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A Study of Population Densities, Habitats, and Foods of Four Sympatric Species of Shrews

James R. Haveman
Northern Michigan University

A Study of Population Densities, Habitats, and Foods of Four Sympatric Species of Shrews

by

James R. Haveman
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This thesis is recommended for approval by the student's thesis committee.

Wm. L. Robinson
Chairman

Philip A. Doepker

Martin Kopenski

Approved by Roland S. Strolle Dean of Graduate Studies.

12/21/73
Date

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ABSTRACT

The relationship between the populations of four shrew species (*Sorex cinereus*, *Blarina brevicauda*, *Microsorex hoyi*, and *Sorex arcticus*) and the invertebrate fauna was examined on five different habitat types during the summers of 1972 and 1973 on the McCormick Forest in the Upper Peninsula of Michigan. The habitat types were described as the Hardwoods, Spruce Swamp, Spruce Barrens, Bog, and White Pine - Hardwoods sites.

An attempt was made to determine how habitats and prey characteristics affect food selection by a shrew species. Habitats that produced a high standing crop of invertebrate biomass also produced a high standing crop of shrew biomass.

While invertebrate fauna composition seemed to vary only slightly between habitats, the invertebrate biomass varied significantly between habitats. This seemed to indicate that invertebrate fauna biomass rather than invertebrate composition seemed to be an important nutritional factor in regulating the shrew population levels in each habitat.

A significant correlation was also observed between temperature and shrew trappability by the pit-fall method, indicating a possible change in shrew behavior during cooler temperatures.

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TABLE of CONTENTS

LIST of TABLES

Table Page

LIST of FIGURES

This study was coordinated with a survey of mammals on the Cyrus H. McCormick Experimental Forest conducted by William L. Robinson of Northern Michigan University under a contract with the U.S. Forest Service. In the summer of 1972, Robinson trapped a number of habitats to census the small mammals present. Although shrews were caught in all habitats, a large variation in shrew abundance among habitats was observed. This prompted me to investigate shrew food preferences and invertebrate abundance on various habitat types.

Some work has been completed regarding the behavior (Blair, 1940), foods (Hamilton, 1930, 1941; Whitaker and Ferraro, 1963; Whitaker and Mumford, 1972), population levels and home ranges (Blair, 1948; Buckner, 1957, 1966) of various shrew species. Little, however, has been published relating shrew densities to food abundance and habitat characteristics.

The main purpose of my study was to examine the relationship between the invertebrate fauna, as an indicator of food availability, and the populations of four shrew species in five habitat types in Upper Michigan. The shrew species were the short-tailed shrew (*Blarina brevicauda*), masked shrew (*Sorex cinereus*), pigmy shrew (*Microsorex hoyi*) and arctic shrew (*Sorex arcticus*). The northern water shrew (*Sorex palustris*) was not captured in this study but occurs in small numbers in the McCormick Forest (Robinson, 1973).

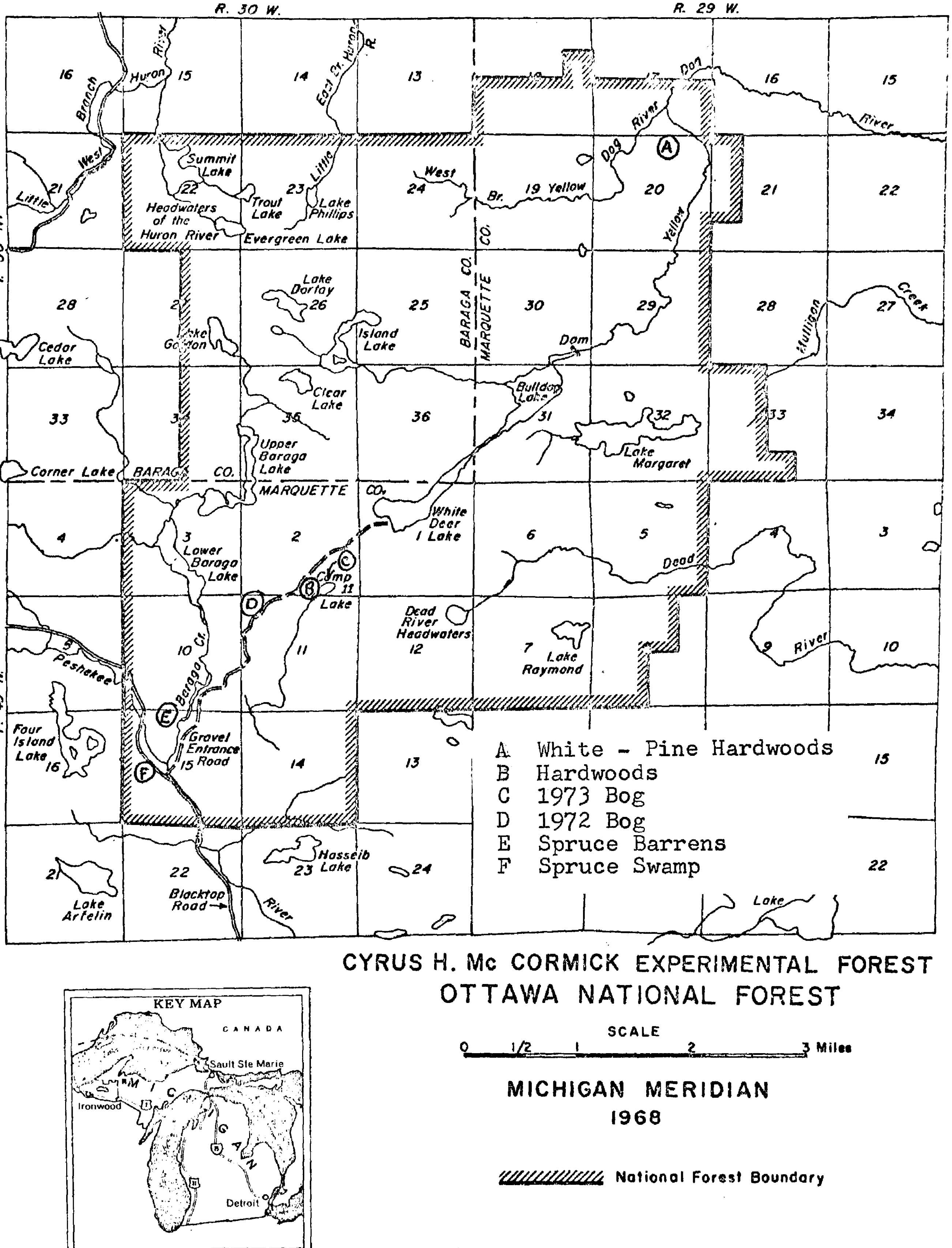
METHODS

The study area was located in the Cyrus H. McCormick Experimental Forest which is an area in northwestern Marquette County and northeastern Baraga County in the Upper Peninsula of Michigan (Figure 1). This 17,124 acre tract was donated to the United States Government in 1968. It is presently under the management of the U.S. Forest Service and is administered as a wilderness research area. Much of the tract has been logged and burned at various times in the past century, resulting in numerous habitat variations. Metzger (1973) has recently published a description of past and present vegetation in the McCormick Forest.

In 1972 four habitats within the tract were chosen because of their apparently varying shrew densities and obvious ecological differences. These were designated as the Hardwoods, Spruce Swamp, Spruce Barrens, and Bog sites. In 1973 a White Pine - Hardwoods site and a second Bog site were also brought into the study. Figure 1 is a map showing the location of these habitats within the forest.

The White Pine - Hardwoods and the Spruce Barrens sites were both located on Pence soils, which are a sandy loam soil usually overlying sands and gravels. The Hardwoods site was on Champion - Michigamme soils, which are deep soils composed of fine, sandy loam

Figure 1 - Location of the McCormick Forest in the Upper Peninsula and the Location of the Habitats Within the Tract.



commonly occurring over fragipan or bedrock. The Spruce Swamp was on Carbondale - Linwood soils which are organic soils. The Bog sites can also be considered as having organic soils. They were less developed, however, and more water saturated than the Carbondale - Linwood soil. A more complete description of these soil types can be obtained by consulting the Soils of the Northcentral Region of the U.S. (Wisconsin Agricultural Experimental Station, 1960).

The Hardwoods site was a mature maple climax forest having a density of 303 trees per acre with an average basal area of 92.2 in^2 per tree. Densities and basal areas were determined from 28 samples using the point-quarter method (Cottam and Curtis, 1956). Sugar maple (*Acer saccharum*), red maple (*Acer rubrum*), and balsam fir (*Abies balsamea*) comprised 75 % of the trees present. Ground cover consisted largely of maple seedlings with balsam fir and yellow birch (*Betula lutea*)seedling growth. The northern hardwoods cover type is the most prevalent in the tract and comprises 8,070 acres of the McCormick Forest. Figure 2 consists of two photographs of the Hardwoods plot.

The Spruce Barrens had a density of 164 trees per acre. Most were immature trees with an average height of 6 feet. Black spruce (*Picea mariana*), tamarack (*Larix laricina*), and balsam fir comprised

(A)

(B)

Figure 2 - Photographs of the Hardwoods Plot.

Picture A was taken from trap 2 and picture B was taken from trap 4, both while looking across the narrow portion of the grid.

80 % of the trees on the Spruce Barrens. Ground cover consisted of sparse grasses, blueberries (Vaccinium spp.), mosses, and lichens. The Spruce Barrens occupied approximately 1900 acres in the McCormick Forest, all which was located in the southeastern corner of the tract. Figure 3 consists of two photographs of the Spruce Barrens plot.

The Spruce Swamp had a density of 258 trees per acre with a mean basal area per tree of 43.0 in^2. Balsam fir and black spruce made up 80 % of the trees with ground cover consisting of mosses, lichens, and spruce and fir seedlings. Lowland spruce, fir, and cedar comprised 3,005 acres in the tract. Figure 4 consists of photographs of the Spruce Swamp. Both the Spruce Barrens and Spruce Swamp had been burned over in the late 1920's or early 1930's.

The Bog site trapped in 1972 was mature, with scattered tamarack and black spruce, some as large as 6 inches in diameter. Ground cover was common to that of a northern bog, with Sphagnum spp., pitcher plants (Sarracenia purpurea), leatherleaf (Chamaedaphne calyculata), bog rosemary (Andromeda glaucophylla), and various sedges (Carex spp.) and grasses prevailing. Figure 5 is a picture of this bog.

The Bog site trapped in 1973 was located on the edge of Camp 11 Lake within the tract. The eastern end of the plot was near the edge of the lake, and was characteristic

(A)

(B)

Figure 3 - Photographs of the Spruce Barrens Plot.
Picture A was taken from trap 2 and picture B was taken from trap 4, both while looking across the narrow portion of the grid.

(A)

(B)

Figure 4 - Photographs of the Spruce Swamp Plot.

Picture A was taken from trap 2 and picture B was taken from trap 5, both while looking across the narrow portion of the grid.

Figure 5 - Photograph of the 1972 Bog Plot.

of a bog in early succession, with practically no trees (see Picture 6a). The frequency of black spruce and tamarack increased with distance from the lake (see Picture 6b), and at the farthest end of the plot tag alder (*Alnus rugosa*) was also prevalent. The trapping plot occupied approximately one-half of the total bog habitat available in this location. Ground cover was similar to the 1972 bog with *Sphagnum spp.*, leatherleaf, pitcher plants, bog rosemary, and various sedges again common.

The White Pine - Hardwoods area was similar to the Hardwoods site and was considered as part of the 8,070 acres of northern hardwoods within the tract. The White Pine - Hardwoods site had a density of 241 trees per acre and a mean basal area of 66.3 in^2 per tree. Sugar maple, yellow birch, and hemlock (*Tsuga canadenses*) made up 83 % of the trees. An occasional virgin white pine (*Pinus strobus*) was also present, as was red maple, but not to the extent it was on the Hardwoods site. Ground cover, though mainly composed of maple seedlings, was light, possibly because the crown was more complete than in the Hardwoods area. This was within the Natural Area designated by the U.S. Forest Service. Little or no evidence of logging was present. Figure 7 is two photographs of this area.

A more detailed description of the vegetation on

(A)

(B)

Figure 6 - Photographs of the 1973 Bog Plot.

Picture A was taken from between traps 4 & 5 and picture B was taken from between traps 2 & 3, both while looking across the narrow portion of the grid.

(A)

(B)

Figure 7 - Photographs of the White Pine - Hardwoods Plot.
Picture A was taken from trap 2 and picture B was taken from between traps 3 & 4, both while looking across the narrow portion of the grid.

these habitats will soon be available (Robinson, unpublished).

In 1972 each site was live trapped for a 5 day period using 28 specially designed metal live traps, supplied by Richard Buech of the U.S. Forest Service in Rhinelander, Wisconsin. The traps were set in a 4 by 7 grid, 50 feet apart. Following this, 18 4-gallon metal cans, serving as pit-falls, were sunk into the ground 50 feet apart and in the center of the squares formed by the live trap sites. These pit-falls were also checked for a 5 day period. The pit-fall trapping plot, using the boundary strip method (Stickel, 1954), thus covered an area of one acre (see Figure 8). Table 1 lists the the specific trapping and sampling dates for each habitat. Mice captured by live traps were tagged and released, while those captured in pit-falls were preserved for later analysis.

Six ground litter samples were selected from each 1972 plot. Two samples were taken randomly from each line of six traps. The location of each sample was determined by randomly selecting two trap numbers from each line and one of four quadrats about each trap with a table of random numbers (Arkin and Colson, 1950).

The location of the sample within the quadrat was determined by randomly choosing two distances. The first distance chosen was any random number from 1 through 25 feet. The end point of this distance fell

Figure 8 - The Pit-fall Trapping Grid with the traps respective Quadrat Numbers.*

150 Feet

300 Feet

1		2	25		26	49		50
	1			7			13	
3		4	27		28	51		52
5		6	29		30	53		54
	2			8			14	
7		8	31		32	55		56
9		10	33		34	57		58
	3			9			15	
11		12	35		36	59		60
13		14	37		38	61		62
	4			10			16	
15		16	39		40	63		64
17		18	41		42	65		66
	5			11			17	
19		20	43		44	67		68
21		22	45		46	69		70
	6			12			18	
23		24	47		48	71		72

* Underlined numbers represent trap numbers. All other numbers represent quadrat numbers.

along a line which extended away from the trap along the right hand margin of a quadrat. The second distance extended perpendicularly away from the first line and was a random number from 0 through 25 feet. The distances were paced off and the sample taken at the end point, (see Figure 10, picture A, p. 22).

A one pound coffee can having a diameter of 9.84 cm with its lip removed was used to collect the samples. The sharpened edge made it relatively easy to cut through the ground litter and collect material from beneath a constant area of .32 ft^2. The sample included only material from the surface of the ground litter to mineral soil. If a mineral soil was not present or within reach, as was the case on the bog, the sample was taken to a depth of 10 cm, because this could be considered as being the layer most accessible to shrews.

These samples were examined by hand under a dissecting microscope and all invertebrates recorded, dried, and later weighed. Because they were stored in a refrigerated condition for a period of time and not examined immediately, it was impossible to distinguish those invertebrates that were living at the time of sampling from those not living. Therefore all invertebrate material was recorded whether it was alive or not. These samples thus indicate a total invertebrate index of an area rather than only the living invertebrates present at the time of sampling.

In 1973 the four 1972 habitats were to be retrapped and a more extensive sampling of the ground litter completed. In addition shrews were to be captured and stored with the primary purpose of obtaining stomach samples. Because beavers had flooded the bog site used in 1972, a new bog location was chosen. Also a new upland White Pine - Hardwoods site was included in the study.

The same 3 by 6 grid pattern (see Figure 8) was used for the pit-fall traps. Although traps were not placed in the exact locations, the 1973 grids did overlap the 1972 grids by a minimum of 90 % on the Hardwoods, Spruce Swamp, and Spruce Barrens.

Traps remained closed during the first 2 days of the 5 day trapping period and were opened these 2 days 1 hour prior to sunset and closed at sunrise. The temperature, in °C at ground level, was taken while the traps were checked for the final time. On the last 3 days, traps were left open 24 hours a day to sample the small mammal activity during the day.

The White Pine - Hardwoods plot was checked every morning except for the weekend of July 14 and 15. The other four plots were checked the first three nights at 2 or 3 hour intervals, in order to obtain stomach samples before digestion would render food items unidentifiable. When a shrew was found alive in a trap, it was anesthetized in a chloroform bottle and, with its body cavity cut open, placed in 70 % ethanol until its stomach contents could be examined in the laboratory. During these first three nights of a trapping period a shrew would be placed in ethanol within 3 hours of capture. However, when traps were not checked for a 2 day period, this time may have extended up to 48 hours.

Each shrew was weighed after the majority of the alcohol was blotted off. Body measurements were also taken at this time. Each stomach was examined, materials identified, and the volume of each material determined.

The volume of a food item was measured with the volumeter pictured in Figure 9a. This volumeter was made by using a disposable 1 ml pipette, with .01 ml calibrations, and a common eye dropper. The terminal 8 cm section of the pipette was heated and bent forming a U with its end pointing directly upward, parallel to the larger portion of the pipette. The last 1 cm tip of the pipette was removed and the glass portion of a 2 ml eye dropper, cut in half, and joined to it end to end, with a short piece of surgical tubing.

A section of plastic ruler 6 mm by 4 cm, calibrated in millimeters, was attached to the larger eye dropper tube with a rubber band. The millimeter marks were used to note the location of the miniscus.

(A)

(B)

Figure 9 - Photographs of the Volumeter.

A 5 cm piece of rather stiff rubber hose, that would slide easily over the mouth of the larger tube, was used as a bulb by placing the fore finger over the hole and squeezing the sides gently with the thumb and the index finger. This would force the liquid level in the larger eye dropper tube to go down, and cause the liquid in the smaller tube to rise.

Because the shrews were stored in 70 % ethanol, this was also the liquid used in the volumeter. The tube was filled with ethanol until the liquid level was approximately 1 cm from the top of the larger tube. This level was marked with a line on the movable piece of plastic rule. A reading was then taken in the smaller tube to the closest .0005 ml. The food material was placed in the larger tube and the miniscus readjusted to its original location by using the rubber hose as a bulb (see Figure 9b). A new reading was then taken in the smaller pipette tube, with the change determining the volume.

The trapping dates and sampling periods for each 1973 habitat are listed in Table 1. Ground litter samples were collected, 72 from each habitat, in a manner so that all samples on a plot were taken within a 3 week period.

The trapping plot was divided into 72 square quadrats, four around each trap, with the 25 foot sides of a

Table 1 - Trapping and Sampling Dates for Habitats.

1972

Habitat	Trapping Dates: Live traps	Trapping Dates: Pit-fall	Sampled	Number sampled
Bog-1972	July 1-7	July 9-14	August 11	6
Hardwoods	July 17-20	July 21-25	August 11	6
Spruce Swamp	July 24-29	July 29-Aug 2	August 11	6
Spruce Barrens	July 31-Aug 4	August 7-11	August 11	6

1973

Habitat	Trapping Dates	Sampling Dates	Number sampled
Spruce Barrens	May 21-25	May 21-25	35
		June 3-9	37
Spruce Swamp	May 21-25	May21-25	35
		June 3-9	37
	August 22-27	August 22-27	36
Hardwoods	May 28-June 3	May 28-June 3	35
		June 10-16	37
	August 22-27	August 22-27	36
Bog-1973	May 28-June 3	May 28-June 3	35
		June 10-16	37
White Pine-Hardwoods	July 9-19	July 9-16	72

quadrat extending half way to the next trap or 25 feet off the edge of the grid for border traps.

To take 72 litter samples per site in two 5 day periods, seven were taken per day with two additional samples taken on the last day. The samples taken on day one were those located in the first seven quadrat numbers chosen from a table of random numbers (Arkin and Colton, 1950). Only one sample was taken from each section, therefore once a quadrat number was used it was no longer picked from the random table. The location of the sample within the quadrat was determined by the same method used in 1972.

Each litter sample was taken to the laboratory and placed in one of 14 Tullgren Funnels (MacFadyen, 1953; Figure 10) for a 24 hour period. The living invertebrates which emerged were collected in 70 % ethanol, labeled, and stored for later analysis. This method has been shown to be an effective means of extracting invertebrates from soil and litter samples (MacFadyen, 1961).

Later analysis consisted of placing the sample from a Tullgren Funnel in a 15 cm petri dish which was divided into sections with parallel lines 2 cm apart. Once the sample was spread out in the dish, those invertebrates readily seen with the naked eye were removed. Next the dish was scanned, section by section, with a dissecting microscope and those invertebrates

(A)

(B)

Figure 10 - Picture A displays the tools used in collecting the ground litter samples. Picture B shows the Tullgren Funnel set-up in the laboratory.

approximately 1 mm or larger were removed. Finally those invertebrates less than 1 mm, mainly soil mites and collembola, were removed.

Because of the numerous samples, invertebrates were only identified as far as order or family. They were then dried at 52 °C for 24 hours, and weighed on a Mettler Balance to the closest milligram.

The numerical percent, which is a proportion of the number of one invertebrate type to the total number of invertebrates sampled times 100, was determined for each habitat. The percent frequency of occurrence, which is a proportion of the occurrences of one invertebrate's occurrences to the total number of invertebrate occurrences sampled times 100, was also determined for each site. The mean of the numerical percent and percent frequency of occurrence for each category was utilized as an invertebrate index of abundance.

In August 1973 the Hardwoods and Spruce Swamp sites were again trapped and the ground litter sampled (see Table 1) to examine the relationship between shrew trappability and temperature and also to determine how the invertebrate composition changed from May. Traps were checked every morning for a 5 day period with the temperature (°C) taken just prior to sunrise.

RESULTS

Shrew Densities

Nine species of small mammals were captured during this study by the pit-fall method. Because mammals were trapped to virtual extinction in each one acre plot, a species density was considered as the number of those species captured per one acre plot in each habitat. Table 2 lists the density of each species per acre in the various habitats in 1972 and 1973.

The shrew biomass per square foot was determined for each habitat trapped in 1972 and 1973 (see Table 3). The 1972 biomass was calculated from shrews captured in 5 days of trapping effort, 24 hours a day. In 1973, the biomass was also captured by 5 days of trapping but on the first 2 days the traps were closed during daylight hours. The White Pine - Hardwoods site, however, was trapped for 7 days, 24 hours a day.

The shrew biomass per square foot was obtained by dividing the total shrew weight captured per habitat per year by the square footage in a plot. The exact shrew weight was known for habitats trapped in 1973, but it was necessary to estimate this biomass for 1972 trappings because many shrews had been discarded, since they were partially eaten.

A mean weight was determined for each shrew species by finding the average weight for all specimens of that

Table 2 - Small Mammal Densities per Acre on the Habitats in 1972 and 1973.

	Peromyscus	Microtus	Zapus	Clethrionomys	Synaptomys	Blarina	S. cinereus	M. hoyi	S. arcticus
1972									
Hardwoods	10	0	2	10	1	19	9	0	4
Spruce Swamp	1	0	0	1	1	7	11	2	0
Spruce Barrens	1	0	0	0	0	1	4	1	0
Bog	0	7	0	0	1	5	6	2	4
1973									
Hardwoods (June)	0	0	0	0	0	3*	0	0	0
Hardwoods (August)	0	0	0	0	0	0	2	0	0
Spruce Swamp (June)	0	0	0	0	0	0	3	0	0
Spruce Swamp (August)	0	0	0	0	0	1	2	2	0
Spruce Barrens	0	0	0	0	0	3	0	1	0
Bog	0	0	0	0	0	3	5	3	0
White Pine-Hardwoods	2	0	0	6	0	7	4	0	0

* Captured after formal 5 day trapping period, therefore not used when comparisons are made, of equal trapping effort, between habitats.

Table 3 - Invertebrate Biomass and Shrew Biomass Estimates per Square Foot for 1972 and 1973.

Habitat Type	Invertebrate Biomass (gms) 1972	Invertebrate Biomass (gms) 1973	Shrew Biomass (gms) 1972	Shrew Biomass (gms) 1973
Hardwoods	.0360	.0195 (May) .0202 (August)	.0086	.0000*
Spruce Swamp	.0233	.0150 (May) .0147 (August)	.0032	.0003
Spruce Barrens	.0200	.0103	.0007	.0009
White Pine-Hardwoods	x	.0095	x	.0028
Bog-1973	x	.0085	x	.0017
Bog-1972	.0007**	x	.0033	x

* No shrews were captured in formal 5 day trapping period in May.

** Invertebrate estimate is probably low, due to flooding of site.

species captured in the two year period. This mean weight for a species was then multiplied by the number of individuals of that species captured on each habitat during 1972.

<u>Invertebrate Fauna Biomass and Composition</u>

To determine whether the weight of invertebrates within a sample was correlated with the ground litter sample, correlation coefficients were calculated comparing these two weights. No significant correlation existed (see Table 4), thus suggesting that the presence of more ground litter at a sampling site does not necessarily mean a greater abundance of invertebrates present.

The invertebrates extracted from each sample were weighed and the mean of these weights, for each habitat, determined. Table 5 lists these weights, in grams per sample area (.322 ft^2), with the .05 % confidence limits. This mean weight per habitat was used to calculate the invertebrate biomass per square foot. Table 3 lists the 1972 and 1973 invertebrate biomass estimates for each habitat.

When these invertebrate biomass estimates were compared for 1972 and 1973 in the Hardwoods, Spruce Swamp, and Spruce Barrens the 1972 estimates were considerably higher. The reason for this difference was that a different method of extraction was used each year

Table 4 - Observed and Expected (.05%) Correlation Coefficients (r) for Ground Litter Sample Weights versus Invertebrate Biomass Within.

Habitat	Observed r	.05% r
Spruce Barrens	.338	.444
Bog-1973	.086	.423
Hardwoods	.061	.433
White Pine-Hardwoods	.096	.404
Spruce Swamp	.001	.423

Table 5 - The Mean Invertebrate Weight Determined from Litter Samples Collected at each Habitat.

Habitat	$\bar{x}$ Wt. (gms)*	.05% Confidence Limits
Hardwoods (May)	.00632	$\pm$.00227
Hardwoods (August)	.00662	$\pm$.00347
Spruce Swamp (May)	.00485	$\pm$.00078
Spruce Swamp (August)	.00483	$\pm$.00163
Spruce Barrens	.00334	$\pm$.00131
Bog-1973	.00275	$\pm$.00078
White Pine-Hardwoods	.00312	$\pm$.00117

* Weight is per .322 ft^2.

and not that the invertebrate biomass was higher in 1972 than in 1973. By both methods however, invertebrate biomass was was highest in the Hardwoods site, next highest in the Spruce Swamp, and least on the Spruce Barrens.

In the 1972 invertebrate biomass estimates, the Bog site estimate was the lowest. Shrew trapping had occurred in July, but by August 11, when the ground litter samples were collected, the site was partially flooded by a beaver dam. This rising water level may have reduced the invertebrate biomass present. Thus the estimated invertebrate biomass may not be representative, and is probably low.

Tables 6 through 10 present the invertebrate fauna obtained from ground litter samples collected in 1972 and 1973. To compare the invertebrate fauna composition between habitats or between sampling periods of a habitat, the 1973 invertebrate index values of abundance were totalled, starting from the highest value, until a figure of 75 or greater was reached. The invertebrate types added to reach this value on each habitat, may be considered as the most abundant or common invertebrates for that habitat or period.

On the Spruce Barrens the most abundant invertebrate groups,in decreasing index values, were formicids, soil mites, dipterous larvae, collembola, and sowbugs forming

Table 6 - Invertebrate Fauna Composition on the Hardwoods Site.

Invertebrates	Summer-1972 n=6 Num. Per cent	Summer-1972 Per cent Occ.	Summer-1972 Index	May-1973 n=72 Num. Per cent	May-1973 Per cent Occ.	May-1973 Index	August-1973 n=35 Num. Per cent	August-1973 Per cent Occ.	August-1973 Index
Mites	___	___	___	38.78	15.17	26.97	40.36	16.32	28.34
Dipterous larvae	7.14	5.26	6.20	13.46	12.05	12.75	16.36	11.22	13.79
Collembola	___	___	___	11.55	11.16	11.35	9.17	10.71	9.94
Coleoptera larvae	7.14	7.89	7.52	5.85	8.92	7.38	9.45	10.20	9.82
Spiders	1.78	2.63	2.21	4.63	7.58	6.10	3.36	7.65	5.50
Annelids	17.85	10.52	14.19	6.31	5.58	5.94	5.19	6.63	5.91
Pseudoscorpionidae	21.42	15.78	18.60	2.96	6.02	4.49	3.97	7.65	5.81
Staphylinidae	___	___	___	2.66	5.35	4.00	2.29	5.10	3.69
Diplopoda	1.78	2.63	2.21	2.58	5.13	3.85	2.90	6.63	4.76
Diptera adults	1.78	2.63	2.21	1.97	3.12	2.54	.45	1.53	.99
Insect eggs	1.78	2.63	2.21	1.29	2.67	1.98	___	___	___
Dipterous pupae	3.57	5.26	4.42	1.06	2.90	1.98	.15	.51	.33
Formicidae	___	___	___	1.52	2.00	1.76	1.37	1.53	1.45
Coleoptera adults	5.35	7.89	6.62	1.14	1.78	1.46	1.83	4.59	3.21
Chilopoda	___	___	___	.68	2.00	1.34	.30	1.02	.66
Hymenoptera adults	1.78	2.63	2.21	.76	1.78	1.27	.91	3.06	1.98
Snails	7.14	7.89	7.52	.53	1.56	1.04	.30	1.02	.66
Hemiptera adults	3.57	5.26	4.42	.76	1.11	.93	.15	.51	.33
Curculionidae	___	___	___	.45	1.33	.89	___	___	___
Lepidopterous larvae	___	___	___	.30	.66	.48	___	___	___

Table 6 - continued.

Invertebrates	Summer-1972 Num. Per cent	Summer-1972 Per cent Occ.	Summer-1972 Index	May-1973 Num. Per cent	May-1973 Per cent Occ.	May-1973 Index	August-1973 Num. Per cent	August-1973 Per cent Occ.	August-1973 Index
Nematodes	3.57	2.63	3.10	.22	.66	.44	____	____	____
Homoptera	____	____	____	.15	.44	.29	____	____	____
Sowbug	____	____	____	.07	.22	.14	____	____	____
Orthoptera adults	____	____	____	.07	.22	.14	____	____	____
Earthworms	1.78	2.63	2.21	.15	.44	.29	.91	2.55	1.73
Apididae	____	____	____	____	____	____	.15	.51	.33
Thysanoptera	____	____	____	____	____	____	.30	1.02	.66
Carabidae	1.78	2.63	2.21	*	*	*	*	*	*
Hymenoptera pupae	5.35	7.89	6.62	____	____	____	____	____	____
Slug	3.57	2.63	3.10	____	____	____	____	____	____
Unident. Insect larvae	1.78	2.63	2.21	____	____	____	____	____	____

* combined with coleoptera adults.

Table 7 - Invertebrate Fauna Composition on the Spruce Swamp Site.

Invertebrates	Summer-1972 n=6			May-1973 n=72			August-1973 n=35		
	Num. Per cent	Per cent Occ.	Index	Num. Per cent	Per cent Occ.	Index	Num. Per cent	Per cent Occ.	Index
Mites	1.44	2.94	2.19	52.12	18.37	35.24	57.80	19.14	38.47
Collembola	____	____	____	8.72	10.54	9.63	13.90	13.29	13.59
Spiders	10.14	8.82	9.48	5.97	11.62	8.79	4.93	10.10	7.24
Dipterous larvae	1.44	2.94	2.19	6.62	8.37	7.49	3.53	8.51	6.02
Staphylinidae	____	____	____	4.87	8.37	6.62	.73	3.19	1.96
Coleoptera larvae	2.86	5.88	4.37	2.90	5.94	4.42	7.31	11.17	9.24
Diplopoda	____	____	____	2.75	5.13	3.94	1.58	4.78	3.18
Annelids	____	____	____	3.93	3.78	3.85	1.70	5.85	3.46
Pseudoscorpionidae	2.86	5.88	4.37	1.72	4.32	3.02	2.07	4.78	3.42
Chilopoda	1.44	2.94	2.19	1.57	4.05	2.81	.12	.53	.32
Diptera adults	2.86	2.94	2.90	1.96	4.32	3.14	.60	2.65	1.62
Formicidae	____	____	____	2.35	1.62	1.98	1.21	3.19	2.20
Coleoptera adults	1.44	2.94	2.19	.62	1.89	1.25	1.95	5.31	3.54
Hemiptera adults	1.44	2.94	2.19	.47	1.62	1.04	.12	.53	.32
Lepidopterous larvae	1.44	2.94	2.19	.07	.27	.17	.12	.53	.32
Nematodes	____	____	____	.39	1.35	.87	.12	.53	.32
Dipterous pupae	7.24	11.76	9.50	.31	1.08	.69	____	____	____
Hymenoptera adults	2.86	5.88	7.23	.31	1.08	.69	.24	1.06	.65
Insect eggs	____	____	____	.47	.81	.64	.24	1.06	.65
Earthworms	8.69	11.76	10.23	.23	.81	.52	.12	.53	.32

Table 7 - continued.

Invertebrates	Summer-1972 Num. Per cent	Summer-1972 Per cent Occ.	Summer-1972 Index	May-1973 Num. Per cent	May-1973 Per cent Occ.	May-1973 Index	August-1973 Num. Per cent	August-1973 Per cent Occ.	August-1973 Index
Curculionidae	____	____	____	.23	.81	.52	____	____	____
Spider eggs	____	____	____	.23	.81	.52	____	____	____
Aphididae	____	____	____	.15	.54	.34	.24	1.06	.65
Homoptera	1.44	2.94	2.19	.07	.27	.17	.36	1.59	.97
Hymenoptera pupae	11.59	5.88	8.74	.15	.27	.21	____	____	____
Hymenoptera larvae	____	____	____	.15	.27	.21	____	____	____
Snails	____	____	____	.07	.27	.17	____	____	____
Sowbugs	____	____	____	.07	.27	.17	1.34	1.06	1.20
Trichoptera adult	____	____	____	____	____	____	.12	.53	.32
Carabidae	8.69	14.70	11.70	*	*	*	*	*	*
Scarabaeidae	1.44	2.94	2.19	*	*	*	*	*	*
Mycetophilidae	30.43	2.94	16.70	____	____	____	____	____	____

* combined with coleoptera adults.

Table 8 - Invertebrate Fauna in the 1972 and 1973 Bog Sites.

Invertebrates	Bog-1972 n=6 Num. Per cent	Per cent Occ.	Index	Bog-1973 n=72 Num. Per cent	Per cent Occ.	Index
Mites	5.00	6.25	5.63	70.73	18.75	44.74
Dipterous larvae	5.00	6.25	5.63	8.54	14.13	11.33
Collembola	____	____	____	4.45	11.14	7.79
Coleoptera larvae	10.00	6.25	8.13	2.81	8.42	5.61
Staphylinidae	5.00	6.25	5.63	1.30	7.60	4.45
Homoptera	____	____	____	.99	3.53	2.62
Diptera adults	____	____	____	.75	4.34	2.54
Pseudoscorpionidae	5.00	6.25	5.63	.85	4.07	2.46
Formicidae	____	____	____	.78	4.07	2.43
Hymenoptera adults	5.00	6.25	5.63	.54	3.26	1.90
Coleoptera adults	15.00	12.50	13.75	.37	2.17	1.27
Dipterous pupae	5.00	6.25	5.63	.17	1.08	.62
Lepidoptera	5.00	6.25	5.63	.06	.54	.30
Aphididae	____	____	____	.06	.27	.16
Snails	____	____	____	.03	.27	.15
Diplopoda	____	____	____	.03	.27	.15
Annelids	5.00	6.25	5.63	.03	.27	.15
Spiders	30.00	25.00	27.50	____	____	____
Unident. larvae	5.00	6.25	5.63	____	____	____

Table 9 - Invertebrate Fauna on the Spruce Barrens Site.

Invertebrates	Summer-1972 n=6 Num. Per cent	Summer-1972 Per cent Occ.	Summer-1972 Index	May-1973 n=72 Num. Per cent	May-1973 Per cent Occ.	May-1973 Index
Formicidae	18.75	18.75	18.75	51.34	15.52	33.43
Mites	____	____	____	12.12	14.28	13.20
Dipterous larvae	____	____	____	10.21	14.90	12.55
Collembola	____	____	____	8.43	13.04	10.73
Sowbug	____	____	____	7.23	6.52	6.87
Spiders	____	____	____	1.41	5.90	3.65
Coleoptera larvae	3.12	6.25	4.69	1.77	4.34	3.05
Aphididae	____	____	____	1.13	3.10	2.11
Dipterous pupae	____	____	____	.85	2.48	1.66
Annelids	6.25	6.25	6.25	.85	2.48	1.66
Homoptera	____	____	____	.70	2.48	1.59
Coleoptera adults	6.25	6.25	6.25	.63	1.86	1.17
Carabidae	31.25	25.00	28.13	*	*	*
Scarabaeidae	3.12	6.25	4.69	*	*	*
Hemiptera adults	3.12	6.25	4.69	.49	1.86	1.17
Staphylinidae	____	____	____	.42	1.86	1.14
Insect eggs	____	____	____	.35	1.55	.95
Curculionidae	____	____	____	.38	1.24	.79
Aradidae	____	____	____	.21	.93	.57
Diplopoda	____	____	____	.21	.93	.57
Pseudoscorpionidae	6.25	12.50	9.38	.21	.93	.57
Chilopoda	____	____	____	.21	.62	.41
Diptera adults	____	____	____	.14	.62	.38
Hymenoptera	____	____	____	.14	.62	.38
Orthoptera	____	____	____	.14	.62	.38
Nematodes	____	____	____	.14	.62	.38
Earthworms	21.87	12.50	17.19	.14	.31	.22
Snails	____	____	____	.07	.31	.19

* combined with coleoptera adults.

Table 10 - Invertebrate Fauna on the White Pine-Hardwoods Site.

July-1973
n=72

Invertebrates	Num. Per cent	Per cent Occ.	Index
Mites	26.74	16.35	21.55
Coleoptera larvae	8.79	11.60	10.19
Collembola	18.52	3.95	11.23
Dipterous larvae	8.79	11.60	10.19
Spiders	8.51	10.02	9.26
Annelids	7.10	8.76	7.92
Pseudoscorpionidae	2.99	6.86	4.92
Staphylinidae	2.24	5.80	4.02
Diplopoda	1.96	3.95	2.95
Snails	1.30	2.63	1.96
Hemiptera	1.12	2.63	1.87
Chilopoda	1.12	2.63	1.87
Orthoptera adults	2.52	.79	1.65
Formicidae	.93	1.84	1.38
Diptera adults	.65	1.84	1.24
Insect eggs	.39	.79	.58
Thysanoptera	.46	.52	.49
Coleoptera adults	.28	.52	.40
Coleoptera pupae	.18	.26	.22
Lepidopterous larvae	.09	.26	.17
Hymenopterous larvae	.09	.26	.17
Aphididae	.09	.26	.17

a total index value of 76.78.

The most abundant invertebrate groups on the 1973 Bog site were soil mites, dipterous larvae, collembola, coleoptera larvae, staphylinids, and homoptera yielding a total index value of 76.64.

The most common invertebrate groups on the White Pine - Hardwoods site were soil mites, coleoptera larvae, collembola, dipterous larvae, spiders, annelids, and pseudoscorpionids forming a total index value of 75.26.

The most common invertebrate groups for the Spruce Swamp were soil mites, collembola, spiders, dipterous larvae, staphylinids, coleoptera larvae, and diplopods forming a total index value of 76.13. During the August sampling period, the most common invertebrates were soil mites, collembola, coleoptera larvae, spiders, dipterous larvae, and coleoptera adults yielding a total index value of 78.09.

The invertebrate fauna composition on the Hardwoods was very similar to the fauna collected from the White Pine - Hardwoods site. In May, soil mites, dipterous larvae, collembola, coleoptera larvae, spiders, annelids, and pseudoscorpion formed a total index value of 74.98. During August soil mites, dipterous larvae, collembola, coleoptera larvae, annelids, pseudoscorpionids, and spiders dominated, giving a total index value of 78.31.

Shrew Stomach Analysis

Tables 11 through 15 list the stomach contents of

Table 11– Stomach Contents of Shrews Captured on the Hardwoods Site.

Month	Blarina n=3		S. cinereus n=0		M. hoyi n=0	
May	Num. Per cent	Per cent Vol.	Num. Per cent	Per cent Vol.	Num. Per cent	Per cent Vol.
Coleoptera	50	83	-	-	-	-
Unident. Insect	50	16	-	-	-	-

	Blarina n=0		S. cinereus n=2		M. hoyi n=0	
August	Num. Per cent	Per cent Vol.	Num. Per cent	Per cent Vol.	Num. Per cent	Per cent Vol.
Coleoptera	-	-	100	100	-	-

Table 12– Stomach Contents of Shrews Captured on the Spruce Swamp Site.

	Blarina n=0		S. cinereus n=3		M. hoyi n=0	
May	Num. Per cent	Per cent Vol.	Num. Per cent	Per cent Vol.	Num. Per cent	Per cent Vol.
Small Mammal Hair	-	-	25	5	-	-
Unident. Insect	-	-	50	25	-	-
Hymenoptera	-	-	25	70	-	-

Table 12- continued.

August	Blarina n=1* Num. Per cent	Blarina n=1* Per cent Vol.	S. cinereus n=2 Num. Per cent	S. cinereus n=2 Per cent Vol.	M. hoyi n=2 Num. Per cent	M. hoyi n=2 Per cent Vol.
Vegetation	-	-	20	1	-	-
Coleoptera	-	-	40	1	-	-
Small Mammal Remains	-	-	20	28	-	-
Lepidoptera	-	-	20	70	-	-
Snail	-	-	-	-	33	35
Insect Eggs	-	-	-	-	33	30
Spider	-	-	-	-	33	35

* If n value indicates an animal, and no material is listed below it, the animals stomach was empty.

Table 13- Stomach Contents of Shrews captured on the 1973 Bog Site.

	Blarina n=3 Num. Per cent	Blarina n=3 Per cent Vol.	S. cinereus n=5 Num. Per cent	S. cinereus n=5 Per cent Vol.	M. hoyi n=3 Num. Per cent	M. hoyi n=3 Per cent Vol.
Unident. Insect	20	31	-	-	25	12
Vegetation *	60	63	50	28	25	12
Unident. Arthropod	20	6	12	28	25	12
Annelids	-	-	12	14	-	-
Coleoptera	-	-	12	14	25	62
Spider	-	-	12	14	-	-
Diptera	-	-	-	-	25	12

* All vegetation was Sphagnum spp..

Table 14- Stomach Contents of Shrews captured on the Spruce Barrens Site.

Material	Blarina n=3 Num. Per cent	Blarina n=3 Per cent Vol.	S. cinereus n=0 Num. Per cent	S. cinereus n=0 Per cent Vol.	M. hoyi n=1 Num. Per cent	M. hoyi n=1 Per cent Vol.
Coleoptera	100	100	-	-	-	-

Table 15- Stomach Contents of Shrews captured on the White Pine - Hardwoods Site.

Material	Blarina n=7 Num. Per cent	Blarina n=7 Per cent Vol.	S. cinereus n=4 Num. Per cent	S. cinereus n=4 Per cent Vol.	M. hoyi n=0 Num. Per cent	M. hoyi n=0 Per cent Vol.
Unident. Insect	7	64	25	14	-	-
Diptera	14	2	50	71	-	-
Diptera pupae	-	-	25	14	-	-
Diptera larvae	7	trace	-	-	-	-
Lepidoptera	14	9	-	-	-	-
Coleoptera	28	21	-	-	-	-
Vegetation	14	trace	-	-	-	-
Earthworms	14	2	-	-	-	-

shrews captured on various habitats in 1973. Shrews were grouped according to species within each habitat and the numerical percent and percent volume of their foods listed. Tables 11 and 12 were further divided to indicate the stomach contents of shrews captured at different periods during the summer.

Correlations Between Shrew and Invertebrate Densities

The 1972 data suggested that shrew densities may be higher in areas of higher invertebrate density (see Figure 11, line A). Although no significant correlation was observed ($r=.384$, $r(05)=.950$), when the Bog site was excluded from the 1972 data, because of the apparent effect the beaver dam had upon the invertebrate fauna, a more realistic correlation ($r=.859$, $r(05)=.950$) was observed(see Figure 11, line B). Although neither correlation was significant, the positive correlation suggests that more extensive data was warranted to examine the relationship between shrew and invertebrate density between and within habitats.

In 1973 the Hardwoods, Spruce Swamp, and Spruce Barrens, which were all trapped the previous year, produced very low numbers of shrews, while two similar habitats trapped for the first time in 1973(Table 16), both produced a more average shrew population. This indicated that some factor had seriously depleted the populations of the plots trapped in 1972, making a correlation

Figure 11 - Comparison of Shrew Captures per Habitat to Mean Invertebrate Biomass.

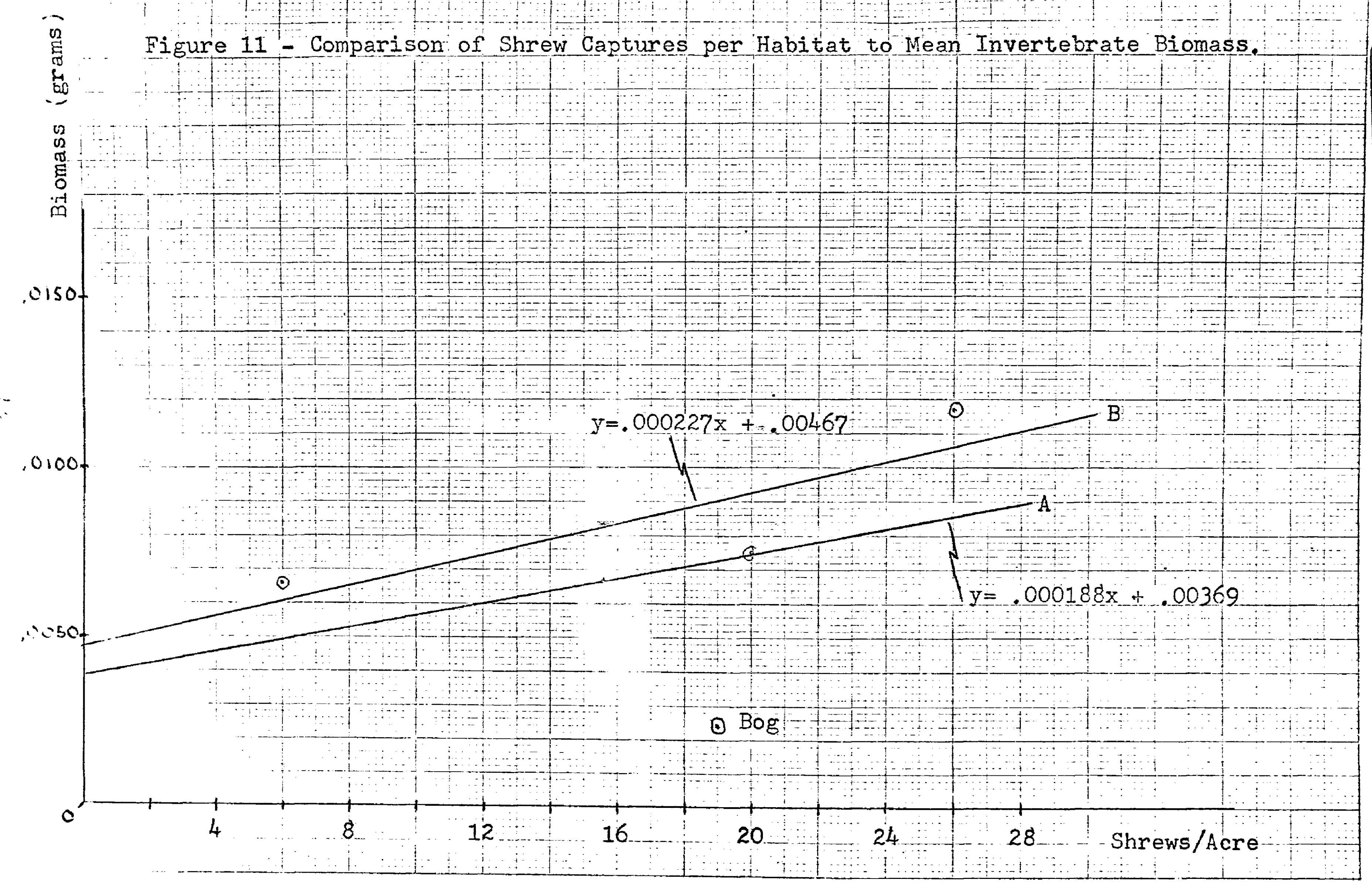


Table 16 - Total Number of Shrews and Non-shrew Mammals Captured on Habitats in 1972 and 1973.

1972	Mice & Voles Per Acre	Shrews Per Acre
Hardwoods	23	32
Spruce Swamp	3	20
Spruce Barrens	1	6
Bog	8	17
1973		
Hardwoods (June)	0	3*
Hardwoods (August)	0	2
Spruce Swamp (June)	0	3
Spruce Swamp (August)	0	5
Spruce Barrens	0	4
Bog	0	11
White Pine - Hardwoods	8	11

* Captured after formal five day trapping period.

between 1973 trapping and sampling data unrealistic.

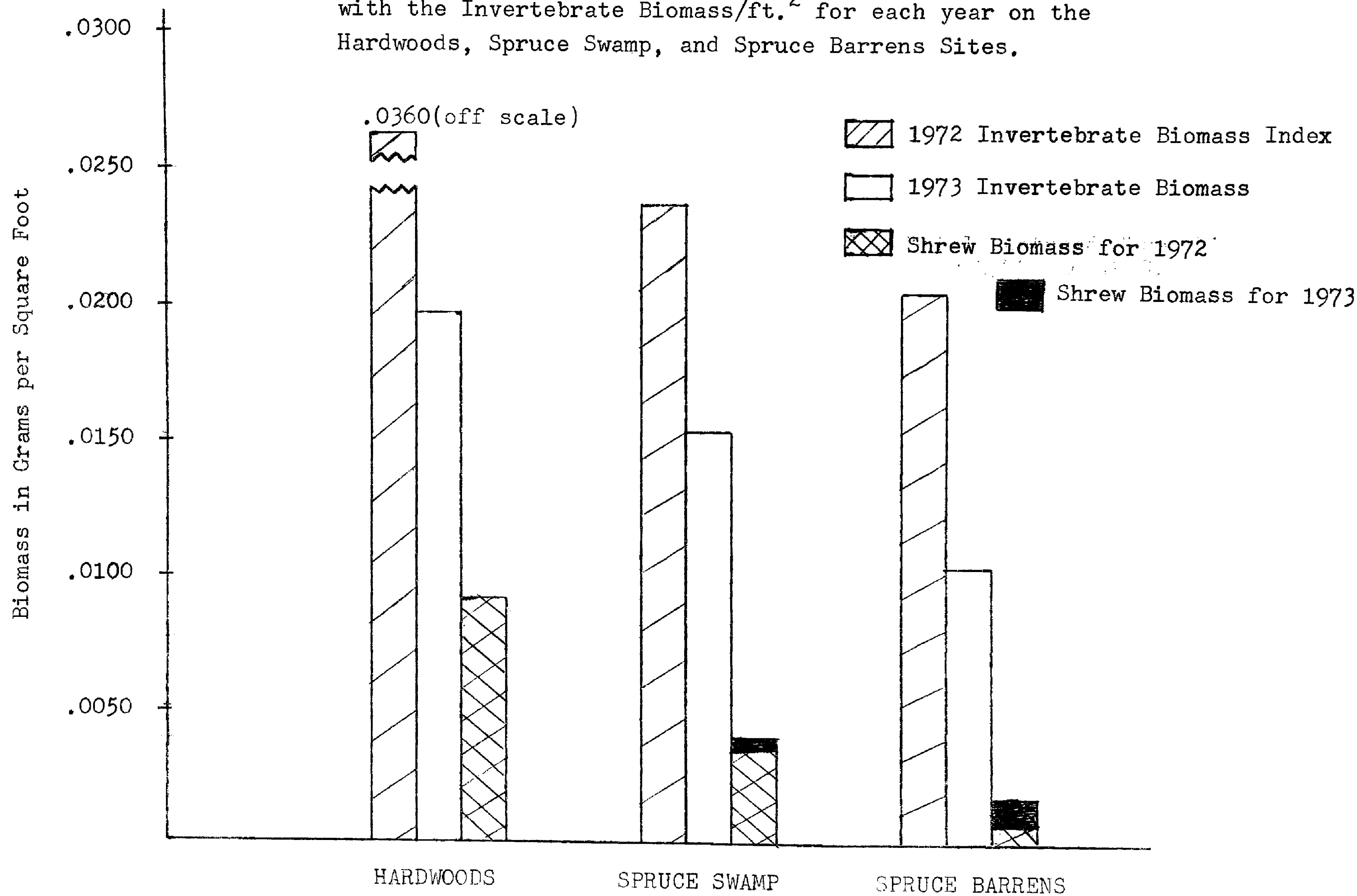
For this reason, shrew biomass was combined, from equal trapping effort for 1972 and 1973, and compared to the invertebrate biomass estimates for each year on the Hardwoods, Spruce Swamp, and Spruce Barrens. If these three habitats are compared (see Figure 12), the Hardwoods had the highest invertebrate biomass for both 1972 and 1973 and also had the highest combined shrew biomass for both years. The Spruce Swamp was next highest in invertebrate biomass and combined shrew biomass and the Spruce Barrens site last.

Because they were both trapped and sampled in 1973, the White Pine - Hardwoods site and the Bog site (1973) can not be compared directly to the Hardwoods, Spruce Swamp, and Spruce Barrens sites. When compared between themselves, the White Pine - Hardwoods site was highest in invertebrate biomass and also highest in shrew biomass (see Table 3). These data for the 2 years seem to suggest that invertebrate density may affect shrew abundance in an area.

In order to test whether shrew densities were also correlated with invertebrate densities within plots, four ground litter samples were collected near each trap in 1973.

The mean invertebrate weights of samples taken around unsuccessful traps were compared with those

Figure 12 - The Captured Shrew Biomass/ft.^{2} totaled for both 1972 and 1973, with the Invertebrate Biomass/ft.^{2} for each year on the Hardwoods, Spruce Swamp, and Spruce Barrens Sites.



collected near successful traps. Table 17 lists these weights for each habitat trapped in 1973.

A t-test (Sokal and Rolf, 1969) was run between these mean weights in each habitat. The only means significantly different were located on the Bog and Spruce Swamp sites. In the Bog the mean invertebrate weight was significantly higher for unsuccessful traps rather than for successful traps, however, in the Spruce Swamp this was just reversed. Although overall it appears that invertebrate biomass was higher around unsuccessful traps, no significant conclusions can be drawn from this data.

This relationship was further examined by considering all unsuccessful and successful traps, independently of their respective plots, by making a comparison between the mean invertebrate weights of samples taken where zero, one, two, or three shrews were captured (see Table 18). Again no significant correlation was observed (r=.-520, r(05)=.-950) between shrew and invertebrate biomass densities.

The Correlation Between Shrew Captures and Temperature

During the trapping periods in the Hardwoods, Spruce Swamp, Spruce Barrens, and Bog sites the temperature was recorded,following each night of trapping, so as to examine the relationship of temperature upon shrew activity. A significant correlation (r=.902, r(05)=.735)

Table 17 - Mean Invertebrate Weight Collected at Successful and Unsuccessful Traps.

Habitat	Invert. Wt.(gms) at Successful Traps	Invert. Wt.(gms) at Unsuccessful Traps
Bog-1973 *	.00201	.00354
Spruce Barrens	.00263	.00354
Spruce Swamp *	.00659	.00415
Hardwoods	.00510	.00656
White Pine-Hardwoods	.00302	.00318

* significant difference between means.

Table 18 - Mean Invertebrate Weights (gms) at Traps that Captured 0, 1, 2, or 3 Shrews. **

Traps that Captured the Indicated No. of Shrews	Mean Weight of Invertebrates
0	.00426
1	.00380
2	.00243
3	.00369

** no significant correlation, (r=-.520, r(.05%)=-.950).

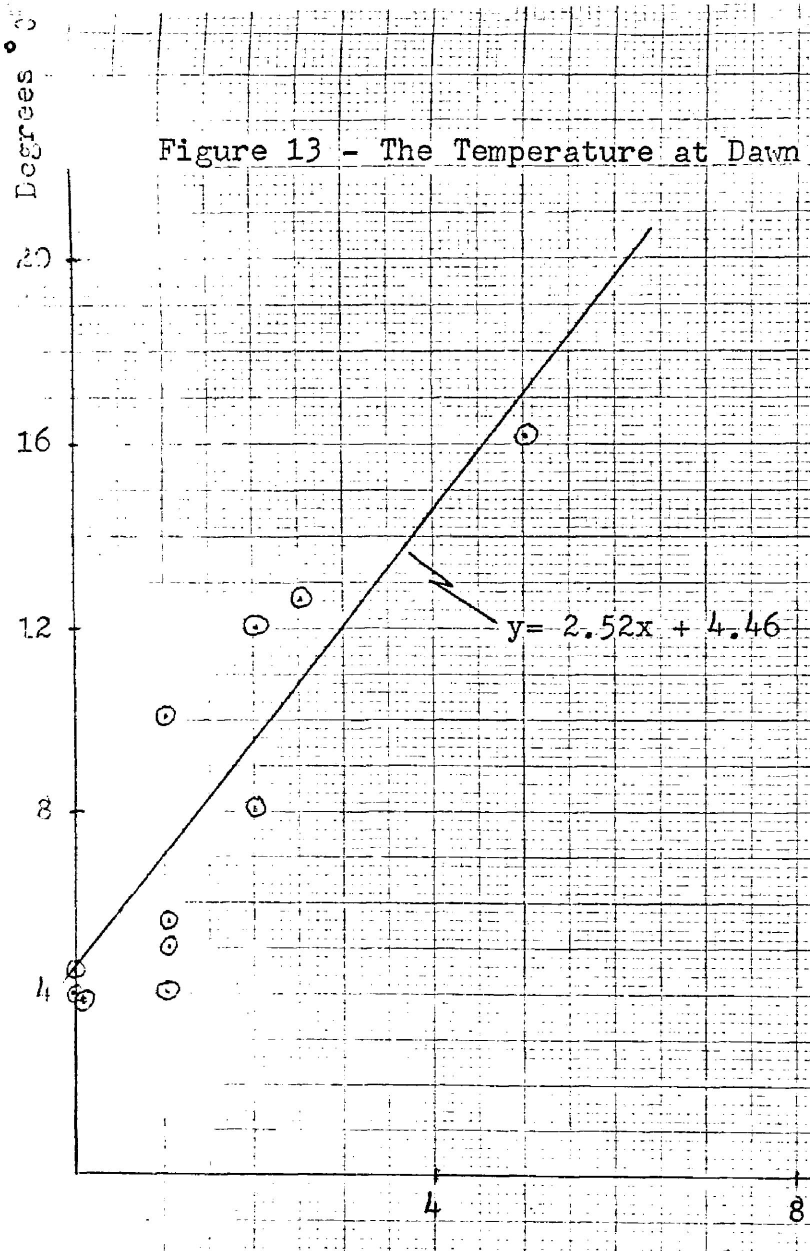
was observed between the temperature at dawn and the shrew captures the previous night (see Figure 13). During both weeks the traps were checked every day with the exception that they were not checked on the second to the last day. At the end of this final 48 hour period the traps were checked and the temperature taken.

Although it was assumed that one-half of the final 48 hr catch was taken on the last night, some of these shrews may have been captured during the daylight hours. However, each trapping period in 1973 included one 24 hour period in which the traps were left open during the day and checked at sunset. In all cases no shrews were captured during this daylight period. Buckner (1966) in studying shrew activity, determined that although shrews are active all hours of the day, extreme peak activities occur during the night.

Therefore, the last 2 day period of each trapping session was represented on the graph by one point which represents one-half of the final 2 day catch and the temperature reading for the last morning.

In late August, when the Hardwoods and Spruce Swamp were again trapped, temperatures were also taken on both sites. The temperature on the Hardwoods plot were generally higher than those taken on the Spruce Swamp. This probably occurred because the Spruce Swamp was checked first each morning, prior to sunrise, and the

Figure 13 - The Temperature at Dawn compared to Shrew Captures the Previous Night.



	Shrew Captures	Temperature C
Period one	1	4.0
	0	4.0
	1	5.5
	0	5.0
	2.5	12.5
Period two	0	4.5
	0	4.0
	2	12.0
	2	8.0
	1	10.0
	5	16.0

Hardwoods some 60 minutes later. During this period an increase in temperature generally takes place. Table 19 lists the temperature on each site and the number of shrews captured in the 24 hours prior.

Table 19 - Temperature at Dawn versus Shrew Captures the Previous Night on the Hardwoods and Spruce Swamp sites During the Late August Trapping Period.

	Temperature (°C)		Shrews Captured	
Days	Spruce Swamp	Hard-woods	Spruce Swamp	Hard-woods
1	4.5	8.5	0	0
2	14.5	18.0	5	2
3	2.0	5.0	0	0
4	16.0	15.0	0	0
5*	x	x	x	x
6	21.0	24.0	0	0

* Temperature and trapping data was not collected, however, day 5 was warm and comparable to days 4 & 6.

DISCUSSION

Small Mammal Populations

Because mammals were apparently trapped to virtual extinction in all habitats, the resulting captured individuals were considered in species densities per acre (see Table 2). The DeLury Method (DeLury, 1951) of catch per unit effort versus cumulative catch could also have been used to calculate the small mammal populations. However in 1972, traps were seldom checked at specific intervals, which considerably reduced the quality of the data for the DeLury Method.

All plots that were trapped in 1972 produced low numbers of shrews in 1973 (see Table 16). Mice and voles were also captured by the pit-fall method on these plots in 1972, but in 1973 no small mammals other than shrews were captured. This reduced number of small mammal captures per habitat, may be explained by two interpretations. Either these habitats were virtually trapped out in 1972 with little repopulation occurring, or all population levels in the area had a general decline from 1972 to 1973.

A indication of the effectiveness of pit-fall trapping for shrews may be interpreted from the data in Table 19. In August of 1973 the Hardwoods and Spruce Swamp were retrapped to examine the relationship between shrew trappability and temperature. On the second night warm temperatures were prevalent and 7 shrews were captured between the 2 plots. However on the final three nights, temperatures were again warm but no shrews were captured, suggesting that the shrew populations had been depleted to extinction on these areas.

There seems to be no doubt that when the small mammals are extensively removed from an area, lower population levels may be expected the following year. Buckner (1966) found that extensive removal of shrews in an area may have prolonged and severe effects on a population.

The Bog and the White Pine - Hardwoods sites were both trapped for the first time in 1973. The 1973 Bog, although similar to the 1972 Bog, did not produce as many shrews or other small mammals as the 1972 Bog did (see Table 16). The White Pine - Hardwoods site which was similar to the Hardwoods site, produced only one-third the number of shrews and one-fourth the number of mice and voles as did the Hardwoods in 1972 (see Table 16). This suggests that the small mammal populations were generally lower in 1973 than in 1972.

The 1972 sites were also trapped in mid-summer when temperatures may not have been as cool as they were in May or late August, which was when these sites were again trapped in 1973. Because of these warmer temperatures during the 1972 trapping period, small mammals may have been more susceptible to trapping. However, the White Pine - Hardwoods site was also trapped during mid-summer in 1973 and as previously shown, it still did not produce as many small mammals as a similar site trapped at the same time in 1972.

I feel that several lines of evidence indicate that extensive trapping in 1972 was the prime reason for lower small mammal densities on these previously trapped areas in 1973. In addition, the small mammal populations were generally lower throughout the areas trapped.

When the pit-fall trapping data, comprised of equal effort from both 1972 and 1973, was combined for the Hardwoods, Spruce Swamp, and Spruce Barrens, the Hardwoods was readily seen as having the greateat density of small mammals. Mice and voles comprised 23 animals, representing four species, and 32 shrews, representing three species were captured. The Spruce Swamp produced 3 mice or voles, comprised of three species, and 23 shrews also composing three species. The Spruce Barrens produced 1 mouse and 10 shrews representing three species.

On the 1972 Bog site 8 mice or voles, of two species, and 17 shrews, reprsenting four species, were captured. Overall this bog produced more mammals than the Spruce Swamp in 1972, however the Spruce Swamp captured more shrews than the Bog. The 1973 Bog site produced 11 shrews, comprising three species. A water shrew was captured non-systematically on this bog in 1972, thus making four species of shrews inhabiting the bog. The specific species captured in these habitats can be obtained from Table 2.

It was observed in this study that those habitats with the least small mammal densities were still substantially utilized by shrews. Shrews made up 58 % of the small mammals captured in the Hardwoods site, 88 % of the small mammals captured on the Spruce Swamp, and 90 % of the small mammals captured on the Spruce Barrens. Since shrews are carnivorous they may not be confined by vegetation requirements as strictly as the mice and voles, which are more herbivorous than shrews.

Shrew Trappability

Although some authors have had success with trapping the larger shrew species using live traps (Dapson, 1968), the most successful way of sampling all shrew species has been with the pit-fall or tumble trap (Buckner, 1955). It has also been determined that the mortality of trapped shrews is lower with this method of trapping (Buckner, 1957).

What shrew behavior has been responsible for the success of this trapping technique? The term "tumble trap" suggests that the animal, while racing along, steps headlong into an empty container. However, possibly the shrews investigative curiosity and lack of knowledge concerning natural sheer vertical surfaces may be the behavioral cause behind pit-fall trapping.

In an attempt to explain the reduced trappability of shrews at cooler temperatures (see Figure 13 & Table 19), various lines of reasoning were explored. As the temperature decreases, the metabolism would increase in order to maintain body temperature. Because of increased metabolism, a shrew would need to increase its food intake, therefore increasing its activity in search of food. However, if shrews were more active one would expect more of them to be falling into traps more frequently at lower temperatures. Perhaps, because of increased metabolism a shrew must concentrate on finding food, and may have less time or desire to investigate the surroundings and is therefore less susceptible to pit-fall trapping.

Lower temperatures may cause shrews to seek warmer areas, causing them to "hunt" in a deeper stratum of the forest floor. Since shrews are active burrowers and readily explore natural holes or burrows of other animals, decreasing temperatures may cause them to spend a greater percentage of time below ground rather than on the surface where they are susceptible to pit-fall traps.

Burrows or holes were commonly seen in the Hardwoods, Spruce Swamp, and Spruce Barrens but were scarce to nonexistent in the Bog site. The reduced trappability at lower temperatures was observed on all four habitats. Although not conclusive, this may support the reasoning that shrews are still active on the surface but are not as investigative at these cooler temperatures.

Although rain did occur during the trapping periods, no relationship was observed between it and trapping success.

These questions concerning shrew behavior and temperature could be answered by further study using an artificial situation in which temperatures are controlled and shrew activity monitored on various predesigned habitats. This could also help answer questions concerning shrew behavior during times of snow cover.

<u>Invertebrate Fauna Composition and Biomass</u>

Tables 6-10 list the invertebrate fauna collected in each habitat. If the 1973 invertebrate index values of abundance are compared between habitats, relatively little variation is observed from one habitat to another. The only habitat noticeably different was the Spruce Barrens because its highest index value was for formicids which, on other habitats were considerably lower in abundance.

Both the Hardwoods and the Spruce Swamp were sampled twice in 1973, so as to note any change in invertebrate fauna composition during this period (see Tables 6 & 7). When the invertebrate index values of abundance were compared between May and August on these two habitats, little change in invertebrate fauna composition was observed.

To determine the relative quantity of invertebrates available to shrews in each habitat, the mean dry weight of the invertebrates collected from ground litter samples was used to determine the invertebrate biomass (see Table 3). While the difference between habitats with respect to invertebrate composition was not always apparent, the invertebrate biomass varied considerably from one habitat to another.

However, when the 1973 invertebrate biomass estimates, from the May and August sampling periods of the Hardwoods and Spruce Swamp sites, were compared by a t-test no significant difference of means was observed. When the biomass estimates were compared between these two sampling periods at specific trap sites, variation was observed, but again a t-test between mean weights showed no significant difference.

This may suggest that the invertebrate productivity of a natural habitat type remains relatively constant during the productive periods of the year with no sizeable areas extremely high or low in invertebrate biomass. Although certain invertebrate groups may vary in the amount of biomass they tie up at certain times in the year, those invertebrate types best suited to a habitat will consistently control the major portion of the total biomass. This is supported by Voute (1946) who found that insect populations in cultivated forests fluctuate violently, whereas in virgin or mixed forests the populations are more stable.

Shrew Stomach Analysis

Other published reports of stomach analysis of shrews have not been specific regarding the habitat of the subjects.

I attempted to determine whether food selection by a species of shrew remained the same or varied between habitat types. If the proportion of the food items in a species stomach varies from the proportion of these items present in the ground litter, selection is taking place. Or, if the food items selected by a species remains the same on all habitats, even though this item is present in varying amounts in these habitats, they are high preference foods and are actively being sought out by a shrew species. However, if these food selections by a species are inconsistent between habitats, shrews very likely are feeding primarily on those invertebrates most abundant in a habitat rather than searching out high preference foods.

In examining stomach analysis data collected, the only species that appeared to select the same food item on different habitats was Blarina. In the Hardwoods site (see Table 11) 83 % of the food, by volume, consumed by 3 Blarina was coleoptera material. In the Spruce Barrens 3 Blarina had nothing but coleoptera material in their stomachs (see Table 14). But in this case the only material present consisted of small pieces of elytra, which may have remained in the stomachs longer because of their slower digestibility. However, because of the low number of stomachs analysed, this observation is only tentative.

Buckner (1964), dealing with food preferences and caged shrews, found that to some degree the food items eaten by shrews appeared to be related to the abundance of the prey species.

Some work has also dealt with shrews being predatory on other small mammals (Eadie, 1944, 1948, 1952; Maurer, 1971). Two specimens of Sorex cinereus, in this study, had small mammal remains in their stomach. One shrew had eaten another shrew while in the trap (see Table 12). The other was not in a trap with another small mammal, but yet had a small amount of mouse or vole hair in its stomach along with other food material (see Table 12). This shrew may have killed and eaten a mouse, fed on mouse carrion, or possibly had been in a fight and had ingested a few pieces of hide.

I feel that within normal population levels, shrew-mouse predation is uncommon and has little consequence to either species. However, if large population levels of both occur, confrontation probably increases and detrimental effects may occur to the mice populations.

Shrew Food Selection

The size, taste, smell (Holling, 1958), texture, activity, density (Errington, 1946), or niche location of a prey species and characteristics of the predator (Holling, 1959) may all affect a prey's likelihood of being consumed. Although some work has been completed on caged shrews with regards to food preferences (Mosely, 1930; Buckner, 1964), more work in this area may yet answer many questions concerning shrew preferences.

Of these variables, size may be the easiest to determine. When examining the invertebrate fauna collected from various habitats, soil mites, collembola, and pseudoscorpionids were extremely abundant on all habitats. But they were seldom, if ever, found in the stomachs of shrews (see Tables 11 to 15; Whitaker and Ferraro, 1963; Whitaker and Mumford, 1972; Whitaker and Schmeltz, 1973; Hamilton, 1930, 1941). This may be either because they are rapidly digested or because they are so small (< 1 mm) that they fail to stimulate the feeding response of most shrew species.

Other invertebrates collected, such as certain dipterous larvae, coleoptera larvae, and annelids also fall in this size class and may also be ignored by many shrews. This observation may be partially supported by Buckner (1964) who stated that *Blarina*, exhibited preferences which appeared to be related to prey size.

As stated previously, formicids were the most numerous invertebrate found on the Spruce Barrens. If ants are low preference food for shrews (Buckner, 1964) they would seldom be selected, therefore greatly reducing the available food biomass to shrews in this habitat. This could account for the low shrew biomass in the Spruce Barrens, even though the habitat supported a relatively high amount of invertebrate biomass (see Table 3).

Correlations Between Shrew and Invertebrate Biomass Density

An attempt was made to correlate shrew densities with invertebrate densities not only between habitats but also within separate habitats.

A significant correlation was observed when the invertebrate biomass and shrew biomass was compared in the Hardwoods, Spruce Swamp, and Spruce Barrens (see Figure 12). The Hardwoods site had the highest 1972 and 1973 invertebrate estimates and also the highest 1972-1973 shrew biomass, the Spruce Swamp was next highest in productivity and the Spruce Barrens last.

However, when the correlation between invertebrate and shrew density was examined within habitats by comparing the mean invertebrate weights around traps that captured zero, one, two, or three shrews (see Table 18), or when the mean invertebrate weight around successful traps was compared to unsuccessful traps (see Table 17), no significant correlation was observed.

Since this invertebrate - shrew biomass correlation can be observed between habitats but not within habitats, it may support the previous statement that invertebrate biomass within a separate habitat is relatively constant. Shrew densities within a habitat are more likely controlled by some habitat characteristic rather than an abundant food supply in a specific area of this habitat.

Very little difference in invertebrate fauna composition was observed between most habitats, although this could result from the broad taxonomic groupings used. What little difference that was found to exist among invertebrates could not account for the variation in abundance of the different shrew species in these habitats. It appears that some habitat characteristic, other than the kind of food available, may determine what species of shrews occupy a habitat and the invertebrate quantity may determine in part to what the shrew population levels will be.

Holling (1959) found that S. cinereus populations had a marked response to increased prey densities both in a functional and numerical manner. Blarina however did not respond numerically to increased prey density and Holling suggested that some other agent was limiting their numbers. Perhaps Blarina was affected more strongly by some prey characteristic than S. cinereus, possibly the prey's niche location.

Habitat Characteristics Affecting Shrew Species

Habitat characteristics, other than food supply, affecting shrew densities have been investigated by a few workers. Buckner (1966) has shown a significant correlation between *S. arcticus* and the depth of water tables in southeastern Manitoba. On various habitats Buckner found that the deeper the water table the higher the arctic shrew populations tended to be.

Only eight specimens of *S. arcticus* were captured during this study, four in the Hardwoods and four in the Bog. The Hardwoods site may have had a deep water table but the water table in the Bog was less than a few centimeters below the surface, thus these limiting data do not support Buckner's correlation between arctic shrews and the depth of water table.

As discussed previously, population levels seemed to be high in 1972. If this were true, arctic shrews may have been occupying marginal habitat, which may have accounted for their presence in a bog habitat (Odum, 1971).

Although the Hardwoods and White Pine - Hardwoods sites both produced a relatively high density of small mammals, *S. cinereus* was never captured on either of these upland sites. Buckner (1966) found that the densities of *S. arcticus* tend to vary inversely with the densities of *S. cinereus*. The Hardwoods, which caught 4 *S. arcticus* and no *S. cinereus*, supports this, however, 1972 Bog does not since it captured 4 S. arcticus and 6 S. cinereus. Again this limited information does not support Buckner's findings. Buckner's inverse correlation between S. arcticus and S. cinereus may suggest that those habitat requirements essential to S. arcticus may somewhat detrimentally affect S. cinereus.

Getz (1961), when examining the relationship between habitat characteristics and shrew species location, found moisture to be the main factor in determining the presence or absence of Blarina and S. cinereus on habitats in southeastern Michigan. Blarina preferred dry conditions whereas S. cinereus preferred a more wet habitat. The only importance Getz found concerning habitat cover was its role in regulating the moisture conditions in an area.

Morris (1955) found that small mammal populations are very much related to the percent ground cover, since it decreases the effectiveness of predators. Buckner (1966) found no indication of predators or parasites as important factors in shrew population dynamics.

Buckner's reasoning was that the activity of shrews above ground during the day was quite restricted, therefore limiting diurnal predators, as the hawk. Owls, however, are active when the shrews do forage above ground, but Buckner could not successfully relate shrew population trends to changes in the owl population. He also could not correlate mammalian predators with trends in the shrew populations.

Verme (1968), when examining the small mammal populations in various habitats in the Upper Peninsula of Michigan, found that the younger even-age stands were least productive of small mammals, despite lush ground cover.

Although this study did not concern itself with shrew predation one obvious aspect concerning ground cover was noticed. Cover in the Spruce Swamp, was considerably heavier than in the Bog site. Both, however, produced relatively the same number of shrews when trapped in 1972 (see Table 16). Cover may have some bearing upon shrew predation but it does not seem to be a major factor in shrew abundance.

Conclusions

The major conclusions, concerning shrew population dynamics, resulting from this study, are as follows:

1. Shrews seem to utilize habitats of a wider variety than mice or voles.
2. Colder nights during the summer period may cause a change in shrew behavior.
3. Invertebrate fauna composition, based upon this study's taxonomic groupings, varied little between most habitats.

4. Invertebrate standing crop was found to be directly related to the shrew standing crop.
5. The only prey characteristic observed, that appeared to affect shrew selection, was a prey's size.
6. Invertebrate biomass, in an area, seemed to be more important in regulating shrew abundance than the invertebrate fauna composition.

Further investigation of the population determinants for each shrew species is basic to a better understanding of their function in the habitat communities.

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