The Efficiency of Discarded Drink Containers for Small Mammal Detection on a Mediterranean Mountain

Authors: Ignasi Torre, Irene Jiménez, Alexis Ribas, and Antoni Arrizabalaga

Source: Mammal Study, 44(4) : 1-10
Published By: Mammal Society of Japan
URL: https://doi.org/10.3106/ms2019-0025

Mammal Study 44 (2019) DOI: 10.3106/ms2019-0025

Original paper

The efficiency of discarded drink containers for small mammal detection on a Mediterranean mountain

Ignasi Torre[1,*], Irene Jiménez[2], Alexis Ribas[3] and Antoni Arrizabalaga[1]

[1] *Museu de Ciències Naturals de Granollers, C/ Francesc Macià 51, 08402 Granollers, Barcelona, Spain*
[2] *Departament de Biologia Evolutiva, Ecologia i Ciències Ambientals, Facultat de Biologia, Universitat de Barcelona, Av. Diagonal, 643, 08028, Barcelona, Spain*
[3] *Institute of Vertebrate Biology of the Czech Academy of Sciences, Kvetna 8, 603 65 Brno, Czech Republic*

Abstract. We investigated the efficiency of discarded drink containers compared with other methods widely used in small mammal studies (live trapping and diet of generalist predators). We collected 225 beverage containers (bottles and cans) from 44 sampling places, and 376 small mammals of seven small mammal species were identified. Species accumulation curves emphasized significant differences between methods, with higher species density detected by genet scats, intermediate by live trapping, and lower species density by discarded drink containers. The frequency of small mammal guilds in bottles and cans was significantly biased, shrews being oversampled and rodents undersampled, with a reversed pattern in genet scats. Our results suggested that the efficiency of discarded containers was limited by several factors: spatial issues concerning small sampling area (few square meters) and aggregation, temporal issues regarding long-lasting (and undetermined) effects in the field, trapping issues related to multiple capture power (capturing one or more individuals simultaneously), container size, selectivity (shrew-biased), and low detectability of some common species.

Key words: bottles, cans, conservation, rodents, shrews.

Small mammals, such as rodents and insectivores, are the most diverse group of species within mammals, showing wide range of sizes (from less than 2 g to 50 kg), behaviour, and niche use (fossorial, arboreal, etc.; Nowak 1999). Certainly, some difficulties arise when investigators are facing comprehensive descriptions of small mammal communities (i.e., species composition and species abundance) within a defined area and a delimited time frame. In fact, sampling methods for the inventory of small mammal communities can be biased (Torre et al. 2004), thus providing partial estimates of species composition and abundance in a certain way that is not yet fully understood. In Mediterranean Regions, estimating small mammal composition of communities can be especially challenging since diversity is mostly affected by temporal and spatial turnover due to climatic instability and strong elevation-climate-landscape gradients (Blondel and Aronson 1999; Doblas-Miranda et al. 2015). However, obtaining precise data on present and past small mammal species distribution is necessary to understand what will happen with species ranges in the face of different threats like climate change (Ibáñez et al. 2006).

Despite being selective (Caceres et al. 2011), trapping is one of the most commonly used techniques to investigate the composition of small mammal communities (Fonturbel 2010). Indeed, traps are passive devices since small mammals need to be attracted to them (i.e., by using baits), and some species cannot be captured or their abundance barely estimated (Torre et al. 2018). More promising methods to investigate the composition of small mammal communities are indirect sampling techniques. The analysis of the diet of owls can be more useful than trapping for small mammal's inventories (Heisler et al. 2016), since owls are active hunters that can capture trap-elusive species and have high spatial ranges covering number of habitats. However, small mammal preys can be over or underrepresented in their diets (Torre et al. 2004) because some raptors showed strong habitat and prey selection. Going further, the analysis of the diet of forest generalist predators can

*To whom correspondence should be addressed. E-mail: ignasitorre@gmail.com

be used to study the small mammal communities' composition in forest habitats. Since common genets (*Genetta genetta*) are forest-dwelling generalist predators with an eclectic nutrition (Virgós et al. 1999), frequencies of occurrence of the small mammal preys in the diet can be considered as surrogates of species abundance along environmental gradients (Torre et al. 2013). In this regard, the diet of genets was considered as an exhaustive source of small mammal information (Torre et al. 2015a) complementary to barn owls (*Tyto alba*) (Torre et al. 2004). Nevertheless, since the distribution of those predators is restricted either by cold temperatures (Virgós et al. 2001) and habitat suitability (Askew et al. 2007), the obtention of genet scats and owl pellets may be problematic in woodlands of northern countries or highlands, thus making difficult to apply these methods in some geographic areas.

The search for discarded drink containers like bottles and cans as a source of small mammals remains is another indirect sampling technique with a long history (Morris and Harper 1965). Gathering discarded bottles in the field informed about the distribution of poorly known species in remote areas (Morris 1970), but was considered as an ancillary technique for studying small mammal distribution (Pagels and French 1987). The utility of discarded bottles as a sampling technique may be limited due to biases related to species selectivity (Pagels and French 1987; Arrizabalaga et al. 2016), spatial distribution (i.e., near roadways; Hamed and Laughlin 2015), and long lasting effects (i.e., bottles may remain in the field for decades; Brannon and Bargelt 2013). Even with those limitations, discarded bottles were used for distribution studies of small mammals (Brannon et al. 2010). However, the efficiency of discarded bottles and cans as a sampling technique for small mammal inventory has not been investigated so far. In other words, sampling performance of discarded drink containers against other techniques (i.e., trapping; Gerard and Feldhamer 1990) needs to be evaluated to ascertain whether frequencies of occurrence of species found are representative of their abundance in the field (Torre et al. 1998). Furthermore, picking up bottles from the field will contribute to small mammal conservation by providing records of some rare shrews (Arrizabalaga et al. 2016) and by removing bottles from natural habitats due to potential threats to the endangered small fauna (Davenport et al. 2001).

The objective of this study was to assess the performance of discarded drink containers as an indirect sampling technique to evaluate the composition of small mammal communities in forest landscapes. To do so, we compared this technique with live trapping and genet scats, which are the other traditional methods for the inventory of communities within the same study area (Montseny Natural Park and Biosphere Reserve), assessing their possible biases and accuracy for community estimation.

Materials and methods

Study area

The study area is about 400 km^2 in size and is situated between the provinces of Barcelona and Girona (Catalonia, NE Spain; Fig. 1), being delimited by the Montseny Natural Park and Biosphere Reserve and its near surrounding plains. The area shows strong spatial variation in climate, elevation, and landscape composition, with the presence of well-established mid-European plant and animal communities within Mediterranean areas. During the last decades the Montseny has experienced a strong process of climate and landscape change (Peñuelas and Boada 2003) with an increase of the surface of forest and urban areas, and a decrease of crops and shrublands (Vicente et al. 2014).

Sampling methods

From 1996 to 2009 we collected 225 beverage containers (67.7% bottles and 23.3% cans) from 44 sampling places in the Montseny area (Fig. 1). Mean capacity of 141 bottles was 0.79 L (range 0.18–5 L), and mean capacity of 67 cans was 0.34 L (range 0.25–0.35 L). Mean neck diameter of bottles was 18.76 mm (range 5.5–34 mm), and mean neck diameter of cans was 16.66 mm (range 14–18 mm). The mean elevation of the localities sampled was 828.60 m ± 305.52 *SD* (range 137–1285 m above sea level [a.s.l.]). Active searching of bottles and cans was done by walking along sides of secondary roads (Brannon et al. 2010) which accumulated litter. Their content was separated by decantation under a jet of water and filtered with a sieve. All skeletal remains were dried and were put on a plasticine support to be identified under the microscope. The minimum number of small mammals present in every sample was counted from the skeletal remains following a standard procedure outlined elsewhere (Arrizabalaga et al. 2016). We established 40 trapping stations (774 ± 329.14 m a.s.l.; range 300–1450 m a.s.l.) following a design of 7 × 7 trapping grids with 49 live-traps (Sherman folding small animal trap; 23 × 7.5 × 9 cm; Sherman Co., USA) spaced 15 m apart, which

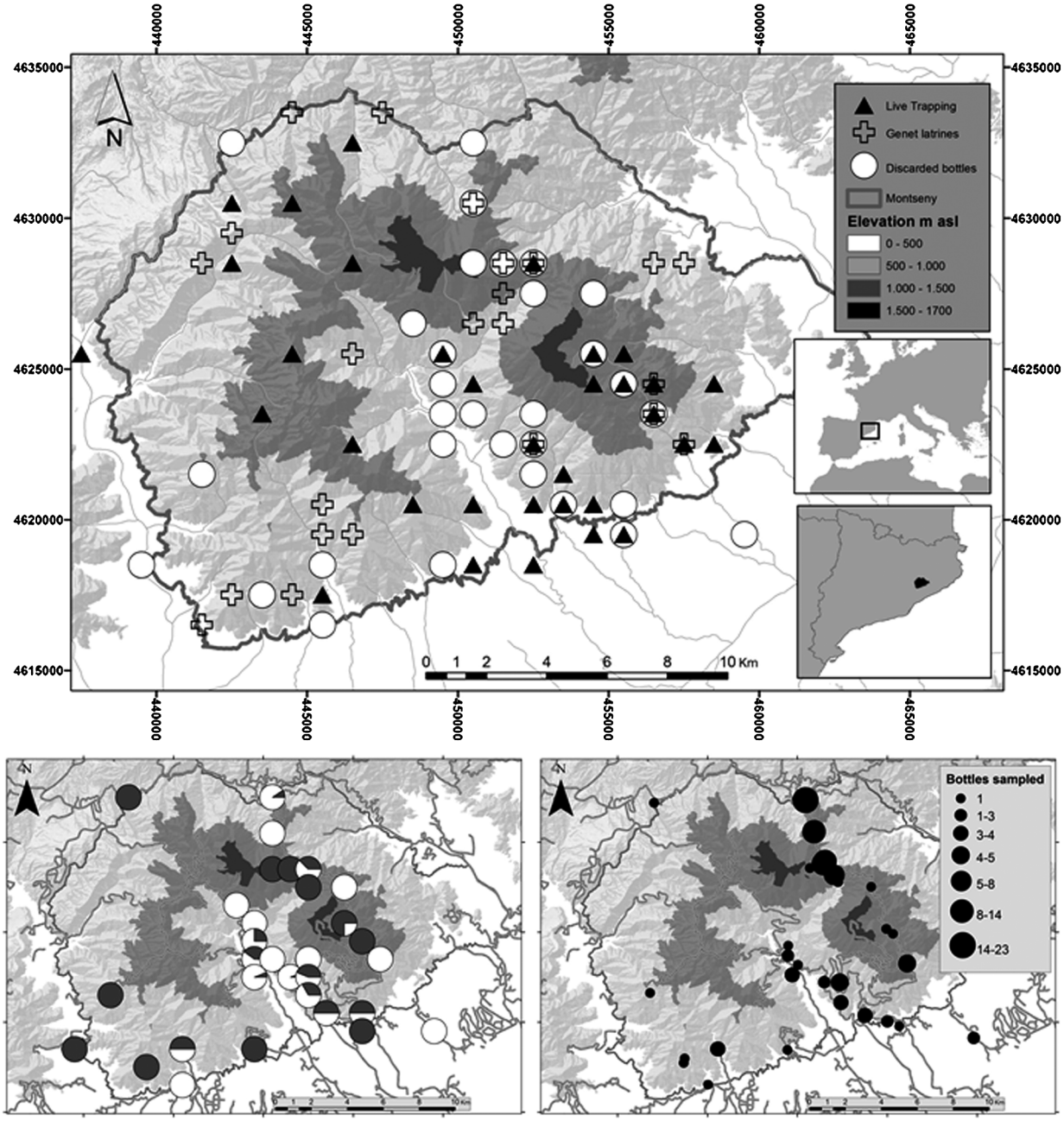

Fig. 1. Distribution of sampling effort performed (UTMs 1 km^2) by three methods for the inventory of small mammal communities in the Montseny Natural Park and Biosphere Reserve (top panel). Below left, frequency of positive drink containers (with small mammal remains, dark grey) per locality. Below right, number of bottles and cans collected per locality (1–23).

were left open for three consecutive nights. Traps were baited with a mixture of tuna, flour, and oil, and were set under cover of shrubs or dense herbs in order to be concealed and to provide some thermal insulation. Small mammals caught were identified to species, marked, and released at the point of capture (Gurnell and Flowerdew 2006). Since some trapping stations were repeated in time, we gathered all this information as single samples related to its geographic location. All samples were recorded during the end of the last century (1980–1997). We also used information on genet diet for 35 sites/latrines, but those containing less than 30 small mammals were rejected (Torre et al. 2013). The latrines are sites where scats are deposited, and they were distributed from 500 to 1132 m a.s.l. (818.13 ± 198.37 m a.s.l.). To obtain the dry weight, the content of every latrine was oven-

dried at 60°C for a day, and the dry content was then separated by decantation under a jet of water and filtered with a sieve. All skeletal remains were dried and were put on a plasticine support to be identified under the microscope. The minimum number of small mammals present in every sample was counted from the skeletal remains (i.e., number of teeth; Rosalino and Santos-Reis 2002). All samples were recorded between 1983 and 2006.

Sampling effort by method was unbiased by altitude since sampling stations were evenly distributed along elevation ($F_{2,78} = 0.19$, $P = 0.82$). Besides, our sampling scheme was intended to handle with temporal heterogeneity, providing samples of several years and seasons owing to the high turnover rates of communities in short time periods.

Species identification of skeletal remains in bottles and latrines was performed by means of an identification key (Gosálbez 1987). The pair of sibling species *Apodemus sylvaticus* and *A. flavicollis* are the bulk of small mammal communities in the study area (Torre et al. 2018). However, we considered them as a single category (*Apodemus* spp.) since accurate separation of the two species is difficult for live-trapped individuals due to the lack of conspicuous differences in body size and fur color in the studied populations (Torre et al. 2015b). All the material used for this study was deposited in the collection of the Museum of Granollers.

Statistical analyses

Samples of small mammals collected by the three sampling methods were gathered in discrete sampling units (Universal Transverse Mercator-UTM- 1 km^2; van Strien et al. 2015) to have comparable measures of sampling effort by method. Indeed, the number of species detected per sampling unit is a measure of species density, that is, a value of species richness related to a defined sampling area (Gotelli and Colwell 2001). Species accumulation curves based on sample-based rarefaction were used to estimate actual species richness of the small mammal species detected by the three sampling methods (Gotelli and Colwell 2001). The expected richness function was calculated with EstimateS version 9.1.0. (Colwell 2013) after 100 randomizations of the observed number of species as far as samples accumulated. To assess the completeness of the inventory performed, we fitted the Clench equation to the observed species accumulation curve (Moreno and Halffter 2001) using the non-linear estimation module of Statistica v7.0 (Stat Soft Inc.), following Jiménez-Valverde and Hortal (2003). All curves were extrapolated to the maximum number of sampling units for the method with more units sampled (36 UTMs with live trapping), by means of asymptotic richness estimators (Colwell 2013). Since the number of individuals collected per sample differed between methods, we also used individual-based rarefaction to provide a meaningful interpretation of species richness, allowing comparisons of assemblages of equivalent number of individuals (i.e., rarefied to the maximum number of individuals collected by the method with lower sample size). ANCOVA was used to test whether species richness differed amongst methods controlling for sampling effort (i.e., number of individuals per sample). In this case, variables were Log-transformed to achieve linearity and homoscedasticity.

Log-linear analysis of frequency tables was used to determine differences in species composition and abundance by the three sampling methods. This technique allowed us to determine what species were under or over-sampled by each sampling method, by fitting the interaction in a two-way table with the factors (species and method). The standardized residuals after the log-linear analysis were used to represent the degree of deviance from the null model, which means no under- or over-sampling of a species by a sampling method. Standardized residuals ± 1.96 were considered as significantly deviated from the null model (Anthony et al. 2005). The statistical significance was verified by examining the components of maximum likelihood comparing these values with the critical level of significance ($\chi^2 = 3.84$, $df = 1$, $P < 0.05$).

To test the efficiency of the three methods in detecting the spatial distribution of the common small mammal species, we fitted occupancy models accounting for species detectability (MacKenzie et al. 2002). Occupancy (psi) can be defined as the probability that a sampling unit is occupied by a species, and detectability (p) is probability of detecting the species in a survey given the species is present at the sampling unit (MacKenzie 2012). Since samples obtained by every method were heterogeneous at the spatial (i.e., elevation) and temporal (i.e., several years) scales, we created temporal pseudo-replicates by splitting the whole sample in two half-batches by random (van Strien et al. 2015). Default models with constant occupancies and detection probabilities were tested and analyzed with the program Presence (MacKenzie 2012).

Results

The mean number of drink containers collected per locality was 5.35 ± 6.73 *SD*. Positive containers (i.e.,

Table 1. Frequencies of occurrence of small mammals (number and percentage) in the whole samples collected for discarded drink containers, genet latrines, and live trapping stations

Order	Species	Bottles and cans		Genet		Trapping	
		n (%)	Std. Residuals	*n* (%)	Std. Residuals	*n* (%)	Std. Residuals
Eulipotyphla	*Sorex minutus*	5 (1.33)	**3.68**	8 (0.41)	0.74	3 (0.11)	**–1.97**
	Sorex araneus	3 (0.8)	1.50	3 (0.15)	–1.62	14 (0.5)	0.79
	Crocidura russula	128 (34.04)	**16.42**	38 (1.96)	**–10.09**	283 (10.04)	**2.32**
	Suncus etruscus	3 (0.8)	1.81	14 (0.72)	**2.85**	0 (0)	**–3.03**
	Talpa europaea	0 (0)	–0.08	6 (0.31)	**2.18**	0 (0)	–1.78
Rodentia	*Sciurus vulgaris*	0 (0)	–0.45	11 (0.57)	**3.12**	0 (0)	**–2.43**
	Eliomys quercinus	0 (0)	–0.32	4 (0.21)	0.27	5 (0.18)	–0.11
	Glis glis	0 (0)	–0.17	6 (0.31)	1.84	1 (0.04)	–1.46
	Myodes glareolus	19 (5.05)	**–2.71**	129 (6.66)	**–3.85**	331 (11.75)	**4.19**
	Microtus duodecimcostatus	0 (0)	0.73	1 (0.05)	0.57	0 (0)	–0.74
	Microtus agrestis	0 (0)	–0.17	3 (0.15)	0.16	4 (0.14)	–0.07
	Apodemus spp.	216 (57.45)	**–4.96**	1685 (86.99)	**3.79**	2171 (77.04)	–1.31
	Rattus rattus	0 (0)	–0.32	9 (0.46)	**2.78**	0 (0)	**–2.19**
	Mus spretus	2 (0.53)	0.21	20 (1.03)	**2.81**	6 (0.21)	**–2.41**

Standardized residuals after a log-linear model (Species × Method) showing values larger than ± 1.96 were considered deviated from the null model and hence significant (in bold, $P < 0.05$).

those with small mammals), represented the 30.85% of the total collected. Despite the number of containers collected ranged from 1 to 23 per locality, only from 1 to 6 per locality contained small mammals remains (Fig. 1). Bottles were more efficient than cans (37.5% vs. 8.9% of containers with small mammals, respectively: Yates corrected $\chi^2 = 10.16$, $P = 0.0014$). Considering the whole sample, capture efficiency was directly correlated to container size, and small containers (≤ 0.5 L) were less efficient in catching small mammals than larger ones (> 1 L) (Efficiency × Size: L-R test = 20.76, $df = 2$, $P = 0.0003$). Albeit correlated, container size was barely associated to neck diameter ($r = 0.31$, $P < 0.05$, $n = 59$ containers), suggesting that larger containers with larger diameter necks were more prone to capture small mammals. The number of positive containers correlated with the number of containers collected per locality ($r = 0.66$, $P < 0.0001$, $n = 44$ localities), but the frequency of positive containers (positive/total × 100) correlated negatively ($r = –0.43$, $P = 0.002$, $n = 44$). Thus, success in detecting small mammal remains within discarded bottles and cans decreased as far as the number of sampled items per locality increased. Containers captured more rodents than shrews (Wilcoxon Matched-pairs test: $Z = 2.61$, $P = 0.008$, $n = 41$ non-tied pairs). The ANCOVA using the frequency of occurrence of both mammal guilds (shrews/rodents, fixed factor) and the number of individuals found within containers (covariate) indicated an interactive effect ($F_{1,87} = 9.62$, $P = 0.002$), suggesting that shrews increased their frequency in containers with more individuals, whereas rodents decreased. In fact, the number of shrews correlated with the total number of small mammals found within containers ($r = 0.88$, $P < 0.0001$, $n = 44$).

We identified 376 small mammals of seven small mammal species in discarded drink containers, 2818 individuals of ten species by Sherman live trapping, and 1937 individuals of 14 species by analyzing genet scats (Table 1). Species accumulation curves emphasized significant differences between the three methods, with higher species density (i.e., the number of species per sampling unit) detected by genets, intermediate by live trapping, and lower species density by discarded bottles (Fig. 2a). The three species accumulation curves fitted the Clench function ($r^2 > 0.99$ all), showing moderate slopes (< 0.03) and suggesting asymptotic patterns. Inventories were almost complete for the three methods but being more comprehensive for live trapping (91.75% of the species present), followed by genets (89.70%) and discarded bottles and cans (86.77%). However, samples were biased since drink containers showed low number of individuals (mean = 12.12 ind. ± 2.75 *SE*, $n = 31$) than samples of the other two methods ($F_{2,87} = 12.36$, $P < 0.0001$), whereas scats and trapping showed similar number of individuals per sampling unit (mean = 84.21 ind. ± 17.03 *SE*, $n = 23$; mean = 82.94 ind. ± 17.08 *SE*, $n = 36$; respectively: $F_{1,87} = 2.27$, $P =$

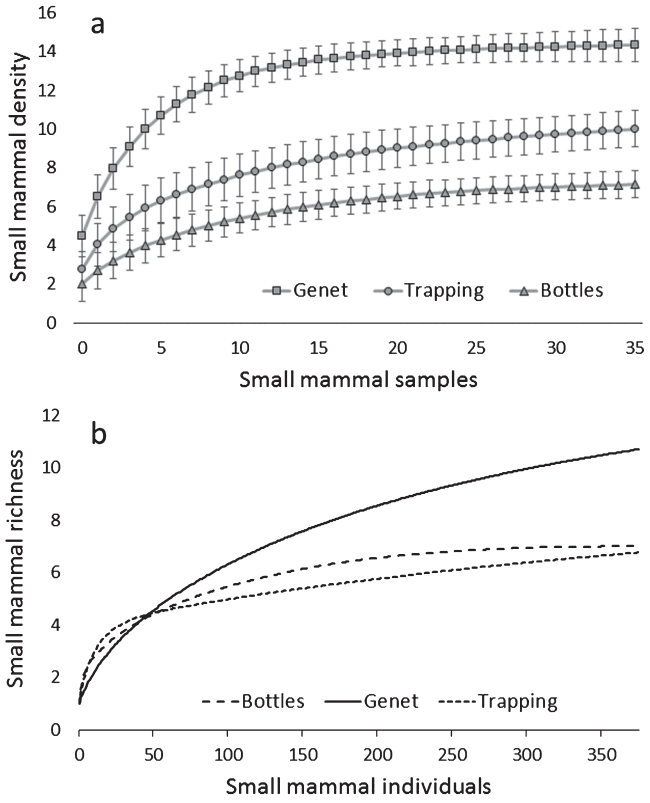

Fig. 2. Species accumulation curves for the three sampling methods used after, a) sampled-based rarefaction by sampling unit (± *SD*) extrapolated to the same sampling effort (36 UTMs) and, b) individual based rarefaction of species richness by sampled individual rarefied to the maximum number of individuals collected by discarded bottles and cans (376 individuals). The first can be considered as a measure of species density, that is, the number of species detected in sampling units (UTMs) irrespective of individuals sampled; the second, is a measure of species richness by individual sampled.

0.13). Analysis of covariance (separate slopes model) showed non-significant differences of species richness between methods ($F_{2,87}$ = 0.68, P = 0.50) once controlling for sampling effort ($F_{1,87}$ = 83.68, P < 0.0001). The lack of interactive effects (Method × Individuals: $F_{2,87}$ = 1.84, P = 0.16) indicated that the mean number of species detected per sampling unit related to sampling effort was similar between the three methods. Furthermore, individual-based rarefaction showed a different pattern of species accumulative curves per sampled individual (Fig. 2b). Genets showed higher species richness (10.75 ± 0.05 *SD*) than drink containers (7.00 ± 0.48 *SD*) and live trapping (6.77 ± 0.04 *SD*), once the number of species was rarefied to the number of individuals collected by bottles and cans (376 ind.). Interestingly, for small samples (< 50 individuals), bottles and cans showed higher species richness than genets and similar to live trapping. In fact, both species curves for drink containers and live trapping had similar slopes, whereas genets' slope was steeper.

Log-linear analyses for contingency tables highlighted strong differences in species frequencies between methods (Species × Method: L-R test = 497.86, P < 0.0001, *df* = 26; Table 1). Wood mice (*Apodemus* spp.) were the most frequent species detected by any method, being especially abundant in genet diet (87%), followed by trapping (77%), and discarded drink containers (57%). Indeed, rodents were overrepresented in genet scats (96%) and live trapping (89%), with lower values in bottles and cans (63%). The frequency of the white-toothed shrew (*Crocidura russula*) was the most biased between methods (L-R test = 309.33, P < 0.0001), being oversampled by bottles, undersampled by genets, and slightly oversampled by trapping. Examination of standardized residuals allowed to determine that shrews always showed positive values in the case of bottles (oversampled), and mixed values (either positive or negative) in the case of genet and trapping. For the seven species captured in bottles, four shrews showed positive residuals but only two significantly deviated from zero, and two rodents showed negative residuals (undersampled, Table 1). Conversely, for the nine rodent species captured by genets, five out of eight showed significant positive residuals, and for shrews, two showed positive and two negative residuals, but only one of each were significant. Live trapping undersampled small shrews and rodents (but bank voles, *Myodes glareolus*). When small mammal guilds were considered (shrews and rodents), a clearer pattern emerged (Guild × Method: L-R test = 324.29, P < 0.0001, *df* = 2). The frequency of both guilds in bottles was significantly biased, shrews being oversampled (χ^2 = 370.15, P < 0.0001) and rodents undersampled (χ^2 = –170.39, P < 0.0001), with shrews being undersampled and rodents oversampled in genet scats. Live trapping represented an intermediate (and neutral) condition, since standardized residuals showed no under/over sampling of both guilds. Significant deviations of the null model were mostly accounted for by bottles (61.59%), followed by genet scats (37.72%), with a non-significant contribution of live trapping (0.67%).

Occupancy models showed that species detectability (and derived occupancy) was roughly similar for the three methods in the case of *C. russula* (*p* between 0.47 and 0.54, and *psi* between 0.91 and 1.0) and wood mice (*p* between 0.92 and 1.0, and *psi* = 1.0 all), but was very different for bank voles and Algerian mice (*Mus spretus*); detectability was lower for containers (*p* = 0.13 and

0.045), followed by trapping (p = 0.50 and 0.32), and genets (p = 0.86 and 0.60).

Discussion

In this study we have shown that the efficiency of discarded drink containers as a source of information on small mammals' distribution and abundance was limited by spatio-temporal biases and capture specificity along an elevation gradient in the mountains of Montseny Natural Park and Biosphere Reserve. Rodents were the most frequent guild trapped by any method (from 63% in containers to 96% in genet scats), suggesting that rodents were more abundant than shrews in natural habitats during the study period (see Torre et al. 2018, for similar results from live-trapping data during 2008–2015). A relevant goal when inventorying small mammal communities is to achieve a sampling scheme allowing precise estimates of actual occupancy and abundance of all the species present without significant biases within a defined area and a delimited time frame. However, in practice, investigators are unable to determine what sampling scheme approaches the reality of communities due to several sources of sampling heterogeneity (Colwell et al. 2004). Spatial scale and sampling method are relevant issues for perceived patterns of variation in diversity along elevation gradients (Rowe and Lidgard 2009). In our study, the three sampling methods used were conditioned by the spatial scale at which data were collected. There are two components of the spatial scale, the extent was unaffected by method (i.e., samples by method were evenly distributed along elevation), but grain (area of collection) was significantly biased. Indeed, sampling methods worked at very different spatial scales, with drink containers having an influence area of a few square meters, live trapping stations less than 1 ha, and genet latrines—shared by different individuals—having a trapping influence of a few square kilometers (Torre et al. 2013). In fact, containers sampled the microhabitat scale, live trapping stations the habitat scale, and genet latrines the landscape scale. Nevertheless, sampling scales need to be adapted to the target species and human effort to obtain sound results. Sampling at small scales like the area of influence of a single trap or a drink container will provide pseudo-replicated results, but sampling at larger scales to encompass all habitats (landscape level) will be overwhelming due to limited availability of human resources and devices to be allocated to a sampling scheme. An intermediate scale (habitat), easily achieved by live trapping schemes, will be more adequate. However, the information provided by every method will be affected by scale.

As expected, the number of species detected by each method correlated with the collecting area, following widely accepted species-area curve patterns (Blondel and Aronson 1999). Once samples were aggregated in the same area units (1 km^2 UTM), the expected number of species predicted by sample-based species curves was lower for drink containers (8.06 species), intermediate for trapping (10.90 species), and higher for genets (15.60 species). Besides, the assessment of communities by sampling drink containers was strongly biased towards shrews, rodents being undersampled. This pattern arose due to a combination of neck diameter because small diameters are a filter for larger rodents (Morris and Harper 1965), and size of containers since escaping from large containers is more difficult for shrews than for rodents due to jumping abilities of the latter (Torre et al. 1998). Bottles showed roughly similar efficiency than pitfall traps, capturing more shrews than rodents in the study area (Torre et al. 2010) and elsewhere (Gambalemoke et al. 2008; see however Caceres et al. 2011, for different results). Indeed, bottles overestimated shrew abundance in front of livetraps set within the same plots (Torre et al. 1998), suggesting that bottles are useless for true abundance estimates (Gerard and Feldhamer 1990).

Spatial variation involves temporal variation when sampling methods are not assigned to short time periods (i.e., population closure). In fact, our sampling scheme was intended to handle with temporal heterogeneity by providing samples of several years and seasons, owing to the expected high turnover rates of communities in relatively short time periods (Blondel and Aronson 1999). Estimating the actual number of species present and their abundances at the moment of sampling can be difficult for indirect sampling methods like discarded bottles which remain in the field for decades (Brannon and Bargelt 2013). After being exposed for very long time periods, the number of species captured by bottles will increase encompassing changes in communities due to temporal turnover rates, and owing to their multiple capture power (i.e., a single bottle can trap a huge number of individuals; Arrizabalaga et al. 2016). However, divergence between bottles' composition and the actual composition and abundance of small mammals in the field will increase as far as time exposure increases. This will provide biased information of occupancy and abundance of species that are not yet found in the area, or that are at very different

densities. Since we found higher proportion of the ratio shrew/rodent in bottles with large number of individuals trapped, bottles exposed for long time (i.e., those with more captures) will retain more shrews than expected. Bottles can trap more shrews because of low locomotion abilities in front of mice, the latter being able to escape from inside bottles under the same environmental conditions (Torre et al. 1998). Further studies should elucidate if the higher proportion of shrews inside containers could be attributed in part to the occurrence of invertebrates, which are the main preys of the shrews, and/or to the odor of small mammals and invertebrates in decomposition.

Furthermore, biases in detecting species (and guilds) can be attributed to differences in species detectability by the sampling methods. Detectability depends on species abundance, but also on several factors influencing individual responses in front of sampling devices (Doherty et al. 2003). Our results suggested that bottles could be used to estimate occupancy of widespread habitat generalist species (*C. russula* and *Apodemus* spp.) but failed to estimate occupancy due to low detectability of habitat specialists (*M. glareolus* and *M. spretus*). Detectability below a threshold ($p < 0.3$ Mackenzie et al. 2002) involved biases in perceived occupancy for common small mammal species. All these species are considered as widespread in the area and highly detectable under live-trapping schemes (Torre et al. 2018), but results from bottles showed some biases in detectability and derived occupancy estimates.

Despite that only seven species were found in discarded bottles, they provided similar number of species per individual for small samples (< 50 ind.) compared to the other sampling methods. Once species curves were re-scaled to individuals, a different pattern emerged, bottles and trapping showing similar curves, and genet scats showing higher slope. This means that both bottles and trapping showed similar sampling efficiency (species/individual ratios) but showing higher species richness in the latter due to a significantly higher number of individuals sampled. Long time exposure and multiple capturability of bottles (Moates 2018) compensated for the reduced spatial influence, increasing sampling efficiency. But in the end, live trapping represented an intermediate (between bottles and genets) and less biased method for estimating the frequency of small mammal guilds. Nonetheless, the efficiency of this method depends on the type and size of traps used (Caceres et al. 2011).

The studied area has experienced a continuous process of landscape and climate change in the last 50 years with increased temperatures, afforestation, and field crop loss as main quantified changes (Peñuelas and Boada 2003, Vicente et al. 2014). In this area, small mammal changes were strongly correlated with climate and human-induced habitat change (Díaz et al. 2010; Torre et al. 2015c). Nonetheless, the impossibility to assign a narrow temporal frame to samples of bottles precluded its usefulness in studies of community change, which are mostly performed by using other direct and indirect sampling techniques (Moritz et al. 2008; van Strien et al. 2015). Moreover, since samples of drink containers were spatially aggregated (near roads, camping/picnic sites, etc.) they might sample common species/habitats, thus providing limited information at the spatial scale. According to this, biased data provided by bottles and cans will limit its application as an inventory method since some species will be under or oversampled. Nonetheless, discarded drink containers provided a complementary method for inventory, covering areas where information is lacking, since the use of other more time-consuming methods limits the number of surveyed places (Moates 2018). In addition, the collection of discarded bottles and cans can be done by volunteers with non-specific training in mammalogy. While producing a source of data, it can also promote the elimination of garbage from the environment at the same time.

In summary, the efficiency of discarded drink containers to estimate the composition and abundance of small mammal species was limited by several factors: first, spatial issues concerning small sampling area (few square meters) and aggregation; second, temporal issues regarding long-lasting (and undetermined) effects in the field; and thirdly, trapping issues related to multiple capture power and selectivity (shrew-biased) and detectability of some common species. According to our results showing that discarded containers act as effective traps for shrews, picking up bottles from the field could contribute to small mammal conservation by providing records in areas where inhabit rare and/or endangered shrews are found and by eliminating a potential threat to the endangered small fauna.

Acknowledgments: We are indebted to the staff of Montseny Natural Park (Àngel Miño, Joana Barber, Daniel Guinart) and Diputació de Barcelona for kindly providing funds and logistic for small mammal studies along the years. The comments of Pat Morris and three anonymous reviewers greatly improved the last version of the article.

References

Anthony, N. M., Ribic, C. A., Bautz, R. and Garland, Jr. T. 2005. Comparative effectiveness of Longworth and Sherman live traps. Wildlife Society Bulletin 33: 1018–1026. DOI: 10.2193/0091-7648(2005)33[1018:ceolas]2.0.co;2.

Arrizabalaga, A., González, L. M. and Torre, I. 2016. Small mammals in discarded bottles: a new world record. Galemys 28: 63–65. DOI: 10.7325/Galemys.2016.N4.

Askew, N. P., Searle, J. B. and Moore, N. P. 2007. Agri-environment schemes and foraging of barn owls *Tyto alba*. Agriculture, Ecosystem and Environment 118: 109–114. DOI: 10.1016/j.agee.2006.05.003.

Blondel, J. and Aronson, J. 1999. Biology and Wildlife of the Mediterranean Region. Oxford University Press, New York, 328 pp.

Brannon, M. P. and Bargelt, L. B. 2013. Discarded bottles as a mortality threat to shrews and other small mammals in the southern Appalachian Mountains. Journal North Carolina Academy of Sciences 129: 126–129.

Brannon, M. P., Burt, M. A., Bost, D. M. and Caswell, M. C. 2010. Discarded bottles as a source of shrew species distributional data along an elevational gradient in the southern Appalachians. Southeastern Naturalist 9: 781–794. DOI: 10.1656/058.009.0412.

Caceres, N. C., Napoli, R. P. and Hannibal, W. 2011. Differential trapping success for small mammals using pitfall and standard cage traps in a woodland savannah region of southwestern Brazil. Mammalia 75: 45–52. DOI: 10.1515/mamm.2010.069.

Colwell, R. K. 2013. EstimateS: Statistical Estimation of Species Richness and Shared Species from Samples. Version 9. User's Guide and Application. Available at http://viceroy.eeb.uconn.edu/estimates (Accessed June 2018).

Colwell, R. K., Mao, C. X. and Chang, J. 2004. Interpolating, extrapolating, and comparing incidence-based species accumulation curves. Ecology 85: 2717–2727. DOI: 10.1890/03-0557.

Davenport, J., Hills, J., Glasspool, A. and Ward, J. 2001. Threats to the critically endangered endemic Bermudian skink *Eumeces longirostris*. Oryx 35: 332–339.

Díaz, M., Torre, I. and Arrizabalaga, A. 2010. Relative roles of density and rainfall on the short-term regulation of Mediterranean wood mouse *Apodemus sylvaticus* populations. Acta Theriologica 55: 251–260.

Doblas-Miranda, E., Martínez-Vilalta, J., Álvarez, A., Ávila, A., Bonet, F. J., Brotons, L., Castro, J., Curiel Yuste, J., Díaz, M., Ferrandis, P., et al. 2015. Reassessing global change research priorities in the Mediterranean Basin: how far have we come and where do we go from here? Global Ecology and Biogeography 24: 25–43.

Doherty, P. F., Boulinier, T. and Nichols, J. D. 2003. Local extinction and turnover rates at the edge and interior of species' ranges. Annales Zoologici Fennici 40: 145–153.

Fonturbel, F. E. 2010. A methodological approach to assess the small mammal community diversity in the temperate rainforest of Patagonia. Mammalian Biology 75: 294–301. DOI: 10.1016/j.mambio.2009.03.012.

Gambalemoke, M., Mukinzi, I., Amundala, D., Katuala, G.-B., Kennis, J., Dudu, A., Hutterer, R., Barriere, P., Leirs, H. and Verheyen, E. 2008. Shrew trap efficiency: experience from primary forest, secondary forest, old fallow land and old palm plantation in the Congo River basin (Kisangani, Democratic Republic of Congo). Mammalia 72: 203–212. DOI: 10.1515/mamm.2008.039.

Gerard, A. S. and Feldhamer, G. A. 1990. A comparison of two survey methods for shrews pitfalls and discarded bottles. American Midland Naturalist 124: 191–194.

Gosálbez, J. 1987. Insectívors i rosegadors de Catalunya. Ketres Editora S.A., Barcelona, 241 pp.

Gotelli, N. J. and Colwell, R. K. 2001. Quantifying biodiversity: procedures and pitfalls in the measurement and comparison of species richness. Ecology Letters 4: 379–391. DOI: 10.1046/j.1461-0248.2001.00230.x

Gurnell, J. and Flowerdew, J. R. 2006. Live trapping small mammals. A practical guide. Mammal Society Occasional Publications 3: 1–48.

Hamed, M. K. and Laughlin, T. F. 2015. Small-mammal mortality caused by discarded bottles and cans along a US Forest Service road in the Cherokee National Forest. Southeastern Naturalist 14: 506–515.

Heisler, L. M., Somers, C. M. and Poulin, R. G. 2016. Owl pellets: a more effective alternative to conventional trapping for broad-scale studies of small mammal communities. Methods in Ecology and Evolution 7: 96–103.

Ibáñez, I., Clark, J. S., Dietze, M. C., Feeley, K., Hersh, M., LaDeau, S., McBride, A., Welch, N. E. and Wolosin, M. S. 2006. Predicting biodiversity change: outside the climate envelope, beyond the species-area curve. Ecology 87: 1896–1906. DOI: 10.1890/0012-9658(2006)87[1896:PBCOTC]2.0.CO;2.

Jiménez-Valverde, A. and Hortal, J. 2003. Las curvas de acumulación de especies y la necesidad de evaluar la calidad de los inventarios biológicos. Revista Ibérica de Aracnología 8: 151–161.

MacKenzie, D. I. 2012. PRESENCE User Manual, U.S. Geological Survey, 78 pp. Available at https://www.mbr-pwrc.usgs.gov/software/presence.shtml (Accessed April 2018).

MacKenzie, D. I., Nichols, J. D., Lachman, G. B., Droege, S., Royle, J. A. and Langtimm, C. A. 2002. Estimating site occupancy rates when detection probabilities are less than one. Ecology 83: 2248–2255.

Moates, G. 2018. Small mammal mortality in discarded bottles and drinks cans—a Norfolk-based field study in a global context. Journal of Litter and Environmental Quality 2: 2–13.

Moreno, C. E. and Halffter, G. 2001. On the measure of sampling effort used in species accumulation curves. Journal of Applied Ecology 38: 487–490. DOI: 10.1046/j.1365-2664.2001.00590.x.

Moritz, C., Patton, J. L., Conroy, C. J., Parra, J. L., White, G. C. and Beissinger, S. R. 2008. Impact of a century of climate change on small-mammal communities in Yosemite National Park, USA. Science 322: 261–264. DOI: 10.1126/science.1163428.

Morris, P. A. 1970. The study of small mammal remains from discarded bottles. School Natural Science Society 41: 1–8.

Morris, P. A. and Harper, J. F. 1965. The occurence of small mammals in discarded bottles. Proceedings of the Zoological Society of London 145: 148–153.

Nowak, R. M. 1999. Walker's Mammals of the World. Sixth edition. John Hopkins University Press, Baltimore, 1732 pp.

Pagels, J. F. and French, T. W. 1987. Discarded bottles as a source of small mammal distribution data. American Midland Naturalist 118: 217–219. DOI: 10.2307/2425647.

Peñuelas, J. and Boada, M. 2003. A global change-induced biome shift in the Montseny mountains (NE Spain). Global Change Biology 9: 131–140. DOI: 10.1046/j.1365-2486.2003.00566.x.

Rosalino, L. M. and Santos-Reis, M. 2002. Feeding habits of the common genet *Genetta genetta* (Carnivora : Viverridae) in a semi-natural landscape of central Portugal. Mammalia 66: 195–205. DOI: 10.1515/mamm.2002.66.2.195.

Rowe, R. J. and Lidgard, S. 2009. Elevational gradients and species richness: do methods change pattern perception? Global Ecology and Biogeography 18: 163–177. DOI: 10.1111/j.1466-8238.2008.00438.x.

Torre, I., Arrizabalaga, A. and Flaquer, C. 2004. Three methods for

assessing richness and composition of small mammal communities. Journal of Mammalogy 85: 524–530. DOI: 10.1644/bjk-112.

Torre, I., Arrizabalaga, A., Freixas, L., Ribas, A., Flaquer, C. and Diaz, M. 2013. Using scats of a generalist carnivore as a tool to monitor small mammal communities in Mediterranean habitats. Basic and Applied Ecology 14: 155–164. DOI: 10.1016/j.baae.2013.01.005.

Torre, I., Arrizabalaga, A. and Ribas, A. 2015a. The diet of the genet (*Genetta genetta* Linnaeus 1758) as a source of information on local small mammal communities. Galemys 27: 71–75.

Torre, I., Bosch, M. and Arrizabalaga, A. 1998. Botellas de uso doméstico como trampas selectivas para micromamíferos. Galemys 10: 53–59.

Torre, I., Fernández, L. and Arrizabalaga, A. 2015b. Using barn owl *Tyto alba* pellet analyses to monitor the distribution patterns of the yellow-necked mouse (*Apodemus flavicollis* Melchior 1834) in a transitional Mediterranean mountain. Mammal Study 40: 133–142.

Torre, I., Gracia-Quintas, L., Arrizabalaga, A., Baucells, J. and Díaz, M. 2015c. Are recent changes in the terrestrial small mammal communities related to land use change? A test using pellet analyses. Ecological Research 30: 813–819. DOI: 10.1007/s11284-015-1279-x.

Torre, I., Guixé, D. and Sort, F. 2010. Comparing three live trapping methods for small mammal sampling in cultivated areas of NE Spain. Hystrix 21: 147–155. DOI: 10.4404/hystrix-21.2-4462.

Torre, I., Raspall, A., Arrizabalaga, A. and Díaz, M. 2018. SEMICE: an unbiased and powerful monitoring protocol for small mammals in the Mediterranean Region. Mammalian Biology 88: 161–167. DOI: 10.1016/j.mambio.2017.10.009.

van Strien, A. J., Bekker, D. L., La Haye, M. J. J. and van der Meij, T. 2015. Trends in small mammals derived from owl pellet data using occupancy modelling. Mammalian Biology 80: 340–346. DOI: 10.1016/j.mambio.2015.04.002.

Vicente, P., Başnou, C., Isern, R., Álvarez, E. and Pino, J. 2014. Canvis recents (1956–2006) en les cobertes del sòl i fragmentació dels hàbitats oberts al Parc Natural del Montseny. Sèrie Territori 25: 72–84.

Virgós, E., Llorente, M. and Cortés, Y. 1999. Geographical variation in genet (*Genetta genetta* L.) diet: a literature review. Mammal Review 29: 117–126. DOI: 10.1046/j.1365-2907.1999.00041.x.

Virgós, E., Romero, T. and Mangas, J. G. 2001. Factors determining "gaps" in the distribution of a small carnivore, the common genet (*Genetta genetta*), in central Spain. Canadian Journal of Zoology 79: 1544–1551.

Received 21 March 2019. Accepted 9 July 2019.
Editor was Shinsuke Sakamoto.