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Biotic, Abiotic, and Behavioral Patterns Associated with the Nocturnal Movements of Shrews

Patrick T. Sullivan

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Biotic, abiotic, and behavioral patterns associated

with the nocturnal movements of shrews

(TITLE)

Patrick T. Sullivan

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Abstract

Thirteen trails left by shrews coated with fluorescent powder were examined for microhabitat documentation. Thirteen data parameters were collected from each trail, two of which differed significantly between *Blarina brevicauda* and *Sorex longirostris*. The small soricid *Sorex longirostris* was captured in areas with higher grass content, and lower wooded content, than the larger *Blarina brevicauda*. The difference in microhabitat use may be a key mechanism in reducing competition between these two species.

INTRODUCTION

Shrews (Insectivora: Soricidae) are one of the most ubiquitous mammals of North America. They are found in practically all habitats, including two species found in desert (Vaughan, 1986), but are most common in woody terrain (Williams, 1991). Of even greater importance to ecologists is the fact that several species of shrew may coexist in a given habitat (Williams, 1991). Typically, these coexisting species have similar size, diet and activity patterns which suggests that competition between them exists (Kirkland, 1991). Until recently this aspect of shrew biology has been largely ignored by researchers (Kirkland, 1991), and relatively little is known of the mechanisms by which competition is reduced or avoided. Much of what is known at present comes from natural history studies (Blair, 1940; Getz, 1961, 1989; Hamilton, 1944; Kelt, 1991; Platt, 1976; Rose, 1980; Rose and Seegert, 1982; Williams, 1991), or microhabitat studies (primarily of forest rodent assemblages) where a single

(usually) species of shrew was compared to one or more rodent species (Dueser and Shugart, 1978, 1979; Scheibe, 1985; Seagle, 1985; Zegers and Ha, 1981). These investigations provide useful information on interspecies competition, and provide a basis for making hypotheses on interspecific competition between sympatric Soricids. One study of note, in that it deals only with shrews, is that of Churchfield (1991); it is based on the partitioning of food resources rather than microhabitat analysis.

Six species of shrews are known to occur in Illinois, three of which (*Blarina brevicauda, Cryptotis parva, and Sorex longirostris*) have been captured in Coles County, (Hoffmeister, 1989) the site of this study. All are found in a variety of habitats. Little is known about their mechanisms for coexistence.

Analysis of the natural history studies of the three species of shrews provides a framework for generalized speculation on the precise methods by which competition is reduced. First, the three species vary greatly in size (weight: *Blarina* 14-28g, *Cryptotis* 2-5g, *Sorex* 2g, {Schwartz and Schwartz, 1981}). *Blarina* is probably the best studied of these. The general consensus is that the species prefers moist habitats (Getz, 1961; Pruit, 1953) and relies on earthworms and beetles as its main source of food (Blackburn, 1988; Whitaker and Mumford, 1972). *Sorex* is poorly studied in Illinois, but the Illinois data combined with that from other states indicate a varied habitat preference (Hoffmeister, 1989; Rose, 1980) and reliance on beetles and spiders for food (Blackburn, 1988; French, 1980; Whitaker and Mumford, 1972). *Cryptotis* seems to be rare in Illinois (Hoffmeister, 1989), but can be locally abundant (Andrews, 1974). Habitat preference is widely variable, but oldfields generally produce the most captures (Dusi, 1959; Hamilton, 1944) although it may also be found in wooded areas (Hoffmeister, 1989; Lyon, 1925; Scheibe, 1985). Diet seems to be equally variable (Blackburn, 1988; Hamilton, 1934, 1944; Mohr, 1935).

More specific speculation can be drawn from the studies dealing with microhabitat selection. Dueser and Shugart (1978, 1979) showed significant microhabitat utilization by the rodent species captured, but *B. brevicauda* was not subjected to the same analysis because of small sample size. The indication from these two studies suggests that *B. brevicauda* was poorly adapted to the study site (a second-growth mesic forest). Seagle (1985) showed a different microhabitat use by *B. brevicauda* when compared to *Peromyscus leucopus* in a deciduous forest. *B. brevicauda* was assigned the status of "microhabitat specialist" in both cedar glade and deciduous forest habitats. The data also strongly suggested that "no-capture sites are not merely sites at which animals were accidentally not captured. " In other words, the fact that no animals were captured at those sites reflects their lack of suitable microhabitat. Scheibe (1985) gives some insight into the microhabitat used by *C. parva*. This species was captured in a variety of habitats but was most frequently associated with oldfields. Its habitat utilization was consistent with the prediction that preference is given to more open, drier, and less wooded terrain. Little microhabitat data is currently available for *S. longirostris*. Churchfield (1991) deals with shrews found in England. Her data on food resource partitioning in a multi-species community of shrews suggests that this may be an important component of other such assemblages.

In these microhabitat analysis studies, the data are based on the location of the trap. Since there is no way of knowing via this method whether or not the animal was captured near the center of its home range or at one of the edges, the data may not truly reflect the habitat used by the animals. Additionally, there may be bias in the location of the traps, leading to higher or lower capture rates than that which would reflect the true population of a species in an area. These, and other problems with trap-based data are discussed in Ingles' (1961) paper on the calculation of home range of *Sorex vagrans*. Another potentially important

factor related to trap-location based data which is not discussed is the fact that as the traps are checked over long periods of time, the vegetation in the area around them is flattened and destroyed by the researcher. This point is not addressed in any previous microhabitat study involving shrews. The reasons behind the omission are not clear, but the fact that none of them address the problem may be a significant weakness in the their methodology.

To partially compensate for these problems, this study bases the collection of data on the central point of a trail left by the animal after it was released from the trap. The procedure that allowed this is the use of fluorescent powder (Magruder Color Co., Elizabeth NJ) tracking first used by Leman and Freeman (1985). The trail that is left can then be followed by exposing the area to ultraviolet light and evaluated with reduced influence from man.

METHODS AND MATERIALS

Procedures

A total of five study sites were trapped at various times between July 24, and September 20, 1990, and from March 11 to June 28, 1991. The original two study areas, Burgner Acres woodland and roadside ditch, were the only areas trapped in the fall 1990 session. The other three sites, two oldfields (designated east and west oldfield) and a steep wooded hillside overlooking a riverbed, were trapped along with the original sites in the spring and summer of 1991.

Burgner Acres is a small (4.05 hectares) deciduous woodlot located approximately 8 miles west-northwest of Charleston, Illinois (E 1/2, W 1/2, SW 1/4, NE 1/4, Sec 1, T12N, R8E). The area is divided into three sections by a stream that meanders through it. The primary vegetation varies within these three sections but is predominantly white ash (*Fraxinus americana*), hackberry (*Celtis occidentalis*), and elm (*Ulmus* sp.) (Lehnen and Ebinger, 1984). The area is surrounded by agricultural fields on three sides, with a road bordering it on the

north. Directly across the road to the north of the woodlot is a cattle pasture which is bordered by a grassy ditch. This ditch and the woodlot were the original study sites. Vegetation in the ditch is almost entirely bluegrass (*Poa pratensis*).

The study was expanded in the spring and summer of 1991 to include three new areas. Two of these areas were oldfields. Study site 3 is located about one mile west of Charleston (SE 1/4, NE 1/4, Sec 17, T12N, R9E) in a 13.6 hectare oldfield adjacent to Riley Creek (SE 1/4, NE 1/4, Sec. 17, T12N, R93). Ground cover was dominated by meadow fescue (*Festuca pratensis*) but also included bluegrass (*P. pratensis*), purple-top (*Tridens flavus*), tall goldenrod (*Solidago canadensis*) white sweet clover (*Melilotus alba*), common milkweed (*Asclepias syriaca*), and cup-plant (*Silphium perfoliatum*). Patches of Amur honeysuckle (*Lonicera maacki*) were also common. Study site 4 is just outside the city of Charleston on its east side (SW 1/4, SE 1/4, NE 1/4, Sec 23, T12N, R9E) and is 2.0 hectares. Groundcover was dominated by bluegrass (*P. pratensis*) with scattered patches of broom sedge (*Andropogon virginicus*). Herbaceous plants included tall goldenrod (*Solidago canadensis*)and beggar tick (*Desmodium* sp.). The final study site was a 4.0 hectare, steep wooded, hillside located one mile southeast of Charleston (S 1/2, NE 1/4, NE 1/4, Sec 26, T12N, R9E) near the Embarras River. Red oak (*Quercus rubra*), white oak (*Quercus alba*) and yellow chestnut oak (*Quercus prinoides*) were the dominate trees in the area. Understory trees were sparce, but included sugar maple (*Acer saccharum*), and hop hornbean (*Ostrya virginiana*). Herbaceous plants included snakeroot (*Sanicula* sp.) and goldenrod (*Solidago* sp.). The Embarras river runs east to west at the bottom of the slope.

Pitfall traps were used exclusively in this study, due to the higher capture rates obtained when using them for shrews (Blackburn and Andrews, 1992). The pitfall trap used was a plastic container approximately 20 cm deep with a circular

opening roughly 15 cm across. These traps were usually made of white plastic, but a few smaller ones of other colors were also utilized. A straight line of six to fifteen traps was installed at ten meter intervals in the area to be studied, the number based on the size of the area. All traplines were checked for captures between 10:00 PM and 3:00 AM. The basic procedure was to remove the animal from the trap, place it in a bag containing the powder, gently shake the bag to coat the animal with the powder, and then release it. Live animals were not manipulated in any way, other than marking them with the powder, in order to reduce stress related bias in their subsequent movements. Dead animals in good condition were preserved or prepared for later use by the Eastern Illinois University Mammal Collection.

Data Collection Techniques

After releasing a marked animal, 24 hours was allowed to pass before the trail was marked out. The procedure was to observe the trail under ultraviolet light and place marker flags at regular points along the way. Later, during daylight hours, the actual data were collected. The first step was to carefully recreate a map of the trail on paper, using a compass to determine direction of movement. Notable features along the trail were also recorded on the map, such as burrow locations and perceived obstacles to the animal's movements (such as logs). The mid-point of the trail was then calculated based on the total length of the trail, and a new marker flag of a different color than the trail markers was placed at that point. Microhabitat data were collected from this point and evaluated based on protocols discussed in Dueser and Shugart (1978). Soil moisture levels were also collected.

The data for parameters based on north, south, east, and west section transects were averaged for analysis purposes, as were the data for NE, SE, NW, and SW sectional areas.

Woody and Herbaceous Density: These data were collected by laying out a 10 meter long piece of string directly north, south, east, and west of the mid-point point of the trail. The line was raised one meter off the ground, and was used to guide a one meter long stick which was placed across it and centered. The stick was then moved from the mid-point to the end of the line, with counts of woody and herbaceous stems encountered by the stick recorded. This procedure was repeated for all four compass directions.

Vegetative Cover: This procedure used a 3.5 meter long stick, placed at the mid-point of the trail in a vertical position, which was clearly marked by white tape at 0.5 meter intervals. The pole was observed from the origin point of the trail at ground level, and each marker along its length which could be seen from that position was recorded.

Overstory Tree Size: This parameter was also based on the previously described partitions. A standard diameter tape was used to measure the D.B.H. of the nearest overstory tree (defined as a tree which was at least 7.5 cm D.B.H. and at least four meters tall) .

Overstory Tree Distance: Using the lines utilized in determining density of woody and herbaceous vegetation as a guide, the area around the mid-point was divided into four sectors; northeast, northwest, southeast, and southwest. The distance to the nearest overstory tree was measured from the mid-point and recorded.

Woody Stem Count: A square, 0.5 meter quadrat was centered at the mid-point of the trail with one edge perpendicular to the trail. The number of woody stems inside the quadrat was counted, regardless of size.

Forbs Count: This was a count of the non-grass, non-woody stems inside the same 0.5M quadrat used in the woody stem count.

Grass Count: The same guidelines as above for areas with relatively low numbers of grass stems (such as in wooded areas). In areas of high grass density (such as the roadside ditch), the area counted was based on a 0.10 meter square quadrat. The results were then multiplied by a factor of 25 to provide an estimate of the grass stems present in the full 0.5 meter square quadrat.

Tree Stump Density: The number of tree stumps >7.5cm in diameter (at top of stump) were counted in the region defined by a square quadrat, 10m x 10m, for all of the four quadrats around the mid-point of the trail.

Tree Stump Distance: The distance to the closest tree stump meeting the above qualifications was measured for all four quadrats.

Tree Stump Diameter: The diameter of the closest tree stump was measured using a standard diameter tape. The stump diameter was measured at the top of the stump.

Log Density: The number of logs >7.5cm in diameter and at least 0.5 meters long were counted in the 10m x 10m quadrat defined above.

Log Distance: This was measured via the same procedure used for log distance, but measured the distance to nearest log meeting the required specifications.

Log Diameter: The diameter of the nearest log was measured. The log was measured at its thickest point. In the case of logs which were too large to move, the area under them was dug out until the tape could be properly used.

Soil Moisture: Three 10cm deep core samples were taken, one at the mid-point of the trail and the other two midway to each end of the trail. The soil samples were immediately sealed to prevent evaporation, and weighed as soon as they were brought back to the lab. They were then placed in a drying oven at 100^{O} Celsius for 48 hours. The soil sample was

then weighed again, and soil moisture was calculated by comparing it to its original weight.

Other Parameters: The total length of each trail was recorded, along with the number of burrows discovered along its path. Number of right and left turns were also calculated to give an indication of the movement pattern of the animal after release.

The mean, standard deviation, variance, and coefficient of variation were calculated from the data obtained from the trails of two species (*S. longirostris* and *B. brevicauda*). The Mann-Whitney *U* test was used to test for significant difference between the two species populations (α =.05). Because only one *C. parva* trail was collected, it is not subject to comparative analysis but is included for completeness.

RESULTS

A total of 7930 trapnights produced a total of 33 captures. Of these, only 4 were non-shrews. Sixteen (55%) of the shrews caught were either dead when found or died shortly after release. The trapping results are summarized in table 1.

Of the 33 animals captured, 69.6% were taken in the woody area of Burgner Acres. *Blarina brevicauda* was caught more frequently in the spring and summer months (11 out of 15 [73.33%]), while *S. longirostris*was taken more often in the fall months (8 out of 12 [66.67%]). Both *Cryptotis parva* were captured in the spring and summer months. On a per 100 trapnights basis, the roadside ditch produced the highest success rate (1.8 animals per 100 trapnights {average}). Unfortunately the wet weather experienced during the spring and summer 1991 trapping season prevented this trapline from producing any captures during that time. The non-shrews totalled one live *Peromyscus* sp. at

Burgner Acres woodland, and three dead *Microtus* sp. from this and other areas. The hillside produced no captures whatsoever.

Table 1- Capture results for the five areas trapped between 11 August, 1990 and 28 June 1991.

Species	Burgner Woods	Roadside Ditch	West Oldfield	East Oldfield	Hillside
Live/Dead	L/D	L/D	L/D	L/D	L/D
B. brevicauda	5/9	0/0	1/0	0/0	0/0
S. longirostris	3/4	3/1	0/1	0/0	0/0
C. parva	0/0	0/0	1/1	0/0	0/0
Other	1/1	0/0	0/1	0/1	0/0
Trapnights	5014	220	610	1736	350
Total Captures	23	4	5	1	0

Trail Data

The data for these trails reflect a great deal of diversity, which makes each trail highly unique. There was no preference between choice of left or right turns in *B. brevicauda* (21:21), while *S. longirostris*showed slight preference for turning right (39:34). The average length of the trails, 4. 84M for *B. brevicauda* and 8.7M for *S. longirostris*was also not significantly different, due to the high standard deviation (4.61 and 5.44, respectively).

Trail #1: The first shrew captured was a *B. brevicauda* on August 5, 1990. The animal was caught in the wooded area of Burgner Acres, and was marked and released at 2:50am. Another trap held a dead *B. brevicauda*, and the *Peromyscus* sp. was in another. This first animal's trail was marked out the next

evening. The trail ended at the entrance to an underground burrow after travelling a total distance of 107.9cm. The trail was basically u-shaped.

Trail #2: The second animal captured was a *S. longirostris* on 20 August 1990. The animal was captured in the wooded area of Burgner Acres at 11:30pm. The trail was marked the next day, but rain seemed to have limited its visibility. The trail was 5.327M long and z-shaped.

Trail #3: The third animal captured was also a *S. longirostris*, also from the wooded area of Burgner Acres, and also at 11:30pm. Capture date was 21 August, 1990. The trail was 3.078M long, and shaped like a question mark.

Trails 4, 5, and 6: These three trails are from the ditch which borders the pasture land north of the wooded area at Burgner Acres. All three are *S. longirostris* trails, and all three were taken on 16 September, 1990 at 12:45am. Trail #4 was 18.673M long and z-shaped, Trail #5 was 8.833M long and roughly circular, and trail #6 was 6.552M long, and travelled north along the ditch in a nearly straight line. A burrow was detected along the path of trail #4, making it the only *S. longirostris* trail with that feature. These trails were the last of the fall 1990 trapping session.

Trail #7: The first trail of the new trapping season was from a *C. parva* captured in the west oldfield. This animal represents two unique departures from all of the other trails in that it was the only *C. parva* trail and it was also the only daylight trail. The animal was captured on May 21, 1991 at 1:00pm. The trail was 3.418M long and u-shaped.

Trail #8: This was the last *S. longirostris* trail. The animal was captured in the wooded area of Burgner Acres on 8 June 1991 at 2:00am. The trail was the longest of all the *Sorex* trails, travelling a distance of 9.738M. The trail moved south for approximately 6 meters, then abruptly veered west giving it an upside-down L shape.

Trail #9: This animal was a *B. brevicauda*, captured in the wooded area of Burgner Acres at 2:00am on June 8, 1991. The trail was basically a straight line, and very similar to trail #1 in that it travelled a short distance before disappearing into an underground burrow. The trail was 1.741M long.

Trail #10: This animal was also captured on June 8, and was also a *B. brevicauda*, but trap location was the west oldfield. The animal was discovered and released at 2:30am. The trail was 9.597M long and u-shaped.

Trails 11 and 12: These two trails are from a double capture in a single pitfall trap in the wooded area of Burgner Acres. The two animals were *B. brevicauda*, and were acting aggressively towards each other when I discovered them at approximately 2:00am. Trail #11 proceeded east in an almost straight line, travelling a distance of 3.461M before ending near an underground burrow. Trail #12 headed south, paralleling a fallen branch for its full distance of 2.75M. There was a burrow at the midpoint of the trail but no indication that the animal had entered. No burrow was detected at the end of the trail.

Trail #13: This was the last trail marked out, and belonged to a *B. brevicauda* in the wooded area of Burgner Acres. The animal was captured at approximately 2:00am. This trail was the longest of all the trails, travelling a distance of 12.923M in a western direction. The path was zig-zagged in shape, and paralleled a large log. Three burrows were located along the trail, but there was no indication that the animal entered any of them.

Habitat Data

In general, there was a very high degree of variation in all of the data collected. This was expected, given the diversity of habitats sampled. Variance ranged from 0.11 to 16,138.17, and the coefficient of variation ranged from 6.42% to 215.94%. These data are summarized in table 2.

Two of the parameters measured showed significant difference at the 0.05% level between *Blarina brevicauda* and *Sorex longirostris*. Grass count was significantly higher for *S. longirostris*, and woody vegetation density was significantly higher for *B. brevicauda*.

The data for the only *Cryptotis parva* trail are also presented in table 2. Statistical comparisons could not be made, but the data for woody and herbaceous density, vegetative cover, and central forbs count were higher than *B. brevicauda* or *S. longirostris*, while data for woody stem count grass count and soil moisture placed between those two species. No trees of appropriate size, or stumps were associated with this trail.

Table 2- Microhabitat characteristics of *Blarina brevicauda*, *Sorex longirostris* and *Cryptotis parva* captured in Coles County Illinois.

Habitat Variables	*Blarina brevicauda* (N=6)				*Sorex longirostris* (N=6)				*Cryptotis parva* (N=1)
	Mean	Std. Dev	Variance	Co. of Var.	Mean	Std. Dev	Variance	Co. of Var.	
Herbaceous Density	7.63	12.38	153.37	162.25%	1.67	1.91	3.64	114.37%	44.25
Woody Density *	5.54	1.16	1.34	20.94%	1.96	2.37	5.64	120.92%	7.25
Vegetative Cover	5.8	0.75	0.57	12.93%	6.67	0.52	0.27	7.80%	7
Overstory Tree Size	22.24	11.36	129.01	51.08%	38.95	27.25	742.57	69.96%	n/a
Overstory Tree Distance	3.49	1.81	3.29	51.86%	3.14	2.91	8.44	92.68%	n/a
Woody Stem Count	2.67	2.66	7.07	99.63%	0.83	0.98	0.97	118.07%	7.25
Forbs Count	18.67	6.74	45.47	36.10%	28.17	19.06	363.37	67.66%	44
Grass Count *	11	19.19	368.4	174.45%	126.17	127.04	16138.17	100.69%	45
Tree Stump Density	0	0	0	n/a	0.5	0.84	0.7	168.00%	n/a
Tree Stump Distance	0	0	0	n/a	5.14	0.33	0.11	6.42%	n/a
Tree Stump Diameter	0	0	0	n/a	14.05	3.04	9.25	21.64%	n/a
Log Density	2.96	1.54	2.38	52.03%	2.21	4.76	22.67	215.94%	n/a
Log Distance	5.04	0.32	0.1	6.35%	4.03	4.35	18.96	107.94%	n/a
Log Diameter	13.18	2.92	8.55	22.15%	11.1	6.22	38.75	55.99%	n/a
Soil Moisture	15.27	3.35	11.19	21.94%	11.33	4.17	17.38	36.80%	13.7

* Significant difference at 0.005%

Behavioral Observations

The shrews did not seem harmed by the coating procedure, and moved off into the underbrush as soon as they were released. None attempted to return in the direction of the trap, giving the impression that they were not disoriented by the marking. One half of the *B. brevicauda* trails ended at or near a small hole in the ground, presumed to be a burrow. In one other case the animal bypassed at least three such holes. Only one of the *S. longirostris* trails intersected with a burrow, and the trail continued on from there.

Obstacles encountered during movement were dealt with in one of three ways; going over it, going under it, or moving parallel to it for a while before going under it. No large scale vertical movements were observed; the shrews showed a tendency to remain on the ground and never stayed on top of an obstacle for very long.

DISCUSSION

The trapping efficiency of this study compares almost identically to that of Feldhamer et al. , (1993) but is much lower than that of Blackburn and Andrews, (1992). The capture of 29 shrews in 7930 trapnights produces an average of 0.003656 shrews captured per trapnight, compared with 0.003525 and 0.012074 for Feldhamer et al. , and Blackburn and Andrews respectively. Only one of the study sites, the west oldfield, produced all three species. The lack of success in capturing *C. parva* may indicate a decline in its numbers since the study by Blackburn, (1988).

Application of Gause's principle of competitive exclusion to the data leads to the conclusion that *B. brevicauda* and *S. longirostris* may be in direct competition for the resources examined in this study over much of their range. Use of the two significantly differing parameters, woody density and grass count,

allows construction of a predictive chart showing the zones of competition and exclusion between the two species (figure 1). The data from figure 1 suggest that *B. brevicauda* would be found exclusive of *S. longirostris* in habitats which were woodier and grassier than those utilized exclusively by *S. longirostris*. *Sorex longirostris*, conversely, would be found exclusive of *B. brevicauda* in habitats

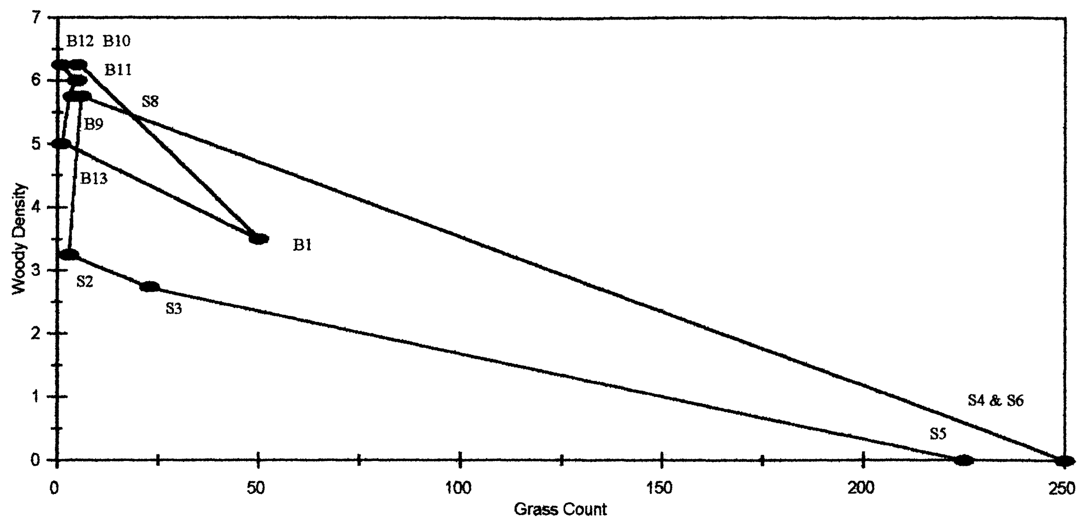

Figure 1. Predicted areas of competition and exclusion between *Blarina brevicauda* and *Sorex longirostris* based on two significantly differing parameters.

which were more grassy than woody. The problem with this approach is that the optimal habitat of *B. brevicauda* appears to be much more restricted than that of *S. longirostris*. This is not likely a true representation of the larger shrew's habitat requirements, given the fact that its geographical range is much larger than *S. longirostris* (Hoffmeister, 1989; Schwartz & Schwartz, 1981). Addition of another factor to the table, that of soil moisture, yields a result which is arguably much closer to the true nature of the relationship.

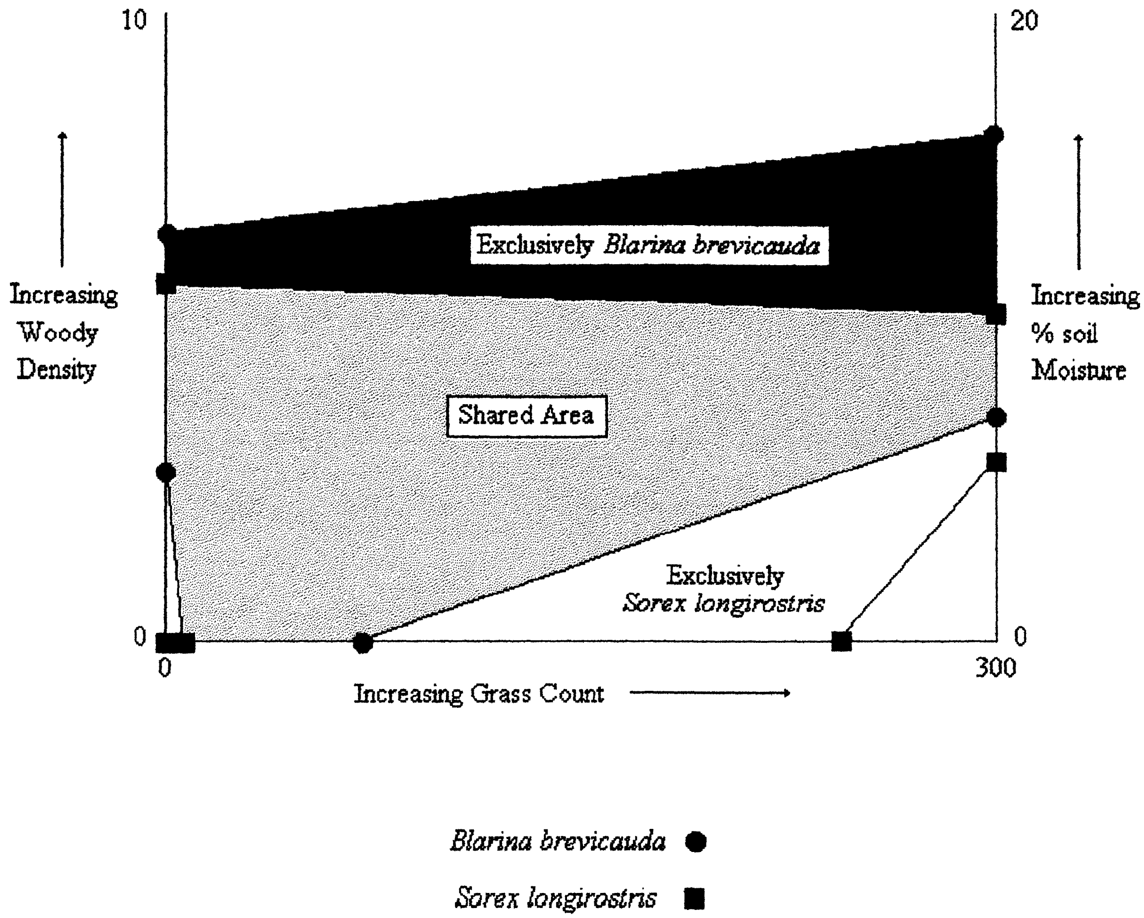

Figure 2. Predicted areas of competition and exclusion between *B. brevicauda* and *S. longirostris* based on two significantly differing parameters and one non-significant parameter.

The work of Getz (1961) includes the statement: "The most important factor influencing the local distribution of *Sorex cinereus* and *Blarina brevicauda* is moisture", and is the primary reason behind inclusion of a non-significant parameter in figure 2 (*Sorex cinereus* is a species which is morphologically very similar to *S. longirostris*). Additional supporting evidence for this hypothesis is found in Kirkland (1991) and Wrigley et al. (1979). Plant nitrogen content has also been proposed as a limiting factor (Huntly and Inouye, 1987) but was not measured in this study.

Microhabitat partitioning has been demonstrated for shrews based on food resources (Churchfield, 1991), and more recently, via habitat itself (Feldhamer, et al. , 1993). Feldhamer et al. , also reports on a species assembly rule for multi-species communities of shrews proposed by Fox and Kirkland (in press). The hypothesis states that each of three niches sizes (small, medium, and large) must be occupied before another species of the same size could be found in that habitat. This rule implies that there is no habitat which contains, for example, two large sized shrews, and no medium or small sized shrews. In their work, the second species was the pygmy shrew (*Sorex [Microsorex] hoyi*), occupying the same size niche as *S. longirostris*. The extrapolation is that Coles county currently has all of these niches filled. The large size niche is occupied by *B. brevicauda*, medium by *C. parva*, and small by *S. longirostris*. Coles county is therefore eligible to include either *Sorex cinereus*, or *Sorex [Microsorex] hoyi* in the future. This pattern should be observed carefully by researchers over the next few years, paying particular attention to areas known to have provided members of all three species. Predicting which is most likely to appear as a new species in Coles county is impossible, although the current range of *Sorex [Microsorex] hoyi* is geographically closer (Schwartz and Schwartz, 1981).

The disappearance of half the *B. brevicauda* trails after entering a burrow is an interesting phenomena not previously reported for other species which were tracked via this technique. Behavioral observations of captive animals has shown *B. brevicauda* to be exceptionally fastidious concerning its coat condition (Rood, 1958). The presumption is that the animal proceeded to its burrow after being marked, and licked the powder off its coat. This seems the only viable explanation given the fact that no further trail was found.

Appendix 1. Literature Review of Shrews and their Movements.

Three species of shrew commonly occur in Coles county Illinois: *Blarina brevicauda*, *Sorex longirostris*, and *Cryptotis parva*. Three other species of shrew occur in the state: *Sorex hoyi*, *Blarina carolinensis*, and *Sorex cinereus*, but are not known to occur in Coles county (Hoffmeister, 1989).

Blarina brevicauda is the largest of the six, and is also the best studied (Getz, 1961, 1989; Martinson, 1969; Blair, 1940; Platt, 1976). Although it was once thought to be a non-territorial species (Blair, 1940), more recent research has shown this to be incorrect (Platt, 1976). Male home range varies from less than 0.25 acres to over 4.0 acres, while female home range varies from 0.25 acres to just under 0.9 acres (Blair, 1940). It was also thought that these animals needed to be almost continually in search of food to stay alive, but Martinson (1969) showed them able to get by on only 10% of their body weight in food per day. Given free access to food, Rood, (1958) observed captive animals consuming 1/2 their body weight in food per day. In captivity, *Blarina brevicauda* spends most of its day inactive, using only 16% of the day for foraging and other activities. Their distribution is believed to be influenced to great extent by moisture, a characteristic it seems to share with *Sorex cinereus* (Getz, 1961; Spencer & Pettus, 1966). *Blarina brevicauda* is not often seen in open areas, where evaporation may limit the available water. Dueser and Shugart (1978 & 1979) caught *B. brevicauda* in pine and oak-hickory forests during the summer, but not in chestnut oak forest. Subsequent analysis of the ecological characteristics indicated the species was poorly adapted to the watershed, although the information was hampered by the small sample size used. Wet habitat preference was also shown by Wrigley, Dubois, and Copland (1979). Food preferences are known from several studies, (Blackburn, 1988; Rood, 1958; Whitaker and Mumford, 1972), with beetles and other invertebrates

forming the largest part of their diet. Small mammal remains have also been obtained from their stomachs, but Rood (1958) reported some captive animals appeared to fear mice of the genus *Peromyscus*. Mohr, (1935), however, has criticized the value of stomach content analysis, pointing out that volume is independent of number of prey items obtained.

Little is known of the ecology of *Sorex longirostris*, but it is thought that its behavioral repertoire is similar to others in the genus (Eisenberg, 1964). Rose, (1980) proposed the idea that *S. longirostris* is only able to reach high densities in oldfield habitats. A later study, (1982) was unable to support this contention: more *Sorex longirostris* were taken in forest habitat than oldfields in Kentucky. Their nests have been observed in dead trees, further indication of their adaptation to forest living (Negus & Dundee, 1965). The species is seldom common throughout its range (Rose, 1982), and some local records of its occurrence rely on owl pellets or single captures (Dusi, 1959; Brown, 1961). Habitat preference is poorly understood overall, possibly a result of the species rarity. In Illinois, Hoffmeister (1989) notes their occurrence in woodlands near streams, in tallgrass prairie, and grassy fields. Food is mainly invertebrates, with one study (Blackburn, 1988) showing beetles as the predominate prey item, while two others (Whitaker and Mumford, 1972; French, 1980) report spiders as the main prey.

The habits of *Cryptotis parva* are little better understood than *Sorex*. Rose, (1982) took them in oldfield habitats but not in woodland. In thousands of trapnights, Hamilton, (1944) took not a single animal in woodlands, but Lyon (1925) reported taking them in moist woods. Three were obtained by Hamilton (1934) in a New York field, and one from Alabama was taken in an oldfield (Dusi, 1959). Scheibe, (1985) captured the species in deciduous forest and wet lowland habitats, and noted a correlation in their preference for "habitats with less cover and more homogenous understory vegetation". Andrews (1974) found

the species to occur in high numbers when conditions are favorable. Their life expectancy in captivity averages 249 days, with a maximum of 889 days (Mock, 1982). Major prey items include spiders (Whitaker and Mumford, 1972), beetles (Blackburn, 1988) and even cinch bugs (Mohr, 1935).

Several methods have been employed to study animal movements. Each has its drawbacks and benefits. The most common method in the past has been trap-recapture, where the trap locations and recapture data are combined to give an overall pattern for species movements.

The use of toe-clipped animals and smoke-paper has also been used with some success (Justice, 1961; Metzgar, 1973,) and is considered an improvement on trap-recapture. Toe-clipped animal trails can be identified by their presence on smoke coated paper. It is of limited use because of the difficulty involved in accurately identifying marked animal tracks on heavily travelled paper, a problem compounded by the presence of unmarked animals in the study area. Home range has also been determined by the use of smoke-paper techniques (Metzgar, 1973; Kotler, 1985). The home range estimates obtained with this method often differ greatly from those obtained by the traditional trap-recapture method (Metzgar, 1973).

Another technique is tracking by the use of radioactive isotopes. It is a useful method for determining where an animal is, but is best used at short ranges (Lardet, 1988). Isotopes have also been used in determining species abundance via scat collection (Conner and Conner & Labisky, 1985). The number of individual animals that can be tracked via this method is limited by the number of different isotopes available. The scat collection technique relies heavily on the ability of the researcher to find and correctly identify species scats, a problem it shares with the use of colored dye in food (New, 1958).

Radio telemetry is another often used method. It provides spot information and is widely used for large animal tracking but has also been used successfully

with small mammals with no apparent ill effects (Douglas, 1989; Ormiston, 1985). The major drawback to this technique is cost, but it also requires skilled technicians to accurately collect data. With respect to soricids, the size of the radio collar becomes another limitation to its use.

Other techniques include photography (Osterberg, 1962) and direct observation (Vispo, 1988). An interesting use of the latter is the attachment of small beta-lights to the heads of small animals so their movements can be observed at night (Thompson, 1982).

Recently, a technique has been developed utilizing fluorescent pigments (Lehmen and Freeman, 1985). Small mammals are coated with a fluorescent powder and released, so that later, the trail can be clearly seen when exposed to ultraviolet light. The pigment is supposed to remain in the environment until the next heavy rain. Since it was first described, the technique has been used successfully several times (Kaufman, 1989; Etheredge et al. , 1989; Mullican and Baccus, 1990). Data which can be collected via this technique include home range estimation, microhabitat use, movement patterns, and even intraspecific sociability (Kaufman, 1989). It has the advantage of being relatively inexpensive and easy to use, and also reduces handling of the animal to a minimum and involves no mutilation. Its disadvantages include limited range (probably dependent on the size of the marked animal and its ability to retain the powder) short duration, and limited use in wet conditions.

Shrews are widely distributed geographically, but genera vary enormously in their distribution and ecology (Barnard, 1984). They are logical candidates for the use of the fluorescent pigment method. Their small size restricts the use of radio telemetry devices, and it also makes the use of mutilation (toe clipping) or other manipulative methods such as using beta-lights difficult. The increasing use of this technique will no doubt answer many questions regarding shrew biology.

Appendix 2. Form used for data collection.

Trail #_______

1. Thickness of vegetation T1N__________ T2E__________

   (10m line carrying ms) T3S__________ T4W__________

2. Vegetative cover _____ _____ _____ _____ _____ _____ _____

3. Overstory tree size Q1NE__________ Q2SE__________

   Q3NW__________ Q4SW__________

4. Woody stem distance Q1NE__________ Q2SE__________

   Q3NW__________ Q4SW__________

5. Woody stem count in quadrat (. 5m^2) _________

6. Forbs count in quadrat (. 5m^2) _________

7. (a) Grass count in quadrat, woods (. 5m^2) _________

   (b) Grass count in quadrat, ditch (. 32m^2) _________

8. Tree stump counts Q1NE__________ Q2SE__________

   (>7. 5cm diameter) Q3NW__________ Q4SW__________

9. Nearest stump distance Q1NE__________ Q2SE__________

   Q3NW__________ Q4SW__________

10. Nearest stump diameter Q1NE_________ Q2SE_________

    Q3NW_________ Q4SW_________

11. Fallen log counts Q1NE__________ Q2SE__________

    (>7. 5cm diameter) Q3NW__________ Q4SW__________

12. Nearest log distance Q1NE__________ Q2SE__________

    Q3NW__________ Q4SW__________

13. Nearest log diameter QINE__________ Q2SE__________

    Q3NW__________ Q4SW__________

14. Soil moisture % __________ can#______

Literature Cited

Andrews, R. D. 1974. An irruption of least shrews, Cryptotis parva in Illinois. Trans. Ill. State Acad. Sci., 67:5-6.

Barnard, C. J. 1984. Shrews. Pp. 758-763, *in* The Encyclopedia of Mammals (D. MacDonald, ed.). Facts of File Publications, New York, 895pp.

Blackburn, L. D. 1988. Habitat analysis and foods of shrews in east central Illinois. M. S. Thesis, Eastern Illinois University, 17pp.

Blackburn, L. D. and R. D. Andrews. 1992. Higher efficiency of pitfall traps in capturing three shrew species for analysis of diet and habitat. Trans. Ill. State Acad. Sci., 85:173-181.

Blair, W. F. 1940. Notes on the home ranges and populations of the short-tailed shrew. Ecology 21:284-288.

Brown, L. N. 1961. *Sorex longirostris* in southwestern Missouri. J. Mamm. 42:527.

Churchfield, S. 1991. Niche dynamics, food resources, and feeding strategies in multispecies communities of shrews. Pp. 23-34, *in* The biology of the Soricidae (J. S. Findley and T. L. Yates, eds.). Special Publication, Museum of Southwestern Biology, University of New Mexico, 1:1-91.

Conner, M. C. & R. F. Labisky. 1985. Evaluation of radioisotope tagging for estimating abundance of raccoon populations. J. Wildl. Mgmnt. 49:326-332.

Douglas, R. J. 1989. Use of radio-telemetry to evaluate microhabitat selection by deer mice. J. Mamm. 70:648-652.

Dueser, R. D. & H. H. Shugart. 1978. Microhabitats in a forest-floor small mammal fauna. Ecology 59:89-98.

Dueser, R. D. & H. H. Shugart. 1979. Niche pattern in a forest-floor small-mammal fauna. Ecology 60:108-118.

Dusi, J. L. 1959. *Sorex longirostris* in eastern Alabama. J. Mamm. 40:438-439.

Eisenberg, J. F. 1964. Studies on the behavior of *Sorex vagrans*. Amer. Midland Nat. 72:417-425.

Etheredge, D. R., Engstrom, M. D., and R. C. Stone. 1989. Habitat discrimination between sympatric populations of *Peromyscus attwateri* and *Peromyscus pectoralis* in west-central Texas. J. Mamm. 70:300-307.

Feldhamer, G. A., Klann, R. S., Gerard, A. S., and A. C. Driskell. 1993. Habitat partitioning, body size, and timing of parturition in pygmy shrews and associated soricids. J. Mamm. 74:403-411.

French, T. W. 1980. Natural history of the southeastern shrew, *Sorex longirostris* Bachman. Amer. Midland Nat. 104:13-31.

Getz, L. G. 1961. Factors influencing the local distribution of shrews. Amer. Midland Nat. 65:67-88.

Getz, L. G. 1989. A 14-year study of *Blarina brevicauda* populations in east-central Illinois. J. Mamm. 70:58-66.

Hamilton, W. J. Jr. 1934. Habits of *Cryptotis parva* in New York. J. Mamm. 15:154-155.

Hamilton, W. J. Jr. 1944. The biology of the little short-tailed shrew, *Cryptotis parva.* J. Mamm. 25:1-7.

Hoffmeister, D. F. 1989. Mammals of Illinois. University of Chicago Press, Urbana and Chicago, 348pp.

Huntly, N. and R. S. Inouye. 1987. Small mammal populations of an old-field chronosequence: successional patterns and associations with vegetation. J. Mamm. 68:739-745.

Ingles, L. G. 1961. Home range and habits of the wandering shrew. J. Mamm. 42:455-462.

Justice, K. E. 1961. A new method for measuring home ranges of small mammals. J. Mamm. 42:462-470.

Kaufman, G. A. 1989. Use of fluorescent pigments to study social interactions in a small nocturnal rodent, *Peromyscus maniculatus*. J Mamm. 70: 171-174.

Kelt, D. A. 1991. Composition and biogeography of small mammals in northwestern Illinois based on pitfall trapping. Trans. Ill. State Acad. Sci. , 84:175-184.

Kirkland, G. L. , Jr. 1991. Competition and coexistence in shrews (Insectivora: Soricidae). Pp. 15-22, *in* The biology of the Soricidae (J. S. Findley and T. L. Yates, eds.). Special Publication, Museum of Southwestern Biology, University of New Mexico, 1:1-91.

Kotler, B. P. 1985. Microhabitat utilization in desert rodents: a comparison of two methods of measurement. J. Mamm. 66:374-378.

Lardet, J. P. 1988. Spatial behaviour and activity patterns of the water shrew, *Neomys fodiens* in the field. Acta. Theriologica 21:293-303.

Lehnen, L. Jr. , and J. Ebinger. 1984. Woody vegetation at Burgner acres, east-central Illinois: composition and changes since 1964. Trans. Ill. State Acad. Sci. 77:35-42.

Leman, C. A. & P. W. Freeman, 1985. Tracking animals with fluorescent pigments: a new technique. J. Mamm. 66:134-136.

Lyon, M. W. Jr. 1925. New record of the small short-tailed shrew in Indiana. Proc. Indiana Acad. Sci. 34:391.

Martinson, D. L. 1969. Energetics and activity patterns of short-tailed shrews (*Blarina brevicauda*) on restricted diets. Ecology 50:505-510.

Metzgar, L. H. 1973. A comparison of trap-and track-revealed home ranges

in *Peromyscus*. J. Mamm. 54:513-515.
Mock, O. B. 1982. The least shrew (*Cryptotis parva*) as a laboratory animal. Lab. Anim. Sci. 32:177-179.
Mohr, C. O. 1935. Value of prey-individual analysis of stomach contents of predatory mammals. J. Mamm. 16:323-324.
Mullican, T. R. and J. T. Baccus. 1990. Horizontal and vertical movements of the white-ankled mouse (*Peromyscus pectoralis*) in central Texas. J. Mamm. 71:378-381.
Negus, N. C. & H. A. Dundee. 1965. The nest of *Sorex longirostris*. J. Mamm. 46:495.
New, J. G. 1958. Dyes for studying the movements of small mammals. J. Mamm. 39:416-429.
Ormiston, B. G. 1985. Effects of a subminiature radio collar on activity of free-living white-footed mice. Canadian J. Zool. 63:733-735.
Osterberg, D. M. 1962. Activity of small mammals as recorded by a photographic device. J. Mamm. 43:219-229.
Platt, W. J. 1976. The social organization and territoriality of short-tailed shrew (*Blarina brevicauda*) populations in old-field habitats. Animal Behav. 24:305-318.
Pruit, W. O. 1953. An analysis of some physical factors affecting the local distribution of the shorttail shrew (*Blarina brevicauda*) in the northern part of the lower peninsula of Michigan. Miscellaneous Publications of the Museum of Zoology, University of Michigan 79:5-39.
Rood, J. P. 1958. Habits of the short-tailed shrew in captivity. J. Mamm. 39:499-507.
Rose, R. K. 1980. The southeastern shrew, *Sorex longirostris* in southern Indiana. J. Mamm. 61:162-164.
Rose, R. K. & G. L. Seegert. 1982. Small mammals of the Ohio river floodplain in western Kentucky and adjacent Illinois. Trans. Ky. Acad. Sci. 43:150-155.
Scheibe, J. S. 1985. Ecological characteristics of small mammals at three sites in southeast Missouri. Trans. Missouri Acad. Sci. 19:31-40.
Schwartz, C. W. & E. R. Schwartz. 1981. The wild mammals of Missouri. University of Missouri Press and Missouri Dept. of Conservation, Columbia and London, 356pp.
Seagle, S. W. 1985. Patterns of small mammal microhabitat utilization in cedar glade and deciduous forest habitats. J. Mamm. 66:22-35.
Sharp & Millar, 1990.
Spencer, A. W. & D. Pettus. 1966. Habitat preferences of five sympatric species of long-tailed shrews. Ecology 47:677-683.
Thompson, S. D. 1982. Structure and species composition of desert heter-

omyid rodent species assemblages: effects of a simple habitat manipulation. Ecology 63:1313-1321.

Vaughan, T. A. 1986. Mammalogy. Sanders College Publishing, Philadelphia, 576pp.

Vispo, C. R. 1988. An observation of a wild group of masked shrews, *Sorex cinereus*. Can Field Nat. 102:731-733.

Whitaker, J. O. & R. E. Mumford. 1972. Food and ectoparasites of Indiana shrews. J. Mamm. 53:329-335.

Williams, D. F. 1991. Habits of shrews (genus *Sorex*) in forest communities of the western Sierra Nevada, California. Pp. 1-14, *in* The biology of the Soricidae (J. S. Findley and T. L. Yates, eds.). Special Publication, Museum of Southwestern Biology, University of New Mexico, 1:1-91.

Wrigley, R. E. , Dubois, J. E. , and H. R. W. Copland. 1979. Habitat, abundance, and distribution of six species of shrews in Manitoba. J. Mamm. 60:505-520.

Zegers, D. A. , and J. C. Ha. 1981. Niche separation of *Peromyscus leucopus* and *Blarina brevicauda*. J. Mamm. 62:199-201.