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Abstract: A total of 2,445 discarded bottles were inspected for skeletal remains at 50 roadside pull-off sites along the southeastern Blue Ridge escarpment of North Carolina and Georgia to assess their mortality risk to shrews. Of these, 1,196 bottles were open and served as potential traps, with an average of about 239 open bottles per km of roadside searched. Small mammal remains were found in bottles at 54.0% of the study sites and in 4.7% of the open bottles we examined. A total of 126 specimens were found in bottles representing 4 species of shrews, 2 species of rodents, and one mole, with approximately 25 entrapped specimens per km of roadside examined. Frequency of small mammal entrapment was 10.6% due in part to multiple captures in individual bottles, and the overall mortality rate was calculated as 32.3 animals per year across all sites. Although accumulation of new bottles in this region is slow, those that persist along roads generate enormous numbers of trap-nights which could potentially result in many small mammal fatalities.

Key Words: Discarded bottles; shrews; small mammals; Soricidae; southern Appalachians.

INTRODUCTION

Entrapment in bottles discarded along roadways has been recognized as a cause of small mammal mortality since the 1960s (Morris and Harper 1965; Clegg 1966). Animals frequently enter a bottle during exploratory activities and become unable to escape because of its steep angle of incline, slippery interior surface, and narrow neck (Morris and Harper 1965), or they may drown if the bottle contains rainwater (Clegg 1966). This phenomenon has been found to be widespread and affect numerous species, particularly shrews (Pagels and French 1987; Benedict and Billeter 2004; Brannon et al. 2010).

Most previous studies have examined discarded bottles as a source of small mammal distributional and taxonomic data (Pagels and French 1987; Pagels and Handley 1989; Brannon et al. 2010), or to compare trapping effectiveness to other methods (Gerard and Feldhamer 1990; Taulman et al. 1992). A few have addressed the potential conservation implications of discarded bottles. For example, Pagels and French (1987) estimated mortality to be 24 to 71 small mammals per km at sites across Virginia, while Benedict and Billeter (2004) found that it may exceed 183 animals per km for more heavily trafficked areas with larger accumulations of bottles. Brannon et al. (2010) found that in the southern Appalachians, 4.5% of open discarded bottles contained small mammal remains, with frequency of capture exceeding 10% at higher elevations and in mesic forests.

The southern Appalachian Mountains are characterized by a diversity of habitat types and moisture regimes along steep elevational gradients with associated patterns of soricid species richness (Ford et al. 2001, 2005; Brannon et al. 2010). At least eight species of shrews, representing a convergence of northern and southern assemblages, are known to occur in the Blue Ridge physiographic province, some of which are uncommon or rare (Laerm et al. 1999). Bottles may pose a considerable threat to small mammals in this region where on steep slopes they are more likely to land in an effective trapping position with their openings facing uphill (Benedict and Billeter 2004), and where large concentrations may often persist for long periods (Brannon et al. 2010).

Brannon et al. (2010) searched for small mammal remains in discarded bottles at 220 sites along the southeastern Blue Ridge escarpment of North Carolina, South Carolina, and Georgia as a technique to examine the regional distributions of shrews. However, in that study and in others (Pagels and French 1987; Benedict and Billeter 2004), the researchers relied on examinations of bottles that were already in place, and the time interval since those bottles were discarded was unknown. Consequently, calculations of actual rates of small mammal entrapment were not possible, and estimates of mortality were based solely on the proportion of bottles yielding skeletal remains. Furthermore, no previous study has examined the rate of accumulation of discarded bottles and the resulting increase in potential trap-nights. During their study however, Brannon et al. (2010) emptied but did not remove bottles from each site. With the number of days elapsed since their original study known, our objective was to revisit many of these sites and determine actual discarded bottle accumulation and trapping rates, in order to better assess their potential mortality threat to shrews and other small mammals in this region of the southern Appalachian Mountains.

METHODS

Bottles were inspected for skeletal remains at 50 of the 220 sites of Brannon et al. (2010) from September through November 2012. Sites were located along primary and secondary roads in Macon and Jackson counties in North Carolina and Rabun County in Georgia, and were selected to re-examine based on accessibility and their proximity to the Highlands Biological Station. These 50 sites were originally searched between September 2007 and February 2009, and were restricted to established vehicle pull-offs, scenic overlooks, and parking areas where copious amounts of bottles and other trash accumulate, especially near ravines (Brannon et al. 2010). Elevations ranged from 448 to 1,188 m, while habitats consisted primarily of northern hardwood, cove hardwood, and montane streamside communities (Ford et al. 2001; Brannon et al. 2010).

''Bottles'' were defined as any plastic or glass container of any size including soda or beer bottles, jars, milk jugs, or similar items of trash. Aluminum cans were excluded because, like Brannon et al. (2010), none were ever found that contained vertebrate remains. Bottles were located visually by walking along the sides of roads and down embankments into the surrounding forest, and by shuffling our feet to expose those buried in leaf litter. The size of the search areas varied according to individual site conditions such as the steepness of the slope and thickness of the vegetation, but each was approximately 100 m in length and extended as far downhill from the shoulder of the road as bottles could be found.

The number of open bottles (i.e., potential traps), including those with skeletal remains, and bottles with caps were recorded for each site. Those appearing to contain specimens were usually located far downhill, covered by leaf litter, and positioned at steep angles. Small mammal remains were indicated by evidence of dried fur, foul odors, murky water, and dead invertebrates such as carrion beetles (Gerard and Feldhamer 1990). Contents were extracted and carefully teased apart with forceps to find bones (Brannon et al. 2010). Skulls, mandibles, and other bones were placed into labeled bags for each site and deposited at the Highlands Biological Station. Shrews and other small mammals were identified to species by dentition and other distinctive cranial characteristics (Caldwell and Bryan 1982), and through comparisons with reference collections.

Data from the previous study were taken from the unpublished field notes of Brannon et al. (2010). Bottle accumulation rates were determined as the number of new bottles divided by the number of elapsed days since the original study at each site. Calculations were made on the basis of minimum number of trap-nights as determined by the number of open bottles present in the original study (n = 1,047), because we were unable to precisely determine when additional bottles were discarded since the previous site examination. Individual species entrapment frequencies were determined as the number of specimens collected divided by the total number of open bottles. Annual small mammal capture rates were calculated as the number of captures divided by the average annual minimum trap-nights, and annual mortality rates as annual capture rates multiplied by the total number of open bottles. Potential increases in shrew mortality from the accumulation of additional discarded bottles were assessed by comparing current numbers of open bottles to those from the earlier study.

RESULTS

Of the 2,455 bottles we examined, 1,196 (48.7%) were open and served as potential traps for small mammals, with an average of 23.9 open bottles per site. An average of about 491 (239 open) bottles per km was found for the approximately 5 km of roadside searched at pull-off sites, although we may have overlooked some buried in the deep leaf litter that occurred in late autumn. A mean ($\pm$1 SE) of 1,631.3 $\pm$ 31.3 days had elapsed since the previous study, with the original 1,047 open bottles accounting for a minimum of 1,705,325 trap-nights (382,155 trap-nights per year) across all sites. Despite periodic removal of some bottles from the shoulders of roads by cleanup crews (pers. observ.), there was a net gain of 149 open (321 total) bottles discarded since the original study (Brannon et al. 2010) with a mean annual gain of 0.7 $\pm$ 0.4 open bottles (271.3 $\pm$ 171.0 trap-nights) per site.

Skeletal remains were found at 27 (54.0%) of the sites and in 4.7% of the open bottles, with a mean of 2.5 $\pm$ 0.7 specimens per site and approximately 25 animals per km of roadside searched. Bottles contained 126 specimens of small mammals (Table 1), representing 4 species of shrews, 2 species of rodents, and one Hairy-tailed Mole (*Parascalops breweri*). This is the first record of any mole collected from discarded bottles. Most of the remains (89.7%) were those of shrews (Table 1). Individually, the small mammal species with the highest incidence of capture was *Blarina brevicauda*, the Northern Short-tailed Shrew (n = 82; 65.1% of captures). The Smoky Shrew (*Sorex fumeus*) was also collected in abundance (n = 26; 20.6% of captures). Bottles also entrapped one rare species, the Pygmy Shrew (*S. hoyi*), as well as the Masked Shrew (*S.*

Table 1. Summary of small mammal captures and site occurrences based on 1,196 open bottles and 50 sites. Skeletal remains were collected from discarded bottles at roadside pull-offs along the southeastern Blue Ridge escarpment of North Carolina and Georgia in autumn of 2012. Entrapment frequency was defined as the number of specimens/total number of open bottles.

Family and Species	Common Name	n	% of Captures	Entrapment Frequency (%)	No. Sites
Soricidae:					
Blarina brevicauda	Northern Short-tailed Shrew	82	65.1	6.9	23
Sorex fumeus	Smoky Shrew	26	20.6	2.2	13
S. cinereus	Masked Shrew	4	3.2	0.3	4
S. hoyi	Pygmy Shrew	1	0.8	0.1	1
Talpidae:					
Parascalops breweri	Hairy-tailed Mole	1	0.8	0.1	1
Muridae:					
Peromyscus maniculatus	Deer Mouse	11	8.7	0.9	4
Myodes gapperi	Southern Red-backed Vole	1	0.8	0.1	1
Totals		126		10.6	

cinereus), the Deer Mouse (*Peromyscus maniculatus*), and the Southern Red-backed Vole (*Myodes gapperi*). The carcass of one Blue Ridge Two-lined Salamander (*Eurycea wilderae*) was also found in bottles in addition to the small mammal remains, as was an abundance of beetles, millipedes, and snails.

Although not analyzed statistically, skeletal remains were collected in abundance from both glass and plastic bottles, especially from those positioned at steep angles or full of water. Overall entrapment frequency (total number of animals/total number of open bottles) across all sites was 10.6% (Table 1), as individual bottles had often collected multiple specimens (mean = 2.3 ± 0.2). The largest amount removed from a single bottle during this study was 19 skulls, representing three species of small mammals. Annual small mammal capture rate in discarded bottles was 2.7% overall, with an average of 32.3 animals killed per year across all 50 sites.

DISCUSSION

Concentrations of bottles and associated small mammal mortality in this study were similar to that of Pagels and French (1987) for rural areas, although our limited study sites may not be representative of the entire region. Our finding that 4.7% of open bottles contained small mammal remains is consistent with those of Benedict and Billeter (2004) and Brannon et al. (2010). However, an individual bottle can collect multiple animals (Gerard and Feldhamer 1990; Pagels and French 1987; Benedict and Billeter 2004). Consequently, the overall frequency of entrapment may be considerably greater, especially in mesic habitats and at higher elevations (Brannon et al. 2010), as our finding of 10.6% demonstrates.

The wide diversity of species collected underscores the indiscriminate nature of discarded bottles as potential traps. The Northern Short-tailed shrew is one of the most common and widespread of all small mammals in the Blue Ridge (Johnston 1967; Ford et al. 1997; Laerm et al. 1999; Mengak et al. 1987), and as in this study is consistently the species most frequently trapped in bottles (Pagels and French 1987; Benedict and Billeter 2004; Brannon et al. 2010). This is likely a result of the abundance of *Blarina* in forest-floor leaf litter, and its semi-fossorial lifestyle and foraging behavior (George et al. 1986). The quantity of specimens of smaller shrews found in bottles is probably an underestimate of the true number of animals that were actually entrapped (Gerard and Feldhamer 1990), because tiny bones may decompose or be scavenged more quickly, and fragments may be more easily overlooked (Benedict and Billeter 2004). Although shrews comprise the majority of vertebrate captures, bottles are also responsible for the death of many rodents, reptiles, and amphibians (Morris and Harper 1965; Pagels and French 1987; Benedict and Billeter 2004; Brannon et al. 2010). In addition, large numbers of millipedes, snails, beetles, and other invertebrates are also collected in discarded bottles (Gerard and Feldhamer 1990; Benedict and Billeter 2004; Brannon et al. 2010).

Diversity of North American Soricidae is greatest in the southern Appalachians as a result of high levels of precipitation and a variety of forested habitats occurring along steep altitudinal gradients (Ford et al. 2005; Berman et al. 2007). Rural mountain roads with vehicle pull-off areas next to steep ravines, such as our study sites, often serve as illegal garbage dumps. High concentrations of discarded bottles frequently exist in such places, which can reduce the local abundance of individual species of shrews (Courtney and Fenton 1976) and may be a conservation threat to those that are uncommon or rare, such as the Pygmy Shrew (Laerm et al. 1999, 2000). Some such as the Rock Shrew (*S. dispar*) and the Water Shrew (*S. palustris*) are listed as species of special concern in North Carolina, as are several other regional species of small mammals, salamanders and terrestrial snails (LeGrand Jr. et al. 2008).

Discarded bottles may be a greater risk to shrews and other small mammals in mountainous terrain because they are more likely to land in the "kill position" with their openings facing uphill (Benedict and Billeter 2004). Such bottles become more effective traps after prolonged periods (Gerard and Felhamer 1990; Taulman et al. 1992) as they accumulate rainwater and invertebrates which may attract shrews (Morris and Harper 1965; Clegg 1966). Many that roll far down steep slopes into thick vegetation also become covered by leaf litter, and may remain undetected or ignored by road cleanup crews (pers. observ.). Once bottles are in place, they may function continuously as traps until they are removed, broken, or their openings become filled with dirt (Brannon et al. 2010). Numerous bottles that we examined appeared to have been in place for years or even decades, as indicated by their designs and label information.

This is the first study to effectively examine entrapment of small mammals in bottles over a known length of time. Capture rates for discarded bottles is lower than for traditional trapping methods such as pitfalls (Gerard and Feldhamer 1990) or snap traps (Taulman et al. 1992). However, even during extensive, long-term studies such other types of traps are not typically present in the high concentrations frequently observed for bottles (Benedict and Billeter 2004), are less widely distributed (Pagels and French 1987), and do not remain in place for as great a duration (e.g., Laerm et al. 1999). Although comparisons to Brannon's et al. (2010) original study indicate that accumulation of new bottles in this region is slow, the amount of bottles that occur along rural mountain roads and the sheer number of associated trap-nights they generate could potentially result in many animal fatalities. For example, Brannon et al. (2010) found 6,145 open bottles at 220 sites throughout the southeastern Blue Ridge, which represents more than 2.2 million trap-nights each year. Even at the limited pull-off sites of this study approximately 32 small mammals are expected to perish annually. Until greater efforts are made to remove those that remain far down embankments off the shoulders of roads, discarded bottles should be regarded as a considerable mortality threat to shrews and other small mammals in the southern Appalachians.

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