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The Distribution, Ecology and Natural History of Shrews (Insectivora: Soricidae) in Southern West Virginia

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THE DISTRIBUTION, ECOLOGY, AND NATURAL HISTORY OF SHREWS (INSECTIVORA : SORICIDAE) IN SOUTHERN WEST VIRGINIA

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by

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ABSTRACT

A survey of the soricid (shrew) fauna of southern West Virginia was conducted between May 16, 1994 and May 27, 1995. Twenty-five sites were established in Mercer and Summers counties within seven habitat types. Pitfall traps were used and through a limitation of fluid depth within the trap the selectivity for soricids was increased to over 83% of the total capture. Overall, a total of 653 shrews comprising seven species (*Sorex cinereus*, *S. longirostris*, *S. fumeus*, *S. dispar*, *S. hoyi*, *Blarina brevicauda*, and *Cryptotis parva*) was captured. Two of the species taken (*S. hoyi* and S. dispar) are new county records for Mercer County. Another species taken (*C. parva*) had not been captured in West Virginia since 1969. Principal component and canonical discriminant analyses were conducted on a series of environmental data taken at each trap in order to assess the influences of environmental features on the distribution of shrews. Habitat preference for each species was determined and population analyses of temporal activity patterns, age class structure, sex ratios, and breeding season were performed. Soricid community analyses conducted included diversity and similarity indices comparisons of habitat type. Peaks in soricid activity were seen during the year and were highly correlated with precipitation levels. A shift from epigeal to hypogeal activity was also seen in all species. Soil moisture was found to be the most important influence in the microhabitat selection by shrews. Population structure and reproductive analyses indicate that in southern West Virginia shrews are annual in nature, being born in early summer, over-wintering as juveniles, breeding in early spring, and then dying by mid-summer.

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All specimens in this study were collected under WVDNR permit numbers 75-1994 and 37-1995. Voucher specimens were deposited in the Marshall University Mammal Collection (MUMC).

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INTRODUCTION

Shrews (Insectivora : Soricidae) are currently recognized as being a prominent part of almost every terrestrial habitat. In many areas, they may be the most abundant small mammal present. There are currently 20 genera and 266 species which have been identified in the world (Nowak and Paradiso 1983). Of these, four genera and 33 species occur in North America (Hall 1981). Within West Virginia, eight species representing three genera are present (WV DNR), several of which occur sympatrically in some areas of the state.

In order to initiate a study of shrews an understanding of their biology and habits was necessary. This was accomplished by means of a literature review of current material in the field of mammalogy, ecology, and animal behavior. After completing this search, the unique characteristics and behaviors that distinguish shrews from other small mammals could be seen. A summary of this review, including taxonomy, physiology, behavior, ecology, and identification is contained in the following sections.

TAXONOMY

Class : Mammalia
Order : Insectivora
Family : Soricidae
Sub-Family : Soricinae

Tribe :	Soricini (Long-tailed shrews)	Blarinini (Short-tailed shrews)	
Genera :	*Sorex*	*Blarina*	*Cryptotis*
Species :	*cinereus* -Masked shrew	*brevicauda*	*parva*
	longirostris - Southeastern shrew	Short-tailed shrew	Least shrew
	fumeus - Smoky shrew		
	hoyi - Pygmy shrew		
	dispar - Long-tailed shrew		
	palustris - Water shrew		

Morphologically, shrews exhibit a generalized body plan with plantigrade locomotion. The sense of sight in shrews is poorly developed and primarily allows the detection of differences in light intensity (Branis and Burda 1994). Olfactory and tactile senses are well developed and are used effectively in the location and capture of food. Some echolocation, using high frequency twitters and squeaks, assists in navigation and prey location. Other vocalizations, in the form of coarse churls, are used during encounters between individuals. Olfactory development allows shrews to find prey while probing into crevices of logs, through leaf litter, and in soil interstices (Holling 1958; Pernetta 1977). The pigmented dentition is highly specialized for their insectivorous habits; the upper jaw dentition consists of an enlarged procumbent first upper incisor having two hook shaped cusps, a series of four or five unicuspids, and four grinding teeth with sharp cusps arranged in a W-shaped pattern. These dental characteristics assist in the grasping and breaking up of the chitinous exoskeletons of the insect prey which makes up the majority of their diet.

Metabolically, due to their high surface area to volume ratio, shrews must produce enormous amounts of energy in order combat rapid heat loss and death. The shrew *Sorex cinereus*, a fairly common West Virginia shrew species, has been determined to use 9.0 ml O_2 per gram per hour (g.hr), while a mouse under similar circumstances uses 1.8 ml of O_2/g.hr (Klieber 1961, in Churchfield 1990). It is plain to see from this comparison that shrews are metabolically quite unique from the average small mammal. Because of their high metabolic rate and minimal fat storage, shrews must feed at least every two to three hours, day and night, throughout the year

(Sorenson 1962; Churchfield 1990). Shrews are resistant to cold and hot temperatures and adverse weather but are very susceptible to starvation. Deprived of food most shrews die within a matter of hours. This high demand for food almost completely dominates the behavior of shrews during their life. Shrews spend most of their time foraging in a random, but very thorough way. They cover as much area as possible, as quickly as possible, only pausing to probe into crevices for food and quickly devour its prey. On three occasions I have seen this behavior and was impressed with the size of the area covered by the shrew. The whole time it uttered a series of twitters and chirps as it moved through the litter and under logs.

An additional note of importance is that shrews recently have been recognized as potential environmental indicator organisms for heavy metal pollution. Pankakoski et al. (1994) examined the levels of heavy metals among various species of small mammals in Finland. Shrews, with their high metabolism and insectivorous diet, eat large quantities of invertebrates which accumulate large amounts of heavy metals. These heavy metals have been found to accumulate in the organs of the shrew's body (liver and kidneys) which then can be detected through plasma-emmision and atomic spectrophotometers, and a gold film mercury analyzer. Pankakoski found that shrews accumulate significantly higher amounts of cadmium, lead, copper, and mercury than other small rodents.

In West Virginia, studies have been conducted on the effects of dimilin on non-target species of insect (Sample, 1991). Research should be conducted to analyze the effects of the dimilin on small mammal populations, especially shrew populations.

Seidel (1987) investigated the effects of dimilin on *Peromyscus* (White-footed mice). If non-target insect species are being killed, the reduction in insect populations will in turn effect shrew populations by reducing the food resources present in a treated area. Dimilin may also have a direct effect on the shrews when the killed insects are directly ingested.

Shrews have adapted to many habitats and a variety of lifestyles ranging from terrestrial to semi-aquatic. Most shrews are terrestrial and considered epigeal organisms, spending most of their time foraging on the surface of the ground among leaf litter and logs. Some species have more hypogeal lifestyles for the majority of their foraging, searching tunnels of other organisms and the crevices between rocks and within the soil for prey. The great need for food resources requires that, depending on the habitat type and population density, each individual has a large home range. Population densities of up to 124 individuals per hectare have been found in certain habitats (Hamilton 1940; Merrit 1987). Buckner (1966) determined the home range of *Sorex cinereus* to be 5,549 m^2. Other species (*Cryptotis parva*) have larger home ranges of up to 12,000 m^2 (Choate and Fleharty 1973). Within these home ranges fairly distinct territories are established, overlap only slightly, and do not change much with season (Buckner 1966).

The life span of shrews, depending on the species, appears to range from 13 to 18 months with breeding occurring in the spring and early summer (Hamilton 1940; Churchfield 1990). Young become sexually mature over winter and breed the following year. Considering the high metabolic demands, competition for resources, and predation by a number of organisms (owls, foxes, snakes, weasels, cats), shrews have a difficult time surviving to reproductive maturity. Churchfield (1990) found that only 40 to 50% of individuals born into the summer population survive to six months of age and that only 20-30% survive to breed. Hamilton (1940) proposed that almost the entire shrew population (75-80%) dies off in late summer (August) and that fewer than 25% of all individuals of small shrew species (*Sorex*) survive through the winter. Larger species (*Blarina*) also suffer great losses with only approximately 60% of the population dying. This fact alone sets shrews apart from most other small mammals which do not undergo such drastic population fluctuations.

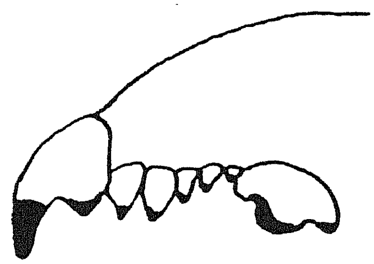
IDENTIFICATION

Although some soricids (shrews) found in West Virginia can be identified accurately by external features and measurements (tail length, body size, pelage color, etc.), most can be positively identified only by examining cranial and dental characters. Two species which are fairly easy to identify by external characters are *Blarina brevicauda* and *Cryptotis parva*. These two are morphologically separated from the other shrews in the state by their short tail length (<15 mm). *Blarina brevicauda*, the largest soricid in the state, is easily recognized by its large size and average weight of 18 grams when compared to *Cryptotis parva* which is smaller in size and weighs an average of five grams. Identification of the *Sorex* species present in the state must be verified by examining cranial and dental features (Figures 1 to 4).

DISTRIBUTION

Figures 5-8 depict the general range of the eight shrew species in West Virginia.

Figure 1. Dental characteristics of *Sorex cinereus* (top) and *Sorex longirostris* (bottom). Adapted from Caldwell (1982).



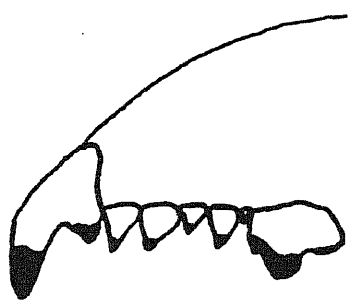


Figure 2. Dental characteristics of *Sorex fumeus* (top)

and *Sorex dispar* (bottom).

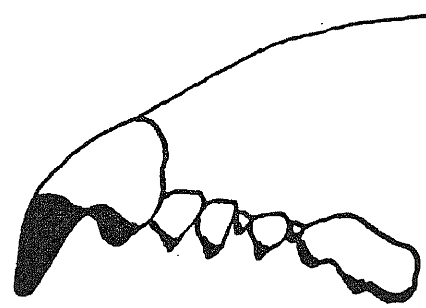
Adapted from Caldwell (1982).

Figure 3. Dental characteristics of *Sorex hoyi* (top)

and *Sorex palustris* (bottom).

Adapted from Caldwell (1982).

(Not drawn to scale)



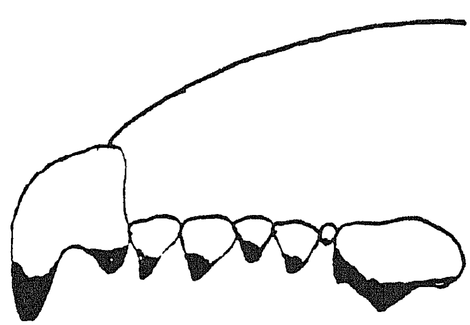


Figure 4. Dental characteristics of *Blarina brevicauda* (top)

and *Cryptotis parva* (bottom).

Adapted from Caldwell (1982).

(Not drawn to scale)

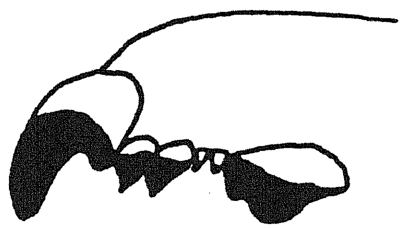
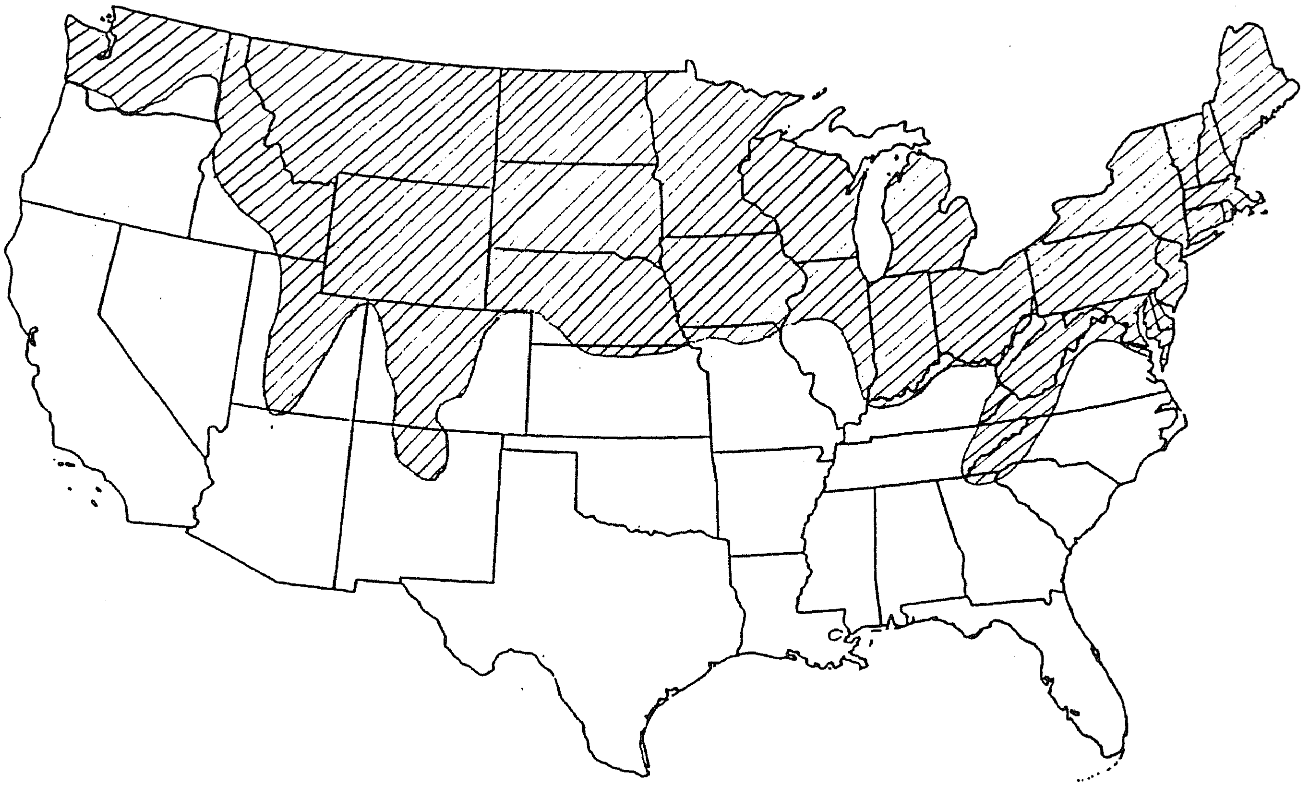


Figure 5. Distribution of *Sorex cinereus* (top) and *Sorex longirostris* (bottom) in the United States.

Adapted from Hall (1981).



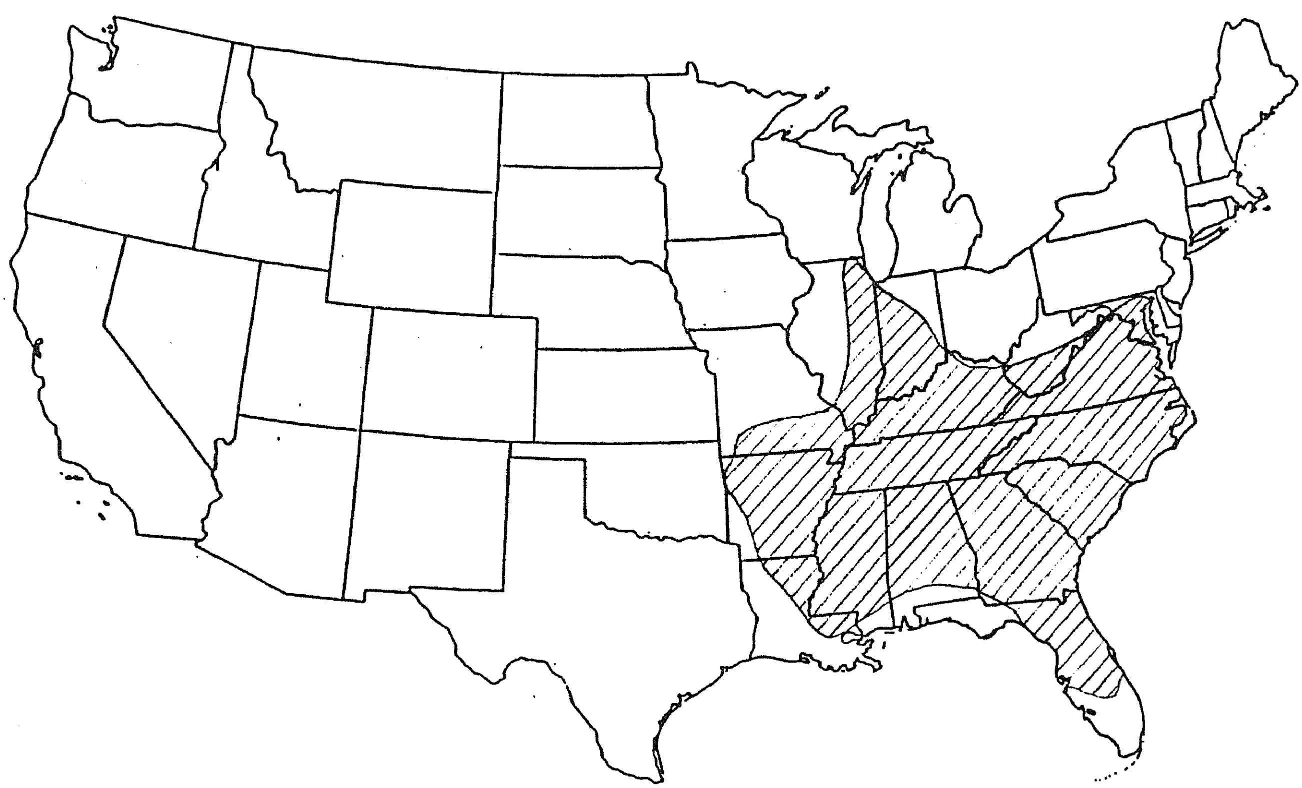


Figure 6. Distribution of *Sorex fumeus* (top) and *Sorex dispar* (bottom) in the United States.

Adapted from Hall (1981).

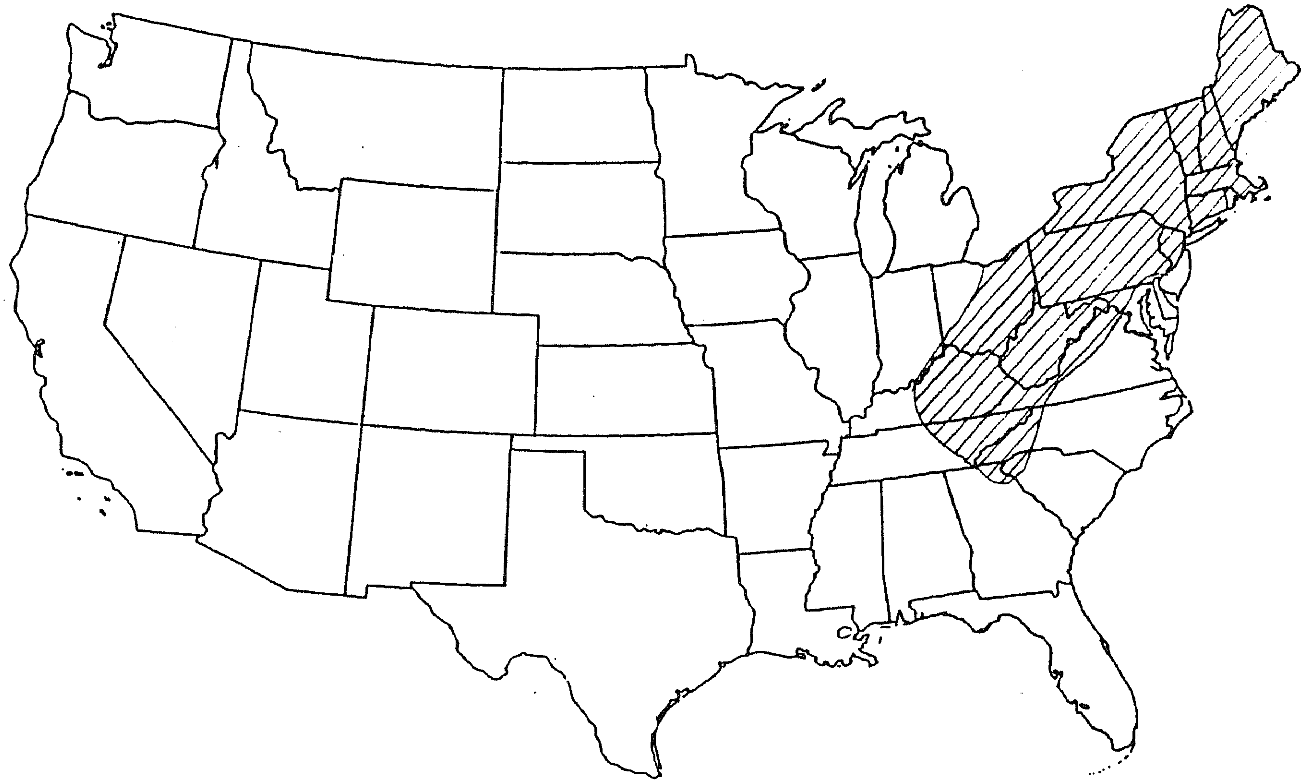
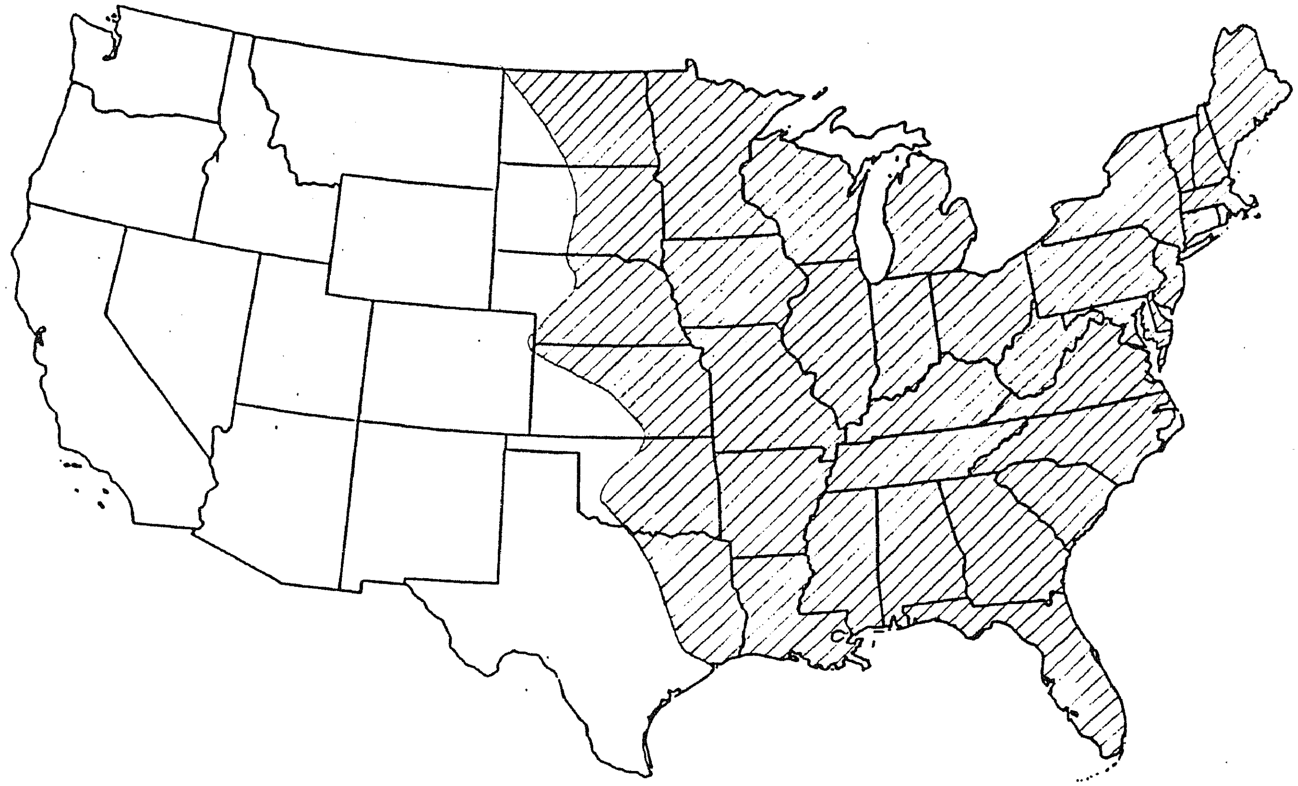


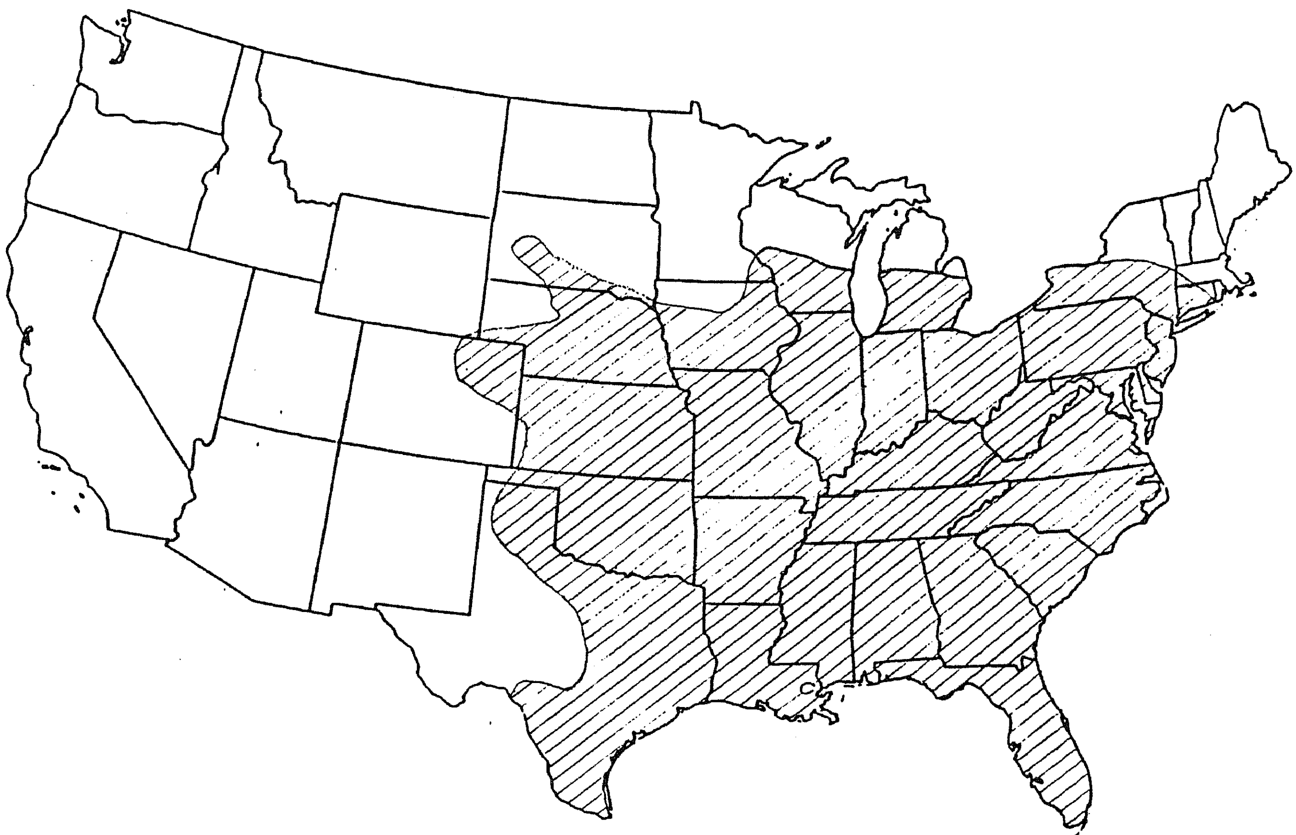
Figure 7. Distribution of *Sorex hoyi* (top) and *Sorex palustris* (bottom) in the United States.

Adapted from Hall (1981).

Figure 8. Distribution of *Blarina brevicauda* (top) and *Cryptotis parva* (bottom) in the United States.

Adapted fron Hall (1981).





Within West Virginia, the earliest and most extensive small mammal surveys have been carried out in the eastern part of the state in Randolph, Pocahontas, and Tucker counties. McKeever surveyed the mammals of West Virginia in both a Conservation Commision project (1951) and in a Ph.D. dissertation (1954). These surveys mainly assessed the presence of absence of species within areas in the state. Within states neighboring West Virginia the distribution and habits of shrew species have been examined fairly extensively (Caldwell 1982; Pagels 1988; Bryan 1991; Cawthorne 1994; Kirkland 1994; Pagels 1994).

One purpose of this study was to tie together the work done in the northeastern portions of the state and the work done in adjacent states to the south. The absence of research in southern West Virginia, along with the unique biology, secretive habits, and lack of distributional data of shrew species led to this study. The main objectives of my study were to:

1.) Conduct a thorough and systematic survey of shrew species present in southern West Virginia.
2.) Collect data on the habitat preferences of shrew species in West Virginia.
3.) Assess the selectivity of pitfall traps for shrew species and determine if manipulation of the pitfall set-up can increase selectivity for shrews.
4.) Examine the population structure of shrew species in southern West Virginia by looking at activity patterns, age classes, sex ratios, and breeding season.
5.) Examine community structure of shrew species present in southern West Virginia.
6.) Contribute research material to the Marshall University Mammal Collection for future studies.

METHODS

In order to assess the soricids present in an area, it was necessary to use a trapping method that accurately and efficiently sample these small mammals. Conventional small mammal sampling methods produce inaccurate results for small mammal species such as shrews (Kirkland *et al.* 1990; Kalko and Handley 1992; Handley and Kalko 1993). These sampling methods, using snap traps and Sherman live traps, fail to capture shrews due to their small size and light weight. Shrew species do not weigh enough to trip traps which were originally designed for larger mice and voles. Pitfall traps are more accurate in representing the mammalian fauna in an area by capturing specimens of all species present regardless of size or behavior (MacLeod and Lethiecq 1963; Gibbons and Semlitsch 1981; Williams and Braun 1983; Bury and Corn 1987; Mengak and Guynn 1987; Kalko and Handley 1992). Kirkland *et al* (1990) investigated this problem and developed a "standard protocol" for the use of pitfall traps in field studies of mammalian communities.

A modification of this method was used in my study. In contrast to Kirkland's method of using three branched drift fence-pitfall arrays, I used a series of line transects of pitfall traps placed through various habitats in portions of Mercer and Summers Counties in southern West Virginia.

Pitfall Trap Construction and Manipulation

The pitfall traps consisted of cylindrical open topped plastic containers approximately 15 cm wide and 18 cm deep. These traps were buried in the ground with the top edge even with or just below the surface. They were filled to a depth of approximately one inch with a 5-7% solution of formalin in order to preserve any specimens captured until they were removed. The formalin also prevented any ingestion of early captures by animals entering the trap later. To examine pitfall selectivity for shrew species, the fluid depth in the trap was limited to less than 1.5 inches. I hoped that by limiting the fluid depth it would allow larger mammal species, such as mice and voles, to escape by pushing off of the bottom of the trap, below the fluid, and jumping out. An analogy is that if a person fell into a swimming pool they would be unable to jump out of the deep end because they could not reach the pool floor. In contrast, in the shallow end of the pool, the person could "escape" the pool by pushing off the bottom. The level of fluid within the trap was limited by the placement of a small hole (1/8 inch) in the side of the trap at a height of approximately 1.5 inches from the bottom. This hole prevented the trap from filling with precipitation to a depth greater than 1.5 inches.

Traps were placed along natural objects (logs, rocks, etc) which served as drift fences to increase the effectiveness of the trap by "funnelling" organisms toward the pitfall. Examples of typical pitfall placement are shown in Figure 9. Ideally, traps placed in areas not having natural drift fences should have artificial drift fences. Due to the high cost and difficulty of one person set-up these were not used.

Field Data

A variety of descriptive field data was taken at each trap during placement. These field data included habitat type, elevation, slope, aspect, dominant vegetation species present, litter depth and composition, soil texture and composition, and soil

Figure 9. Representative examples of pitfall trap placement.

moisture. Habitat type assesment was based on dominant vegetation types in association with certain consistent environmental factors (i.e. moisture, slope, aspect, and elevation). Elevation was determined for each trap by using USGS topographic maps and was field checked using a Navistar Global Positioning Systems unit. Coordinates (longitude and latitude) of sites were also checked using this unit.

The slope and aspect were determined using a Suunto orienteering compass with built-in clinometer. Vegetation of the area was assessed through a direct examination of the species present near the trap. Tree species (> 2 meters mature height) present within 20 meters of the trap were examined for both size and number present. The three or four largest and most abundant tree species were recorded at each trap as being the dominant species. Herb layer species (< 2 meters mature height) within 10 meters of each trap were examined for percent cover. Once again, the three or four species most abundant at each trap were recorded as being dominant. All plants were identified using the Flora of West Virginia (Strausbaugh and Core 1977). Litter depth was measured to the nearest centimeter at each trap. The final environmental parameters of litter composition, soil texture and composition, and soil moisture were recorded as a value based on a partially subjective set of definitions for each (Table 1). This reduced the amount of equipment required in the field yet still provided useful data for use in the statistical analyses. Each of these numerical representations (parameter codes) shows a trend in the environmental variable from one extreme to another (i.e. dry to saturated soil, poor to rich soil, etc.). Eight categories for litter composition, ranging from bare soil to leaf litter and logs, were

Table 1. Characteristics of Parameter Codes used for field data.

	ENVIRONMENTAL PARAMETER VALUE								
Parameter	1	2	3	4	5	6	7	8	0
HABITAT TYPE	Disturbed Area	Cultivated / Grazed	Flood Plain	Stream Bed	Coniferous Forest	Old Field	Edge	Mixed Deciduous	---
LITTER COMPOSITION	Bare Soil	Branches (< 2in.)	Rocky	Logs (>2 in.)	Thick Vegetation	Leaf	Leaf and Branch	Leaf and Logs	---
SOIL NUTRIENT	Poor	Moderate	Rich	---	---	---	---	---	---
SOIL TEXTURE	Compact	Loose	---	---	---	---	---	---	---
SOIL COMPOSITION	Gravel / Rocks	Clay	Sandy	Silt	Loam	---	---	---	---
SOIL MOISTURE	Dry	Moist	Wet	Saturated	---	---	---	---	---
ASPECT	North Facing	Northeast Facing	East Facing	Northwest Facing	Southeast Facing	West Facing	Southwest Facing	South Facing	None

determined. Soil nutrient classification was based on the amount of organic matter present in the soil and the color of the soil. Dark soils high in organic matter were classified as being rich, pale thin soils with no presence of organic matter were classified as poor soils. Soil texture was assessed by looking at the core of soil removed during pitfall placement. If the soil clung together in a hard mass and was difficult to dig, it was considered compact. If it dug with little effort and crumbled easily, it was considered to be loose. Composition of the soils was determined by looking at the particulate make up of the soils; whether it was sandy, silty, rocky or a mixture of these. This variable ranged from rocky to loamy soils. Soil moisture was examined at a depth of approximately two inches below the leaf litter. Soils that released no water when squeezed were categorized as dry. Soils that left the hand wet when squeezed were categorized as moist. Soils that released several drops of water when squeezed were categorized as wet. Soils were considered saturated when the hole dug for the trap at least partially filled with water during trap placement. Differences in environmental characteristics due to weather differences during trap placement over time did not exist due to all sites being placed during a three week period that had no drastic differences in weather patterns.

Trapnights

In order to compare accurately the samples taken at each site with one another when varying numbers of traps and trapping periods existed, a method to standardize the samples was necessary, This was most easily accomplished by calculating the number of captures of a species per unit trapping effort, or captures per trapnight.

Trapnights (TN) are calculated by multiplying the number of traps set in an area times the number of nights the traps were in place. For example, whether ten traps are set out and checked after ten nights or four traps are set and checked for 25 nights the total trapping effort would be 100 trapnights in either case. This standardization allows comparisons of all sites regardless of the number of traps present or the period of time the traps were out.

Specimen Preparation

Voucher specimens were deposited in the Marshall University Mammal Collection (MUMC) housed in the N. Bayard Green Vertebrate Museum at Marshall University. Specimens were prepared by standard museum methods as skull and alcoholic (SA) specimens. This consists of recording the standard external measurements, removal of the cranium, and storage of the body in a 70 % solution of ethyl alcohol. Standard external measurements are:

TTL - Total length of organism from tip of nose to end of tail vertebrae in millimeters
TLL - Tail length from base of tail to end of last vertebrae in millimeters when held dorsally perpendicular to long axis of the specimen's body
HF - Greatest length of hind foot from heel to tip of longest toe nail in millimeters
EL - Ear length from notch at base to tip of pinnae in millimeters
WT - Total weight to the nearest half gram.

In addition, gender, reproductive condition (both current and past), and age of specimens were determined and recorded. In order to determine the gender and reproductive condition of a specimen accurately, it was necessary to examine each one externally and internally with a dissecting scope. Each specimen was examined using the criteria for reproductive status of shrews presented by Churchfield (1990). Males externally, if sexually mature and breeding, exhibited an enlargement of the testes producing an inguinal swelling anterolateral to the anus. These specimens are considered to be sexually mature and are termed scrotal. Females externally, if mature, usually exhibit enlarged nipples; visible nipples are absent from all males. On mature specimens, the length and width of the testes were taken for males and the presence of embryos or placental scars was recorded for females. These are the only reliable external methods to determine the gender of the shrew if it is mature.

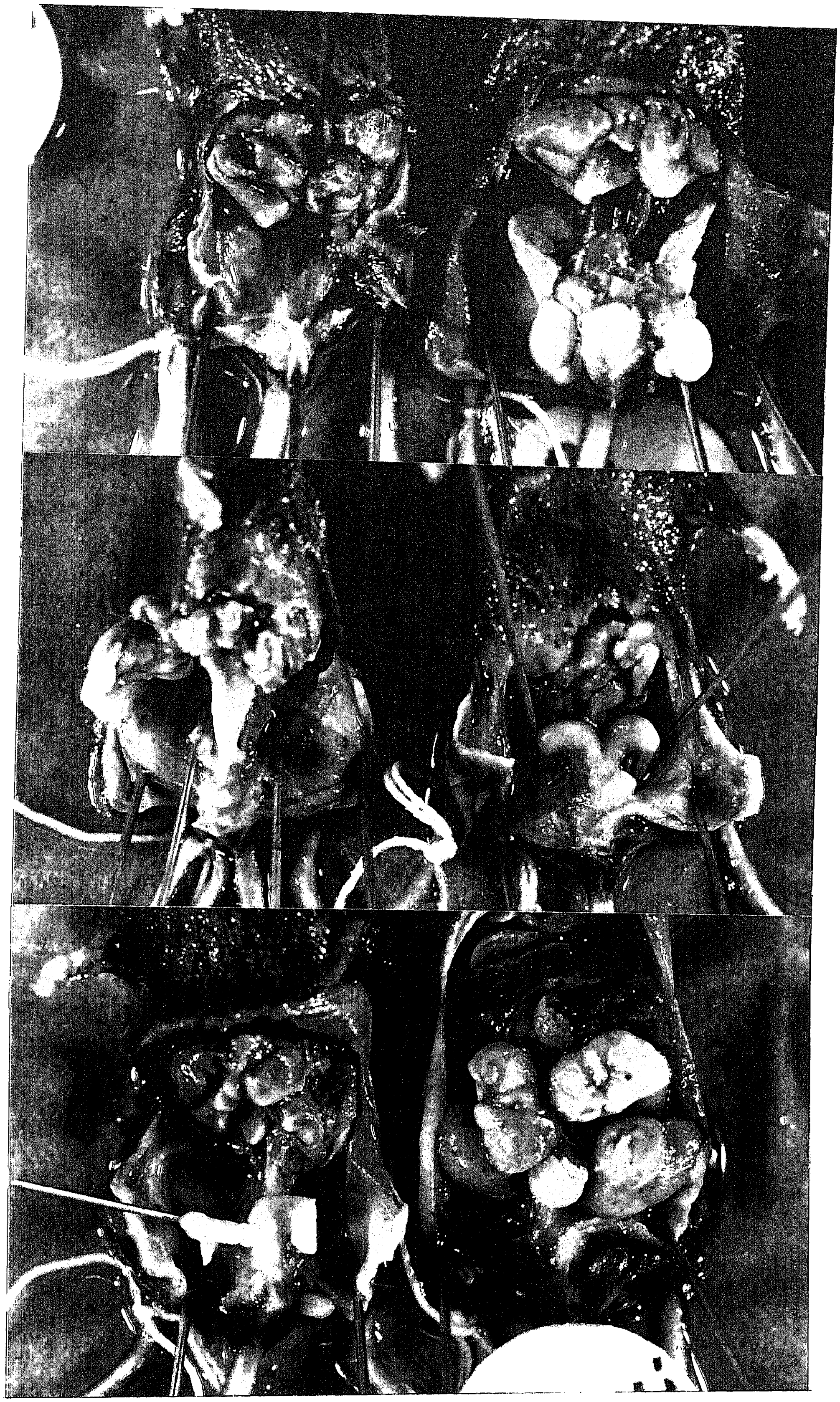
Immature shrews pose a completely different and difficult problem in gender identification. Immature shrews lack the scrotal swelling or enlarged nipples that older, sexually mature shrews posess. The gender of immature shrews can only be determined reliably through internal examination. Internally, though very small in size, the anatomy of male and female shrews is distinctly different and can be used to accurately determine the gender of the specimen regardless of the age of the shrew.

After determining the gender of each specimen, it was necessary to establish the reproductive condition of the specimen. A listing of the various reproductive classes and their characteristics is found below. Figure 10 presents an example for each of the reproductive conditions.

* Male Scrotal - MS - Visibly enlarged testes forming a scrotal sac.
* Males Non-Scrotal - MNS - No visible enlargement of the testes.
* Female Non-Parous - FNP - No placental scars or embryos present.
    - Immature Non-Parous- INP - Vagina and uterine horns relatively small, membranous, and transluecent. Juvenile.
    - Mature Non-Parous - MNP - Vagina and uterine horns muscular and opaque, often curved into short rams horn shape. Adult.
* Female Parous - FP - Presence of placental scars on uterine horns. Adult.
* Female Parous Lactating - FPL - Presence of placental scars and enlarged nipples and mammary glands. Currently nursing litter. Adult
* Female with Embryos - FE - Currently pregnant with embryos present in uterine horns. Adult.

Figure 10. Reproductive conditions of *Sorex cinereus* (from top to bottom).

Left	Right
Non-scrotal male	Scrotal male
Immature, non-parous female	Mature, non-parous female
Parous female	Pregnant female

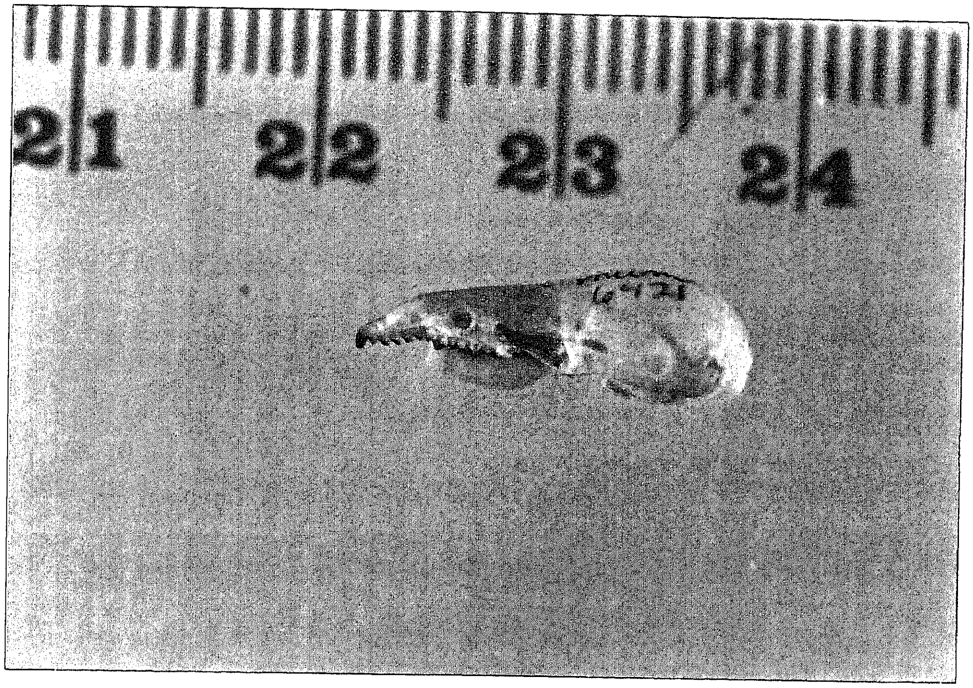


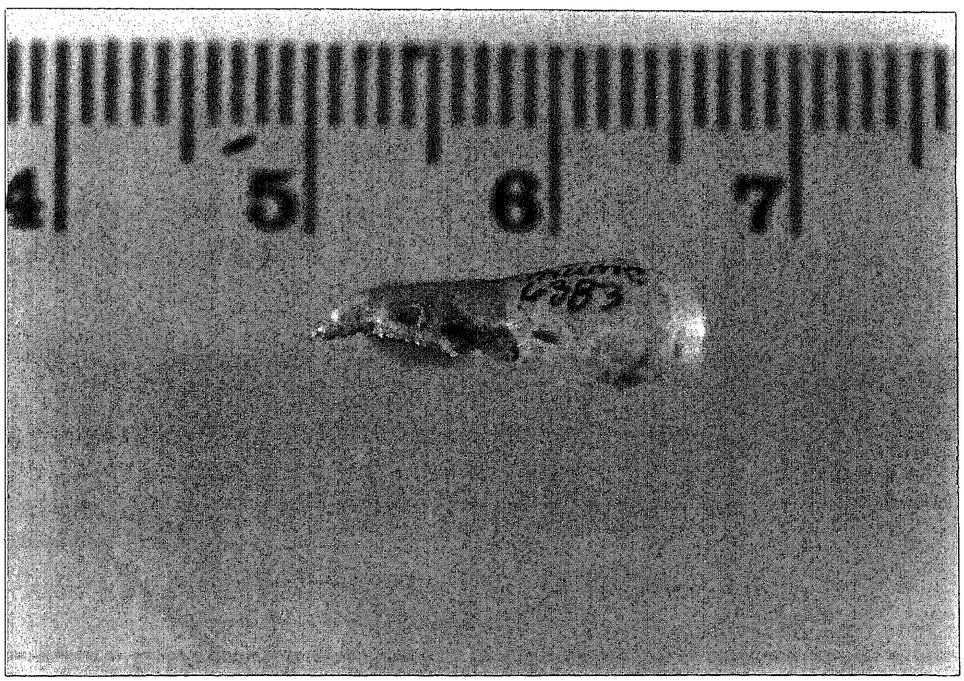
The reproductive condition could not always be used accurately to age specimens. An old adult male might be non-scrotal. This would be the case if the animal had matured, became scrotal, and had since gone out of reproductive condition. After the breeding season is over, the testes regress and the specimen has the superficial appearance of a non-scrotal juvenile. In order to assess the age of this individual some other method of age determination was needed. Pruitt (1954) used tooth wear as a method of aging shrews. Shrews have teeth that, unlike some rodents, are not evergrowing. Therefore, as shrews become older the amount of pigmentation on the teeth is reduced from wear. Thus, the older an individual, the less pigment present on the teeth. An examination of the amount of wear of the teeth was made on all specimens; two age classes, adult and juvenile, were established. Examples of each age class can be seen in Figure 11. After the gender, reproductive condition, and all external measurements were recorded, the cranium was removed, given a catolog number, and placed in a *Dermestid* beetle colony to be cleaned of flesh. The body was given a corresponding catalog number and placed in a 10% solution of formalin until preserved. The specimen was removed from the formalin, rinsed in tap water to remove most of the formalin, and placed in a 70% solution of ethanol for storage. Identifications were made using various taxonomic keys based on external, cranial, and dental characters (Junge and Hoffman 1981; Hall 1981; Caldwell 1982).

Habitat Preference Analysis

Habitat preferences of species were determined through direct examination of the abundance of different species in each habitat, both in percent of total individuals

Figure 11. Representative age classes of *Sorex cinereus* showing tooth wear of juvenile (top) and adult (bottom).


21 22 23 24


4 5 6 7

of a species captured and in numbers of individuals captured per trapping effort (captures per trapnight). Each species was examined by a comparison of the captures per trapnight (TN) in each habitat type. By assuming that the abundance of a species reflects habitat selection, habitat preference was determined; the higher the capture rate (captures per TN) of a species the greater the preference of that habitat type by a species.

Statistical Analyses

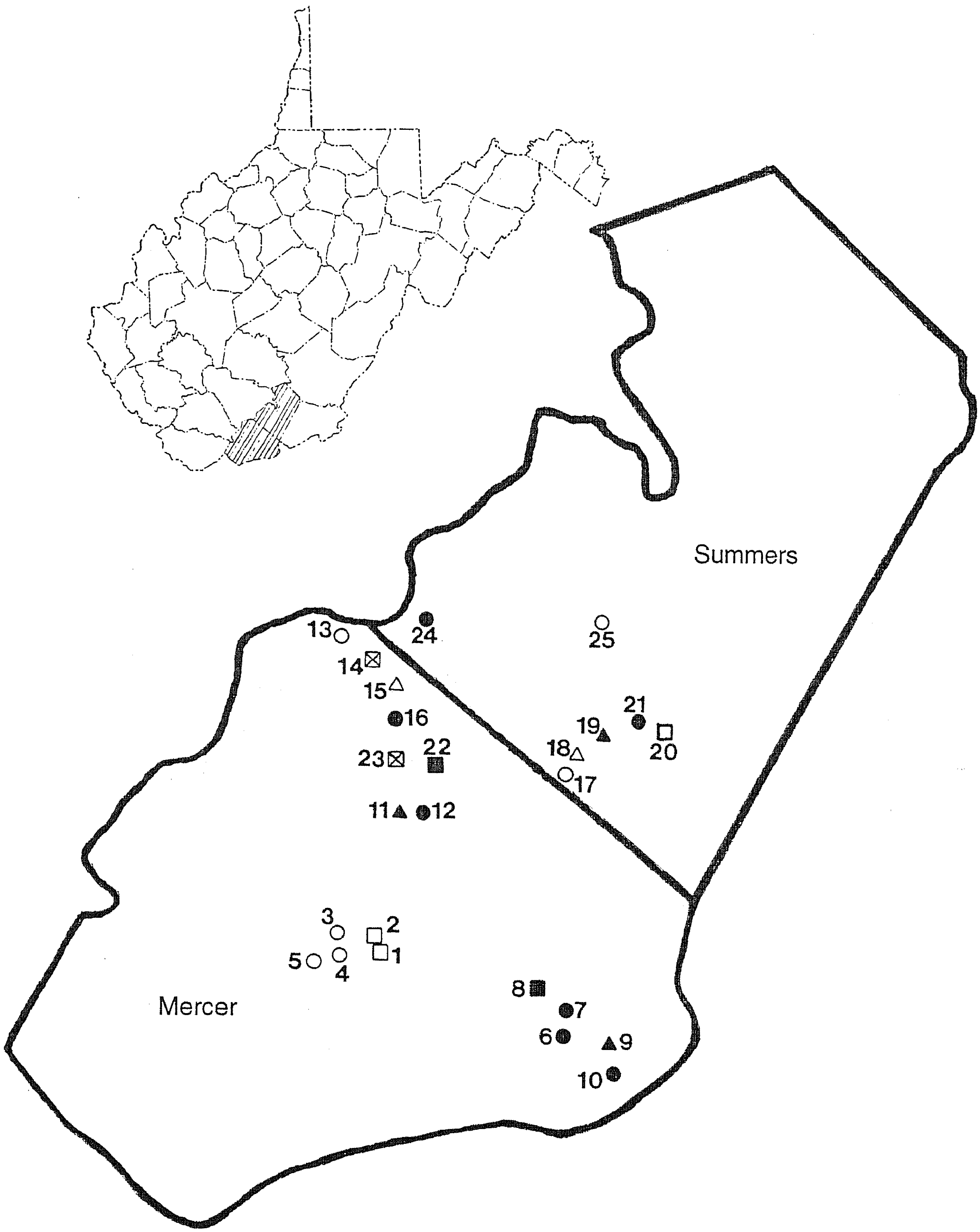
Field data for all 168 traps, in the form of the parameter codes described above, were entered into a Lotus 1-2-3 spreadsheet and was transferred to the VAX cluster at the Marshall University computer center. In order to analyze the degree of similarity between the different habitat types and the sites based on the environmental variables recorded, a specific multivariate statistics program was written using Statistical Analysis Systems (SAS) software (SAS Institute 1988). An analysis of variance (ANOVA), Duncan's multiple range test, principal component analysis (PCA), and canonical discriminant analysis (CDA) were performed on the data set. A copy of the SAS program and the raw data file can be found in Appendix IV.

Overview of Study Area

A total of 168 traps divided between 25 sites was established in Mercer (17 sites) and Summers (8 sites) counties in southern West Virginia (Figure 12). This area contains portions of both the Ridge and Valley and the Allegheny Plateau physiographic provinces of West Virginia. The sites were placed in order to cover as wide a geographic area as possible and still be logistically feasible to visit every two

Figure 12. Map of Mercer and Summers counties West Virginia showing site numbers of areas surveyed and habitat type.

● - Mixed Deciduous Forest
○ - Xeric Mixed Deciduous Forest
▲ - Coniferous Forest
△ - Old Field
⊠ - Stream Bed
□ - Flood Plain
■ - Cultivated / Grazed Field


Summers
Mercer
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25

weeks. In addition, special effort was taken to sample a wide variety of microhabitat conditions with the expectation of increasing the diversity of shrew species.

Site Descriptions

The following section presents a general description of each site surveyed. Additional information on the characteristics of each site, and specific trap descriptions, can be found in Appendix IV and my journal and catalog in the Marshall University Museum. A listing of the locality information of each site can be found in Appendix 1.

Sites 1 and 2 each contained five traps with a spacing of approximately 30 meters. All traps were located adjacent to Brush Creek, a third order stream, on a wide level flood plain at an elevation of 2390 feet. The mixed deciduous forest was dominated by red maple (*Acer rubrum*), tulip poplar (*Liriodendron tulipifera*), and spicebush (*Lindera benzoin*). The dominant herbs were spotted touch-me-not (*Impatiens capensis*), and multiflora rose (*Rosa multiflora).* Leaf litter was less than 2.5 cm deep and the soils were rich, silty, and saturated with water. Upon many occasions during the sampling period the entire area was flooded with approximately 3 dm of water for a several days.

Site 3 consisted of six traps located on a southwest-facing mixed deciduous slope. These traps were placed approximately every 50 meters from 2200 to 2420 feet of elevation. Soils were poor, dry, and loose. Several species of oak (*Quercus* sp.) dominated the area and late-low blueberry (*Vaccinium vacillans*) and small patches of common greenbrier (*Smilax rotundifolia*) made up the herb layer. Leaf litter was present at all traps and averaged 3.8 cm in depth. The slope was approximately 25° at all traps.

Site 4 contained four traps placed in a mixed deciduous forest on a level somewhat rocky area. Traps were spaced 25 meters apart from 2110 to 2150 feet in elevation. Leaf litter was approximately 5 cm deep and covered sandy loose moist soils with numerous buried rocks. Dominant trees were white oak (*Q. alba*) and red maple (*A. rubrum*). Dominant herbs were May apple (*Podophyllum peltatum*), wild geranium (*Geranium maculatum*), and solomon's seal (*Polygonatum biflorum*). The average slope was less than 5°.

Site 5 consisted of five traps and was located in a southwest facing mixed deciduous forest adjacent to a railroad trestle clearing. Traps were placed 50 meters apart from 2150 to 2360 feet. Leaf litter depth was less than 2.5 cm at each trap and the average slope was 10°. Soils were poor, dry, and compact. Dominant trees were red oak (*Q. rubra*) and white oak (Q. alba) and dominant herbs were multiflora rose (*R. multiflora*), wild yam (*Dioscorea quaternata*), and wild columbine (*Aquilegia canadensis).*

Site 6 was located in a mixed deciduous forest near a small second order stream and consisted of four traps. The elevation ranged from 1900 to 1950 feet. The traps were 25 meters apart with an average leaf litter depth of 7.6 cm and a 10° slope. Soils were loose, rich, and moist. Dominant trees included sugar maple (*A. sacharrum*), American beech (*Fagus grandifolia*), and red bud (*Cercis canadensis*). Dominant herbs were Virginia creeper (*Parthenocissus quinquefolia*), stonecrop sedum (*Sedum ternatum*), and Christmas fern (*Polystichum acrostichoides*).

Site 7 contained five traps located in a mixed deciduous forest between 2060 and 2200 feet near a intermittent stream. Traps were placed 35 meters apart and had an average slope of 5°. Leaf litter was approximately 5 cm deep at all traps and soils were loose, rocky, and moderately poor and dry. A mixture of tree species included sugar maple (*A. sacharrum*), american beech (*Fagus grandifolia*), red oak (*Q. rubra*), eastern hemlock (*Tsuga canadensis*), and white oak (*Q. alba*). Herbs included Virginia creeper (*Parthenocissus quinquefolia*), May apple (*Podophyllum peltatum*), wild geranium (*Geranium maculatum*), black cohosh (*Cimifuga racemosa*) and several species of ferns.

Site 8 contained five traps located in a grazed field adjacent to a small first order stream. The traps were 30 meters apart and ranged in elevation from 2520 to 2400 feet. Short grasses were the only ground cover but small patches of multiflora rose (*R. multiflora*) and hawthorne (*Crataegus* sp.) were scattered throughout the field. White oak (*Q. alba*) and black locust (*Robinia pseudo-acacia*) were sparsely distributed along the field edges. The average slope at each trap was 5° and soils were compact, moderately rich and moist.

Site 9 was located in a northeast-facing coniferous forest, made up of eastern hemlock (*Tsuga canadensis*), adjacent to a small second order stream. Four traps were spaced 30 meters apart and ranged in elevation from 1880 to 1960 feet with an average slope of 45°. Leaf litter was less than 2.5 cm at all traps and soils were loose, moist, fairly rich, and loamy. The dominant herb was Christmas fern (*Polystichum acrostichoides*). A small creek was located approximately 45 meters down slope from the transect.

Site 10, the largest transect, was located on East River Mountain above the city of Oakvale, West Virginia in Mercer county. This transect consisted of thirty-eight traps spaced approximately 50 meters apart and ranged in elevation from 2390 to 3490 feet. Although all traps were contained in a northwest-facing mixed deciduous forest, there was great variability in both vegetation and physical conditions. Differences in vegetation, slope, soil characteristics, moisture, litter, and other features necessitated that this transect be broken up into these four sub-sites. In general, each sub-site accurately represents trends in variation found within the transect and can be used to separate the transect into four distinct regions, each with its own set of characteristics. Pictures of each of the sub-sites can be found in Figures 13 and 14.

Sub-site A (traps 1-10) had an elevation range from 2390 to 2620 feet and an average slope of 10° with rich, compact, moist, silty soils and an average leaf litter depth of 3.8 cm. The dominant tree species included sugar maple (*A. rubrum*), slippery elm (*Ulmus rubra*), red bud (*C. canadensis*), and spicebush (*Lindera benzoin*) and the dominant herbs were black cohosh (*Cimifuga racemosa*), and May apple (*P. peltatum*).

Sub-site B (traps 11-20) ranged in elevation from 2630 to 2800 feet and had an average slope of 8° with a leaf litter depth of approximately 4.5 cm. The soils were moderately rich, moist, loose, and silty. Dominant tree species consisted of sugar maple (*A. sacharrum*), and buckeye (*Aesculus octandra*). Herb species present were pale touch-me not (*I. pallida*), goose grass (*Galium aparine)*, and sweet anise (*Osmorhiza longistylis*).

Figure 13. Representative pictures sub-site A (top) and sub-site B (bottom) of site 10.

Figure 14. Representative pictures sub-site C (top) and sub-site D (bottom) of site 10.

Sub-site C (traps 21-30) had an average slope of 19° and covered an elevation of 2825 to 3050 feet. Leaf litter was approximately 6.4 cm deep at all traps and the soils were rich, moist, loose, and loamy. Dominant tree species were sugar maple (*A. sacharrum*), striped maple (*A. pensylvanicum*), and buckeye (*Aesculus octandra*). The dominant herbs present were pale touch-me not (*I. pallida*), and Virginia creeper (*P. quinquefolia*).

Sub-site D (traps 31-38) ranged in elevation from 3080 to 3490 feet and had an average slope of 36° from horizontal. The soils were poor, rocky, loose and dry and had an average leaf litter depth of 5 cm. The dominant tree species included red oak (*Q. rubrum*) and red maple (*A. rubra*). The dominant herbs were wood nettle (*Laportea canadensis*) and white clintonia (*Clintonia umbellata*).

Site 11 was within a level to north-facing coniferous forest made up of white pine (*Pinus strobus*) and contained 10 traps. The traps were placed 35 meters apart at an elevation of approximately 2160 feet. At traps one through five the dominant herb species were ebony spleenwort (*Asplenium platyneuron*) and ground pine (*Lycopodium flabelliforme*), the slope was less than 5°. A 3.8 cm deep pine needle litter was present on soils that were dry, loose, sandy, and poor. Traps six through ten were also located in a white pine coniferous forest although it was heavily damaged by winter ice storms resulting in an uprooted open section approximately 250 by 500 meters. The dominant herbs in this section were Virginia creeper (*P. quinquefolia*), and ground ivy (*Glechoma hederacea*), the slope was between 5 and 10°, and the two inch litter consisted of pine needles and branches. The soils were fairly compact, dry, poor, and had a underlying layer of shale 15 cm below the surface.

Site 12 was located along a stream bed in a south-facing mixed deciduous forest. The five traps ranged in elevation from 1950 to 2080 feet and were spaced 40 meters apart. Traps one, two, and three were located adjacent to a intermittent stream bed; traps four and five were near a second order stream. The average slope was approximately 10°. Soils were moist, rich, fairly loose and were covered with an average of 5 cm of leaf litter. Dominant tree species included sugar maple (*A. sacharrum*) and American beech (*F. grandifolia*). The dominant herb was Christmas fern (*P. acrostichoides*).

Site 13 contained six traps with a spacing of 50 meters and was located in a level mixed deciduous forest at an elevation of 3250 feet. At all traps the leaf litter was approximately 6.4 cm deep covering loose, rich, moderately dry soils. Dominant tree species were red (*A. rubrum*) and striped maple (*A. pensylvanicum*). Dominant herbs contained common greenbrier (*S. rotundifolia*) and late-low blueberry (*Vaccinium vacillans*). The entire area appeared to be an old select cut area in which all oak (*Quercus*) species had been removed and an overall thinning of trees had taken place in the past five or ten years.

Site 14 contained five traps and was located along a small first order stream crossing a power line right-of-way at an elevation of 3150 feet. The traps were placed 25 meters apart and were all on level ground. Three of the five traps had no trees located near them. Two traps (numbers four and five) had great laurel (*Rhododendron maximum*). The tree species located adjacent to but not within 30 meters of the traps were red maple (*A. rubrum*) and tulip poplar (*L. tulipifera*). The herb layer was absent at traps four and five but at traps one, two, and three it consisted of a deep layer of interrupted fern (*Osmunda claytonia*), cinnamon fern (*Osmunda cinnamonea*), hay-scented fern (*Dennstaedtia punctilobula*), and panic grass(*Panicum* sp.). These species dominated the area and formed a dense "thicket" to a depth of nearly 1.25 meters. The soils were wet, loose, fairly rich, and were made up almost entirely of sand and organic matter.

Site 15 consisted of five traps, spaced 40 meters apart, located along the edge of a level old field habitat at an elevation of 2880 feet. The entire field was approximately 400 meters by 200 meters and was bordered by mixed deciduous forest on three sides and a hay field and gravel road on the fourth side. All traps were placed on level ground within a thick area of goldenrod (*Solidago rugosa*) at the edge of the field. The tree species in the northwest-facing forest adjacent to the field were red maple (*A. rubrum*), red oak (*Q. rubra*), and white oak (*Q. alba*), and black locust (R. pseudo-acacia). The field contained only herb species and was made up of dewberry (*Rubus* sp), broom sedge (*Andropogon virginicus*), and various species of grasses. The litter at all traps was made up of fallen goldenrod stems and formed a thick mat approximately 10 cm deep which covered loose; moist, moderately rich soils.

Site 16 was located in a fairly level west-facing mixed deciduous forest with an elevation ranging from 2660 to 2700 feet. Traps were 40 m apart on a slope of less than 5° with at least a 7.6 cm deep layer of leaf litter covering compact, dry, moderately rich, sandy soils. Chestnut oak (*Q. prinus*), red oak (*Q. rubra*) as well as red maple (*A.

sacharrum) dominated the area and late-low blueberry (*Vaccinium vacillans*) was the only herb layer species present. Numerous large American chestnut (*Castanea dentata*) logs were present at all traps.

Site 17 was located in a level stand of mixed deciduous forest at an elevation of 2580 feet and contained ten traps with a spacing of 50 meters between traps. The soil at all traps was loose, sandy, dry, and relatively poor. Leaf litter was approximately 10 cm deep at all traps except numbers one through four. The dominant species of trees included white oak (*Q.alba*), red oak (*Q. rubra*), and red maple (*A. rubrum*). The dominant herb species was late-lowblueberry (*Vaccinium vacillans*). Numerous fallen American chestnut (*Castanea dentata*) logs were present amoung trap numbers three through ten.

Site 18 was located in an old field habitat at an elevetion of approximately 2540 feet. The slope was less than 5° from horizontal and soils were compact, moderately rich, and moist. Traps were spaced at 45 meter intervals. Herbs dominated the site and mature trees were absent from the area. Young black locust (*R. pseudo-acacia*), red maple (*A. rubrum*), sassafras (*Sassafras albidum*), and white pine (*P. strobus*) were scattered throughout the field. The dominant herbs consisted of a thick layer of dewberry (*Rubus* sp.), several species of grasses, steeplebush (*Spirea tomentosa*), Allegheny blackberry (*Rubus allegheniensis*) and several species of goldenrod (*Solidago altissima*, *S. rugosa*, *S. gaminifolia*). The field was not grazed or cultivated in any way during the entire sampling period.

Site 19 consisted of five traps located in a level coniferous forest at an elevation of approximately 2530 feet. Traps were placed every 25 meters. A 2,5 10 5 cm deep litter of pine needles covered dry, compact, sandy soils at all traps. In addition, the area had a unique feature that resembled small (0.5 m deep by 1.5 m wide) sink holes that appeared to be caused by the decay of tree stumps which resulted in shallow depressions in the surface of the ground. The only tree species present at the site was white pine (*P. strobus*) and the dominant herbs were Christmas fern (*P. acrostichoides*) and Virginia creeper (*P. quinquefolia*).

Site 20 was located in a mixed deciduous forest on a level flood plain of the New River at an elevation of 1450 feet. Five traps were spaced every 50 meters through a level area subject to periodic flooding. Leaf litter less than 2.5 cm deep covered soils that were rich, silty, compact, and moist. Dominant tree species were sugar maple (*A. sacharrum*), and box elder (*A. negundo*). Dominant herbs consisted of goose grass (*Galium aparine*), violets (*Viola* sp.), and bittercress (*Cardamine* sp.). During a portion of June and August 1994 the site was covered by at least 3 dm of water for several days.

Site 21 was located on an east-facing mixed deciduous forest at an elevation of 1750 to 1770 feet and contained five traps with spaced 35 meters apart. The slope was approximately 15° at each trap with a 7.6 cm leaf litter covering loose, rich, moist soils. The dominant tree species were sugar maple (*A. sacharrum*), white oak (*Q. alba*), dogwood (*Cornus florida*), and paw paw (*Asimina triloba*). Dominant herbs included scattered specimens of Christmas fern (*P. acrostichoides*), grape (*Vitus* sp.), May apple (*P. peltatum*), and wild geranium (*G. maculatum*).

Site 22 consisted of six traps located near the edge of a level cultivated hayfield at an elevation of 1810 feet. Traps were placed 50 meters apart. Soils were compact, moderately rich, and dry. White oak (*Q. alba*), and hickory (*Carya* sp.) were the dominant tree species nearby although not located within 30 meters of the traps. The only plant species present were poison ivy (*Rhus radicans*) and grasses (various species). The field was cut four times during the sampling period.

Site 23 contained five traps located parallel to a small (3-5 meter wide) second order rocky stream. The traps were spaced every 35 meters on level ground with less than 2.5 cm of leaf litter present. The soil at this site was loose, rich, and moist. Dominant tree species included eastern hemlock (*Tsuga canadensis*) and American beech (*Fagus grandifolia*). Herb species present included May apple (*P. peltatum*), violets (*Viola* sp.), and wild geranium (*G. maculatum*).

Site 24 was located in a north-facing mixed deciduous forest near a grass covered powerline right of way and a first order stream creek. Six traps were spaced 40 meters apart and ran parallel to the right of way. The slope at each trap was approximately 5° from horizontal, soils were loose, sandy, and fairly rich, and leaf litter was at least 5 cm deep at all traps. The dominant tree species present were tulip poplar (L. tulipifera), red maple (*A. rubrum*), and white oak (*Q. alba*). The dominant herbs were Christmas fern *(P. acrostichoides)* and common greenbrier *(S.* rotundifolia).

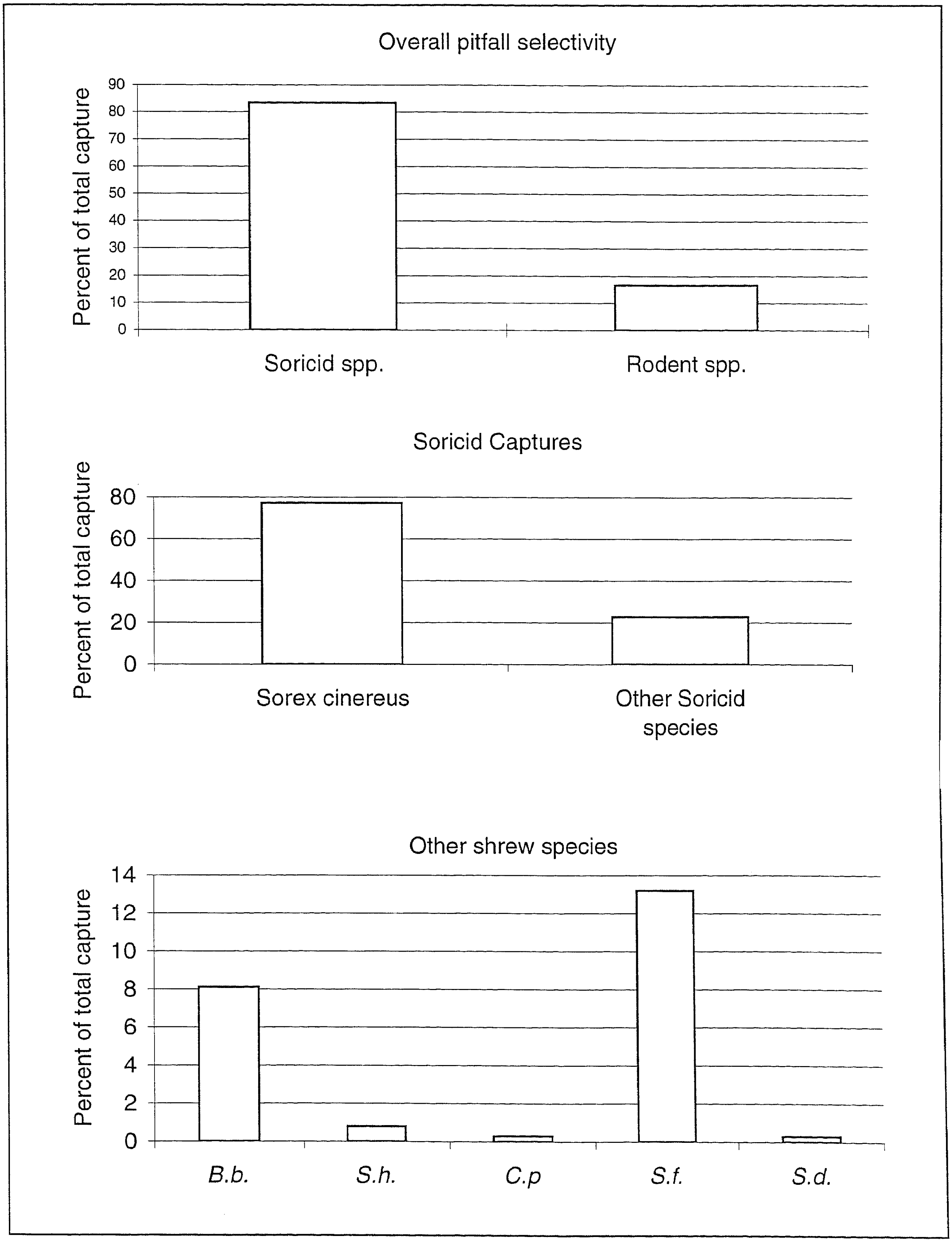
Site 25 consisted of five traps placed in a northeast-facing mixed deciduous forest at an elevation ranging between 1540 and 1670 feet. Approximately 5 cm of leaf litter was present at each trap and soils were loose, sandy, and moderately rich. The dominant tree species included sugar maple (*A. sacharrum*), tulip poplar (*L. tulipifera*), and some eastern hemlock (*T. canadensis*). Herb species present included Christmas fern (*P. acrostichoides*) and Virginia creeper (*P. quinquefolia*). The average slope was 10° from horizontal.

RESULTS

A total of 783 small mammals, representing 15 species, was captured during 34,213 trapnights between 16 May and 29 November, 1994, and between 15 April and 27 May, 1995 (Appendix II). The seven shrew species *Sorex cinereus, S. longirostris, S. fumeus, S. hoyi, S. dispar, Blarina brevicauda*, and *Cryptotis parva* accounted for 83.4% of the total capture. The remainder of the total capture was made up by two mouse species, *Peromyscus leucopus*, and *P. maniculatus* (6.1% combined), two jumping mouse species, *Napaeozapus insignis* (6%), *and Zapus hudsonius* (0.64%), three vole species, *Microtus pennsylvanicus* (0.38%), *M. pinetorum* (0.26%), and *Clethrionomys gapperi* (2.3%), and one lemming species, *Synaptomys cooperi* (0.89%). A representation of the abundance of the species captured can be seen in figure 15. As seen in this figure, the majority of the capture consisted of shrew species (653 specimens). Of the shrew species, *Sorex cinereus* made up 77.3%, *S. fumeus* 13.2%, *S. hoyi* 0.8 %, *S. dispar* 0.3%, *Cryptotis parva* 0.3%, and *Blarina brevicauda* 8.1%.

A total of 25 sites was established for this study. The seven habitat types surveyed, as well as the number of sites and traps in each, are shown below.

Figure 15. Comparison of species captures showing pitfall trap selectivity.


Overall pitfall selectivity
Percent of total capture
90
80
70
60
50
40
30
20
10
0
Soricid spp.
Rodent spp.
Soricid Captures
Percent of total capture
80
60
40
20
0
Sorex cinereus
Other Soricid species
Other shrew species
Percent of total capture
14
12
10
8
6
4
2
0
B.b.
S.h.
C.p
S.f.
S.d.

Habitat Type	Site Numbers	Total Number of Traps
Mixed Deciduous	6,7,10,12,13,16,21,24	74
Xeric Mixed Deciduous	3,4,5,17,25	30
Coniferous Forest	9,11,19	19
Flood Plain	1,2,20	15
Stream Bed	14,23	10
Old Field	15,18	10
Cultivated / Grazed Field	8,22	10

ANOVA and Duncan results

The parameters examined at each trap were subjected to an analysis of variance (ANOVA) procedure, and Duncan's multiple range test, as a preliminary step of the principal component analysis (PCA) and canonical discriminant analysis (CDA). The mean values of the environmental parameters calculated in the ANOVA procedure for each habitat type are given in Table 2 and the raw values taken for each trap in the field in Appendix IV. The mean values of each variable were subjected to an F-test and were all found to be significantly different between habitat types to $p < 0.0001$. Soil texture and soil composition were found to be significant at $p < 0.0008$ and $p < 0.056$, respectively. The results of the ANOVA and F-test assisted in the evaluation of the distribution of eachspecies by showing the differences in environmental variables between different habitat types as well as the amount of within-site variation. This analysis was then used to help evaluate the microhabitat descriptions for each species.

The results of the Duncan analysis are shown in Table 3 but were of little help in discerning overall differences between habitat types. The results of the ANOVA and F-test showed a more accurate representation of the differences present between the

Table 2. Comparison of mean values of recorded environmental variables by habitat type.

	Habitat Type						
Environmental Parameter	Mixed Decid.	Xeric Mixed Decid.	Conifer. Forest	Flood Plain	Stream Bed	Old Field	Cultiv./ Grazed
Litter Composition	6.9	6.47	6.95	5.2	6.0	5.0	5.0
Litter Depth (in.)	2.12	2.63	1.5	1.1	2.65	4.8	2.0
Soil Nutrient	2.09	1.63	1.47	2.8	2.9	1.9	2.0
Soil Texture	1.73	1.8	1.42	1.4	1.7	1.6	1.2
Soil Composition	4.12	3.57	3.79	4.07	3.8	3.7	3.8
Soil Moisture	1.92	1.5	1.3	3.13	3.25	1.9	1.5
Slope (degrees)	11.7	8.27	8.95	1.2	0	0	1.5
Aspect	3.94	3.1	1.7	0.3	0	0	3.5

All parameters were found to have a significant difference of the means between habitat types to $p < 0.0001$ with the exception of soil texture and soil composition which were $p < 0.0008$ and $p < 0.056$, respectively.

Table 3. Duncan's multiple range analysis groupings of habitat types surveyed.

ENVIRONMENTAL VARIABLE	DUNCAN GROUPING						
LITTER COMPOSITION	3	-	1,2	-	2,5	-	4,6,7
LITTED DEPTH	6	-	5,2	-	1,3,7	-	4
SOIL NUTRIENT	5,4	-	1,7	-	2,3,6		
SOIL TEXTURE	2	-	1,3,4,5,6	-	7		
SOIL COMPOSITION	1,2,3,4,5,6,7						
SOIL MOISTURE	5,4	-	1,6	-	2,3,7		
ELEVATION	1,6	-	5,2,3	-	4,7		
SLOPE	1,3	-	2,4,7	-	5,6		

1 - Mixed Deciduous Forest
2 - Xeric Mixed Deciduous Forest
3 - Coniferous Forest
4 - Flood Plain
5 - Creek Bed
6 - Old Field
7 - Cultivated / grazed field

Habitat type numbers are grouped by significant difference of the means with each group being separated by hyphens.

habitat types.

PCA and CDA RESULTS

In order to assess the similarity of the 25 sites sampled, sites was grouped by habitat type and a PCA and CDA were run on the variables present at each site and trap. The results of these seem to have shed very little light on the analysis of the habitats sampled during this study. It was hoped that by running the PCA and CDA that the traps and sites that were similar in environmental conditions would separate into fairly distinct groups. The capture rates of the various species could then be matched up to the habitats to help determine habitat preference. This was not accomplished. The PCA and CDA showed some separation of the habitat types but this separation was based on only a few of the variables analyzed (Figures 16 and 17). The only characteristics that reliably separated the habitats into distinct groups were aspect and habitat type classification. These two charactersistics were obviously different between sites and were removed to allow analysis using only the other environmental parameters. When these variables were removed the plots for the PCA and CDA almost completely overlapped (Figures 18 and 19). From these results it appears as though all habitat types in the areas surveyed are continuations of one another in terms of the environmental variables recorded. Furthermore, through an examination of the correlation matrices of the most abundant shrew species *S. cinereus*, *S. fumeus*, and *B. brevicauda*, the relationships between the species and the environmental variables could be seen but, due to the differences in the number of trapnights in each habitat, these matrices were of little value in determining the habitat

Figure 16. Principal component analysis of habitat types using all environmental variables.

● - Mixed Deciduous Forest
■ - Xeric Mixed Deciduous Forest
○ - Coniferous Forest
◇ - Old Field
□ - Stream Bed
▲ - Flood Plain
▽ - Cultivated / Grazed Field

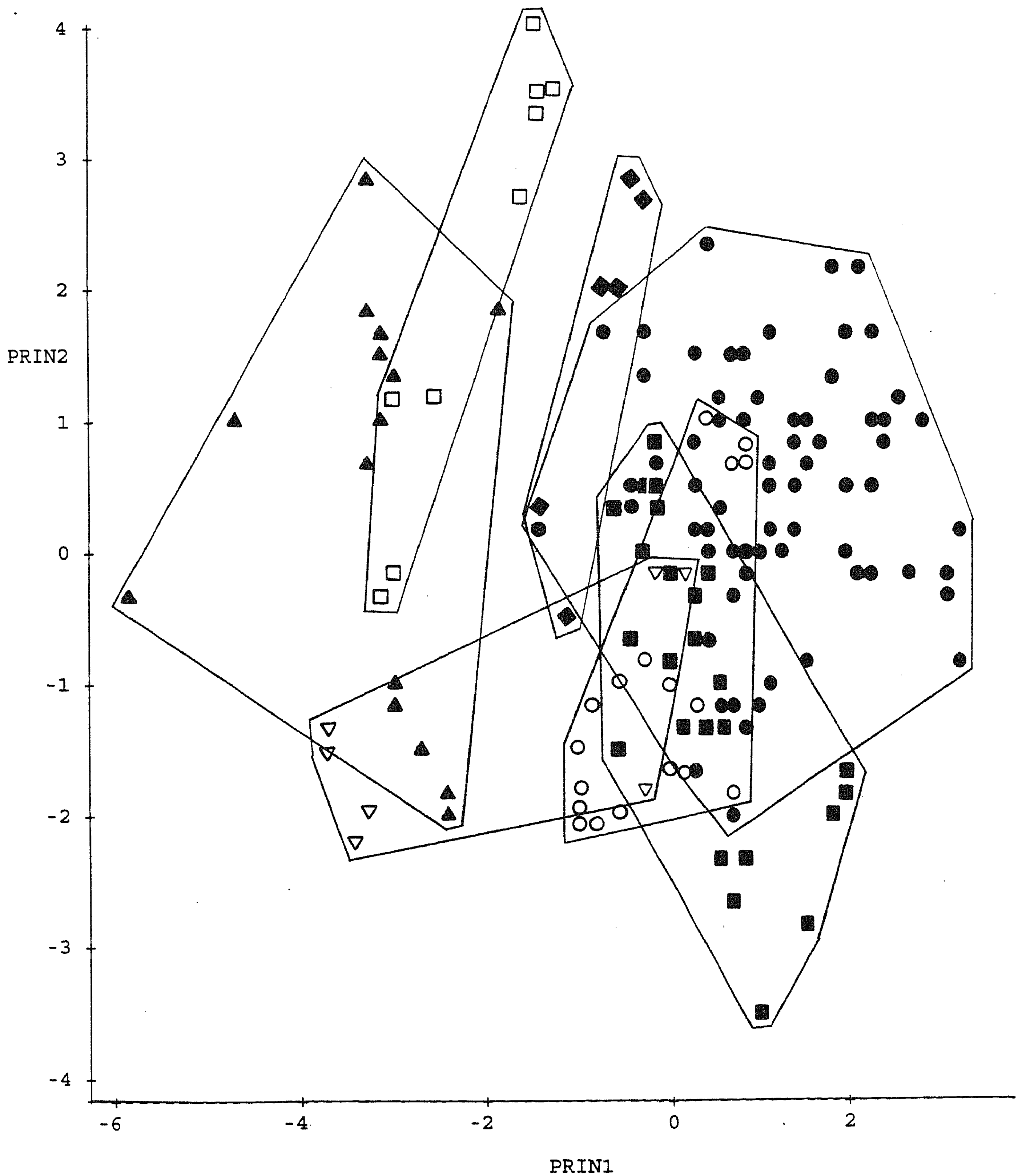

4
3
2
1
0
-1
-2
-3
-4
PRIN2
-6
-4
-2
0
2
PRIN1

Figure 17. Canonical discriminant analysis of habitat types using all environmental variables.

● - Mixed Deciduous Forest
■ - Xeric Mixed Deciduous Forest
○ - Coniferous Forest
◇ - Old Field
□ - Stream Bed
▲ - Flood Plain
▽ - Cultivated / Grazed Field

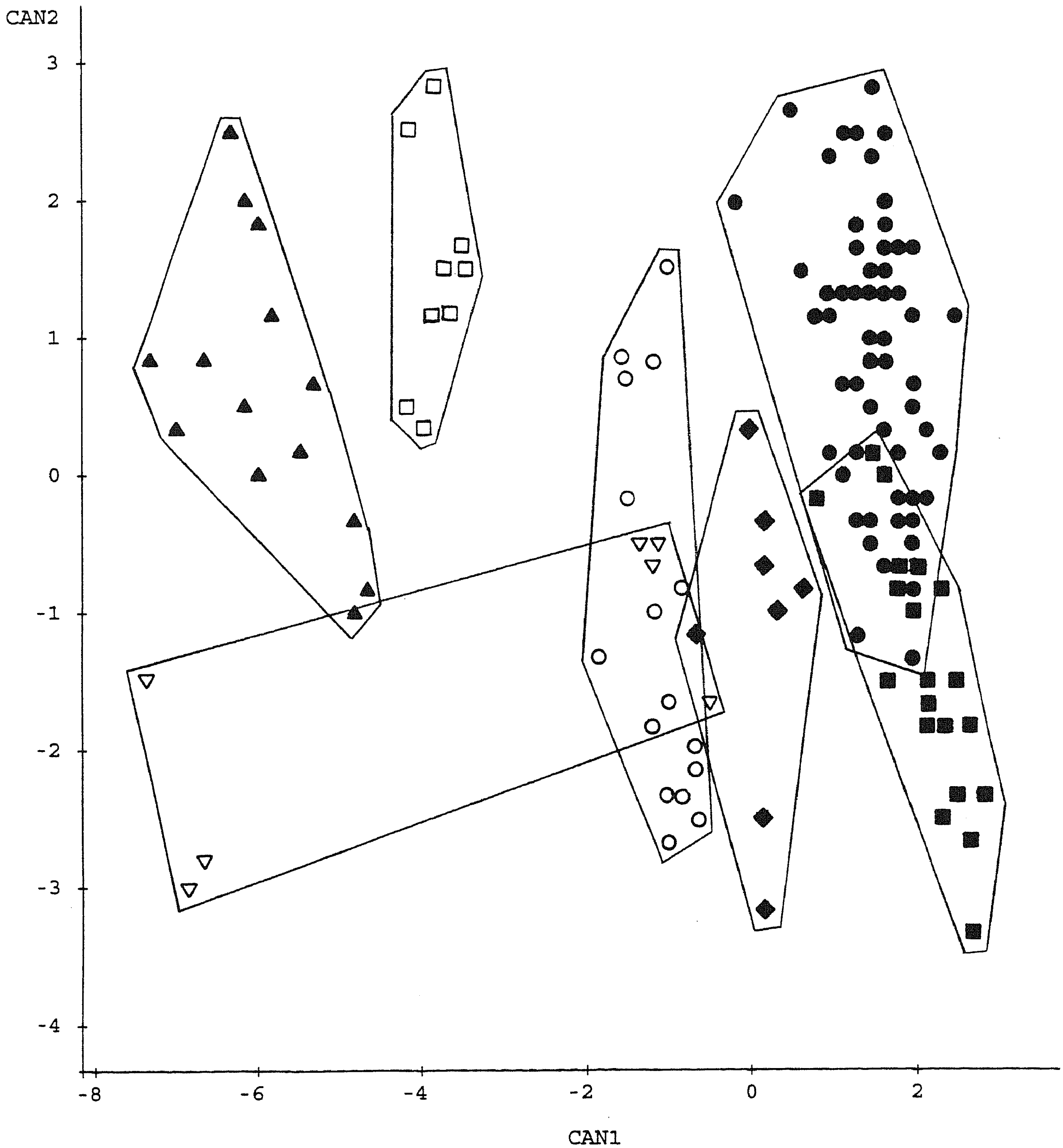

CAN2
3
2
1
0
-1
-2
-3
-4
-8
-6
-4
-2
0
2
CAN1

Figure 18. Principal component analysis of habitat types without the variables of espect, elevation, or habitat type.

● - Mixed Deciduous Forest
■ - Xeric Mixed Deciduous Forest
○ - Coniferous Forest
◇ - Old Field
□ - Stream Bed
▲ - Flood Plain
▽ - Cultivated / Grazed Field

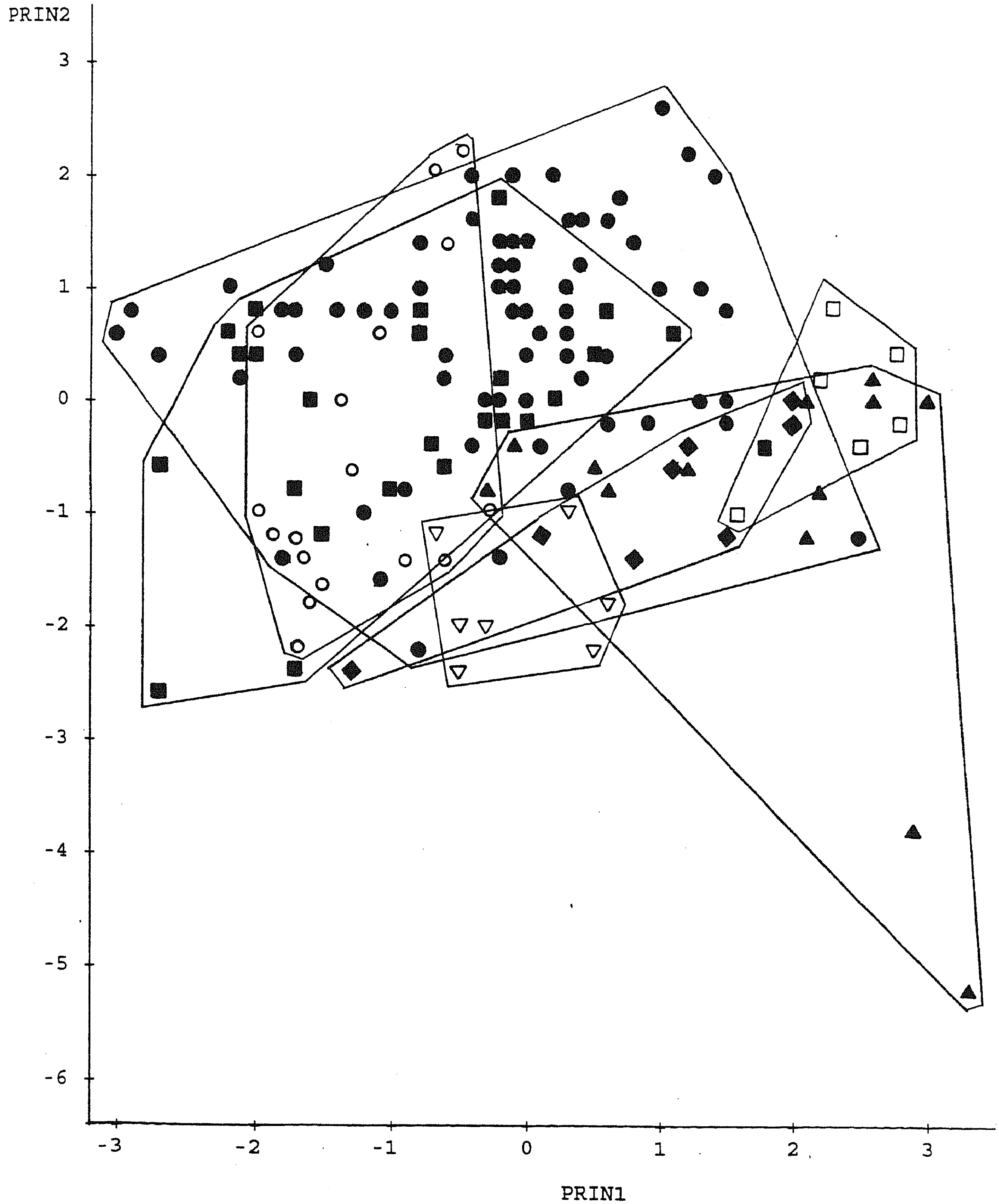
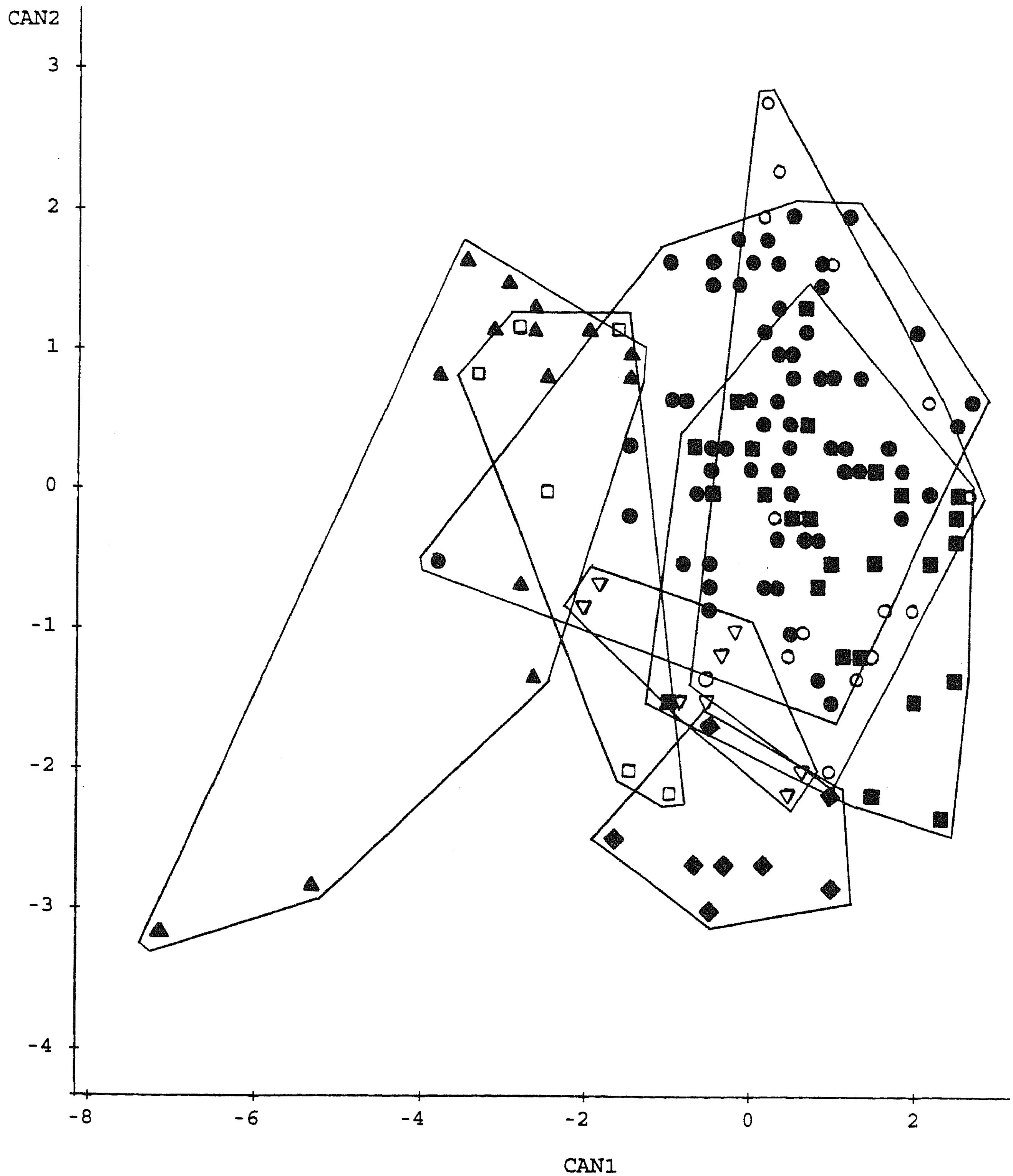

PRIN2
3
2
1
0
-1
-2
-3
-4
-5
-6
-3
-2
-1
0
1
2
3
PRIN1

Figure 19. Canonical discriminant analysis of habitat types without the variables of aspect, elevation, or habitat type.

● - Mixed Deciduous Forest
■ - Xeric Mixed Deciduous Forest
○ - Coniferous Forest
◇ - Old Field
□ - Stream Bed
▲ - Flood Plain
▽ - Cultivated / Grazed Field



CAN2
3
2
1
0
-1
-2
-3
-4
-8
-6
-4
-2
0
2
CAN1

preference. The variables themselves showed correlations with one another but nothing that has not already been discussed elsewhere in ecological research (Table 4).

Trends in habitat preference of each species were examined more closely by keeping the sites grouped by habitat type, and by looking at the species, and the abundance of each captured within each habitat. A listing of the percent of sites, by habitat type, in which a species occurred can be seen in Table 5. Caution must be taken, however, in using this as a representation of the habitat preference of a particular species. The sheer presence of a species at a site does not tell anything about the population density and true habitat preferences; for example, a species may be located in a number of different areas but only be abundant in a few preferred areas.

In order to accurately assess the habitat preference of a species, the capture rates and overall abundance of a species was examined by looking at the number of captures per trapnight within each habitat type. The captures per trapnight can be used to evaluate the population density and temporal (seasonal) activity patterns of a species. By assuming that a greater population density will produce increased activity due to increased competition for resources present in an area, a monthly assessment of the population density was made. Activity levels (captures per trapnight) are increased also by breeding season, both by the male's search for mates and by dispersal of young after weaning. Table 6 shows a comparison of the capture rates for each soricid species based on habitat type and will be discussed in the following sections along with microhabitat notes and individual population structure analysis.

Table 4. Overall correlation values of the environmental parameters examined.

	Habitat Type	Litter Comp.	Litter Depth	Soil Nutrient	Soil Texture	Soil Comp.	Soil Moisture	Elevation	Slope
Litter Comp.	0.4175								
Litter Depth	0.374	0.1038							
Soil Nutrient	-.2287	-.0833	-.0037						
Soil Texture	0.336	0.2351	0.2951	0.1774					
Soil Comp.	0.0052	0.152	-.1484	0.2203	0.0629				
Soil Moisture	-.2398	-.1101	0.009	0.576	0.1821	0.1230			
Elevation	0.3726	0.0823	0.3553	-.0455	0.096	0.0051	-.1192		
Slope	0.4596	0.4237	-.1254	-.2167	0.0281	0.1871	-.2270	-.0036	
Aspect	0.5296	0.2263	-.0526	-.2272	0.0614	-.0022	0.2130	-.0272	0.6927

Table 5. Percent of sites by habitat type at which a soricid species occurred.

	Habitat Type						
	Mixed Decid.	Xeric Mixed Decid.	Conifer. Forest	Old Field	Stream Bed	Flood Plain	Cultiv. / Grazed
Sorex cinereus	62.5	0	66.6	50	100	0	0
Sorex fumeus	100	0	100	50	50	66.7	50
Sorex hoyi	12.5	20	0	50	0	0	0
Sorex dispar	12.5	0	0	0	0	0	0
Blarina brevicauda	62.5	40	66.6	50	50	100	50
Cryptotis parva	0	0	0	50	0	0	0

Table 6. Comparison of soricid species captures per 100 trapnights by habitat type.

	Mixed Decid.	Xeric Mixed Decid.	Conif. Forest	Old Field	Stream Bed	Flood Plain	Cultiv. / Grazed
Sorex cinereus	2.9	0	0.4	1.4	1.15	0	0
Sorex fumeus	0.32	0.02	0.28	0.28	0.86	0.024	0.12
Blarina brevicauda	0.19	0.02	0.05	0.04	0.17	0.43	0
Sorex hoyi	0.02	0.02	0	0.04	0	0	0
Sorex dispar	0.013	0	0	0	0	0	0
Cryptotis parva	0	0	0	0.08	0	0	0
Total Trapnights	14991	4895	4275	2490	1735	4150	1677

Sorex cinereus -- Sorex longirostris

Due to the close morphological similarity of *Sorex cinereus* and *Sorex longirostris*, these two species are discussed together and called *Sorex cinereus* in this section although some of the individuals may indeed be *S. longirostris*.

A total of 505 *Sorex cinereus* was captured during the study period. This species accounted for 77.3% of the soricid capture and 64.5% of the overall capture. Of the habitat types sampled, mixed deciduous forest habitat produced the highest capture per trapnight at 2.8 specimens per 100 TN. Second was old field habitat at 1.4 per 100 TN, and third was stream bed habitat at 1.15 per 100 TN (Figure20).

Microhabitat

Observing that *S. cinereus* appeared to prefer a habitat type of mixed deciduous, characteristics of that habitat type were more closely examined. Data from site 10, which accounted for 80.6% of all *S. cinereus* captured, were subjected to PCA and CDA analyses. An almost complete separation of the sub-sites into four distinct groups was accomplished (Figure 21 and 22). Also, through the ANOVA of the parameters present at each trap, a transition in slope, moisture, vegetation, and soil characteristics along the transect as well as trends in microhabitat selection, by sub-site, were observed (Table 7). This variation of environmental parameters produced differences in the spatial distribution of *Sorex cinereus* and other soricids along the transect (Figure 23), with *Sorex cinereus* being most abundant within sub-site C of site 10.

Seasonal Activity / Population Density

The temporal activity was examined using the data from site 10. With a total of

Figure 20. Soricid species captures per 100 trapnights by habitat type.

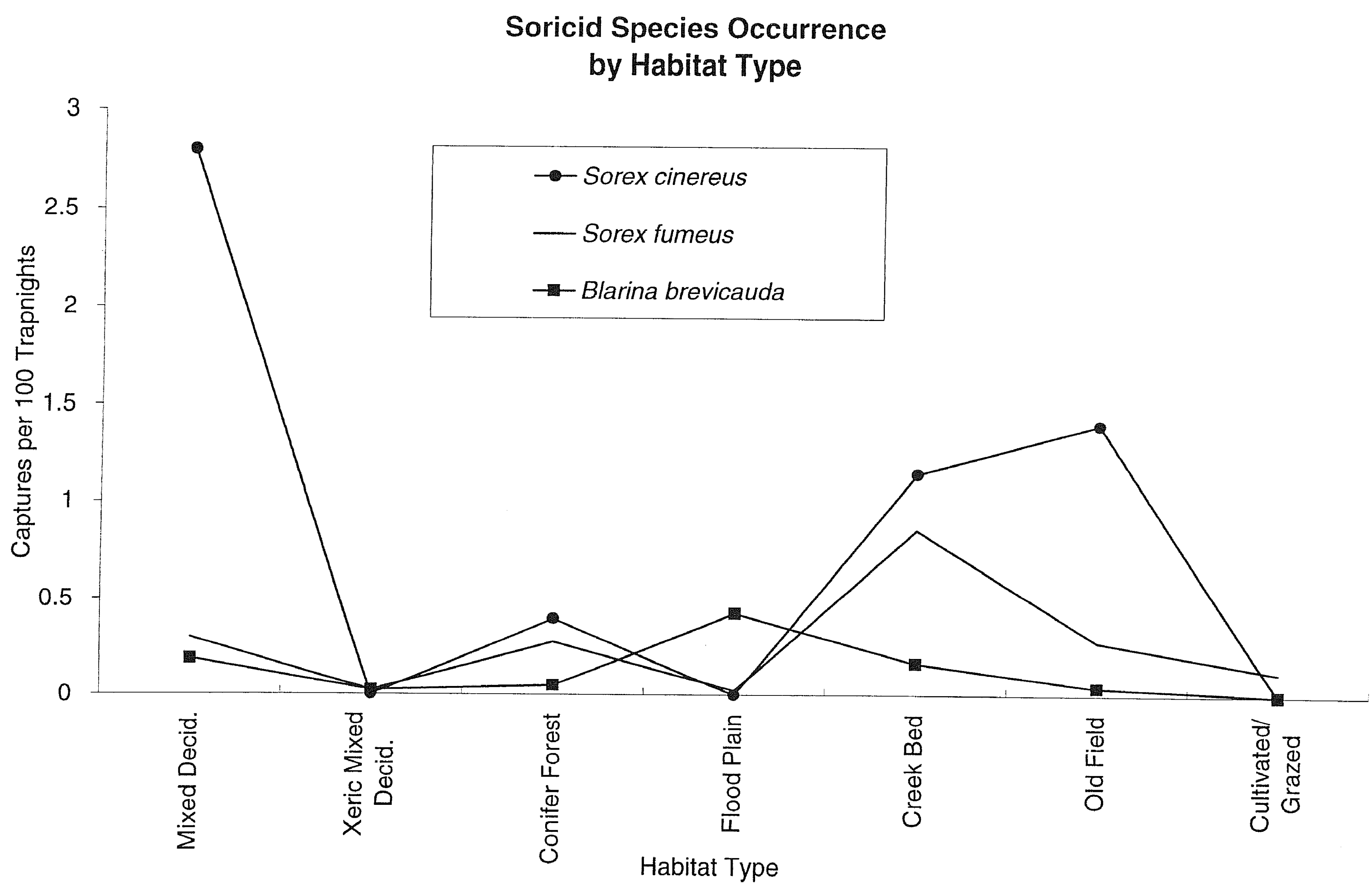

Soricid Species Occurrence
by Habitat Type
Sorex cinereus
Sorex fumeus
Blarina brevicauda
Captures per 100 Trapnights
3
2.5
2
1.5
1
0.5
0
Mixed Decid.
Xeric Mixed Decid.
Conifer Forest
Flood Plain
Creek Bed
Old Field
Cultivated/ Grazed
Habitat Type

Figure 21. Principal component analysis of site 10 environmental data.

○ - Sub-site A
▲ - Sub-site B
● - Sub-site C
■ - Sub-site D

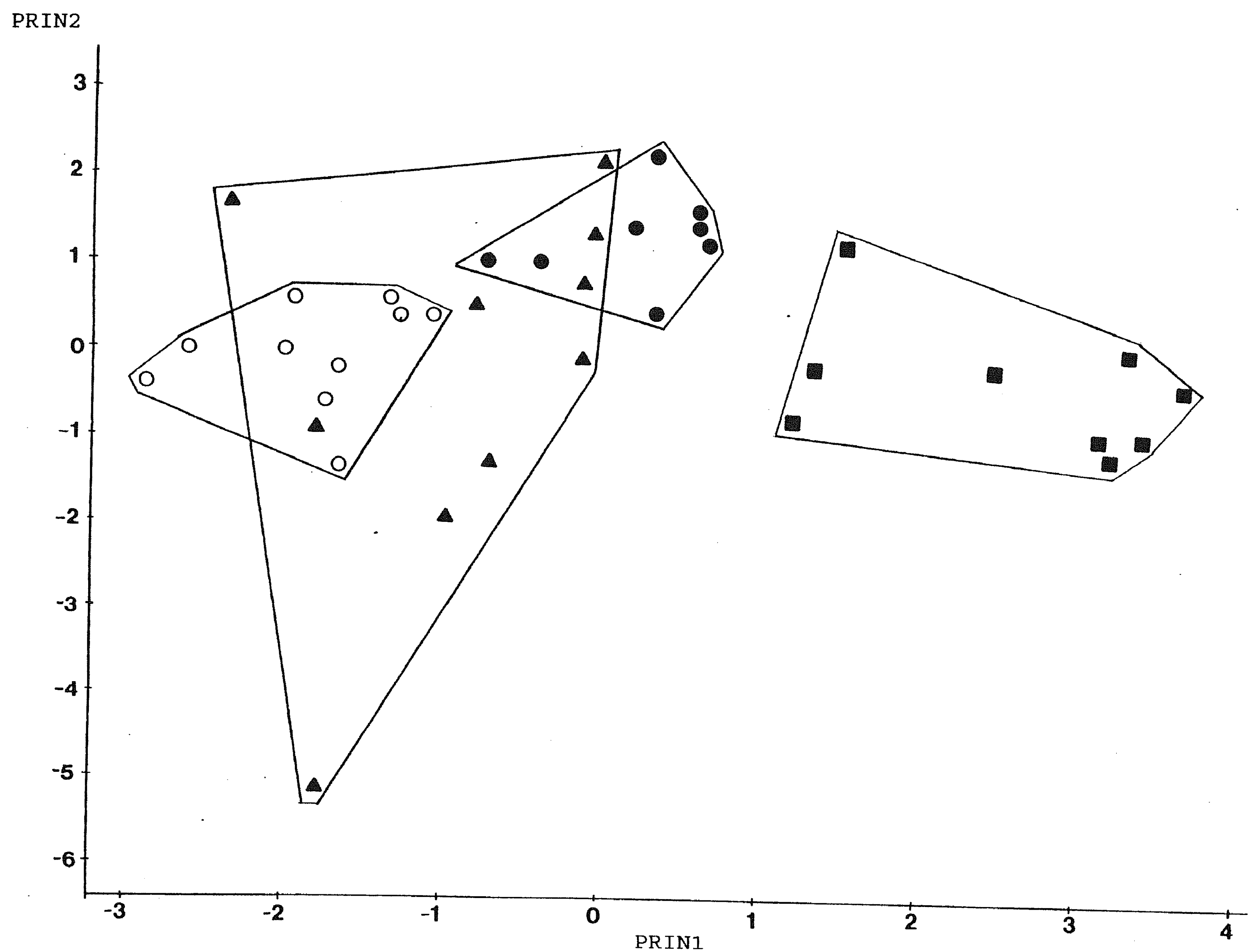

PRIN2
3
2
1
0
-1
-2
-3
-4
-5
-6
-3
-2
-1
0
1
2
3
4
PRIN1

Figure 22. Canonical discriminant analysis of site 10 data.

○ - Sub-site A
▲ - Sub-site B
● - Sub-site C
■ - Sub-site D

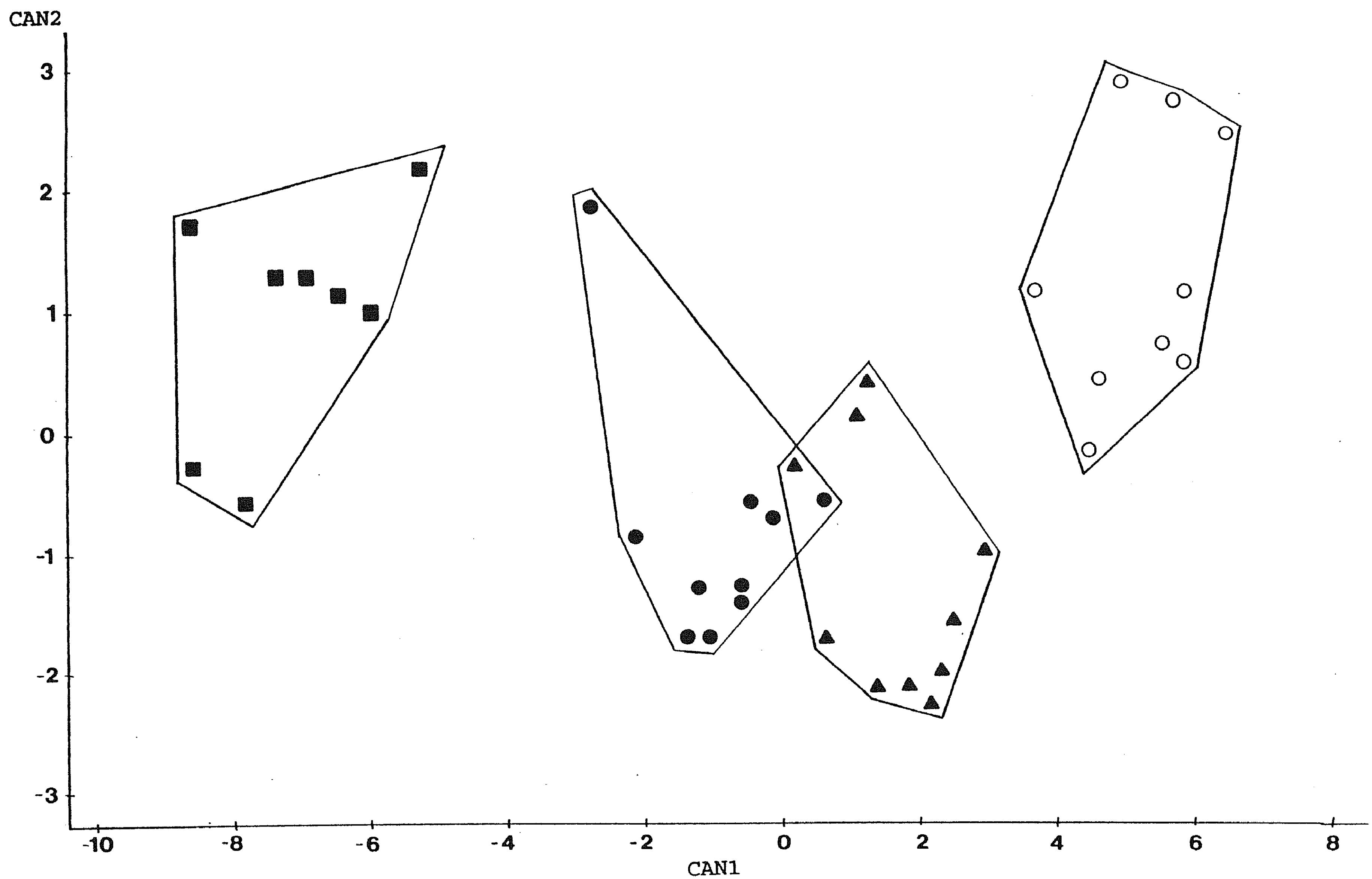
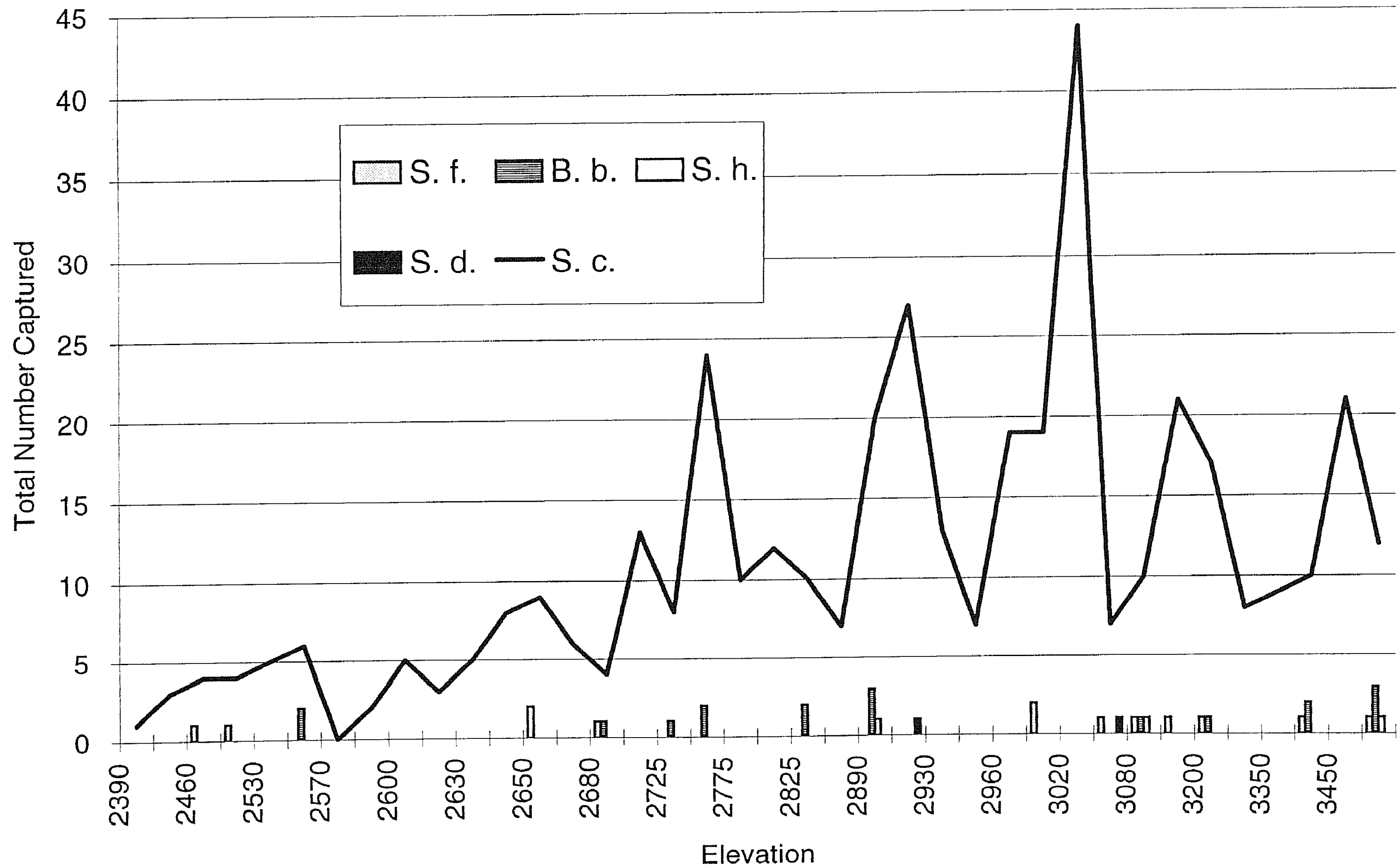

CAN2
3
2
1
0
-1
-2
-3
-10
-8
-6
-4
-2
0
2
4
6
8
CAN1

Table 7. Comparison of the mean values of environmental parameters for sub-site A, B, C, and D of site 10.

Parameter	Sub-site A	Sib-site B	Sub-site C	Sub-site D
Litter Composition	6.7	6.5	7.5	7.13
Litter Depth (in.)	1.55	1.7	2	1.88
Soil Nutrient	2.3	1.7	2.25	1.38
Soil Texture	2	1.8	1.6	1.25
Soil Composition	4.4	3.8	4.1	4.75
Soil Moisture	1.9	1.8	1.86	1.08
Mean Slope	8 °	9 °	19 °	36 °
Mean Elevation (ft.)	2522	2701	2936	3297

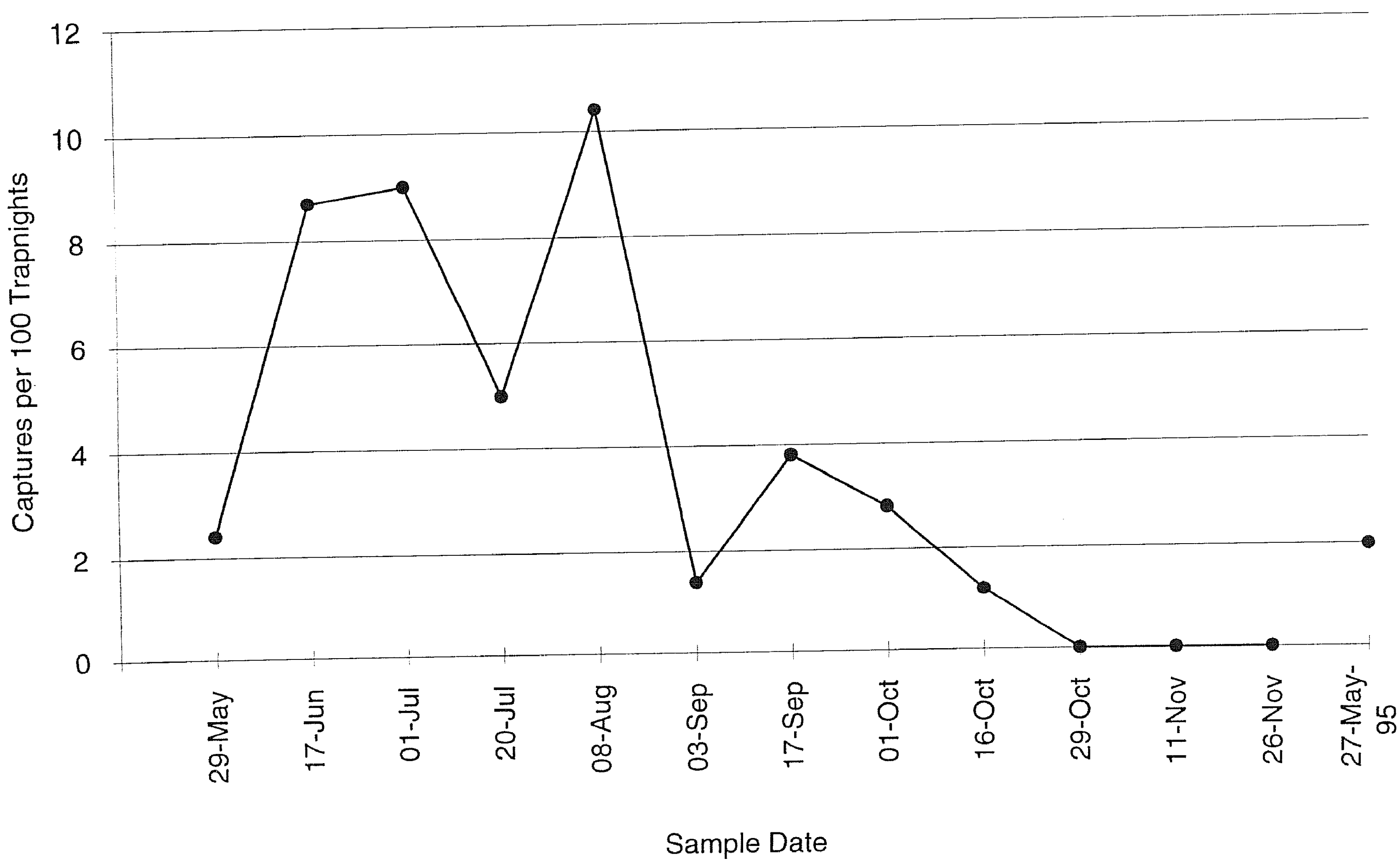
All parameters were found to have a significant difference of the means between sub-sites to $p<0.0001$ with the exception of soil nutrient, soil texture which were significant at $p<0.01$. Litter composition and soil composition were significant at $p<0.05$. Litter depth was not found to be significantly different at $p<0.05$ between sub-sites.

Figure 23. Distribution of soricid species along the site 10 transect.


45
40
35
30
25
20
15
10
5
0
Total Number Captured
S. f.
B. b.
S. h.
S. d.
S. c.
2390
2460
2530
2570
2600
2630
2650
2680
2725
2775
2825
2890
2930
2960
3020
3080
3200
3350
3450
Elevation

407 *S. cinereus* captures made during thirteen sampling dates and 8,808 trapnights (TN), the sample from this site provides an accurate representation of the population. In addition, being a single site, the between-site variations of habitat type, aspect, et cetera that could potentially skew the results did not exist in this species sample. Overall activity of this species had two peaks during the year of sampling. One peak occurred on the 1 July and the second on the September sample dates (Figure 24). These two samples represent captures made during the second half of the months of June and August and produced 9.4 and 11.2 captures per 100 TN, respectively. Weather trends were examined during the sampling period and several interesting trends could be seen. All of the samples had a positive correlation coefficient of 0.607 with precipitation levels and, in most cases, activity fluctuated approximately ten days after the precipitation (Figure 25). This response to precipitation has been supported by other studies (Kirkland and Sheppard 1994; Vickery and Bider 1977; Doucet and Bider 1974; Gentry *et al* 1966) for *S. cinereus*. This increase in activity is most likely in response to increases in invertebrate activity and abundance produced by increased in moisture levels. Another relationship existed between air temperature and activity levels; *S. cinereus* appeared to be most active at temperatures below 68°F and above 58°F (Figure 25). This pattern probably exists as an avoidance to desiccation in hot weather, and hypothermia in cold weather. Also of interest is the fact that beginning with the 17 September sample the capture rate decreased steadily until 29 October at which time no further captures were made through the 26 November when the traps were closed. This led me to believe that the population could possibly be depleted and

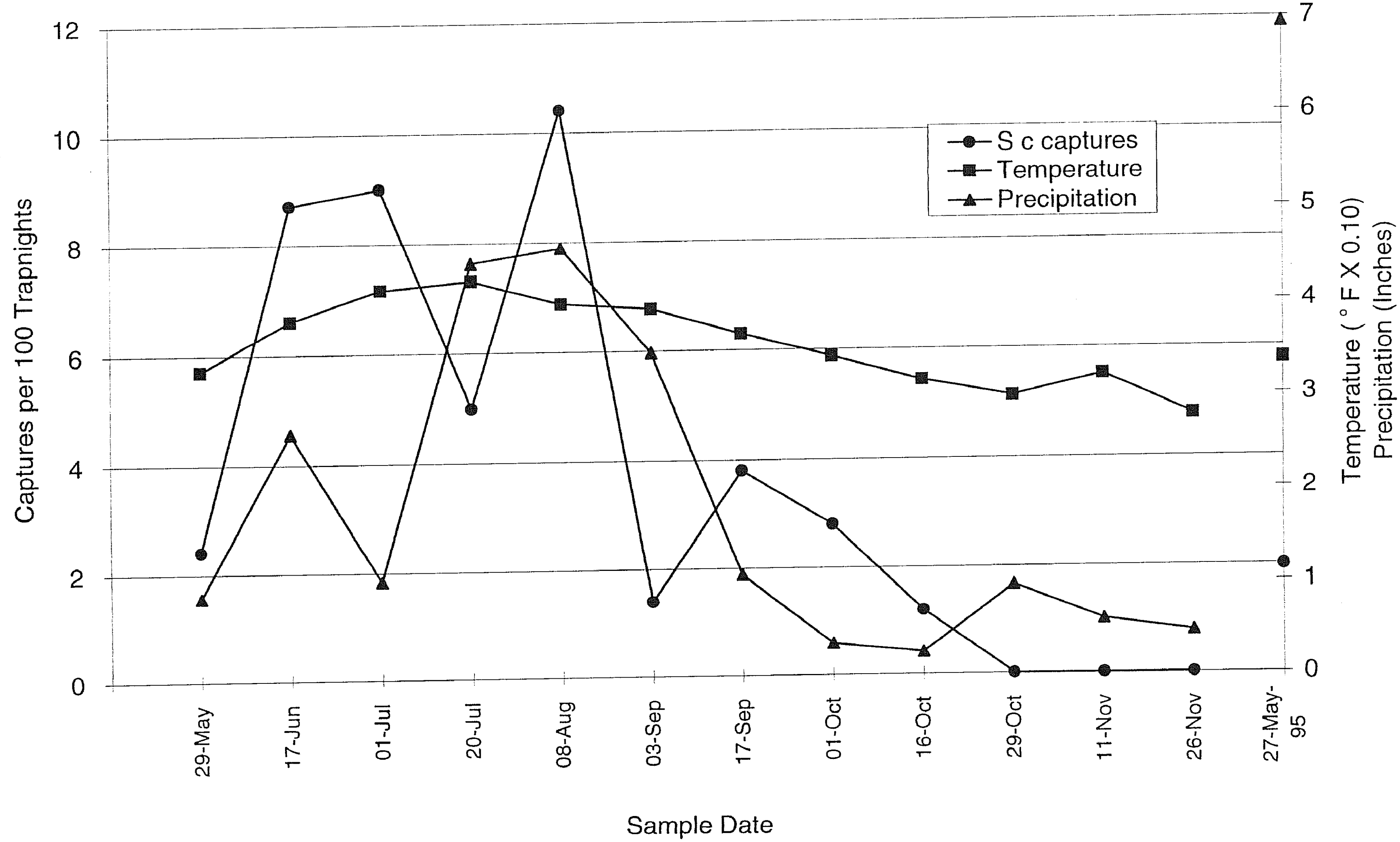
Figure 24. Temporal activity patterns of *Sorex cinereus* at site 10.



12
10
8
6
4
2
0
Captures per 100 Trapnights
29-May
17-Jun
01-Jul
20-Jul
08-Aug
03-Sep
17-Sep
01-Oct
16-Oct
29-Oct
11-Nov
26-Nov
27-May-95
Sample Date

Figure 25. Comparison of temporal activity patterns of *Sorex cinereus* with precipitation and air temperature.

Site 10 Activity Levels



that the remaining individuals of this species had been "trapped out". Upon making the 27 May 1995 sample after reopening the trapline on 15 April 1995, I had to re-evaluate what I thought had occurred the previous fall. The capture levels in May 1995 were as high as the May 1994 samples proving that the population had not been trapped out during the previous year. What appears to have occurred was a seasonal shifting of activity from a epigeal (surface) to a hypogeal (below ground) pattern. The animals had not been extirpated from the area, but were just no longer above ground where the traps could catch them. This is most likely the result of changes in temperature as well as precipitation levels as discussed above. All other sites, termed non-site 10, showed similar trends in monthly activity increases and decreases (Figure 26) although the overall sample size of these sites was greatly smaller (n=98) in comparison to site 10 (n=407).

Age Classes

The age structure of the *S. cinereus* population will also be discussed using the site 10 data. During the months sampled, the most obvious trend seen is the differences in the percentage of juveniles and adults in the population (Figure 27). Beginning in May of both years sampled, the entire sample consisted of adult specimens in breeding condition. Throughout the year the percentages of juvenile and adult specimens varied inversely with one another at a steady rate until October at which time juvenile individuals accounted for almost 90% of the population.

Sex Ratios

Over the year I noticed that the percentage of females in each of the age classes

Figure 26. Temporal activity patterns of *Sorex cinereus* at all sites.

Sorex cinereus

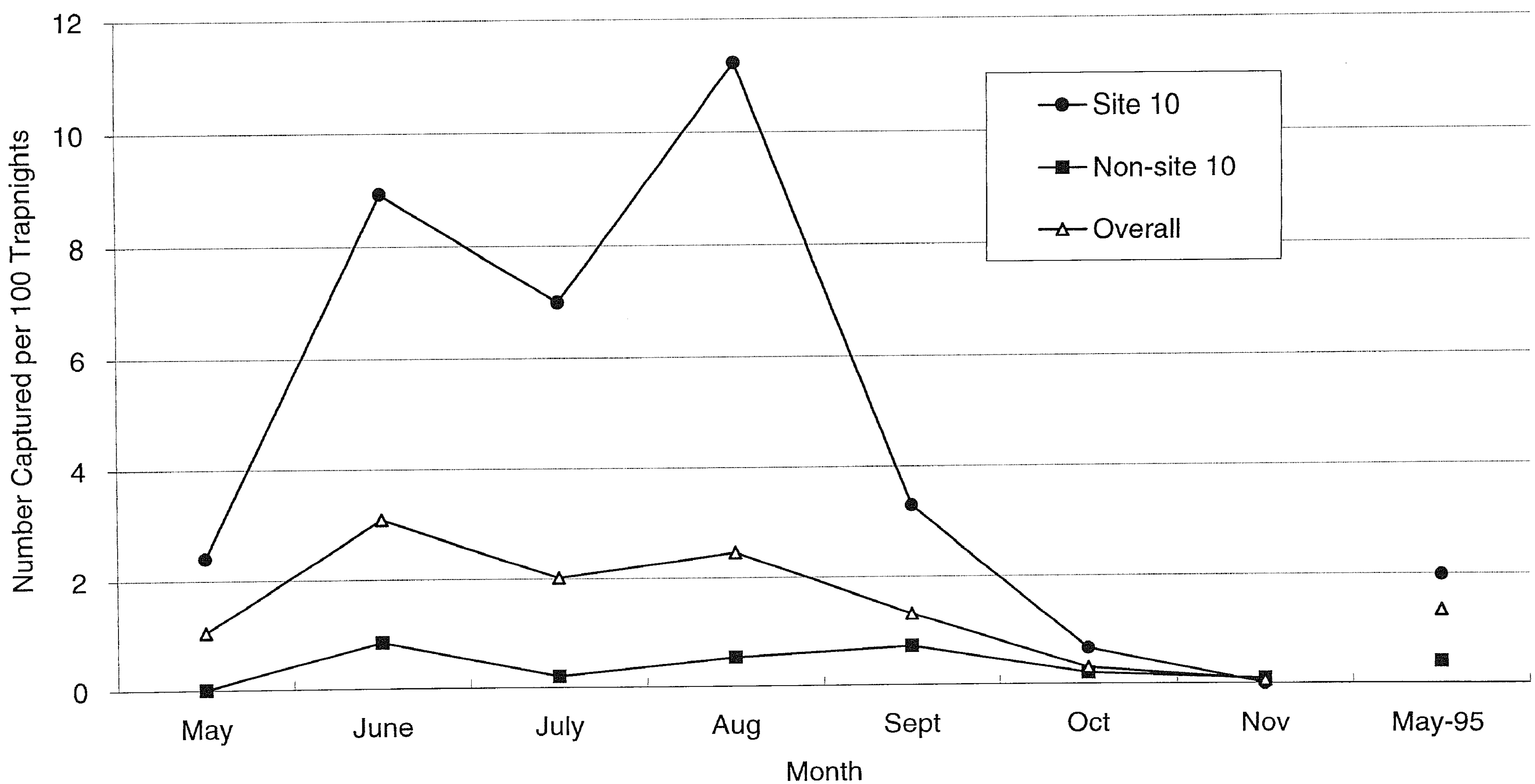
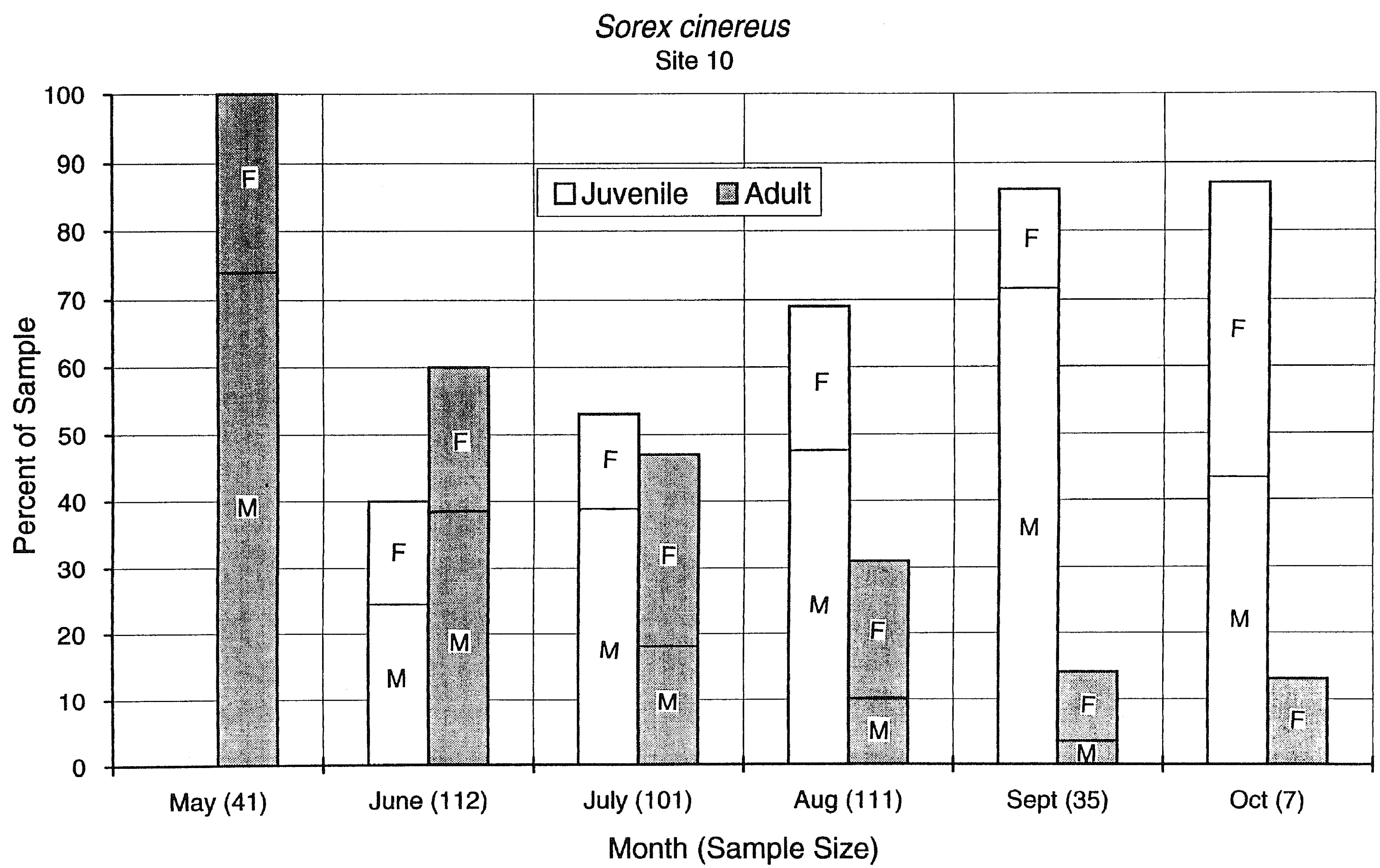


Figure 27. Temporal comparison of *Sorex cinereus* population age class structure and sex ratios of site 10 captures.

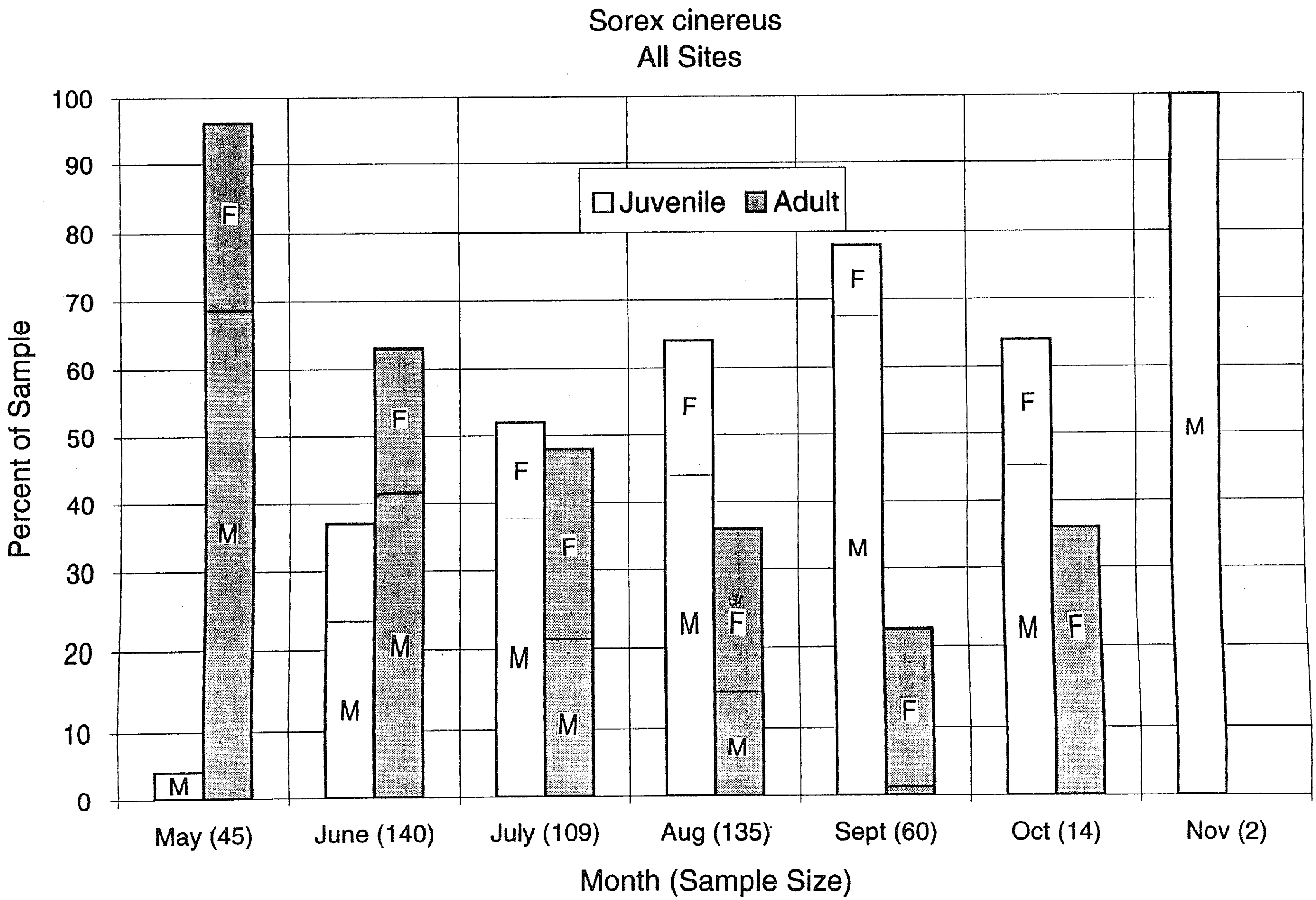

Sorex cinereus
Site 10
Juvenile
Adult
Percent of Sample
100
90
80
70
60
50
40
30
20
10
0
F
M
May (41)
June (112)
July (101)
Aug (111)
Sept (35)
Oct (7)
Month (Sample Size)

remained at an average of 19% until late October at which time the juvenile females increases to just over 40% and the adult sample contained only females. The proportion of adult males decreased steadily from May through September. Numbers of juvenile males increased steadily from May to a maximum of over 70% in September (Figure 27). Overall, the males were 1.5 times as abundant in the samples as females. The site 10 sample taken in October, is most likely misleading due to the small sample size of only seven individuals and should be of value only in activity level evaluation.By examining the reproductive data from the *S. cinereus* taken at all sites (Figure 28), an increased picture of the population structure was accomplished. Very similar trends in population sex ratios and age classes were also seen within the other areas samples and therefore add to the reliability of the patterns seen for the *S. cinereus.*

Reproduction

The breeding season for *S. cinereus* appears to begin in early April and lasts through late September in southern West Virginia. The onset of the breeding season was determined by the presence of one parous female and two non-scrotal males, one of which was a juvenile, taken during the 15 April 1995 sample. In addition, two pregnant, two parous, and one lactating female as well as 31 scrotal males were taken in the 27 May sample of 45 specimens from site 10. The end of the breeding season was determined by the absence of scrotal males and the capture of only one lactating female in the October sample. (Appendix III). An average of 5.2 young (n=57) are born after a gestation period of approximately 20 days. Young become sexually mature in two to three months although most mature over winter. The maximum lifespan is

Figure 28. Temporal comparison of *Sorex cinereus* population age class structure and sex ratios of overall captures.



Sorex cinereus
All Sites
Juvenile
Adult
Percent of Sample
100
90
80
70
60
50
40
30
20
10
0
May (45)
June (140)
July (109)
Aug (135)
Sept (60)
Oct (14)
Nov (2)
Month (Sample Size)

approximately 14 months based on the age class analysis discussed above.

Sorex fumeus

A total of 86 *Sorex fumeus* was captured during the study comprising 13.2% of the total soricid capture and 11% of the total capture. Overall, *S. fumeus* was most abundant in the stream bed habitat at 0.86 captures per 100 TN; second was mixed deciduous forest at 0.32 captures per 100 TN. This species was also taken in coniferous forest and old field habitat at 0.28 per 100 TN each (Figure 20).

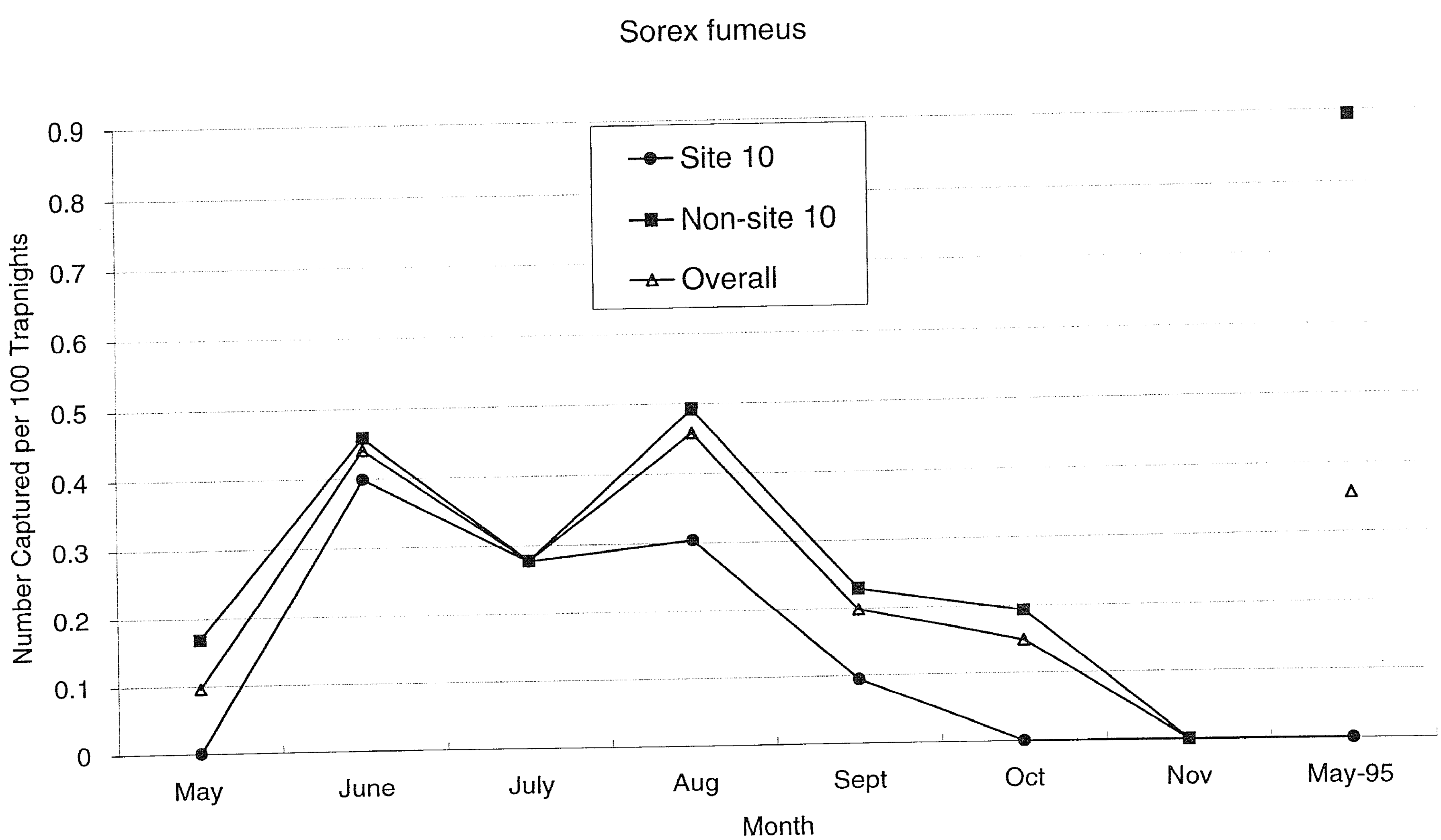
Microhabitat

At almost every site where *S. fumeus* was captured in abundance (sites 6, 9, 10, 14, 15), a dominant feature was the presence of a year-round water source within 50 meters of the site. By looking at the ANOVA of the stream bed habitat features that were most dominant include loose, moist, rich soils, with deep leaf litter. In comparison to all other habitat types, the one environmental variable that was most unique to the stream bed habitat was high levels of soil moisture (Table 2).

Seasonal Activity / Population Density

The activity of *S. fumeus* was highest at two times in the year. The first peak in activity occurred in June and the second in August. These two peaks produced 0.44 and 0.46 captures per 100 TN, respectively (Figure 29). It is interesting to note that this pattern of two peaks of activity, as discussed above, was also seen in *S. cinereus*. The activity levels of the two species (*S. cinereus* and *S. fumeus*) produced a correlation coefficient of 0.9472. This activity trend in S. fumeus supports the analysis of the effect of precipitation on *S. cinereus*. One noticeable difference in the *S. fumeus*

Figure 29. Temporal activity patterns of *Sorex fumeus* at all sites.



Sorex fumeus
Site 10
Non-site 10
Overall
Number Captured per 100 Trapnights
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
May
June
July
Aug
Sept
Oct
Nov
May-95
Month

sample, when compared to the *S. cinereus* sample, was seen between the May 1994 and May 1995 samples. Unlike the *S. cinereus* sample, the May 1995 sample was much higher in captures per 100 TN than the May 1994 (0.36 vs. 0.096). The only noticeable difference between the two years was the level of precipitation. In 1995 the precipitation for the May sample was over seven inches while the precipitation for May 1994 was only 0.9 inches. This supports the idea that precipitation positively effects the activity of *S. fumeus.*

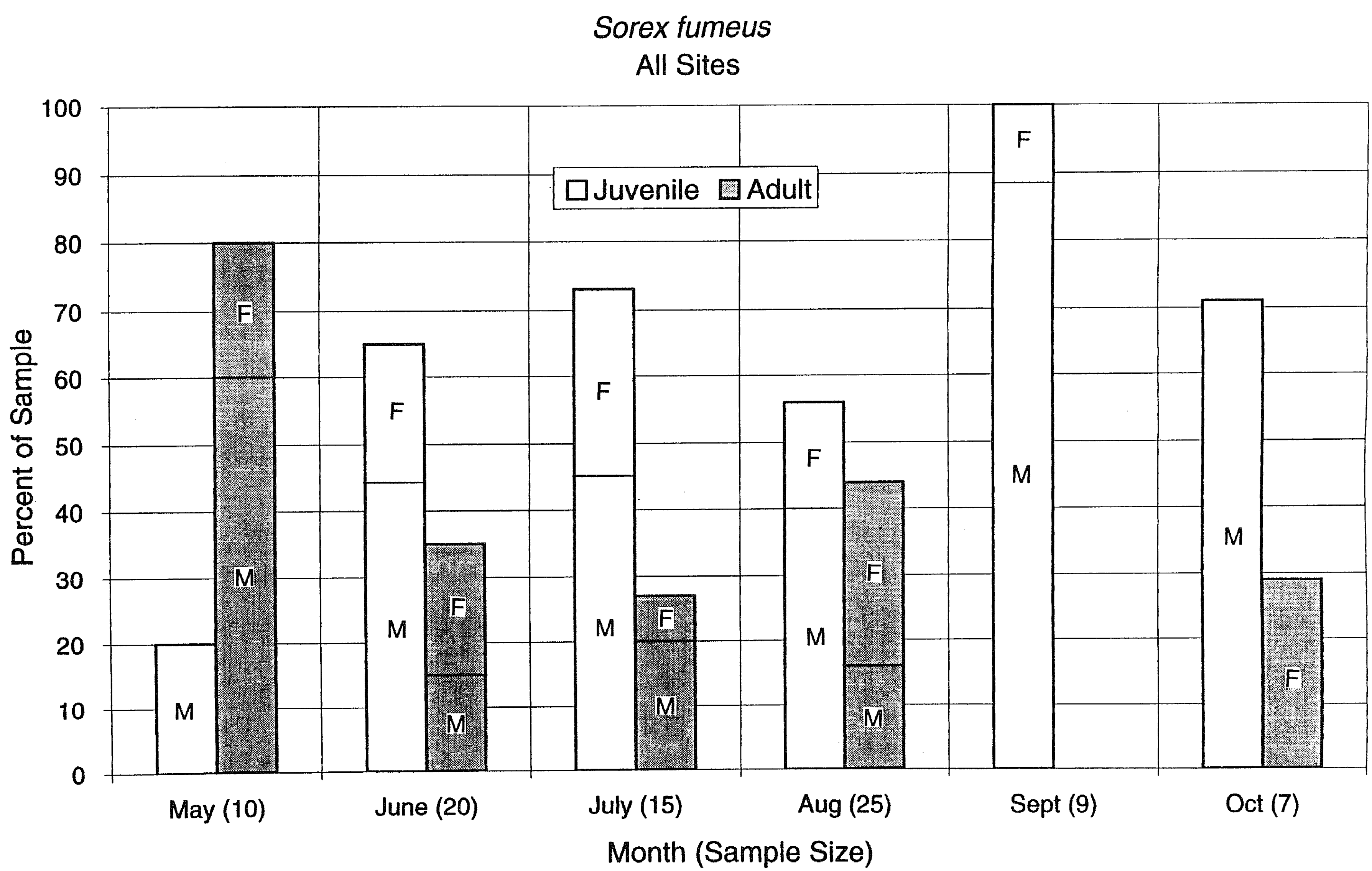
Age Classes

Beginning in May, 80% of the *Sorex fumeus* population consists of adult individuals. As the year progressed, the number of adults decreased until July after which a slight increase was seen (Figure 30). This increase is most likely due to the maturation of the individuals born earlier in the year. The percentage of juveniles increased from May through July and then decreased in August. September consisted of only juvenile specimens and October contained 70% juvenile specimens but I believe that these values are the result of a small sample size.

Sex Ratios

Over the year sampled, the fraction of the *S. fumeus* population that was female remained relatively constant at an average of 19%. The only difference was in the October sample at which time all adults were female and all juveniles were male (Figure 30). The majority of the population throughout the year consisted of males. Males were almost twice as abundant in the samples as females in all samples taken.

Figure 30. Temporal comparison of *Sorex fumeus* population age class structure and sex ratios of overall captures.



Sorex fumeus
All Sites
Juvenile
Adult
100
90
80
70
60
50
40
30
20
10
0
Percent of Sample
M
F
May (10)
June (20)
July (15)
Aug (25)
Sept (9)
Oct (7)
Month (Sample Size)

Reproduction

The breeding season of *S. fumeus* appears to extend from mid April to early September in southern West Virginia. This is based on a scrotal male taken in the 15 April sample and the presence of scrotal, parous, and juvenile specimens in the 27 May sample. The end of the breeding season was determined by the absence of any reproductive condition males in any samples after August (Appendix III). An average of five young was born (n=7) and appear to be gestated approximately 21 days. Only two sexually mature female specimens were taken in August indicating that maturation takes no less than three months although most do not mature until over winter. The maximum life span appears to be approximately 15 months.

Blarina brevicauda

Blarina brevicauda was represented by a total of 53 specimens and accounted for 8.1% of the soricid capture and 6.8% of the total capture. Among the habitats sampled, *B. brevicauda* was most abundant in flood plain habitat at 0.43 captures per 100 TN. Second in capture rates for this species was mixed deciduous at 0.19 per 100TN and third at 0.17 per 100 TN in stream bed habitat type (Figure 20).

Blarina brevicauda captures show a great number of confusing trends and appears to be an inaccurate sample of the population. A more thorough examination of the possible errors and their causes will be included in the discussion section.

Microhabitat

The characteristics of the flood plain habitat, that produced the highest capture rates for *B. brevicauda* included rich, moderately loose, wet soils, with a leaf litter depth of approximately 2.5 cm (Table 2). The abundance of this species and lack of other soricids is significant and will be examined in the discussion section. In comparison to the other habitat types, the main feature of the flood plain habitat type is the lack of deep leaf litter and the wet soils.

Seasonal Activity / Population Density

The seasonal activity of *B. brevicauda* shows a quite different pattern than the other species examined. Beginning in May a great deal of variation in capture rates was seen between sites. Overall, though, the capture rate showed a rather steady decline from May through November (Figure 31). The site 10 captures, in contrast, showed a steady increase from May to July and then decreased to November. No peaks in activity were seen as in the other shrew species. Some sites produced large numbers of captures per trapnight and others produced no captures at all.

Age Classes

A pattern can be seen by examining the age classes taken throughout the year. In all but one month, the percent of juveniles in the sample was over 75% (Figure 32). This seems to indicate that the samples taken did not provide an accurate assessment of the population and that the adults, for some reason, were not being trapped. Possible reasons for this result will be more fully examined in the discussion section.

Sex Ratios

The sex ratio during the year was approximately one to one within the juveniles sampled, and approximately two to one, female to male in the adult samples (Figure 32). These ratios also shed doubt on the accuracy of the samples taken and will be

Figure 31. Temporal activity patterns of *Blarina brevicauda* at all sites.

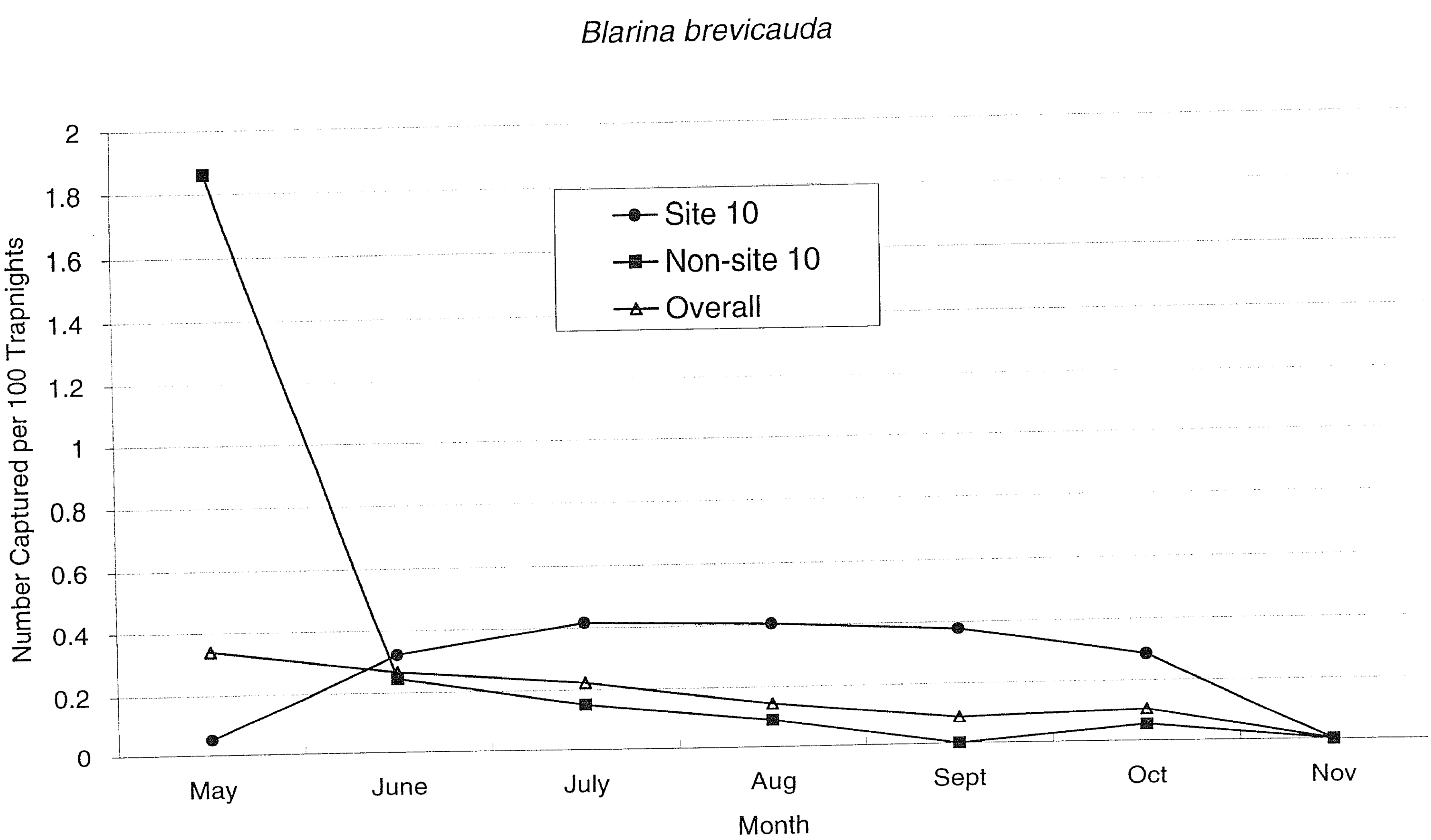
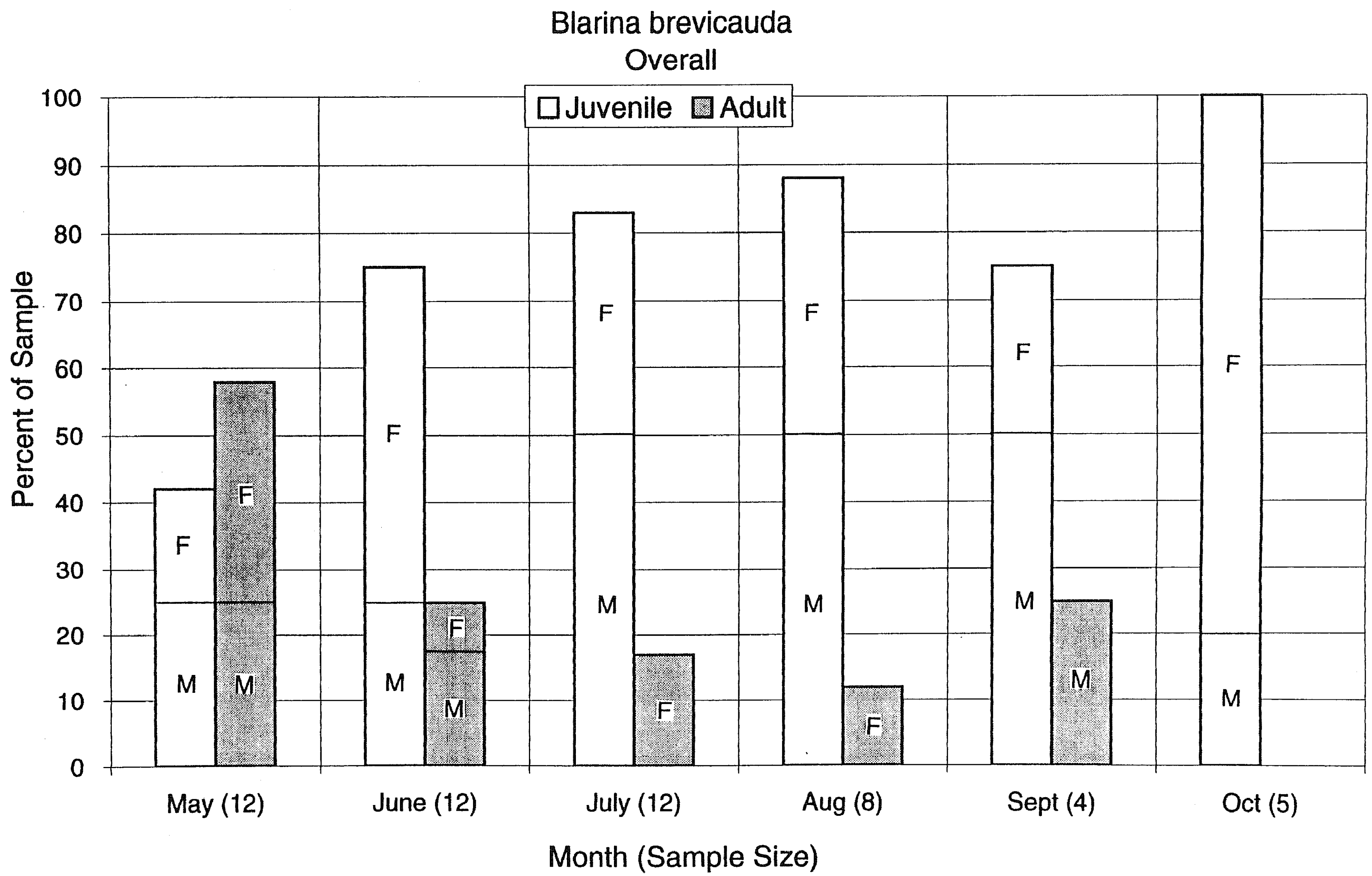

Blarina brevicauda
Site 10
Non-site 10
Overall
Number Captured per 100 Trapnights
2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
May
June
July
Aug
Sept
Oct
Nov
Month

Figure 32. Temporal comparison of *Blarina brevicauda* population age class structure and sex ratios of overall captures.


Blarina brevicauda
Overall
Juvenile
Adult
Percent of Sample
100
90
80
70
60
50
40
30
20
10
0
F
M
May (12)
June (12)
July (12)
Aug (8)
Sept (4)
Oct (5)
Month (Sample Size)

examined in the discussion section.

Reproduction

In southern West Virginia, the breeding season appears to begin in early April and continues through late September based on the high percentage (41%) of juveniles in the May sample and the absence of any adults in the October sample (Appendix III). The gestation period appears to be approximately one month and the young become sexually mature in four months. An average litter size of 4.5 young (n=6) was found to be born and the maximum life span for this species appears to be approximately 17 months.

Sorex hoyi

Sorex hoyi was represented in this study by five specimens accounting for 0.8% of the soricid capture and 0.64% of the total capture. Four of these specimens were taken in Merecer County and represent a new county record. Three of the five were trapped at site 10 on East River Mountain in Mercer county (traps 10.23, 10.31, and 10.38). One specimen was captured on each of the three sample dates of 20 July 1994, 16 October 1994, and 27 May 1995. The other two specimens were captured, one each, at site 15 (Mercer County), and site 17 (Summers County) on 2 September and 25 July 1994, respectively. When assessing the distribution of this species, it is difficult to definitely determine what its habitat preference is due to the small sample size taken, but some evaluation can be made. Of the five specimens taken, four occurred in a mixed deciduous habitat type, three in a mesic habitat and one in a xeric habitat. The remaining specimen was taken at the edge of an old field habitat near a mesic mixed deciduous forest. The average elevation of the specimens taken was 2984 feet indicating that this may be a higher elevation species but specimens of *S. hoyi* have been taken elsewhere in the state at elevations as low as 600 feet (Kanawha Co., MUMC 4366) which sheds doubt on an elevational limit to its distribution.

The microhabitat of the capture sites showed certain trends in the ecological requirements of this species. Of the specific traps at which the captures occurred, the presence of deep litter appeared to be a important parameter for this species. Even though site 17 was classified as a xeric mixed deciduous forest, it had very deep leaf litter and abundant fallen logs which would provide an adequate source of cover, moisture, and prey organisms for this species. This deep litter and presence of fallen logs is also seen at the site 10 captures of *S. hoyi*, and adjacent to the site 15 old field capture. The remaining environmental factors examined appear to have no significant effect on the distribution of this species

The activity levels / density of this species cannot be evaluated extensively due to the small sample size. However, even with only one or two captures per month, a partial description of this species can be made. It appears that, even with the small representative sample taken, *S. hoyi* has a breeding season that begins in early to mid May. This determination is based on the capture of one juvenile male on 27 May showing that breeding had already taken place by that time. The breeding season is believed to continue until mid to late October based on the capture of a fully scrotal male on 16 October. After a gestation period of approximately three weeks an average litter size of three (n=2) is born. This was based on the capture of a pregnant specimen on 25 July and a parous specimen on 2 September. The maximum life span appears to be approximately 13 months with juveniles maturing over winter and reproducing the following spring. The overall distribution of *S. hoyi* seems to be greater than once expected although the abundance of this species is very low in comparison to other small mammal and shrew species.

Sorex dispar

Sorex dispar was represented by only two specimens making up only 0.3% of the soricid capture and 0.25% of the overall capture. This species represents a new county record for Mercer County and was captured only at site 10 on East River Mountain during the entire study period. One capture (trap 10.24) was made on 20 July 1994 and one capture (trap 10.32) was made on 17 September 1994. Each of these captures was in an area that does not seem to fit the typical habitat description for this species. Typical habitat preference is described as being under and among rocks and talus slopes, and along cool mountain streams in areas full of moss-covered rocks (Kirkland, 1981). One of the specimens was captured in a fairly dry, open woodland with red maple (*Acer rubrum*), and white oak (*Quercus* alba) near the transition of sub-sites C and D (trap 32). The other was located in a mesic mixed deciduous forest containing sugar maple (*Acer saccharum*), buckeye (*Aesculus octandra*) and striped maple (*Acer pennsylvanicum*) with deep leaf litter, and loose, moist, rich soils. These two trap sites, upon later examination did appear to not have any characteristics matching the preferred habitat type description listed above. I could find no rocky areas within 500 meters of the traps and the rocky areas I did find were at the crest of the mountain. This area was very sunny and dry and consisted of an exposed rock outcrop and contained very little break down of any sort which would provide suitable cover as described by Kirkland (1981). In addition to the lack of rocky areas, wet areas in the form of seeps or creeks were not located within 1,200 meters of the capture locations. One explanation of the low number of captures made is that the preferred habitat was not present in the immediate area and that the two caught were from other areas and were only captured during extensive foraging at the edge of their home ranges.

The seasonal activity and density of this species was unable to be determined due to the extremely small sample size. Even by assuming that capture rates reflect activity and density, the captures made in July and September reveal almost nothing about the population. The two captures, a scrotal male on 20 July and juvenile male on 17 September cannot be used to evaluate the breeding season and sex ratios. Reproduction can also not be determined although it is probably most similar to that of *S. fumeus* due to their similar size.

Cryptotis parva

Only two Cryptotis parva were captured and these captures made up only 0.3% of the soricid capture and 0.25% of the total capture. The captures were made on 14 October and 2 September 1994 at site 18 in Summers County. The vegetation of this site was fairly unique (see site descriptions in methods section) but not uncommon in the area. The site looks like a typical field that has not been maintained and has been allowed to become overgrown. Trees had not yet invaded the area, nor has significant amounts of multiflora rose (*Rosa multiflora*) of blackberry (*Rubus* sp.) The main growth in the area consisted of a layer of dewberry (*Rubus* sp.) covering the ground and steeplebush (*Spirea tomentosa*) in small patches scattered through the field. In addition, goldenrod (*Solidago* spp.) was present but only in small, thin clumps.

With a sample size of only two specimens, no activity pattern information was determined. In addition, no population analysis can be conducted due to the small sample size. Two specimens, one juvenile male and one juvenile female, were captured within one month of each other thus preventing any age class or breeding season determination. This species is considered very rare in West Virginia and is currently listed as a species of special concern in West Virginia (WVDNR 1990). The last known specimen from the state was taken in 1969 1.5 mi south of Camp Creek in Mercer County. Other specimens have been taken in Cabell and Mason counties in 1968 and 1949, respectively.

COMMUNITY STRUCTURE

In order to achieve an accurate examination of the community structure of shrew species, it is necessary to look at the relative numbers of each species in each habitat. Caution must be taken not to compare captures taken in different habitats consisting of varying numbers of trap nights. Table 8 shows the numbers of captures, by habitat type, of the soricids in this study as well as the percentage of the total capture in each habitat. It should be noticed that even though different habitats may have the same species present, the abundance of each of the species within the habitats is quite varied. By subjecting the habitat types and their shrew communities to a diversity

Table 8. Community structure of soricids during 1994-1995 pitfall trapping in Mercer and Summers counties, West Virginia. Number of specimens captured in each habitat type and percentage of sample total in each habitat.

	Mixed Decid.	Xeric Mixed Decid.	Conifer. Forest	Old Field	Stream Bed	Flood Plain	Cultiv. / Grazed	Total Specimens of Each Species
Sorex cinereus	434 84.1%	0 0%	17 54.8%	34 75.5%	20 52.6%	0 0%	0 0%	505 77.3%
Sorex fumeus	48 9.3%	1 33.3%	12 38.7%	7 15.6%	15 39.5%	1 5.3%	2 100%	86 13.2%
Blarina brevicauda	29 5.6%	1 33.3%	2 6.5%	1 2.2%	3 7.9%	18 94.7%	0 0%	53 8.1%
Sorex hoyi	3 0.6%	. 1 33.3%	0 0%	1 2.2%	0 0%	0 0%	0 0%	5 0.8%
Sorex dispar	2 0.4%	0 0%	0 0%	0 0%	0 0%	0 0%	0 0%	2 0.3%
Cryptotis parva	0 0%	0 0%	0 0%	2 4.4%	0 0%	0 0%	0 0%	2 0.3%
Total Soricid Specimens	516 79%	3 0.5%	31 4.7%	45 6.8%	38 5.8%	19 2.9%	2 0.3%	653 100%
Total Trapnights	14991	4895	4275	2490	1735	4150	1677	34213

index and an analysis of community similarity (Eckblad 1986-89) these factors could all be assessed accurately. The results of this analysis showed that stream bed habitat had the highest diversity, with coniferous forest with the second and old field with the third highest diversity. These habitats, although not the most productive in terms of numbers captured, did provide an even distribution of the species present and were not dominated by one species. The percent similarity of the habitats, based on the taxa and numbers present, can be seen in Table 9.

Table 9. Percent similarity of habitat types based on soricid species captures.

Habitat	Xeric Mixed Decid.	Mixed Decid.	Conifer. Forest	Flood Plain	Stream Bed	Old Field
Mixed Decid.	15.5					
Conifer.	39.8	69.8				
Flood Plain	20	87.7	72.6			
Stream Bed	41.2	67.6	97.8	70.4		
Old Field	38.6	10.9	11.7	7.5	13.2	
Cult/Grazed	33.3	9.3	38.7	15.6	39.5	5.3

It was interesting to find that habitats such as coniferous forest and stream bed, while appearing so superficially different in environmental characteristics, with very similar shrew community structure. This demonstrates that even if habitats appear diverse and productive superficially, they may not always be diverse in terms of the species present.

NON-SORICID CAPTURES

Eight species of rodents were captured during the study. Of these, *Peromyscus* spp. (*P. leucopus* and *P. maniculatus*) and *Napaeozapus insignis* were the most abundant species captured. Within the rodents taken, trends in the ages of the specimens could be seen. In the captures of *Peromyscus* spp., *N. insignis*, and *Zapus hudsonius*the majority of the samples consisted of juvenile specimens. In *Peromyscus* spp., juveniles were more than twice as abundant in the samples as the adults. Voles (*Microtus* spp., and *Clethrionomys gapperi*) were represented by approximately equal numbers of juveniles and adults. The presence of a high percentage of juveniles in the samples indicates that the traps were differentially selective for the age classes of larger mammals. Adults were either able to avoid capture or were able to escape the traps after falling into the trap. Those species that were approximately equal in juvenile and adult captures (*Microtus* sp, *C. gapperi*) are larger species that are more chunky and robust than the field and jumping mice species. For these species, the adults and juveniles were unable to escape the traps due to their lack of agility.

In addition to the small mammals captured many other species of organisms were caught including many types of invertebrates (Arachnida, Coleoptera, Hymenoptera, Diplopoda, Chilopoda, Decapoda) as well as vertebrates (Caudata, Anura, Lacertilia). The vertebrates were given to Dr. Thomas K. Pauley at Marshall University and some of the invertebrates (Arachnida) were given to Dr. W.J. Arnold of Huntington, West Virginia. The Caudata captures consisted of the genera *Plethodon*, *Eurycea*, *Pseudotriton*, *Desmognathus*, and *Ambystoma.* The Anuran captures consisted of the genera *Rana*, *Bufo*, and *Pseudacris.*

DISCUSSION

The results of this study show that pitfall traps are very efficient in capturing the small soricid species which might be misrepresented by conventional sampling methods. In addition, when compared to the pitfall surveys done by Kirkland *et al.* (1990), the selectivity for shrew species, except *Blarina brevicauda*, was increased by the presence of the drain hole which limited the fluid depth to less than 3.8 cm (Table 10). All other features of the trap placement, except the artificial drift fences, were essentially the same between the two studies.

Table 10. Comparison of manipulation of pitfall trap set-up.

Category	Kirkland *et al.*, 1990	This Study
% Soricids	58.1	83.4
% *Sorex*	41.4	76.4
% *Sorex* of Soricid spp	71.2	91.6
% *Blarina* of Soricid spp.	28.8	8.1
% *Peromyscus* spp.	24	6.1
% *Clethrionomys sp.*	12.4	2.3
% *Microtus spp.*	5.4	0.64

Sorex cinereus

Of the species captured, *S. cinereus* is the least limited in distribution although the preferred habitat type was found to be mixed deciduous forest. It is especially abundant in areas in which deep leaf litter and moist soils are found. This species was most completely represented in the study and provided almost limitless information on the population structure and biology of this species. In addition, with over 500 specimens taken from southern West Virginia, an accurate assessment of the distribution and characteristics of the southeastern shrew (*Sorex longirostris*) can be accomplished. I examined over 200 of my specimens and found that approximately 13% appeared to be *S. longirostris*. This was based solely on the size of the third unicuspid relative to the second and fourth unicuspid (Figure 1). These specimens were taken from many sites and appear to indicate that this southern species may be more common and widespread in West Virginia than once thought.

Sorex fumeus

Sorex fumeus is typically found in a habitat within close proximity to a constant supply of moisture. An ideal area in which to find *S. fumeus* would be next to small stream running through mixed deciduous forest. This species, however is not limited to this habitat type. Even at sites located a great distance from a constant water source, moisture is still a major factor in the distribution of this species. At sites where *S. fumeus* was relatively abundant it is possible that the presence of deep vegetation (site 15) and an elevational gradient (site 10) allow the utilization of daily condensation formation in these areas by this species. During many samples taken early or late in the day, I noticed a great deal of condensation on the vegetation of site 15 and on the ground's surface in areas of sub-site C and D of site 10 (Figure 23). The sub-site D captures were especially notable because the moisture of the soils were very low during all visits unless during a strong downpour. An additional reason for the occurrence of *S. fumeus* in non-typical areas may be due to their large home range.

This species can move great distances in search of mates and food. With the ability to travel great distances the need for moisture would not be reflected in the captures made in relatively dry areas such as site 15 and site 10 sub-site D.

Blarina brevicauda

Blarina brevicauda appears to be very widespread in its distribution, probably even more than *S. cinereus*. But the samples of *B. brevicauda* appear to not accurately represent the population present in the areas surveyed. One reason for this conclusion is the overall lack of this species in the study. *B. brevicauda* is known for being very tolerant of environmental extremes and in being able to inhabit almost all terrestrial habitats and should have been captures in abundance. When compared to Kirkland *et al.* (1990) above, this study resulted in almost 20% fewer captures. Another reason I believe the sample was not representative is due to the overall abundance of juvenile specimens in every sample. Two explanations for the skewed population samples are that the traps were unable to capture any *B. brevicauda* or that it was unable to keep any specimens of this species within the trap until removed. The first reason, inability of the traps to capture the species, is based on the possibility that *Blarina* is behaviorally different from *Sorex*. It may be slightly more cautious in its movements and able to detect the drop off at the top of the trap and not fall in. The second possible explanation, the inability of the trap to retain the species, is based on the size of *Blarina* in relation to *Sorex*. *Blarina* is much larger in size and may be able to jump out of the pitfall. This would also explain the dominance of juvenile specimens in the samples taken because younger, smaller specimens are weaker and less agile than adults and cannot escape the traps. Of the adults captured, the presence of embryos, enlarged mammary glands, and enlarged testes would produce weight gain and a possible loss of agility. These adults were no longer able to escape from the pitfalls by jumping out. Concerning the habitat selection of *Blarina*, specimens of *B. brevicauda* were taken at a variety of habitat types, and I believe that this species is not limited, nor does it normally prefer, flood plain habitat. This leads me to hypothesize that some feature of the flood plain habitat is allowing *B. brevicauda* to utilize this habitat. One such feature may be the periodic flooding of the area. Flooding removes the litter layer which has been shown to be an important characteristic of shrew habitat selection both as cover and source of prey supply. This would tend to eliminate small shrew species from the area. In addition, flooding fills crevices in which shrews forage and travel with sediment. Flooding also effects the shrews directly. The inundation of an area leaves small mammals two choices; to flee or perish. *Blarina brevicauda* with its large size and strength would have no problem moving out of the area and returning after the waters had receded. Smaller shrews would most likely drown or not to return to a now bare, muddy area.

Sorex dispar

Sorex dispar appears to not be as limited in range as once thought by researchers. The discussions of habitat preference made of *S. dispar* usually describe the prefered habitat as being a rocky talus slope area or along a cool stream among moss covered rocks. Of the captures made in this study, no such habitat was found during a search of the area adjacent to the capture sites. The nearest areas similar to this "preferred habitat type" were located at the top of site 10 at a rock outcrop on the West Virginia/ Virginia border. Either the captures made in this study show a greater habitat tolerance of the species than once believed or, as discussed for *S. fumeus*, perhaps the specimens captured were not from the direct proximity of the capture sites. They may have been venturing far from preferred habitat after mates, food or have just been in the far edges of their home range.

Sorex hoyi

Sorex hoyi appears to be limited by its small size and high metabolism and high food quantity requirements. This limits it to areas that contain deep layers of leaf litter and large rotting logs that provide moisture and adequate prey supply. Laerm (1994) has discussed the distribution of *S. hoyi* along the southern Appalachian Mountains and determined that it is a habitat generalist. I would agree with his findings and feel that, although locally rare, *S. hoyi* is able to utilize a wide range of habitat types. The most effective way to survey an area for *S. hoyi* would is to look for areas of deep leaf litter (>10 cm) and fallen logs and place high numbers of traps for long periods of time in these areas.

Cryptotis parva

Cryptotis parva, being found only in old field habitat, poses a unique situation to researchers. Old field habitat is currently being cleared and cultivated, or is succeeding to forest, in most areas of the state. This reduction in habitat type, along with limited field surveys, is probably the reason behind the lack of captures in the state in the last 25 years. Highway and powerline right-of-ways could provide suitable habitat although these areas are usually maintained by mowing or clear-cutting. It was seen in this study that cultivated areas (hayfields) do not support shrew species. In order to properly evaluate and manage this species in the state, areas of old field habitat must be located and surveyed.

SORICID CAPTURE TRENDS

Overall, the most important features of an area that determine the distribution and productivity of shrew species are moisture, litter depth, and vegetation. All of these characteristics have both direct and indirect effects on the shrews present. As shown above in the results section, the amount of moisture appears to be an important environmental characteristic which is highly correlated with the numbers of shrews present in an area.

Moisture directly effects shrews by preventing desiccation and death. Shrews with their high surface area to volume ratio are constantly at risk of death by dehydration. While most of their water is acquired through the food they eat, living in a moist environment reduces the amount of moisture lost through evaporation.

The amount of moisture also indirectly effects shrews by being a limiting factor to the numbers of invertebrate prey present in an area. In most situations, more moisture increases the numbers of invertebrate prey. The effects of moisture on the distribution of shrews are most easily seen by comparing xeric and mesic mixed deciduous forest sites. Within the five xeric sites, only three specimens were captured during the entire study. In comparison, the mesic mixed deciduous forest provided 516 specimens representing six species. The capture rates for the xeric and mesic mixed deciduous forest were 3.4 per 100 TN and 0.06 per 100 TN, respectively. In most cases, the amount of moisture determines the numbers of prey organisms present in an area.

Leaf litter depth also effects the numbers of prey organisms present in the area by providing a food source for invertebrate species and by acting as a moisture retaining layer in an area. In general, the deeper the layer of leaf litter, the higher the moisture, and the greater the numbers of invertebrates present. A deep layer of leaf litter also provides cover for the shrews and invertebrates that protects them from predation.

Vegetation effects the distribution of shrews in much the same way as the leaf litter does. The degree of coverage of the area by vegetation determines the amount of insolation the area receives which in turn effects the moisture content of the soil. In addition, vegetation provides a food source for invertebrate prey organisms and provides cover objects which protect the shrews from predators.

For all shrew species, another major limiting factor of the distribution of a species may be the presence of other shrew species, especially *Blarina brevicauda*. *Blarina* is a voracious predator of small mammal species including mice, voles, and other shrews. With its venomous saliva, large size, and powerful jaws, it could easily kill and devour smaller shrew species it encountered. It appeared that in areas with a high *Blarina* population density a low *Sorex* population density existed. In some situations this was due to environmental features of the area (flooding), but at other sites, when *Blarina* was captured, few *Sorex* were taken near the same traps for that sampling period.

Overall, all species showed similar patterns of activity levels. Following periods of precipitation, the activity levels increased in response to increases in invertebrate population numbers. At high and low temperatures epigeal activity was decreased in avoidance of desiccation and hypothermia until a point at which no specimens were captured during any sampling periods (after mid-October in the 1994 samples). Shrews shift from an epigeal to a hypogeal mode of foraging based on the temporal changes in environmental characteristics.

SUMMARY

Overall this study provides a great deal of information on the distribution and natural history of shrews in Mercer and Summers counties, West Virginia. The pitfall traps were very effective in capturing soricids while excluding captures of large numbers of small rodents. Pitfalls, while somewhat labor intensive to install, were inexpensive, lightweight (ca. 70 g), durable, and very easy to maintain. Baiting of the traps was not necessary during the study and, through the use of preservative, the traps could be left unchecked for several weeks. The modification of the fluid depth allowed larger mammals to escape but, by increasing this depth, other species could be captured for use in a overall mammalian community study of an area. The only drawback encountered with the limitation of fluid depth was the ability of *Blarina brevicauda* to escape from the traps.

The statistical analyses (PCA and CDA) of the environmental variables examined did not show the separation that would have helped elucidate the differences between the habitat types and assist in determining the specific variables directing the niche selection of the shrew species caught. One reason for this lack of separation could be the subjective nature of the field data taken. A better method of recording the field data in future studies would be to use more quantitative methods for data collection of each of the variables examined. The GPS unit performed well although, in some areas, dense canopy cover and limited satellite coverage areas (few satellites in view from remote areas) produced errors in readings or an inability to achieve a reading at all.

Of the trapping method itself, improvements could be made to similar studies in the future. One would be to conduct a specific analysis of population density at each site in addition to the transect sampling. This could be accomplished through the use of at least one grid or enclosure of a known size (1 ha^2) at each site or by the use of a mark-recapture study. My use of line transects in combination with the removal captures and an open population did not allow an precise estimate of the population density. The use of a grid or enclosure would have been slightly more labor intensive than just a line transect but would provided more exact population density analyses. The use of mark-recapture studies of shrews are very difficult due to their high mortality after capture which requires that a food supply and cover object be placed in each trap (Cawthorn 1994). Also each trap would need to be checked at least every two hours to insure a low mortality rate of the naimals captured.

An additional improvement to include in future studies would be to check the traps more frequently. With a period of approximately two weeks between trap checks, the population dynamics of the species were only able to be analyzed by month and not by week which would have allowed a more accurate analysis of the population. Also, sampling done earlier in the year (March - April) will allow an extension of the temporal activity and breeding season analyses. These early samples were unable to be taken in this study due to the remote areas sampled and the poor road conditions in the spring of the year.

Additional analyses which could be conducted with the materialtaken in this study include a diet analysis of the soricids caught, an endo- and ectoparasite examination, a thorough morphological examination of the *S. cinereus* and *S. longirostris* captures, an analysis of geographic and non-geographic variation, an analysis of possible seasonal population shifts between habitat types, and a more thorough examination of population age class structure using more than two age classes. Diet analysis will help to avaluate any potential resource partitioning, both in size and type of prey selected. I believe that an endo- and ectoparasite examination of shrews will provide very interesting information on the parasites of small mammals that has not ben investigated in depth. On the 2 September 1994 sample of East River Mountain, I noticed numerous mites on the shrews removed from the traps. Due to multiple captures of shrews in the traps, I was unable to evaluate the number of parasites per individual, or differences the prevalence of these mites on the different sexes and age groups of the shrews. In addition, parasitic roundworms were found encysted in the abdominal mesenteries of specimens examined from the 27 May 1995 sample from East River Mountain. These initial findings lead me to believe that parasites have a large part in the life of a shew and, with the large sample sizes taken, an analysis of parasitic infections of shrews might be easily accomplished. A morphological examination of *Sorex cinereus* and *Sorex longirostris* could also be accomplished with the large sample size taken. Any geographic variation could easily be eliminated by only using specimens from single sites. This analysis should include as many cranial and external characters as possible to accurately evaluate these two species. An analysis of geographic and non-geographic variation can also be accomplished through use of the specimens taken in this study. By looking at the abundance of a species in a particular habitat in different months, I also noticed the movement of species from one habitat type to another. Examination of the ages of the specimens using more than two age classes will provide further understanding on the population dynamics of soricid species.

An additional separate study that I think should be done in southern West Virginia is a comparison of different transects on East River Mountain. After seeing the productivity of the East River mountain site I believe that this mountain range could provide additional information on the biogeography of shrew species in the Appalachian Mountains. These transects could be placed on the mountain along its southern end near Tazewell, Virginia, its northern end at Narrows, Virginia and at locations between these sites. In addition, a comparison of the Virginia sites might be made with similar studies conducted on Peters Mountain in Monroe county. East River and Peters Mountains are portions of the same mountain range which is bisected by the New River at Narrows, Virginia. An examination of these two geographically isolated populations could help to examine the biogeography of the area and the shrew species present there.

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APPENDIX I

Locality designations of study sites.

LOCALITY DESIGNATIONS

SITE 1 and 2
West Virginia, Mercer Co., 0.2 mi. E of Gardner Jctn, 2390', (37 23 45 N, 81 05 00 W)

SITE 3
West Virginia, Mercer Co., 2.0 mi. S, 0.2 mi. E of Spanishburg Church, 2200'-2420', (37 25 30 N, 81 06 15 W)

SITE 4
West Virginia, Mercer Co., 2.5 mi. S, 0.4 mi. E of Spanishburg Church, 2110'-2150', (37 24 40 N, 81 06 40 W)

SITE 5
West Virginia, Mercer Co., 2.9 mi. S, 0.4 mi. W of Spanishburg Church, 2150'-2360', (37 24 05 N, 81 07 00 W)

SITE 6
West Virginia, Mercer Co., 0.4 mi. N, 0.6 mi. W of Goodwyn Chapel, 1900'-1950', (37 21 08 N, 80 58 50 W)

SITE 7
West Virginia, Mercer Co., 0.8 mi. N, 0.4 mi.W of Goodwyn Chapel, 2060'-2200', (37 21 25 N, 80 58 30 W)

SITE 8
West Virginia, Mercer Co., 0.2 mi. S, 2.4 mi. W of Elgood, 2320'-2400', (37 23 50N, 80 58 30 W)

SITE 9
West Virginia, Mercer Co., 0.3 mi. N, 2.5 mi. E of Oakvale Cemetery, 1880'-1960', (37 20 30 N, 80 54 35 W)

SITE 10
West Virginia, Mercer Co., 1.2 mi. S, 2.8 mi E of Oakvale Cemetery, 2390'-3490', (37 19 01 N, 80 54 20 W)

SITE 11
West Virginia, Mercer Co., 2.5 mi. S, 0.5 mi., W of Dunns Church, 2160', (37 30 53 N, 81 33 45 W)

SITE 12
West Virginia, Mercer Co., 2.5 mi. S, 0.3 mi. W of Dunns Church, 1950'-2080', (37 30 53 N, 81 33 20 W)

SITE 13
West Virginia, Mercer Co., 0.8 mi. S, 0.3 mi. W of Huff Knob, 3250', (37 34 45 N, 81 05 37 W)

SITE 14
West Virginia, Mercer Co., 0.7 mi. S, 1.1 mi. E of Huff Knob, 3150', (37 34 45 N, 81 05 37 W)

SITE 15
West Virginia, Mercer Co., 1.7 mi. N, 1.4 mi.W of Dunns Church, 2880', (37 34 35 N, 81 04 45 W)

SITE 16
West Virginia, Mercer Co., 1.3 mi. N, 1.3 mi. W of Dunns Church, 2660'-2700', (37 33 45 N, 81 04 30 W)

SITE 17
West Virginia, Summers Co., 0.3 mi. N, 0.6 mi. E of Pipestem Knob, 2580', (37 01 30 N, 81 57 45 W)

SITE 18
West Virginia, Summers Co., 0.7 mi. N, 1.0 mi. E of Pipestem Knob, 2540', (37 02 00 N, 80 57 15 W)

SITE 19
West Virginia, Summers Co., 1.2 mi. N, 1.8 mi. E of Pipestem Knob, 2530', (37 02 20 N, 80 56 30 W)

SITE 20
West Virginia, Summers Co., 0.1 mi. s, 0.1 mi. W of Steer Island, 1450', (37 32 15N, 80 53 52 W)

SITE 21
West Virginia, Summers Co., 0.3 mi. S, 0.75 mi. W of Steer Island, 1750', (37 32 10 N, 80 54 35 W)

SITE 22
West Virginia, Mercer Co., 0.2 mi. S, 0.3 mi. E of Dunns Church, 1810', (37 32 30 N, 81 02 50 W)

SITE 23

West Virginia, Mercer Co., 0.9 mi. N, 0.1 mi. W of Dunns Church, 1870', (37 33 20 N, 81 03 25 W)

SITE 24

West Virginia, Summers Co., 0.9 mi N, 3.2 mi.E of Huff Knob, 2940', (37 36 15 N, 81 03 25 W)

SITE 25

West Virginia, Summers Co., 0.1 mi.S, .05 mi W of Rt 20 Bridge over Bluestone River, 1540'-1670', (37 36 40 N, 80 55 10 W)

APPENDIX II

Table of mammal specimens captured during study by site number.

Site	Sc	Sf	Bb	Sh	Sd	Cp	Psp	Ni	Zh	Cg	Mp	Mpi	Sc
1	0	1	12	0	0	0	0	2	0	0	0	0	0
2	0	3	4	0	0	0	2	3	0	0	0	0	0
3	0	0	0	0	0	0	0	0	0	0	0	0	0
4	0	0	1	0	0	0	1	0	0	0	1	0	0
5	0	0	0	0	0	0	0	0	0	0	0	0	0
6	0	8	1	0	0	0	0	0	0	0	0	0	0
7	0	1	1	0	0	0	1	2	0	0	0	0	0
8	0	2	0	0	0	0	0	0	0	0	0	0	1
9	11	13	2	0	0	0	4	7	0	0	0	0	0
10	407	13	22	3	2	0	25	15	0	12	0	2	1
11	6	5	0	0	0	0	1	0	0	0	0	0	0
12	2	3	0	0	0	0	0	0	0	2	0	0	0
13	10	1	0	0	0	0	5	1	0	2	0	0	0
14	20	19	0	0	0	0	1	11	0	1	0	0	0
15	34	7	1	1	0	0	2	1	0	1	0	0	0
16	8	1	0	0	0	0	0	0	0	0	0	0	0
17	0	0	1	1	0	0	0	0	0	0	0	0	0
18	0	0	0	0	0	2	0	1	5	0	2	0	5
19	0	2	1	0	0	0	1	0	0	0	0	0	0
20	0	0	1	0	0	0	0	3	0	0	0	0	0
21	0	4	2	0	0	0	2	1	0	0	0	0	0
22	0	0	0	0	0	0	0	0	0	0	0	0	0
23	3	0	3	0	0	0	1	0	0	0	0	0	0
24	4	3	1	0	0	0	2	0	0	0	0	0	0
25	0	0	0	0	0	0	0	0	0	0	0	0	0
TL	505	86	53	5	2	2	48	47	5	18	3	2	7

APPENDIX III

Listing of reproductive condition by month of soricid specimens.

MS - Male scrotal
MNS - Male non-scrotal
INP - Immature non-parous female
MNP - Mature non-parous female
P - Parous female
E - Female with embryos
PL - Parous lactating female

M - Male
F - Female
J - Juvenile
A - Adult

OVERALL AGE CLASSES AND SEX RATIOS

Sorex cinereus

MONTH	TOTAL#	MS	MNS	INP	MNP	P	E	PL	M-F	J-A
May	45	31	2	0	7	2	1	2	33-12	2-43
June	140	58	33	19	12	2	14	2	87-49	52-88
July	109	23	41	16	16	6	4	8	63-45	57-52
Aug	135	21	60	27	16	9	2	0	82-54	87-48
Sept	60	1	41	6	7	2	0	2	38-17	47-13
Oct	14	0	6	3	4	0	0	1	5-8	9-5
Nov	2	0	2	0	0	0	0	0	2-0	2-0
TOTAL	505	134	185	71	62	21	21	15	311-184	256-249

Sorex fumeus

MONTH	TOTAL#	MS	MNS	INP	MNP	P	E	PL	M-F	J-A
May	10	6	2	0	0	2	0	0	8-2	2-8
June	20	3	9	4	0	1	1	2	12-8	13-7
July	15	3	7	4	1	0	0	0	10-5	11-4
Aug	25	4	10	4	6	0	0	1	14-11	14-11
Sept	9	0	8	1	0	0	0	0	9-1	10-0
Oct	7	0	5	0	2	0	0	0	5-2	5-2
Nov	0	0	0	0	0	0	0	0	0	0
TOTAL	86	16	41	13	9	3	1	3	57-29	54-32

Blarina brevicauda

MONTH	TOTAL#	MS	MNS	INP	MNP	P	E	PL	M-F	J-A
May	12	3	3	2	1	1	0	2	6-6	5-7
June	12	1	3	6	1	0	0	1	4-8	9-3
July	12	0	6	4	0	0	1	1	6-6	10-2
Aug	8	0	4	3	1	0	0	0	4-4	7-1
Sept	4	1	2	1	0	0	0	0	3-1	3-1
Oct	5	0	1	4	0	0	0	0	1-4	5-0
Nov	0	0	0	0	0	0	0	0	0	0
TOTAL	53	5	19	20	3	1	1	4	24-29	39-14

SITE 10 AGE CLASSES AND SEX RATIOS

Sorex cinereus

MONTH	TOTAL#	MS	MNS	INP	MNP	P	E	PL	M-F	J-A
May	41	30	0	0	7	1	1	2	30-11	0-41
June	112	43	28	17	9	2	11	2	71-41	45-67
Jul	101	18	40	14	13	6	2	8	58-43	54-47
Aug	111	11	53	24	11	7	1	0	64-43	77-34
Sept	35	1	25	5	1	0	0	3	26-9	30-5
Oct	7	0	3	3	1	0	0		2-4	6-0
Nov	0	0	0	0	0	0	0	0	0	0
TOTAL	407	103	149	63	42	16	15	15	252-151	212-195

Sorex fumeus

MONTH	TOTAL#	MS	MNS	INP	MNP	P	E	PL	M-F	J-A
May	0	0	0	0	0	0	0	0	0	0
June	5	3	1	0	0	0	0	1	4-1	4-1
Jul	4	2	1	1	0	0	0	0	3-1	2-2
Aug	3	0	0	1	1	0	0	1	0-3	1-2
Sept	1	0	0	1	0	0	0	0	0	1-0
Oct	0	0	0	0	0	0	0	0	0	0
Nov	0	0	0	0	0	0	0	0	0	0
TOTAL	13	5	2	3	1	0	0	2	7-6	8-5

Blarina brevicauda

MONTH	TOTAL#	MS	MNS	INP	MNP	FP	FE	PL	M-F	J-A
May	1	0	0	1	0	0	0	0	0-1	1-0
June	4	1	1	2	0	0	0	0	2-2	3-1
Jul	6	0	3	2	0	0	0	1	3-3	5-1
Aug	4	0	2	2	0	0	0	0	2-2	4-0
Sept	4	1	2	1	0	0	0	0	3-1	3-1
Oct	3	0	0	3	0	0	0	0	0-3	3-0
Nov	0	0	0	0	0	0	0	0	0	0

NON-SITE 10 AGE CLASSES AND SEX RATIOS

Sorex cinereus

MONTH	TOTAL#	MS	MNS	INP	MNP	P	E	PL	J-A	M-F
May	4	1	2	0	0	1	0	0	2-2	3 - 1
June	28	17	3	2	3	0	3	0	5-23	20-8
July	8	5	1	1	0	1	0	0	2-5	6 - 2
Aug	24	10	8	1	3	1	1	0	9-15	18-6
Sept	25	0	17	2	5	0	0	1	19-6	17-8
Oct	7	0	3	0	3	0	0	1	3-4	3 - 4
Nov	2	0	2	0	0	0	0	0	2-0	2 - 0
TOTAL	98	33	36	6	14	3	4	2	42-55	69-29

Sorex fumeus

MONTH	TOTAL#	MS	MNS	INP	MNP	P	E	PL	J-A	M-F
May	10	6	2	0	0	2	0	0	2-8	8-2
Jun	16	2	6	4	0	1	1	1	10-15	8-7
Jul	11	2	5	3	1	0	0	0	8-3	7-4
Aug	22	4	10	3	5	0	0	0	13-9	14-8
Sept	8	0	8	0	0	0	0	0	8-0	8-0
Oct	7	0	5	0	2	0	0	0	5-2	5-2
Nov	0	0	0	0	0	0	0	0	0	0
TOTAL	73	14	36	10	8	3	1	1	50-23	46-27

Blarina brevicauda

MONTH	TOTAL#	MS	MNS	INP	MNP	P	E	PL	J-A	M-F
May	10	3	2	1	1	1	0	2	3-7	5-5
Jun	9	0	2	5	1	0	0	1	7-2	2-7
Jul	6	0	3	2	0	0	1	0	5-1	3-3
Aug	4	0	2	1	1	0	0	0	3-1	2-2
Sept	0	0	0	0	0	0	0	0	0	0
Oct	2	0	1	1	0	0	0	0	2-0	1-1
Nov	0	0	0	0	0	0	0	0	0	0
TOTAL	31	3	10	10	3	1	1	3	20-11	13-18

APPENDIX IV

SAS programs and raw data file.

SAS Program Using All Variables in Data Analysis

```
Options ls=80;
Data shrews;
infile '[BSC 044] shrews.PRN';
input obs hab litc litd soln solt solc solm elev slp asp sc sf bb site $;
habt=log(hab=1);
litct=log(litc+1);
litdt=log(litd+1);
solnt=log(soln+1);
soltt=log(solt+1);
solct=log(solc+1);
solmt=log(solm+1);
elevt=log(elev+1);
slpt=log(slp+1);
aspt=log(asp+1);
sct=log(sc+1);
sft=log(sf+1);
bbt=log(bb+1);
proc sort; by site;
proc means; by site;
var hab litc litd soln solt solc solm elev slp asp sc sf bb;
proc anova; class site;
model hab litc litd soln solt solc solm elev slp asp sc sf bb=site;
means site / duncan;
proc sort; by site;
proc princomp data=shrews out=prin n=3;
var habt litct litdt solnt soltt solct solmt elevt slpt aspt sct sft bbt;
proc plot; plot prin2*prin1=site;
proc sort; by site;
proc candisc out=disc ncan=3;
classes site;
var habt litct litdt solnt soltt solct solmt elevt slpt aspt sct sft bbt;
proc plot; plot can2*can1=site;
proc sort; by can1;
proc print; id obs; var site can1 can2;
run;
```

SAS program without the variables of elevation, aspect, or habitat type in PCA and CDA.

```
Options ls=80;
Data shrews;
infile '[BSC 044] shrews.PRN';
input obs hab litc litd soln solt solc solm elev slp asp sc sf bb site $;
habt=log(hab=1);
litct=log(litc+1);
litdt=log(litd+1);
solnt=log(soln+1);
soltt=log(solt+1);
solct=log(solc+1);
solmt=log(solm+1);
elevt=log(elev+1);
slpt=log(slp+1);
aspt=log(asp+1);
sct=log(sc+1);
sft=log(sf+1);
bbt=log(bb+1);
proc sort; by site;
proc means; by site;
var hab litc litd soln solt solc solm elev slp asp sc sf bb;
proc anova; class site;
model hab litc litd soln solt solc solm elev slp asp sc sf bb=site;
means site / duncan;
proc sort; by site;
proc princomp data=shrews out=prin n=3;
var litct litdt solnt soltt solct solmt slpt;
proc plot; plot prin2*prin1=site;
proc sort; by site;
proc candisc out=disc ncan=3;
classes site;
var litct litdt solnt soltt solct solmt slpt;
proc plot; plot can2*can1=site;
proc sort; by can1;
proc print; id obs; var site can1 can2;
run;
```

trap #	habitat	litter comp	litter depth	soil nutrient	soil texture	soil comp	soil moisure	elevation	slope	aspect
10.1	8	6	2	2	2	4	2	2390	10	4
10.2	8	7	2	2	2	4	2	2430	10	4
10.3	8	7	1	2	2	4	2	2460	5	4
10.4	8	8	2	2	2	4	2	2490	5	4
10.5	8	6	2	2	2	4	2	2530	5	4
10.6	8	7	1	3	2	5	2	2550	10	4
10.7	8	6	1.5	3	2	5	2	2570	5	4
10.8	8	7	1	2	2	5	2	2580	15	4
10.9	8	7	2	2	2	5	2	2600	10	4
10.10	8	6	1	3	2	4	1	2620	5	4
10.11	8	6	4	2	2	2	2	2630	5	4
10.12	8	6	2	1	1	2	2	2640	20	4
10.13	8	6	2	2	2	4	2	2650	0	4
10.14	8	6	1	1	1	4	2	2660	5	4
10.15	8	6	2	2	2	5	1	2680	0	4
10.16	8	4	0	1	2	4	1	2705	0	4
10.17	8	8	1	2	2	4	2	2725	5	4
10.18	8	8	2	3	2	4	2	2750	10	4
10.19	8	8	2	2	2	5	2	2775	20	4
10.20	8	7	1	1	2	4	2	2800	20	4
10.21	8	8	1	1	2	4	2	2825	15	4
10.22	8	8	2	2	1	4	2	2845	25	4
10.23	8	8	2	3	2	4	2	2890	25	4
10.24	8	7	3	1.5	2	4	2	2915	30	4
10.25	8	7	3	2	1	4	2	2930	15	4
10.26	8	8	2	2	2	4	2	2945	5	4
10.27	8	7	2	3	2	4	1.7	2960	10	4
10.28	8	8	2	3	1	4	2	2980	20	4
10.29	8	7	2	3	2	4	1.9	3020	20	4
10.30	8	7	1	2	1	5	1	3050	25	4

trap #	habitat	litter comp	litter depth	soil nutrient	soil texture	soil comp	soil moisure	elevation	slope	aspect
10.31	8	6	2	2	2	4	1	3080	30	4
10.32	8	7	2	1	1	5	1	3130	35	4
10.33	8	8	2	1	1	5	1	3200	40	4
10.34	8	7	2	1	2	4	1.2	3280	40	4
10.35	8	7	2	2	1	5	1	3350	45	4
10.36	8	7	3	2	1	5	1	3400	40	4
10.37	8	8	1	1	1	5	1	3450	35	4
10.38	8	7	1	1	1	5	1.5	3490	20	4
1.1	3	6	0.5	3	2	4	3	2390	0	0
1.2	3	6	0.5	3	2	4	4	2390	0	0
1.3	3	6	1	3	1	4	4	2390	0	0
1.4	3	6	1	3	2	4	3	2390	0	0
1.5	3	5	3	3	2	4	4	2390	0	0
2.1	3	5	3	3	1	4	3	2390	0	0
2.2	3	5	3	3	2	4	4	2390	0	0
2.3	3	1	0	3	1	4	3	2390	0	0
2.4	3	2	1	3	1	4	3	2390	0	0
2.5	3	6	1	3	2	4	4	2390	0	0
3.1	8	6	2	2	2	4	1	2200	5	7
3.2	8	6	2	1	2	4	1	2250	20	7
3.3	8	6	2	1	2	5	1	2310	25	7
3.4	8	6	1	1	1	4	1	2370	30	7
3.5	8	6	2	1	2	4	1	2400	25	7
3.6	8	6	2	1	2	4	1	2420	30	7
4.1	8	6	2.5	3	2	4	2	2110	3	4
4.2	8	6	2	2	2	3	2	2150	5	4
4.3	8	6	2	1	2	3	2	2150	3	4
4.4	8	6	2	1	2	3	2	2150	2	4
4.5	8	5	3	3	2	4	2	2150	0	6
5.1	8	6	1	1	1	3	2	2200	10	6

trap #	habitat	litter comp	litter depth	soil nutrient	soil texture	soil comp	soil moisure	elevation	slope	aspect
5.2	8	6	1	2	1	3	1	2280	20	6
5.3	8	6	2	2	1	1	1	2360	10	6
5.4	8	6	2	1	1	1	1	2360	10	6
6.1	8	7	2	2	2	5	2	1950	10	2
6.2	8	8	3	2	2	5	2	1920	10	2
6.3	8	8	3	3	2	5	3	1900	10	2
6.4	8	8	3	3	2	5	3	1900	10	2
7.1	8	6	2	2	2	1	2	2060	5	6
7.2	8	7	2	1	2	5	2	2080	5	6
7.3	8	6	3	2	2	4	2	2120	5	6
7.4	8	6	3	1	2	1	2	2160	5	6
7.5	8	6	2.5	1	2	1	2	2200	5	6
8.1	6	5	3	2	2	4	2	2400	2	7
8.2	6	5	3	2	1	4	2	2360	3	7
8.3	6	5	3	2	1	3	1	2340	1	7
8.4	6	5	3	2	1	4	1	2330	4	7
8.5	6	5	3	2	2	5	2	2320	5	7
9.1	5	8	0.5	2	2	5	2	1880	30	3
9.2	5	8	2	2	2	5	2	1900	30	3
9.3	5	7	1	2	2	4	2	1960	45	3
9.4	5	7	1	2	2	5	2	1960	30	3
11.1	5	6	1	2	2	3	1	2170	0	2
11.2	5	7	2	1	2	3	1	2170	0	2
11.3	5	6	1	1	1	4	1	2160	0	2
11.4	5	7	1	2	1	3	1	2160	0	2
11.5	5	6	2	1	1	4	2	2150	0	2
11.6	5	7	2	1	2	4	1	2150	10	2
11.7	5	8	2	2	1	4	1	2120	5	2
11.8	5	7	1	2	1	3	2	2120	10	2
11.9	5	8	2	2	2	3	1	2150	5	2

trap #	habitat	litter comp	litter depth	soil nutrient	soil texture	soil comp	soil moisure	elevation	slope	aspect
11.10	5	6	2	1	1	4	1	2150	5	2
12.1	8	6	2	2	1	5	3	2080	10	8
12.2	8	8	3	3	2	5	3	2040	25	8
12.3	8	7	2	2	1	4	2	1980	15	8
12.4	8	6	2	2	2	4	3	1950	0	8
12.5	8	5	2	3	1	4	4	1950	0	8
13.1	8	7	2	3	2	5	2	3250	0	0
13.2	8	6	3	3	2	3	2	3250	0	0
13.3	8	8	4	3	2	4	2	3250	0	0
13.4	8	7	2	3	2	3	2	3250	0	0
13.5	8	7	2	2	1	4	2	3250	0	0
13.6	8	6	2	3	2	4	1	3250	0	0
14.1	4	5	8	3	2	3	3.5	3150	0	0
14.2	4	5	8	3	2	3	3	3150	0	0
14.3	4	6	3	3	2	4	4	3150	0	0
14.4	4	6	2	2	2	4	3	3150	0	0
14.5	4	8	3	3	2	3	4	3150	0	0
15.1	7	5	6	2	2	4	2	2880	0	0
15.2	7	5	6	2	1	4	3	2880	0	0
15.3	7	5	7	3	2	4	2	2880	0	0
15.4	7	5	8	2	2	4	3	2880	0	0
15.5	7	5	6	2	1	4	2	2880	0	0
16.1	8	6	3	2	1	4	1	2700	3	7
16.2	8	7	4	2	2	4	2	2680	3	7
16.3	8	7	3	2	2	4	2	2660	3	7
16.4	8	8	3	3	2	4	2	2660	3	7
16.5	8	7	4	2	1	4	2	2660	5	7
16.6	8	6	3	2	2	4	2	2690	2	7
17.1	8	6	3	1	2	4	1	2580	5	0
17.2	8	7	3	2	2	4	1	2580	5	0

trap #	habitat	litter comp	litter depth	soil nutrient	soil texture	soil comp	soil moisure	elevation	slope	aspect
17.3	8	6	4.5	1	2	3	1	2580	0	0
17.4	8	6	4	2	2	4	1	2580	0	0
17.5	8	7	4	1	2	4	2	2580	0	0
17.6	8	8	4	2	2	3	2	2580	0	0
17.7	8	7	4.5	2	2	3	1	2580	0	0
17.8	8	8	4.5	2	2	3	2	2580	0	0
17.9	8	7	4.5	1	2	3	2	2580	0	0
17.10	8	8	4.5	2	2	4	2	2580	0	0
18.1	6	5	3	2	2	4	2	2540	0	0
18.2	6	5	3	1	1	3	1	2540	0	0
18.3	6	5	3	1	1	3	1	2540	0	0
18.4	6	5	3	2	2	3	1	2540	0	0
18.5	6	5	3	2	2	4	2	2540	0	0
19.1	5	6	2	1	1	4	1	2520	0	0
19.2	5	6	1	1	1	3	1	2530	0	0
19.3	5	7	2	1	1	4	1	2520	0	0
19.4	5	8	2	1	1	3	1	2530	0	0
19.5	5	7	1	1	1	4	1	2530	0	0
20.1	3	6	0.5	2	1	4	3	1445	2	1
20.2	3	6	0.5	3	1	4	3	1450	3	1
20.3	3	6	0.5	2	1	5	2	1450	4	1
20.4	3	6	0.5	2	1	4	2	1450	5	1
20.5	3	6	0.5	3	1	4	2	1450	4	1
21.1	8	8	2	2	2	4	2	1750	5	3
21.2	8	7	2	2	2	5	2	1750	10	3
21.3	8	6	2	2	2	4	2	1750	20	3
21.4	8	7	4	2	2	4	2	1750	15	3
21.5	8	8	2	2	2	4	2	1770	15	3
22.1	2	5	1	2	1	4	1	1810	0	0
22.2	2	5	1	2	1	3	2	1810	0	0

trap #	habitat	litter comp	litter depth	soil nutrient	soil texture	soil comp	soil moisure	elevation	slope	aspect
22.3	2	5	1	2	1	4	1	1810	0	0
22.4	2	5	1	2	1	3	1	1810	0	0
22.5	2	5	1	2	1	4	2	1810	0	0
23.1	4	6	0.5	3	2	4	3	1870	0	0
23.2	4	6	0.5	3	1	4	3	1870	0	0
23.3	4	6	0.5	3	1	4	3	1870	0	0
23.4	4	6	0.5	3	2	5	3	1870	0	0
23.5	4	6	0.5	3	1	4	3	1870	0	0
24.1	8	7	2	2	1	4	2	2940	5	1
24.2	8	8	2	3	2	5	2	2940	5	1
24.3	8	7	1	2	2	4	2	2940	5	1
24.4	8	8	2	3	2	5	3	2940	5	1
24.5	8	6	1	2	1	4	2	2940	10	1
25.1	8	6	2.5	2	2	4	2	1540	5	1
25.2	8	6	1.5	2	1	4	2	1580	10	1
25.3	8	7	2	2	2	4	1	1620	5	1
25.4	8	8	2	2	2	5	2	1670	10	1
25.5	8	8	2	2	2	5	2	1670	10	1

APPENDIX V

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