratory litters gave a range of 1-5 young, a mean of 2.96, and the most frequent number was 3.

Several females trapped were both pregnant and lactating, indicating litters may follow one another in rapid succession. Breeding condition of trapped females seemed to indicate a spring peak in the breeding cycle. Males showed regressed condition of the reproductive organs by mid-November. Trapping was not conducted during winter, but breeding was already well established in early April. In confinement breeding took place throughout winter.

Building and repair of nests were observed, including one observation of nest repair in the wild. If a nest is disturbed, the mother will remove the young. Young were never observed clinging to the mammae of the mother during flight. Activity of the female in captivity was greatly curtailed during the first few days following birth of her litters. Two young in captivity were successfully nursed and raised by a lactating Microtus pennsylvanicus. Litters were successfully raised either with or without the father in the same cage. Two small young which were trapped in a runway with a lactating female

contained milk as well as green vegetation in their digestive tracts, indicating that they run about while still being nursed.

The growth and development of 28 young was studied in the laboratory. Weight at birth averaged 3.9 (3.1-4.3) grams. The skin of the newborn (within 8 hours of birth) is pinkish, except for a light gray pigmentation on the dorsum. The appearance is naked, but mystacial vibrissae 3 mm. long are present and minute hairs on the dorsum are sometimes visible to the unaided eye. The tail is considerably shorter than the hind foot at birth.

Increase in weight of 21 young in captivity was fairly constant, with a small amount of variation between litters. During the first 3 weeks they increased rapidly in size. Ear pinnae unfolded on the second day. Incisors erupted at about 6-8 days. Eyes opened on about the tenth day. The young began to eat grass shortly thereafter but nursed until 16 days or longer. The dorsal pelage up to about 2 weeks of age was a light, yellowish brown color, and at this stage Synaptomys young were much lighter on the dorsum, feet, and tail than young of Microtus p. pennsylvanicus. The young lemming mice then gradually attained the typical gray juvenile appearance. In the laboratory the juvenile pelage was replaced by a molt with a regular pattern of new hair growth, beginning during the fourth week. After this pelage change the mice had a general adult appearance, but were darker and duller than old adults in captivity. One individual underwent an apparently regular molt during the thirteenth week, when it attained a lighter, brighter pelage resembling that of the older adults.

Principle methods used in studying food habits were analyses of the contents of the digestive tracts and field observations of cuttings and other sign. Various parts of 27 different plant species were recorded as food; no animal remains were recognized in any of the stomachs. Green vegetation (chiefly sedges, rushes, grasses) occurred in 85 per cent of the stomachs and made up 66 per cent of the total bulk. Carex was the most utilized food. Succulent bases and root-stocks of sedges and other plants, green woody twigs of certain shrubs, and huckleberries and blueberries made up appreciable portions of the diet. Bog lemmings frequently fed for long periods of time in one spot, accumulating large piles of cuttings.

Fifteen nests were observed and measured. Most of these were located just under the surface of the tops of sphagnum hummocks or other elevated material in bogs, but were completely concealed from view. Most nests were balls of dry shredded sedge or grass, but at least one nest was composed of other types of leaves. The majority of nests had two distinct entrances; a few seemed to have only one. Diameters of 4 nests measured were 3 1/2, 4 1/2, 4 1/2, and 6 inches, with the hollow space within measuring about 2 1/2 inches.

Surface runways, often heavily littered with cuttings, and tunnels were numerous in Synaptomys areas. Tunnels penetrated a variety of substrates, indicating these mice are efficient diggers. Chambers were observed. The sign (described in detail) was believed to be distinctive and usually separable from that of Microtus pennsylvanicus. Even-lengthed cuttings in large piles, large groups of full length sedge or

grass leaves cut off at the base, and bright, light green droppings seemed to be characteristic.

Bog lemmings are relatively vocal for mice and a large variety of calls were recorded.

Individuals in captivity were usually quite docile and tractable, but numerous individuals died of some sort of nervous or shock condition. All of the young born in captivity died of an unexplained malady after attaining adult size.

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