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Discarded Bottles as a Source of Shrew Species Distributional Data along an Elevational Gradient in the Southern Appalachians

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Abstract - Discarded bottles were inspected for skeletal remains at 220 roadside sites along the southeastern Blue Ridge escarpment of North Carolina, South Carolina, and Georgia as a technique to examine the regional distributions of shrews. Vertebrate remains were found at approximately 63% of our study sites and in 4.5% of the open bottles we examined. Bottles collected a total of 553 specimens of small mammals representing 5 species of shrews and 6 species of rodents. The Northern Short-tailed Shrew (*Blarina brevicauda*) and the Smoky Shrew (*Sorex fumeus*) were abundant and distributed throughout the region, although Smoky Shrews were more strongly associated with mesic environments and higher altitudes ($\bar{x}$ = 940.1 m ± 25.4 m). The Masked Shrew (*S. cinereus*) and the Southeastern Shrew (*S. longirostris*) exhibited contiguous allopatry, with Masked Shrews occurring exclusively in mesic forest habitats at high elevations ($\bar{x}$ = 1126.7 ± 27.4 m), and Southeastern Shrews occurring only in xeric habitats at lower elevations ($\bar{x}$ = 503.7 ± 64.9 m). Our study demonstrates the utility of discarded bottles as a quick and effective alternative method for surveying shrews, without the added mortality that occurs from pitfall- or snap-trapping.

Introduction

Diversity of North American Soricidae is greatest in geographic regions such as the southern Appalachians where precipitation is high and where topography results in a variety of forested habitats (Berman et al. 2007, Ford et al. 2006). The southeastern region of the Blue Ridge escarpment marks the edge of the Appalachians through southwestern North Carolina, northwestern South Carolina, and northeast Georgia. Elevation in this region decreases abruptly over a relatively short geographic distance north to south approaching the mountain-piedmont interface (Ford et al. 2001, Laerm et al. 1999). For example, elevations in the Highlands region of North Carolina, the southernmost high plateau of the Appalachian mountains (Johnston 1967), shift from about 1255 m to 313 m in Walhalla, South Carolina over an approximate distance of only 35 km.

This steep altitudinal gradient is characterized by considerable diversity in habitat type and moisture regimes and the associated patterns of soricid species richness (Ford et al. 2006, Laerm et al. 1999, McCay et al. 2004). In the Blue Ridge region, assemblages of northern boreal species, including *Sorex cinereus* (Kerr Masked Shrew), *S. fumeus* (Miller) (Smoky Shrew), *S. hoyi* (Baird) (Pygmy Shrew), and *Blarina brevicauda* (Say) (Northern Short-tailed

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Shrew), and southern Piedmont and Coastal Plain species, including *S. longirostris* Bachman (Southeastern Shrew), *B. carolinensis* (Bachman) (Southern Short-tailed Shrew), and *Cryptotis parva* (Say) (Least Shrew), converge (Berman et al. 2007, Ford et al. 2006, Johnston 1967, Laerm et al. 1999, Mengak et al. 1987). At transitional elevations, members of the two assemblages may co-occur (Greenberg and Miller 2004), but they are generally segregated by habitat type (Ford et al. 2001, McCay et al. 2004).

Habitat generalists such as Northern Short-tailed Shrews and Smoky Shrews have been found to be common and have wide distributions throughout the southern Appalachians (Laerm et al. 1999). Species with narrower niche breadths such as Masked Shrews and Southeastern Shrews, on the other hand, appear to exhibit contiguous allopatry based on elevation and habitat moisture (Ford et al. 2001, Pagels and Handley 1989). Although these two species may overlap in their latitudinal distribution in the Blue Ridge (Ford et al. 2006, Johnston 1967, McCay et al. 2004), with one exception (Greenberg and Miller 2004), they have not been recorded at the same site (Ford et al. 2001, Laerm et al. 1999, Mengak et al. 1987, Pagels and Handley 1989). Masked Shrews have been collected as far south as the Walhalla Fish Hatchery in Oconee County, SC (Laerm et al. 1995a) and Tray Mountain, White County, GA (Laerm et al. 1999) and at elevations as low as 615 m in mesic hemlock (*Tsuga* spp.)-hardwood forests (Ford et al. 2001). Southeastern Shrews have been reported in North Carolina from Coweeta Hydrological Laboratory in Macon County (Laerm et al. 1999) and Bent Creek Experimental Forest in Buncombe County (Greenberg and Miller 2004, Johnston 1967) and at altitudes as high as 923 m, but only in xeric oak (*Quercus* spp.)-pine (*Pinus* spp.) habitats (Ford et al. 2001).

Previous studies of shrew species distribution and diversity in the southeastern region of the Blue Ridge have relied upon traditional sampling methodologies such as snap- and pitfall- trapping (e.g., Ford et al. 1997, 2001; Greenberg and Miller 2004; Laerm et al. 1995a, 1997a, 1997b, 1999, 2000b; McCay et al. 1998; Mengak et al. 1987). Such techniques are generally effective, but are extremely labor-intensive (Handley and Kalko 1993, Kalko and Handley 1993, Kirkland and Sheppard 1994). However, the presence of shrews also can be determined by examining skeletal remains extracted from discarded bottles, a relatively underused method of collecting small mammals (Clegg 1966, Morris and Harper 1965). Frequently, an animal will enter a bottle when foraging or in search of shelter and become entrapped because of the slope and slippery interior surface, or will drown if the bottle is partially filled with rainwater (Benedict and Billeter 2004). Data collected from discarded bottles have been used effectively to delineate the ranges of Northern Short-tailed, Southern Short-tailed, and Southeastern Shrews in Virginia (Pagels and French 1987, Pagels and Handley 1989). Our objective was to similarly use roadside bottles to examine the general distribution of shrews, and to better demarcate the altitudinal and habitat segregation between Masked and Southeastern Shrews along the southeastern region of the Blue Ridge escarpment.

Methods

We examined bottles for skeletal remains along primary and secondary roads throughout Macon, Jackson, and Transylvania counties in North Carolina, Oconee and Pickens counties in South Carolina, and Rabun County in Georgia (Fig. 1) periodically from September 2007 to November 2009. To maximize the efficiency of our search effort, we limited our study sites to established pull-offs, scenic overlooks, and parking areas where large numbers of bottles and other items of trash have accumulated. Although we were restricted by the availability of such sites at different locations, we attempted to sample from as many elevations and habitats as possible throughout the region. Our study sites were clustered at a few localities because of these constraints, but were counted as independent sites if separated by a minimum distance of 0.8 km, which exceeds the home range of most shrews (Whitaker and Hamilton 1998).

Surrounding or adjacent forest stands generally were ≥50 years old at our survey sites, though stand age appears to have little influence on shrew

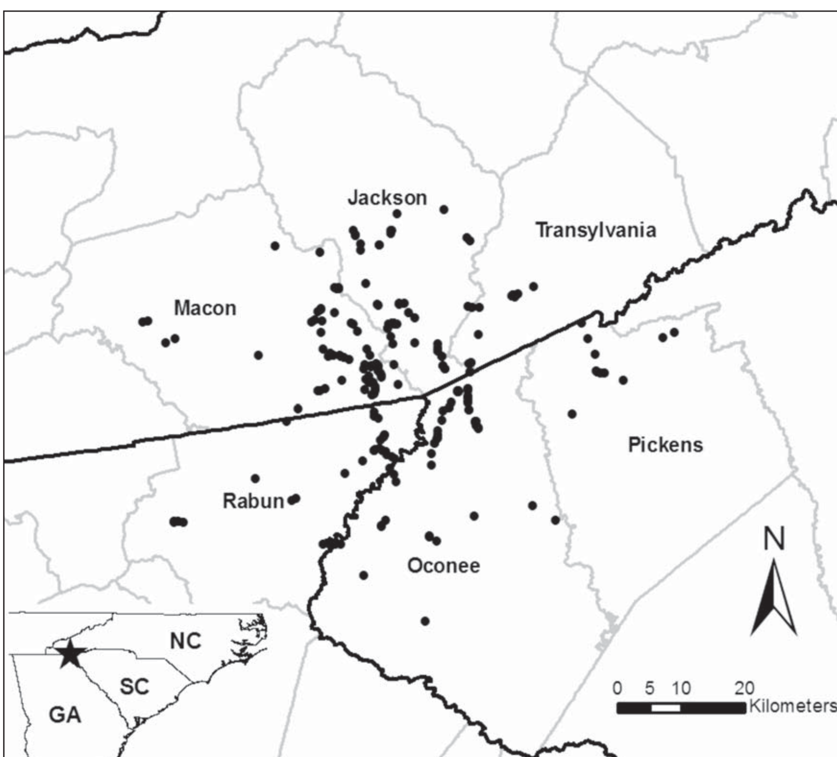


Figure 1. Map of the southeastern Blue Ridge escarpment illustrating locations of study sites. Discarded bottles were examined for small-mammal skeletal remains at 220 localities in regional counties of North Carolina (123 sites), South Carolina (66), and Georgia (31) from September 2007 to November 2009.

abundance (Ford et al. 1997, 2002). We recorded latitude, longitude, and elevation at each site and mapped data using ArcGIS® 9.3 software (ESRI, Inc.; Redlands, CA). Because soricid distribution is greatly influenced by environmental moisture (Brannon 2002a, Getz 1961), we also ranked the vegetational community at each site into one of the five habitat moisture classes described by Ford et al. (2001). We assigned values from xeric to mesic of 1 to pine communities, 2 to mixed pine-hardwood communities, 3 to upland hardwood and riverine communities, 4 to northern hardwood communities, and 5 to cove hardwood and montane streamside communities (Ford et al. 2001).

We located bottles visually at each site by walking along the sides of roads and down embankments into adjacent forested areas, and by shuffling our feet to uncover those buried in leaf litter (Benedict and Billeter 2004). The size of the search area varied according to individual site conditions such as steepness of the slope and thickness of the vegetation, but was generally about 100 m in length and as far off the shoulder of the road into the vegetation as bottles could be found. "Bottles" were defined as any plastic or glass container of any size including beer and soda bottles, jars, milk jugs, or other similar items of trash. Aluminum cans were examined initially but were excluded from analyses because they were never found to contain any vertebrate remains. In addition to the bottles that contained specimens, we recorded both the number of open bottles (i.e., potential traps) and bottles with caps during each search.

Bottles that appeared to contain skeletal remains usually were covered by leaf litter, and often held water, dirt, and dead invertebrates and had a foul odor. The presence of fur, frequently dried to the side of the bottle's interior, was our primary indicator. Contents were extracted and then carefully teased apart to find bones (Benedict and Billeter 2004). Skulls, mandibles, and other bones including any skull fragments were labeled for each site and placed into plastic bags to be deposited at the Highlands Biological Station. We identified small mammals to species by dentition and other distinctive cranial characteristics (Caldwell and Bryan 1982, Pivorun et al. 2006). In many cases, shrew skulls were missing diagnostic unicuspid teeth, but we were able to make positive identifications through comparisons with reference collection specimens.

Species were characterized as present or absent at each study site. We used correlation analysis to examine relationships of elevation and habitat moisture with the relative abundance of each shrew species (Zar 1999). Segregation of Masked Shrews and Southeastern Shrews were analyzed using Student's *t*-tests for elevation, and Mann-Whitney *U*-tests for habitat moisture class (Zar 1999). To assess patterns of soricid diversity, we grouped the total number of captures and site occurrences for each species by habitat moisture class and by 300-m intervals (Ford et al. 2001), and differences between these groups in overall shrew capture rates (# shrews / # open bottles) and species richness (*S*) were examined using chi-square (χ^2) goodness-of-fit tests (Zar 1999).

Results

We examined a total of 10,461 bottles at 220 sites throughout the region (Fig. 1). Of this total, 6145 (58.7%) of the bottles were open and served as potential traps for small mammals, with an average of 27.9 open bottles per site. Skeletal remains were found at 138 (62.7%) of the sites and in 4.5% of the open bottles we examined, with a mean (± 1 SE) of 2.6 ± 0.3 specimens per site (range = 0–30).

Bottles contained a total of 553 specimens of small mammals, representing 5 species of shrews and 6 species of rodents (Table 1). Unlike Benedict and Billeter (2004), we collected skeletal remains in abundance from both glass and plastic bottles. Multiple specimens ($\bar{x}$ = 2.1 ± 0.2) were frequently extracted from individual bottles, especially from ones positioned at steep angles or those containing rainwater (Morris and Harper 1965, Pagels and French 1987). The most collected from a single bottle was 22 skulls, representing 3 species of small mammals. Overall capture rate for small mammals (total # animals / total number of open bottles) was 9.0% across all sites (Table 1), but was more than 12.3% at elevations >900 m and in mesic habitats (moisture classes 4 and 5). Bottles also captured 1 *Desmognathus ocoee* Nicholls (Ocoee Salamander), 4 *Plethodon metcalfi* Brimley (Gray-cheeked Salamander), 2 *P. serratus* Grobman (Southern Red-backed Salamander), and 1 *Carphophis amoenus* (Say) (Eastern Worm Snake). We also found in bottles an abundance of invertebrates, consisting primarily of beetles, millipedes, and snails.

Individually, the small-mammal species with the highest incidence of capture (5.4%) was the Northern Short-tailed Shrew (*n* = 332, 59.9% of

Table 1. Summary of small-mammal captures and site occurrences based on 6145 open bottles and 220 sites. Skeletal remains were collected from discarded bottles along the southeastern Blue Ridge escarpment of North Carolina, South Carolina, and Georgia from September 2007 to November 2009. % = percentage of captures. Overall capture rate (CR) was defined as # animals / total # open bottles and is given as %. Site = site occurrence.

Family and Species	Common name	*n*	%	CR	Site
Soricidae:					
Blarina brevicauda (Say)	Northern Short-tailed Shrew	332	59.9	5.4	94
Sorex fumeus (Miller)	Smoky Shrew	105	19.0	1.7	58
S cinereus Kerr	Masked Shrew	30	5.4	0.5	26
S. longirostris Bachman	Southeastern Shrew	6	1.1	0.1	6
S. hoyi (Baird)	Pygmy Shrew	5	0.9	0.1	3
Muridae:					
Peromyscus maniculatus Wagner	Deer Mouse	36	6.5	0.6	22
P. leucopus (Rafinesque)	White-footed Mouse	27	4.9	0.4	15
Microtus pinetorum (Le Conte)	Woodland Vole	5	0.9	0.1	5
Reithrodontomys humulis (Audubon and Bachman)	Eastern Harvest Mouse	5	0.9	0.1	1
Myodes gapperi (Vigors)	Southern Red-backed Vole	1	0.2	<0.1	1
Ochrotomys nuttalli (Harlan)	Golden Mouse	1	0.2	<0.1	1
Totals		553		9.0	

captures), which we found at 94 (42.7%) of our study sites (Table 1). It was widely distributed across a variety of elevations (Table 2) and habitats (moisture class range = 2–5; Table 3) throughout the region (Fig. 2a). Mean elevation for this species was 815.5 ± 26.9 m (range = 361–1336 m). The presence of Northern Short-tailed Shrews was not significantly correlated with elevation ($r = 0.01$, df = 218, $P = 0.85$) or habitat moisture ($r = 0.11$, df = 218, $P = 0.10$).

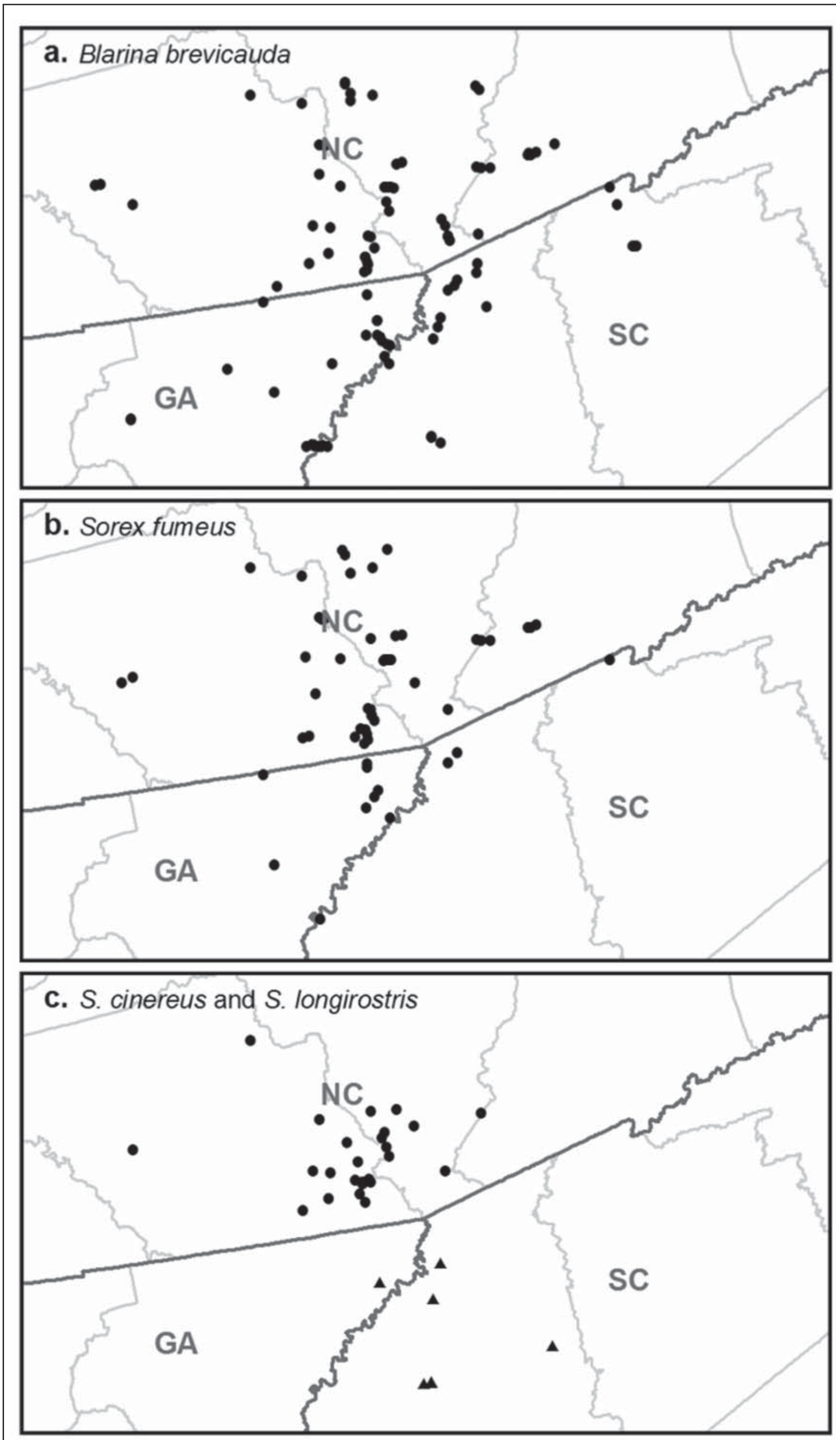
Table 2. Occurrence (site) and abundance (*n*) of individual shrew species at sites within each 300-m elevational range. Specimens were collected from discarded bottles along the southeastern Blue Ridge escarpment of North Carolina, South Carolina, and Georgia from 2007 to 2009. Capture rate was defined as # shrews / # open bottles.

	<300 m		300–599 m		600–899 m		900–1199 m		≥1200 m	
Species	Site	*n*	Site	*n*	Site	*n*	Site	*n*	Site	*n*
Northern Short-tailed Shrew	0	0	25	87	29	104	35	132	5	9
Smoky Shrew	0	0	3	6	16	25	36	67	3	7
Masked Shrew	0	0	0	0	3	4	16	18	7	8
Southeastern Shrew	1	1	3	3	2	2	0	0	0	0
Pygmy Shrew	0	0	0	0	1	1	2	4	0	0
No. of sites:	4		53		71		80		12	
No. of open bottles:	187		1734		2142		1840		242	
Total No. of shrews:	1		96		136		221		24	
Overall capture rate (%):	0.5		5.5		6.4		12.0		9.9	
Species richness (*S*):	1		3		5		4		3	

Table 3. Occurrence and abundance of individual shrew species at sites in habitat moisture classes 1 to 5, most xeric to most mesic. Specimens were collected from discarded bottles along roads on the southeastern Blue Ridge escarpment of North Carolina, South Carolina, and Georgia from 2007 to 2009. Capture rate was defined as # shrews / # open bottles.

	Moisture class									
	1		2		3		4		5	
Species	Site	*n*	Site	*n*	Site	*n*	Site	*n*	Site	*n*
Northern Short-tailed Shrew	0	0	15	38	23	100	28	97	28	97
Smoky Shrew	0	0	3	6	9	15	21	41	25	43
Masked Shrew	0	0	0	0	0	0	11	14	15	16
Southeastern Shrew	1	1	4	4	1	1	0	0	0	0
Pygmy Shrew	0	0	0	0	1	1	1	1	1	3
No. of sites:	6		45		51		56		62	
No. of open bottles:	223		1606		1410		1388		1518	
Total No. of shrews:	1		48		117		153		159	
Overall capture rate (%):	0.5		3.0		8.3		11.0		10.5	
Species richness (*S*):	1		3		4		4		4	

Figure 2 (opposite page). Distributions of individual shrew species along the southeastern Blue Ridge escarpment based on skeletal remains found in discarded roadside bottles: (a) Northern Short-tailed Shrew, (b) Smoky Shrew, and (c) Masked Shrew (dots), and Southeastern Shrew (triangles).


a. Blarina brevicauda
NC
SC
GA
b. Sorex fumeus
NC
SC
GA
c. S. cinereus and S. longirostris
NC
SC
GA

Smoky Shrews also were collected in abundance (*n* = 105, 19.0% of small-mammal captures) at many sites (*n* = 58 sites, 26.4%; Table 1). This species was distributed across a wide range of elevations (Table 2) and moisture classes (range = 2–5; Table 3) in the region, although more commonly in North Carolina (Fig. 2b). The southernmost locality for Smoky Shrews in our survey was near the Chattooga River at Hwy 76 in Oconee County, SC, at an elevation of 486 m. Occurrence of this species was significantly greater at higher elevations ($r = 0.29$, df = 218, $P < 0.01$) and in more mesic environments ($r = 0.31$, df = 218, $P < 0.01$). Mean elevation for Smoky Shrews was 940.1 ± 25.4 m (range = 448–1238 m).

Fewer Masked Shrews were collected than larger species of shrews (*n* = 30; 5.4% of captures), and were found at fewer sites (*n* = 26 sites; 11.8%). This species also was more restricted in its altitudinal (Table 2) and habitat distribution (moisture class range = 4–5; Table 3) along the southeastern Blue Ridge escarpment. Masked Shrews were collected only in North Carolina (Fig. 2c) at high elevations ($r = 0.43$, df = 218, $P < 0.01$) and exclusively in moist habitats such as northern hardwood and cove hardwood-montane streamside communities ($r = 0.32$, df = 218, $P < 0.01$). Mean elevation for Masked Shrews was 1126.7 ± 27.4 m (range = 812–1368 m).

Southeastern Shrews (*n* = 6; 1.1% of captures) were collected from 6 (2.7%) of our study sites (Table 1), but were significantly segregated from Masked Shrews by both elevation ($t = 9.60$, df = 30, $P < 0.01$) and habitat ($U = 156$, $n_1 = 6$, $n_2 = 26$, $P < 0.01$). This species was associated with lower altitudes ($r = -0.185$, df = 218, p < 0.01; Table 2) in South Carolina and Georgia (Fig. 2c) and with more xeric environments ($r = -0.211$, df = 218, $P < 0.01$), such as mixed hardwood-pine communities (moisture class range = 1–3; Table 3). Mean elevation for Southeastern Shrews was 503.7 ± 64.9 m (range = 255–728 m).

Pygmy Shrews are widely distributed in a diversity of vegetational communities and elevations across the Blue Ridge, but appear to be locally uncommon (Johnston 1967, Laerm et al. 2000b). Because in our surveys this species was found at only 3 sites (Table 1), we excluded it from individual statistical analyses. The few Pygmy Shrews that we did collect (*n* = 5; 0.9% of captures) occurred at high altitudes (Table 2) in North Carolina and South Carolina, and in mesic environments (range = 3–5; Table 3). Mean elevation for Pygmy Shrews was 1049.0 ± 87.7 m (range = 882–1179 m).

Overall soricid capture rates differed significantly among both elevational ranges ($\chi^2 = 10.55$, df = 3, $P < 0.05$) and habitat moisture classes ($\chi^2 = 12.17$, df = 3, $P < 0.05$). Capture rate for shrews was highest at altitudes from 900–1199 m (12.0%; Table 2) and in mesic northern hardwood habitats (moisture class 4; 11.0%; Table 3). No significant differences existed for shrew species richness among elevational ranges ($\chi^2 = 2.74$, df = 3, $P > 0.05$) or moisture classes ($\chi^2 = 2.12$, df = 3, $P < 0.05$), although it was greatest ($S = 5$) within the intermediate range of elevations (600–899 m) where Masked Shrews and Southeastern Shrews co-occur near their altitudinal demarcation (Table 2), albeit in different habitats (Table 3).

Discussion

Increases in species richness along elevational gradients are a function of many complex ecological interactions (Ford et al. 2006, Rickart 2001). Soricid diversity is greatest at higher-elevation sites of the southern Appalachians, where environmental conditions resemble those of more northern forests (Laerm et al. 1999, Pagels et al. 1994). Shrews are more abundant in mesic forests than in xeric habitats (Cudmore and Whitaker 1984, Kirkland 1991, Laerm et al. 1999), including those with streams or seeps (Laerm et al. 1997a). Forest communities such as cove hardwoods, northern hardwoods, and mixed oak-hickory (*Carya* spp.) generally provide moist and dense ground cover, high volumes of coarse woody debris in the latter stages of decay, and abundant invertebrate faunas favorable to most shrews (Brannon 2002a, Gist and Crossley 1975, Greenberg and Forrest 2003).

The wide range of elevations and the varied topography of the Blue Ridge escarpment provide aspects where xeric forests used by species such as the Southeastern Shrew are in close proximity to mesic habitats that support other shrew species such as the Masked Shrew (Brannon 2002a, Ford et al. 2006). Environmental moisture is especially important to the distribution of shrews such as the Masked Shrew and Smoky Shrew because it affects not only their water balance and mobility (Chew 1951, Getz 1961), but also the abundance and accessibility of invertebrate prey (Brannon 2002b, Gist and Crossley 1975, McCay and Storm 1997). However, greater numbers of shrews collected from bottles in moist forest habitats may only reflect increased epigeal movement (Brannon 2002b, McCay 1996), and not actual species abundance (Ford et al. 2002).

In mesic forests, soricid communities are not random but rather appear to follow a pattern where ecological separation is achieved through differential exploitation of common resources by species of dissimilar body size (Brannon 2000, Fox and Kirkland 1992, Kirkland 1991). Most areas of the Blue Ridge are dominated by large-sized (Northern Short-tailed Shrew) and medium-sized (Smoky Shrew) habitat generalists, associated with a less abundant and more specialized small-sized species (Masked Shrew) and an uncommon smaller-sized habitat generalist (Laerm et al. 1999, Kirkland 1991, McCay et al. 2004) such as the Pygmy Shrew (Laerm et al. 2000b). Other species such as *Sorex dispar* Batchelder (Rock Shrew) or *S. palustris* Richardson (Water Shrew) sometimes also occur, but fill specialized niches (Kirkland 1991) and are generally rare (Johnston 1967; Laerm et al. 1995b, 1997b, 1999).

The Northern Short-tailed Shrew is the species of small mammal most frequently trapped in bottles (Benedict and Billeter 2004, Pagels and French 1987). It is one of the most common and widespread of all the small mammals in the Blue Ridge (Johnston 1967, Laerm et al. 1999, Mengak et al. 1987) and, like in our study, has been collected previously from a variety of elevations and vegetational communities (George et al. 1986, Laerm et al. 1999). Northern Short-tailed shrews are usually associated with areas having dense ground cover such as rocks, logs, and a deep leaf-litter layer (Getz 1961, Kitchings and Levy 1981), which most sites in our study area provided. Smoky Shrews are most abundant in mesic forest communities with considerable structural debris (Brannon 2000, 2002a; Cudmore and Whitaker 1984; Owen 1984), but are occasionally present in more xeric habitats such as dry south-facing slopes, ridgelines, and meadows (Laerm et al. 1999). Although they generally have a more northern distribution, Smoky Shrews have been reported previously from the mountainous regions of South Carolina in suitable habitats (Johnston 1967, Mengak et al. 1987), as in our study. River gorges in this region are refugia of more typical northern forest communities (Laerm et al. 1995a), and may provide corridors that also facilitate dispersal of Smoky Shrews southward to lower altitudes (Johnston 1967).

The lower elevational distribution limit of 812 m for Masked Shrews and the higher elevational distribution limit of 728 m for Southeastern Shrews observed in our surveys are consistent with the findings of Ford et al. (2001), and show an increasing north-to-south elevation cline demarcating segregation between these two species (Ford et al. 2006). Masked Shrews have been reported from isolated localities in the Blue Ridge region of Georgia and South Carolina at elevations as low as 610 m (Laerm et al. 1995a, 1999), but maintain a continuous distribution at higher elevations in North Carolina (Ford et al. 2001, Johnston 1967). They are uncommon at low elevations (Laerm et al. 1995a), and are generally restricted to mesic habitats with more northern affinities and with substantial ground cover (Brannon 2002a, Laerm et al. 1999, Pagels et al. 1994). The Masked Shrew appears to exhibit contiguous allopatry with Southeastern Shrews based upon altitudinal and habitat gradients (Ford et al. 2001, Pagels and Handley 1989), where its functional role as a small-sized habitat specialist is replaced by the Southeastern Shrew farther south at low elevations and in xeric habitats (Laerm et al. 1999).

Although diminutive species of *Sorex* may be less abundant naturally in southern Appalachian forests than larger habitat generalists such as Smoky Shrews and Northern Short-tailed Shrews (Laerm et al. 1999, 2000b), bottles often underestimate their true population sizes (Gerard and Feldhamer 1990) and may reduce reliability of analyses (Benedict and Billeter 2004). Tiny bones may decompose or be scavenged more quickly, and fragments may be more easily overlooked (Benedict and Billeter 2004). For example, we collected 6 Southeastern Shrews at 220 sites, whereas Ford et al. (2001) captured 217 at 101 sites using pitfalls. Similarly, we collected 30 Masked Shrews compared to 2442 captured by Ford et al. (2001). It is also possible that bottles may not as effectively trap smaller species of shrews (Gerard and Feldhamer 1990).

Nevertheless, our study demonstrates the utility of discarded bottles as an alternate source of small-mammal distributional and taxonomic data, and is one of the few to use bottles as a survey technique to delineate the ranges of shrew species over a wide geographic region (Pagels and French

1987, Pagels and Handley 1989). This method was far less time- and labor-intensive than traditional methods such as pitfall-trapping (Ford et al. 1997, Hanley and Kalko 1993, Kirkland and Sheppard 1994, McCay et al. 1998), yet yielded results comparable to those of previous studies from a community composition standpoint (Ford et al. 2001, Laerm et al. 1999). Because discarded bottles are already in place and function continuously, distributional gaps may be filled in a very short period and reduce the necessity of overnight trapping (Pagels and French 1987). Furthermore, discarded bottles sample small-mammal populations without the added mortality that occurs from pitfall- or snap-trapping (Kalko and Handley 1993, Kirkland and Sheppard 1994, Taulman et al. 1992). Although bottles may be an inferior indicator of actual species abundances (Benedict and Billeter 2004, Gerard and Feldhamer 1990) and are ineffective in short-term studies involving activity patterns (Taulman et al. 1992), the geographic distributional information obtained from bottles for general taxonomic surveys may be limited only by the area sampled and the diversity of the small-mammal fauna (Pagels and French 1987).

Although concentrations of bottles at our limited study sites may not be representative of the entire region, our finding of 4.5% of open bottles containing vertebrates is consistent with that of Benedict and Billeter (2004) for areas with high levels of human disturbance. But because a single bottle can entrap multiple animals, overall capture rates for small mammals may be alarmingly higher, especially in areas with high soricid diversity. Pagels and French (1987) estimated mortality as 24 to 71 small mammals per km at sites across Virginia, but it may exceed 183 animals per km in areas with larger accumulations of bottles (Benedict and Billeter 2004). Many rural localities with vehicle parking, such as our study sites, serve as illegal garbage dumps which may reduce the local abundance of individual shrew species (Courtney and Fenton 1976), including some listed as threatened or of special concern (Laerm et al. 2000a). In mountainous terrain, bottles often roll down steep slopes where they remain undetected by road cleanup crews and may function as traps for extremely long periods. Although we do not know exactly when individual animals were captured (Gerard and Feldhamer 1990), we determined that many of the bottles in our study that contained specimens were years or even decades old, based on their designs and label information. With such a large number of potential trap-nights represented, accumulations of open bottles along roadways in the southern Appalachians pose a considerable mortality risk to small mammals (Benedict and Billeter 2004, Pagels and French 1987), especially shrews (Clegg 1966, Morris and Harper 1965).

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