Methods Used To Survey Shrews (Insectivora: Soricidae) And The Importance Of Forest-Floor Structure

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ABSTRACT--We examined shrew (Insectivora: Soricidae) capture rates using selective (best-site) transects, linear transects, and drift-fence arrays to better understand how pitfall trap arrangement might affect our perception of shrew assemblages in the southern Appalachian mountains. Also, we studied the use of microhabitat structure (coarse woody or rocky debris) by shrews to determine how microhabitat selection might affect capture probabilities. The distributions of shrew captures were similar at selective and linear transects, but different between either transect type and the drift-fence arrays ($P < 0.05$). Differences in the effectiveness of trap arrangements were apparently related to microhabitat use. We found a gradient of selection for habitat structure among *Sorex fumeus*, *S. cinereus*, and *Blarina brevicauda*, although relationships were weak. Captures of *S. fumeus* were most closely associated with the abundance of and distance to woody or rocky debris, and those of *B. brevicauda* were independent of these microhabitat factors. Caution should be used when comparing the results of surveys using different pitfall trap arrangements.

Ecologists studying small mammals often attempt to accurately depict the structure of small mammal assemblages from trapping data. This effort is complicated by differences in size and microhabitat use among species, which can affect species- and trap type-specific probabilities of capture. Some types of sampling, notably mark-and-recapture (Otis et al. 1978), may be used to estimate capture probability and avoid this as a confounding factor. However, survey of shrew (Soricidae) assemblages using live-trapping methods is made problematic by high rates of trap mortality, and removal sampling is commonly employed using pitfall traps (Kirkland and Sheppard 1994). Therefore, particular care must be taken to minimize biases associated with sampling shrew communities.

Many studies have examined differences among types of traps used to sample shrews (e.g., Williams and Braun 1983). However, there is little information regarding biases introduced through the arrangement of traps. Despite recent efforts to promote standardized methods (Handley and Varn 1994, Kirkland and Sheppard 1994), many different pitfall-trap arrangements have been used to survey shrews (Kalko and Handley 1993). Because trap arrangements, like trap types, vary in their effectiveness at catching certain species (Bury and Corn 1987, Mitchell et al. 1993), the assessment of shrew community structure could be affected by trap arrangement.

Pitfall trapping designs often take advantage of patterns of microhabitat use, such as drifting behaviors often observed when small mammals encounter an obstruction (Brillhart and Kaufman 1991). Because these behaviors may vary among species, methods that rely on drifting could selectively under- or over-represent certain species in samples. Two methods that take advantage of drifting behavior are transects of traps placed along natural habitat structures, such as fallen logs or exposed rock (selective transects), and drift-fence arrays, which use artificial obstructions to direct small mammal movement.

To assess how perception of a shrew assemblage might vary with trapping design, we concurrently sampled shrews with selective transects, linear transects, and drift-fence arrays in the southern Appalachians. To gain insight into behaviors that might affect capture success with these trapping techniques, we also examined microhabitat (coarse woody or rocky debris) use by shrews.

METHODS

STUDY AREA

We conducted our study at the Coweeta Hydrologic Laboratory (35°03'N,83°25'W), located in the Nantahala Mountain Range of Macon County, North Carolina (Swank and Crossley 1988). Elevation at our study plots ranged from 792 to 1,524 m above sea level. Study plots were restricted to plant communities typical of cove hardwood and northern hardwood forests (Wharton 1977). Cove hardwood forests were characterized by the dominance of yellow poplar (*Liriodendron tulipifera*), yellow buckeye (*Aesculus octandra*), black cherry (*Prunus serotina*), and birch (*Betula* spp.) in the canopy, sparse woody vegetation below the canopy, and lush herbaceous vegetation. Northern hardwood forests were dominated by black oak (*Quercus velutina*), northern red oak (*Q. rubra*), yellow birch (*B. lutea*), and black cherry in the canopy. Rhododendron (*Rhododendron maximum*) and mountain laurel (*Kalmia latifolia*) were common shrubs, and the composition and density of herbaceous vegetation was variable.

COMPARISON OF TRAPPING METHODS

At each of 12 plots we established one selective transect and one linear transect of pitfall traps in July 1994. Both transects consisted of 20 traps placed at 5-m intervals, were approximately parallel, and were separated by 50 m. Pitfalls in selective transects were placed along logs, rocks, and stumps where our previous experience had indicated that chances for shrew capture might be good. Traps in linear transects were placed without regard to microhabitat conditions. Pitfalls were tapered plastic cups (11-cm lip diameter and 14-cm depth) partially filled with preservative and set flush with the ground surface.

In August 1995, we constructed a series of five Y-shaped drift-fence arrays at each of four plots randomly chosen from among the 12 original plots. Each array consisted of three, 3-m "arms" of 36-cm-wide aluminum flashing radiating from the center of the array. Arms were set at 120° angles, and flashing was buried to 3 cm to prevent mammals from burrowing under the fences (Handley and Varn 1994, Kirkland and Sheppard 1994). Nine pitfall traps were set in association with each array, such that three were placed in the middle, and two at the ends of each of the three arms. The five arrays were set in a line approximately parallel to, and 50 m from, the previously established transects at these plots. Individual arrays were spaced 25 m apart, so that the length of the array series was equal to the length of the transects (100 m).

We operated the two types of transects at 12 plots from 9 to 23 July 1994 for a total of 3,360 trapnights (TN) per method. We operated all three methods at four plots from 4 to 11 August, and again from 18 November to 2 December 1995. Trapping effort was equal at the two types of transects (2,240 TN), but greater at the arrays (4,040 TN). Because pitfalls associated with an array are interdependent, it is not meaningful to compare sampling effort between transects and arrays. Thus, we used methods of analysis that were not influenced by differences in sampling effort. All specimens were identified to species and accessioned into the collections of the University of Georgia Museum of Natural History.

The distributions of capture frequencies using each survey method were compared using likelihood-ratio tests of independence (Agresti 1990). Rejection of the null hypothesis of independence indicated that the methods produced different distributions of capture frequencies, and thus different perceptions of shrew assemblage structure. We also partitioned the data table involving all three methods into several independent, four-fold (2-by-2) tables (Lancaster 1949) to better determine patterns of dependence. For example, capture rates of *Sorex* spp. (both species combined) and *Blarina brevicauda* were compared between transects (both types combined) and arrays. For each four-fold table, we calculated the corresponding odds ratio and tested the hypothesis that the odds ratio was equal to unity (Agresti 1990).

MICROHABITAT ANALYSES

In July 1994, we measured several microhabitat variables surrounding each of the 240 pitfall traps of the linear-transects. Because these traps were placed without regard to microhabitat conditions, surveys provided an unbiased sample of conditions at the forest floor and could be compared to capture frequencies of each species at those locations. Only traps associated with linear transects were considered in this analysis.

At each trap station, we established a circular plot with a 2.5-m radius. Within each plot we measured the diameter and length of all coarse woody debris greater than 4 cm in diameter. We also measured the greatest length and width of all rocky debris, and the diameter at the forest floor of all stumps within each plot. These measurements yielded an index to the abundance of fallen logs, rocks, and stumps surrounding each pitfall trap. We also measured the distance from the pitfall trap to the nearest fallen log, rock, or stump.

Microhabitat measurements were compared to shrew capture frequencies using Pearson product-moment correlations. We regressed capture frequency of each species against distance to nearest structure (Neter et al. 1990).

RESULTS

METHOD COMPARISON

In 3,360 trapnights (TN) at selective transects in 1994 we collected 358 individuals representing four species (Table 1). In 3,360 TN at linear transects we collected 126 individuals from the same four species. *Sorex cinereus* was the most commonly captured shrew, followed by *S. fumeus*, *Blarina brevicauda*, and *S. hoyi*. *Sorex hoyi* was uncommon at our sites and, therefore, was omitted from all statistical analyses. We captured 2.8 times as many individuals in selective as in linear traps, and this ratio was relatively constant among species (Table 1). Consequently, the distribution of shrew captures (relative abundance of each species) did not differ between these two methods ($G^2 = 0.722$; $P = 0.697$; df = 2).

Table 1. Number of captures of four species of shrews using two pitfall transect designs, selective and linear, at the Coweeta Hydrologic Laboratory, July 1994. Traps in selective transects were positioned 5-m apart next to structures such as down logs and rocks. Traps in linear transects were set 5-m apart in a straight line.

	Transect Type			
Species	Selective (TN = 3,360)	Linear (TN = 3,360)	Total	Selective:Linear Ratio
Blarina brevicauda	25	8	3	3.1:1
Sorex cinereus	208	78	286	2.7:1
Sorex fumeus	116	36	152	3.2:1
Sorex hoyi	9	4	13	2.3:1
Total	358	126	484	2.8:1

In 2,240 TN at selective transects in 1995 we captured 124 individuals of the same four species captured in 1994 (Table 2), whereas linear transects yielded 52 individuals. Similar to the 1994 data, we captured 2.4 times as many individuals in selective as in linear transects; however, there was greater variation in this ratio among species than in 1994. In 4,040 TN at drift-fence arrays we captured 81 individuals of the same 4 species. Capture frequencies observed at drift-fence arrays differed from both types of transects, and ratios involving drift-fence arrays varied markedly (Table 2). Consequently, the distribution of shrew captures among sampling methods varied in 1995 ($G^2 = 17.849$; $P = 0.001$; df = 4).

We were able to construct four independent, four-fold tables using the data collected in 1995. Two of the tables compared captures of *S. cinereus* and *S. fumeus* between the two types of transects ($G^2 = 0.021$; $P = 0.884$; df = 1) and between transects (both combined) and arrays ($G^2 = 3.049$; $P = 0.081$; df = 1). In neither case did the data support dependence; therefore, capture frequency of these species was not markedly affected by trapping method.

The remaining four-fold tables compared *Sorex* spp. to *B. brevicauda* with respect to trap arrangement. The first of these, a table comparing *Sorex* spp. and *B. brevicauda* captures by transect type, indicated that capture frequencies for these two taxa differed between the two methods ($G^2 = 6.061$; $P = 0.014$; df = 1). The odds ratio for this table was greater than unity ($\theta = 3.17$; $Z = 2.409$; df = 163), indicating that *Sorex* spp. were more likely than *B. brevicauda* to be captured using selective transects. The second of these tables compared *Sorex*

Table 2. Number of captures of four species of shrews using two pitfall transect designs, selective and linear, and a drift-fence design at the Coweeta Hydrologic Laboratory, August and November 1995.

	Transect Type						
Species	Selective (TN = 2,240)	Linear (TN = 2,240)	Array (TN = 4,040)	Total	Selective: Linear Ratio	Selective: Array Ratio	Linear: Array Ratio
Blarina brevicauda	10	12	2	24	0.8:1	5.0:1	6.0:1
Sorex cinereus	70	27	61	158	2.6:1	1.1:1	0.4:1
Sorex fumeus	33	12	16	61	2.8:1	2.1:1	0.8:1
Sorex hoyi	11	1	2	14	11.0:1	5.5:1	0.5:1
Total	124	52	81	257	2.4:1	1.5:1	0.6:1

spp. and *B. brevicauda* captures between transects and arrays. Likewise, this table supported dependence (G^2 = 8.718; P = 0.003; df = 1). The odds ratio for this table was less than unity (θ = 0.168; Z = -2.375; df = 242), indicating that *Sorex* spp. were more likely than *B. brevicauda* to be captured using arrays.

MICROHABITAT USE

None of the shrews examined showed strong relationships with the abundance of rocks, logs, and stumps within 2.5 m of the trap stations. There is some evidence that *Sorex fumeus* selectively used habitat structure, as the capture success of this species was significantly correlated with the abundance of rocks (r^2 = 0.017; P = 0.050) and logs (r^2 = 0.018; P = 0.047). *Sorex cinereus* was correlated only with the abundance of rocks (r^2 = 0.026; P = 0.016). Finally, *B. brevicauda* was not correlated with any of the habitat features examined. It should be noted that the correlations presented above are, while statistically significant, exceedingly weak. For example, the abundance of rocks accounts for only 1.7% of the variability in *S. fumeus* capture.

In agreement with our microhabitat correlations, capture success of *S. fumeus* showed a highly significant, although weak, relationship with proximity to structure (r^2 = 0.034; P = 0.006; df = 218). *Sorex cinereus* capture success was not significantly related to proximity to structure (r^2 = 0.009; P = 0.158; df = 218), nor was the capture success of *B. brevicauda* (r^2 = 0.002; P = 0.481; df = 218).

Thus, *S. fumeus* showed the strongest relationship with habitat structure and the greatest positive differences between selective transects and linear transects in 1994 (220%) and 1995 (180%; Tables 1 and 2). Captures of *S. cinereus* were less strongly related to habitat structure and showed smaller, positive differences between selective and linear transects in 1994 (170%) and 1995 (160%). *Blarina brevicauda* was not correlated with the abundance of any structural habitat features or proximity to structure and was the only species to exhibit a negative difference between selective and linear transects (-20% in 1995), reflecting a higher capture success at traps placed without regard to microhabitat features than those traps placed selectively.

DISCUSSION

The relative capture frequencies of *Sorex fumeus* and *S. cinereus*, when considered with respect to each other, were not significantly affected by trap arrangement. This suggests that any of the three methods considered would provide a similar depiction of the relative abundance of these species in similar habitats. Furthermore, the capture rates of these species using transects were similar over a two-year period. Thus, our data for *S. fumeus* and *S. cinereus* suggest that in comparisons over time, selective and linear transects provide estimates of relative abundance that are similar to each other and reasonably stable over two years.

Comparisons involving *Blarina brevicauda* must be considered with some caution due to low sample sizes. However, our study provides some evidence that *B. brevicauda* was less likely than *Sorex* spp. to be captured with trap arrangements utilizing natural or artificial structures to direct movement. On encountering a linear structure, *B. brevicauda* may not have followed the structure lengthwise, which was necessary for capture. It is also noteworthy that *B. brevicauda* is largely fossorial (George et al. 1986) and may not spend as much time moving across the forest floor and encountering drift-fences or natural habitat structures.

Largely because of *B. brevicauda* we found that drift-fence arrays provided a different depiction of the southern Appalachian shrew community than did either of two types of transects. Mitchell et al. (1993) and Dowler et al. (1985) also found differences in species richness and numbers of shrews collected using pitfalls set singly and in conjunction with drift-fence arrays. In 1,750 TN at each trap arrangement, Dowler et al. (1985) captured 47 *S. cinereus* at arrays compared to 29 in isolated pitfalls, but they only captured 2 *B. brevicauda* at arrays compared to 3 at isolated pitfalls. Again, inferences are tenuous due to small capture frequencies, and further studies into the movement patterns and behavior of *Blarina* are recommended.

Overall capture success with transects was 7.2% in 1994 and 3.9% in 1995. This disparity provided evidence that numbers of shrews may have decreased between the two trapping periods, perhaps due to the removal of animals during 1994. Thus, for the purposes of these analyses we have had to make the assumption that this change in overall shrew abundance did not affect patterns of shrew microhabitat use.

Among the 3 shrews we studied (*Sorex hoyi* excluded), *S. fumeus* and *S. cinereus* exhibited weak, but significant, relationships with structures on the forest floor, whereas *B. brevicauda* did not. We are aware of no previous studies of microhabitat use by *S. fumeus*. The observations of MacCracken et al. (1985) in southeastern Montana support the importance of litter cover (dead plant parts) to *S. cinereus*; however, they did not separate downed logs from other types of debris. In contrast, Yahner (1986) found that the mean length and density of logs were lower at trap stations where *S. cinereus* was captured than where this species was not captured, and Getz (1961) concluded that microhabitat features have little or no effect on distributions of *S. cinereus*, emphasizing the importance of moisture. Our results suggest that selective use of microhabitat features by *S. cinereus* may be so weak as to require a very large sampling effort to detect.

Our results agree with Getz (1961) and Yahner (1982) who found no evidence for microhabitat selection in *B. brevicauda*. Conversely, Seagle (1985) found that *B. brevicauda* seemed to avoid areas with few fallen logs in deciduous forests in Tennessee.

Our perception of the relative abundance of three shrew species was partially a function of the trap arrangement we used to capture them. Each sampling method takes advantage of certain patterns of microhabitat use, which vary among species. We suggest that caution be used when comparing the results of surveys using different trap arrangements, as well as different traps.

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