Educational Applications of Small-Mammal Skeletal Remains Found in Discarded Bottles

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Abstract - Environmental literacy is becoming an increasingly important part of national and state curriculum standards. Scientists can assist teachers by providing citizen-science research opportunities and other educational outreach programs for local students. Middle school students from Summit Charter School in Cashiers, Jackson County, NC, in conjunction with a roadside litter cleanup community-service project, assisted researchers from the Highlands Biological Station who were examining discarded bottles as a source of small-mammal mortality. Students sorted and weighed recyclable materials and inspected open bottles for small-mammal remains. They collected approximately 141 kg of trash along 2 roads near their school, 59.4% of which was recyclable material consisting primarily of glass and plastic bottles. Students removed 8 specimens from 5 bottles, including 6 *Blarina brevicauda* (Northern Short-tailed Shrew), 1 *Sorex cinereus* (Masked Shrew), and 1 *S. fumeus* (Smoky Shrew). Students learned to distinguish small-mammal skulls based on dentition and other cranial characteristics while using dichotomous keys, and reconstructed skeletons using anatomical diagrams traditionally used for owl-pellet dissections. Educational programs that incorporate immersive, hands-on, real-world experiences, especially those that use the local community as a framework, can enhance students' appreciation for the natural world and provide the knowledge and skills they will require to make informed environmental decisions as future community leaders.

Introduction

Informal science education, such as programs provided by biological field-stations and nature centers, extends student learning beyond the classroom through immersive, outdoor, hands-on activities that allow students to discover and practice science, technology, engineering, and math (STEM) concepts (NGA 2012). The use of the outdoors as a learning laboratory provides students with direct experiences in the natural world (Leopold Education Project 2016). Environment-based education can also significantly improve critical-thinking skills and strengthen students' connections to the community (Ernst and Monroe 2004). Environmental education is not only a key component of science literacy and citizenship education, but also STEM-career development (Sobel 2005).

It is widely recognized that current K–12 education should incorporate methodlogy and curriculum to prepare students to become environmental leaders. The ability to solve complex 21st-century problems will require a scientifically literate

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society (Feinstein et al. 2013). National science-education standards utilize inquiry-based learning interwoven with environmental literacy (Leopold Education Project 2016) to increase students' capacity for abstract, conceptual thinking applicable to real-world scientific issues (Komoroske et al. 2015). Community partners can assist teachers in the effort to guide and encourage student learning (Falco 2004). In addition to conducting primary research, scientists are particularly well-suited to engage in STEM educational outreach because scientific research is inherently an inquiry-based process (Komoroske et al. 2015). Scientists can share their knowledge and expertise in environmental issues and assist students with research projects or other hands-on, community-based programs and activities with curriculum standards as the foundation (Ernst and Monroe 2004, Falco 2004).

Citizen-science inquiries, especially those that apply scientific methodologies in a field setting, inspire, educate, and can produce useful and meaningful data (Bonney et al. 2009, Prisby and Super 2007). Projects based on the identification and investigation of problems by residents, with "action research" as the dominant methodology, are fundamental to the interests of all citizens (Hart 1997). The ability to understand complex human and ecological interactions can help students meet national and state academic standards while providing the knowledge and citizenship skills they will need to make informed environmental decisions (Archie 2004, Wyner et al. 2014).

Many schools, such as Summit Charter School in Cashiers, Jackson County, NC, have adopted "place-based" education, which incorporates the environment into their regular curriculum using explorations of local issues, community service projects, outdoor learning experiences, and themes that integrate multiple disciplines with examples from the immediate region (Archie 2004, Sobel 2005). In conjunction with an Earth Day community-service project to remove trash along roads, middle school students volunteered to assist scientists from the Highlands Biological Station (HBS) who were examining litter as a source of mortality for small mammals. Bottles discarded along roads can frequently serve as lethal traps for wildlife (Arrizabalaga et al. 2016, Benedict and Billeter 2004, Brannon and Bargelt 2013, Hamed and Laughlin 2015, Kolenda et al. 2015). Small mammals may enter bottles during exploratory activities and are often unable to escape because of the steep angle of incline, slippery interior surface, and narrow neck (Morris and Harper 1965); they may drown if the bottle contains rainwater (Clegg 1966). This phenomenon has been found to be widespread and affect numerous species in this region, particularly shrews (Brannon et al. 2010). Remains found in discarded bottles can have various educational applications, such as providing a source of small-mammal distributional and taxonomic data (Brannon et al. 2010, Pagels and French 1987).

Field-based citizen-scientist projects like this can also help to raise student awareness of environmental issues such as the biological effects of littering and other anthropogenic activities (Kolenda et al. 2015). High concentrations of discarded bottles can reduce the local abundance of individual species of small mammals and may be a conservation threat to those that are uncommon or rare

(Hamed and Laughlin 2015, Laerm et al. 2000). Here, we present the results from a school outreach program in which students inspected bottles discarded near their campus for skeletal remains of small mammals. Educational goals of this project were designed to connect to science curriculum standards, including to: (1) learn about "the 3 Rs" (reduce, reuse, recycle); (2) understand the impacts of littering on wildlife; (3) practice using dichotomous keys to identify species by their skulls and other skeletal anatomy; (4) practice using GPS to map species distributions and examine regional small-mammal biogeography; (5) better understand experimental design and the scientific method, including practical field techniques and proper collection and application of data; and (6) learn about STEM careers from a local biologist.

Methods

On 21 April 2008, 3 teachers and 44 science students from grades 6–8 at Summit Charter School performed a "litter sweep" at 2 forested, vehicle pull-off areas along primary roads in Cashiers, NC, where copious amounts of bottles and other trash tend to accumulate (Brannon and Bargelt 2013). We selected sites based on their proximity to the school, and safety for the students, including thickness of the vegetation and steepness of the slope. The first collection site (site #1) was located 1.8 km south of Silver Run Falls on Hwy 107 (35.054N, 83.064W; elevation 1028 m). The second collection site (site #2) was located on Hwy 64 at the junction of Norton Road (35.109N, 83.148W; elevation 1155 m).

Participants wore blaze-orange vests and leather work gloves for safety while collecting litter. At each site, students walked ~400 m of road length and removed any trash they could lift. Students collected litter on the road shoulders and down embankments up to 25 m into the vegetation. We defined bottles as plastic or glass containers of any size, but collected primarily soda and beer bottles. Students located bottles visually and by shuffling their feet to uncover those buried in leaves (Brannon et al. 2010). Students identified the presence of small-mammal remains by evidence of dried fur, foul odors, murky water, and dead invertebrates such as carrion beetles (Gerard and Feldhamer 1990), and placed these bottles into individual re-sealable 4.4-L (1-gal) plastic storage bags to avoid spilling and losing contents. Although we also examined the contents of aluminum cans, we never found any skeletal remains. Participants placed all litter into 185-L (42-gal) plastic garbage bags and labeled each with collection locality.

At the school, students weighed the bags of litter from each collection site, after which they sorted contents into recyclable and non-recyclable materials (Jackson County, NC, Solid Waste and Recycling Department, Sylva, NC, pers. comm.). The students weighed all recyclables together, then further sorted them by material type. Students sorted bottles by the presence of caps, and classified those without caps as potential traps for small mammals (Brannon and Bargelt 2013).

Unlike skeletal remains contained in most commercially available owl pellets, those removed from discarded bottles have not been sterilized. Therefore, the students wore latex gloves and paper dust masks during their inspections. Students carefully extracted and teased apart contents with forceps to find bones (Brannon et al. 2010). We gently rinsed skulls, mandibles, and other bones, and placed them into labeled bags for each site for later deposition at the HBS. Students used dichotomous keys, based primarily on dentition (Key 1996), to sort skulls by regional small-mammal taxonomic group (Johnston 1967). They identified to species all shrew skulls by number and arrangement of the unicuspid teeth and by other distinctive cranial characteristics (Caldwell and Bryan 1982). Three skulls were broken or missing their teeth, but students made identifications through comparisons to HBS reference collections. We calculated entrapment frequencies for each species as the number of specimens collected divided by the total number of open bottles. We also plotted distributions of individual species on maps using GPS coordinates obtained at each site (Brannon et al. 2010). For further educational benefit, students partially reconstructed each small-mammal skeleton using bone-sorting charts and anatomical diagrams traditionally used during owl-pellet dissections (Key 1996).

Results

Students removed a total of ~141 kg (320 lb) of litter, of which 84 kg (59.6%) were recyclable materials consisting of 1.6% aluminum cans, 7.1% cardboard boxes, 40.0% glass bottles, and 10.7% plastic bottles, by weight. We collected a total of 71 bottles—56 glass and 15 plastic. Of these, 39 (54.9%) lacked caps, with an average of 19.5 open bottles (traps) per site. We found small-mammal skeletal remains at both sites and in 5 (12.8%) of the open bottles.

Students identified the bones of 7 shrews in 4 different bottles from site #1. They extracted a total of 6 *Blarina brevicauda* (Say) (Northern Short-tailed Shrew) from 2 glass and 1 plastic bottle, including 3 specimens from a single glass bottle. We also found 1 *Sorex cinereus* (Kerr) (Masked Shrew) in a single plastic bottle. In collections from site #2, students discovered only the remains of 1 *Sorex fumeus* (Miller) (Smoky Shrew) in 1 glass bottle. We calculated small-mammal entrapment frequencies as 15.3% for Northern Short-tailed Shrews, 2.5% for Masked Shrews, 2.5% for Smoky Shrews, and 20.5% across all species.

Discussion

Our project demonstrates how examinations of bottles discarded along highways can have a variety of educational applications for students interested in studying small mammals. This technique is far less time- and labor-intensive than traditional sampling methods such as pitfall-trapping, without any additional small-mammal mortality (Handley and Kalko 1993). Furthermore, with minimal training, anyone can easily perform this type of investigation, including most children, whose work often proves as reliable as that of adults and professionals if they are adequately supervised (Miczajka et al. 2015, Pope et al. 2016) and species identifications are verified (Prisby and Super 2007, Roy et al. 2016).

Our project methodology can also be applied almost anywhere because discarded bottles containing small-mammal remains occur along highways throughout much of the US and the world (Arrizabalaga et al. 2016). Although we only investigated 2 sites in this study, sampling performed at numerous localities across a wider geographic region could yield data that students could utilize to map distributions of regional species (Brannon et al. 2010, Pagels and French 1987). In addition, skeletal remains removed from bottles can function as a source of small-mammal taxonomic and anatomical data, much like those obtained from owl pellets (Key 1996). Similar investigations could also be performed on other organisms frequently extracted from bottles, such as species of land snails (Dourson and Dourson 2006). As citizen-scientists, students can provide many valuable contributions to on-going environmental research (Miczajka et al. 2015, Pope et al. 2016, Prisby and Super 2007).

Small-mammal mortality caused by entrapment in bottles discarded along roadways is an anthropogenic effect that can be mitigated through frequent and thorough highway cleanups, proactive enforcement of anti-littering regulations, and increased public education (Benedict and Billeter 2004, Brannon and Bargelt 2013, Hamed and Laughlin 2015). The inclusion of students in citizen-science projects, such as the one presented here, can further develop an awareness of conservation issues, and can provide science education through direct experience (Archie 2004, Prisby and Super 2007, Wyner et al. 2014). Environmental education programs that incorporate immersive, hands-on, real-world learning experiences using the local community and environment as a framework can increase students' academic performance and enhance their appreciation for the natural world (Ernst and Monroe 2004, Falco 2004, Louv 2008). Children who are exposed to nature and receive education about environmental concerns are not only more likely to advocate for the protection of natural areas and conservation of biodiversity as adults, but to also take action (Bögeholz 2006, Komoroske et al. 2015, Louv 2008, Wells and Lekies 2006). Placed-based environmental education programs, including participation in scientific-research opportunities, can create a stronger commitment to serving as contributing citizens of the local community and as better stewards of the earth (Hungerford and Volk 1990, Leopold Education Project 2016, Sobel 2005).

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