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Efficiency of pitfall traps and snap traps in small terrestrial mammals depends on their diet composition

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Abstract: We compared the monitoring of small terrestrial mammals among forest stands by pitfalls and snap traps. The captures took place in the Czech Republic in the Moravskoslezske Beskydy Mts. (2007–2012) on 16 plots in adult beech and spruce stands between 910 and 1220 m a.s.l. In total, 14 species of small mammals were captured (12 in the snap traps and 10 in the pitfalls). Snap traps captured the broader species spectrum and they were more successful in capturing larger species of small terrestrial mammals consuming a higher proportion of plant food (mice, and in particular voles). The pitfalls were more effective in capturing smaller species with a predominance of animal food (shrews). To cover the widest species spectrum of small mammals, it is appropriate to use both types of traps. To observe the functional diversity of the community in terms of food composition, it is sufficient to use snap traps.

Key words: Snap trap, pitfall, small terrestrial mammal, diet composition, rodent, shrew

Small terrestrial mammals are of extraordinary importance in most terrestrial ecosystems (Barrett and Peles, 1999; Weldy et al., 2019). Their biomass, relatively high and variable abundance, short generation interval, and rapid response to changing conditions make them one of the most sensitive bioindicators of change throughout the environment (e.g., Pearce and Venier, 2005; Heroldová et al, 2018). At the same time, small terrestrial mammals are among the vertebrates that are most difficult to trace (Zejda, 1991). Different types of traps (snap traps, pitfalls, live traps) are mostly used to describe communities of small mammals (e.g., Sheftel, 2018).

Numerous studies have already been devoted to comparing the effectiveness of different trapping methods and types of traps. Some have also been devoted to the direct comparison of the different ways of using pitfalls and snap traps under different habitat conditions (e.g., Pucek, 1969; Pelikan et al., 1977; Zejda et al., 1977; Williams and Braun, 1983; Mengak and Guynn, 1987; Kalko and Handley, 1993; Butet et al., 2006; Nicolas and Colyn, 2006; Santos-Filho et al., 2006; Leso and Kropil, 2010). There is a predominant consensus that snap traps are more suitable for trapping rodents, while for the description of shrew communities, it is preferable to use pitfalls (Pelikan et al., 1977; Zejda et al., 1977; Mengak and Guynn, 1987; Kalko and Handley, 1993; Stanko et al., 1999; Nicolas and Colyn, 2006). Some authors recommend to combine both types of traps to capture the overall community of small terrestrial mammals because they give different results (Kalko and Handley, 1993; Nicolas and Colyn, 2006). The difference in results given by these types of traps is explained mainly by the size of mammals (Nicolas and Colyn, 2006; Torre et al., 2016), which may vary depending on the species (Walters, 1989; Maddock, 1992) or sex (Pelikan, 1970) of captured individuals.

Taxonomic affiliation is more important than body size (i.e. regardless of their size, shrews are more likely to fall into pitfalls). This comes from the results of catches in areas where there are both small (up to about 10 g) and larger (about 40 g) species of rodents and shrews (Nicolas and Colyn, 2006; Santos-Filho et al., 2006).

The above-mentioned points lead to the hypothesis that higher shrew affinity to pitfalls can be caused by a difference in the usual food composition of both groups. There is no answer to the question of how the spectrum and frequency of small terrestrial mammal species in pitfalls and snap traps are affected by the food composition of such species. The aim of this study is to evaluate, using modern statistical methods, some factors that may affect the different preference of different species of small terrestrial

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mammals to pitfalls or snap traps. We concentrated on the body mass and usual food composition of small mammals and on their species and functional diversity detected by each type of trap.

Small mammals were captured in the Moravskoslezske Beskydy Mts. (the Czech Republic) in the areas of Mt. Knehyne and Mt. Smrk. The variability of the environment was minimized by selecting plots in the same or similar conditions (in the fir-beech, spruce-beech, and beech-spruce forest vegetation zone and in the same or similar edaphic series) (according to Pliva, 1987 (in Czech); in English in Viewegh et al., 2003), in the mature (masting) stands with closed canopy, with proportion of dominant tree species (European beech or Norway spruce) over 90% and with limited occurrence of undergrowth (Table 1).

Small mammals caught in the pitfalls and snap traps were monitored twice a year between 2007 and 2012.

Pitfalls were primarily used for monitoring invertebrates; however, it is not possible to avoid catching small terrestrial mammals. At each plot, there were 5 pitfalls 10 m apart. Jars (glass round-neck-shaped with a volume of 4000 mL, diameter of 90 mm, and active perimeter for trapping of 283 mm) containing a 4% formaldehyde solution were used as pitfalls. The whole pitfall trap was buried so that the top edge of the neck was level with the terrain. It was covered with a metal sheet roof (200 × 200 mm) 30 mm above the ground, blocking dirt and rainfall. Pitfalls were activated every year at the end of April and early September. They were checked after 6 weeks (see Table 2 for details). If small mammals were trapped, they were labeled by a ticket with a date and location and stored in glasses with 75% denatured ethanol.

Snap traps were primarily used to obtain material for monitoring distribution of hantaviruses among the small mammal population. We put snap traps in lines of 100 or 50 pieces with a spacing of 3–5 m, according to Pelikan (1975). They were sampled twice a year at the end of spring and at the beginning of fall. An oiled kerosene lamp wick dusted with flour greased with peanut butter (according to Mengak and Guynn, 1987) was used as bait. The traps were exposed for 4 days (i.e. 3 nights) and checked every morning. Trapped animals from snap traps were weighed, dissected, and identified to species level according to standard methods (Macdonald and Barrett, 2005).

For each species in each area, we found the relative abundance (rA = the number of individuals related to the monitoring effort, here to the number of trap nights - see Magurran, 2004; Table 3). The results were grouped by the predominant tree species and forest vegetation zone.

Values of the usual food composition for each species were taken from the literature (Holisova, 1965; Churchfield and Rychlik, 2006; Butet and Delettre, 2011).

The work complies with Council Directive 86/609/EEC on the approximation of laws, regulations, and administrative provisions of the EU member states regarding the protection of animals used for experimental and other scientific purposes.

Table 1. Details for plots (FVZ = forest vegetation zone; ES = edaphic series; both according to Pliva, 1987; Viewegh et al., 2003).

Plot	Trap	GPS	FVZ	ES	m a.s.l.	Dominant tree
S1	Snap	49°29′33.1″N, 18°18′08.4″E	6	S	1125	Spruce
S2	Snap	49°29′40.5″N, 18°18′37.8″E	7	S	1220	Spruce
S3	Snap	49°29′41.3″N, 18°19′03.3″E	7	S	1140	Spruce
S4	Snap	49°30′29.3″N, 18°18′56.7″E	5	K	970	Beech
S5	Snap	49°29′55.4″N, 18°19′00.0″E	7	S	1165	Spruce
S6	Snap	49°30′31.1″N, 18°18′13.1″E	6	K	1015	Beech
S7	Snap	49°30′28.1″N, 18°18′15.7″E	6	B	1000	Spruce
P1	Pitfall	49°29′04.5″N, 18°22′16.0″E	5	B	910	Beech
P2	Pitfall	49°30′10.9″N, 18°23′04.4″E	6	S	1005	Spruce
P3	Pitfall	49°30′15.5″N, 18°23′02.0″E	6	S	1040	Spruce
P4	Pitfall	49°30′32.6″N, 18°18′13.2″E	6	S	1010	Beech
P5	Pitfall	49°30′40.6″N, 18°18′10.7″E	6	S	1020	Beech
P6	Pitfall	49°29′45.2″N, 18°21′34.2″E	6	S	1100	Spruce
P7	Pitfall	49°30′18.9″N, 18°22′14.8″E	7	S	1190	Spruce
P8	Pitfall	49°30′17.4″N, 18°22′08.1″E	7	S	1215	Spruce
P9	Pitfall	49°30′08.5″N, 18°22′20.6″E	6	S	1095	Spruce

Table 2. Details of sampling effort (NTP = number of trap nights).

Year	Pitfall sampling								Snap trap sampling					
	Spring				Fall				Spring			Fall		
	From	To	Days	NTP/ plot	From	To	Days	NTP/ plot	From To	NTP/plot (S1–S5)	NTP/plot (S6, S7)	From To	NTP/plot (S1–S5)	NTP/plot (S6, S7)
2007	28. IV.	15. VI.	48	240	5. IX.	16. X.	41	205	12. VI 14. VI.	300	150	2. X. 4. X.	300	150
2008	25. IV.	13. VI.	49	245	8. IX.	19. X.	41	205	10. VI. 12. VI.	300	150	14. X. 16. X.	300	150
2009	30. IV.	15. VI.	46	230	7. IX.	29. X.	52	260	3. VI. 5. VI.	300	150	15. X. 17. IX.	300	150
2010	23. IV.	16. VI.	54	270	6. IX.	24. X.	48	240	9. VI. 11. VI.	300	150	14. X. 16. IX.	300	150
2011	21. IV.	14. VI.	54	270	7. IX.	21. X.	44	220	8. VI. 10. VI.	300	150	20. X. 22. IX.	300	150
2012	26. IV.	14. VI.	49	245	15. IX.	26. X.	41	205	-	0	0	18. X. 20. IX.	300	150

Table 3. Species and their rA (relative abundance) per plot.

	Snap traps								Pitfalls									
Species/plot	S1	S2	S3	S4	S5	S6	S7	In total	P1	P2	P3	P4	P5	P6	P7	P8	P9	In total
Apodemus agrarius							0.06	0.01										
Apodemus flavicollis	2.58	1.27	1.15	2.9	1.3	2.73	1.15	1.68	0.14	0.04	0.07	0.32	0.28	0.28	0.07	0.14	0.14	0.16
Apodemus sylvaticus	0.36	0.12	0.15	0.15	0.09	0.12	0.48	0.2	0.18	0.07		0.07	0.35	0.21	0.04			0.1
Clethrionomys glareolus	1.64	1.48	1.36	0.73	1.24	0.61	0.18	1.14	1.2	0.07	0.11	0.63	0.39	0.63	0.49	0.32	0.46	0.46
Glis glis		0.03						0.01										
Microtus agrestis	0.06	0.27	0.09	0.09	0.21	0.06		0.13		0.04							0.07	0.01
Microtus arvalis			0.06					0.01										
Microtus subterraneus	0.09	0.24		0.06	0.09	0.06		0.09										
Muscardinus avellanarius		0.09	0.03			0.06		0.03					0.04			0.04		0.01
Neomys fodiens														0.04		0.04		0.01
Sicista betulina					0.03			0.01						0.04				0
Sorex alpinus															0.07	0.04		0.01
Sorex araneus	0.18	0.27	0.18	0.09	0.39	0.06		0.19	0.35	0.71	0.32	0.71	0.14	0.85	0.53	0.46	0.71	0.53
Sorex minutus		0.03						0.01	0.04	0.28	0.14	0.28	0.21	0.25	0.74	0.21	0.53	0.3
Total rA	4.91	3.82	3.3	3.21	3.9	3.7	1.88	3.47	1.73	1.2	0.63	2.1	1.41	2.29	1.94	1.23	1.9	1.6
Total number of species	6	9	7	6	7	7	4	12	5	6	4	5	6	7	6	7	5	10

All analyses were performed within the R environment (R Core Development Team, 2016) and CANOCO for Windows 5 (ter Braak and Smilauer, 2012). To investigate the taxonomic composition of communities caught by the two sampling methods, we used only seven species that reached sufficient numbers of incidences, namely *Apodemus flavicollis*, *A. sylvaticus*, *Clethrionomys glareolus*, *Microtus agrestis*, *M. subterraneus*, *Sorex araneus*, and *S. minutus*. We investigated the taxonomic composition of a community obtained by the two sampling methods by partial redundancy analysis (RDA). The data were log (x+1)-transformed prior to the analysis to approach normal distribution (Smilauer and Leps, 2014). The statistical significance was tested by the Monte Carlo permutation test using 1000 iterations. The type of trap was an explanatory variable while year, habitat, and elevation acted as the covariates. We used the proportion of animal food in the diet and body mass (for both see Table 4) as functional traits to study the functional composition of the communities caught by the two types of traps. We explored the functional composition by means of community weighted mean (CWM), where the value of a functional trait of a species is weighted by its abundance (Smilauer and Leps, 2014). We compared the CWM by linear mixed

Table 4. Medium body mass and food composition of sufficiently numerous species.

Species	Medium weight (g)	Proportion of animal food (%)	Proportion of plant food (%)	Source of food composition
Apodemus flavicollis	26.17	28	72	Butet and Delettre, 2011
Apodemus sylvaticus	25.44	20	80	Butet and Delettre, 2011
Clethrionomys glareolus	20.24	8	92	Butet and Delettre, 2011
Microtus agrestis	28.98	2	98	Butet and Delettre, 2011
Microtus arvalis	18.5	4	96	Butet and Delettre, 2011
Microtus subterraneus	18.97	0	100	Holisova, 1965
Sorex araneus	9.1	100	0	Churchfield and Rychlik, 2006
Sorex minutus	4.6	100	0	Churchfield and Rychlik, 2006

effect models (LME) using the R package 'nlme' (Pinheiro et al., 2017). The type of trap acted as the fixed effect. In the initial model, nested random effects were represented by year, habitat, elevation, and locality ID. The structure of random effects was determined by comparing the competing models with AIC (Pekar and Brabec, 2012). Locality's ID acted as the random effect in the final model. We used the 'varIdent' variance function as the data were heteroscedastic (Pinheiro et al., 2017).

We compared the species and functional richness by means of individual-based rarefaction within the R package 'BAT' (Cardoso et al., 2015). We used a dendrogram-based measure of functional richness that is expressed as the sum of lengths of all branches (Swenson, 2014). We used hierarchical cluster analysis with UPGMA agglomeration method and Gower distances. We compared the taxonomic and functional richness of communities obtained by the two types of traps separately and to the community when both traps would be used together. However, as the abundances were measured as ind./trap hours, we multiplied the data by 100 and rounded to integers. We then pooled all samples within a trap type or all samples together. We rarefied the number of individuals to the smallest number of caught individuals (i.e. 1717) and performed 1000 permutations. The statistical inference is based on the overlap of 95% confidence intervals.

Capture success (relative abundance) of the snap traps was more than twice higher than those of the pitfalls (Table 3). The communities caught by the two traps differed significantly in their species composition (RDA, pseudo-F = 26.4, P = adox 0.001, R^2_{adj} = 0.24, Figure 1). The communities obtained by the two types of traps significantly differed in the functional composition: pitfall traps caught significantly more carnivorous (LME, $F_{1,14}$ = 112.2, P < 0.001, Figure 2A) but smaller mammals (LME, $F_{1,14}$ = 101.0, P < 0.001, Figure 2B), and snap traps caught more herbivorous and larger mammals.

Snap traps caught significantly more species than pitfall traps (rarefaction, P < 0.05, Figure 3A), but the communities would be the most rich in species if sampled by both traps together (rarefaction, P < 0.05, Figure 3A). Snap traps caught significantly functionally richer communities than pitfall traps (rarefaction, P < 0.05, Figure 3B) but functional richness would not differ significantly if both methods were used together or if only snap traps were used (rarefaction, P > 0.05, Figure 3B).

Snap traps proved to be more effective than pitfalls in our study. This is consistent with the findings of most authors (Kalko and Handley, 1993; Stanko et al., 1999; Nicolas and Colyn, 2006; Santos-Filho et al., 2006). However, there is also evidence that pitfalls are more effective (Pelikan et al., 1977; Pucek et al., 1993). The effectiveness of traps may also vary depending on the period of the year (Pucek, 1969; Mengak and Guynn, 1987).

The objectivity of the results obtained in the monitoring of small terrestrial mammal communities is influenced by differences in logistics and efficiency.

Snap traps have higher purchase price and are much more time-consuming to prepare and operate in the field since they have to be checked daily. They allow intensive monitoring by using a high number of traps (several hundreds) in a short period of time (usually several days). This means that their use requires on-site presence throughout the entire observation period. Results given by snap traps are also significantly influenced by the weather (Wiener and Smith, 1972; Zejda et al., 1977; Lee, 1997; Janova et al., 2011). Some individuals and some species are initially suspicious of new objects and catch up later (so-called trap-prone and trap-shy (Andrzejewski et al., 1971; Kalko and Handley, 1993; Dickman, 1995)). Such species would be undervalued by snap traps.

Pitfalls are more difficult to install and therefore they are usually used in much lower numbers than snap traps. The lower number of pitfalls is replaced by a longer monitoring period. After field deployment, pitfalls do not

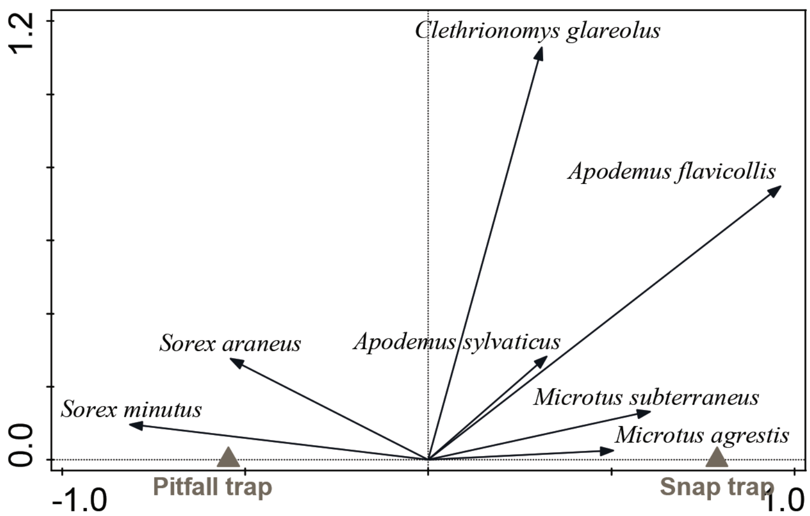

Figure 1. RDA biplot (first two axes) summarizing the effect of sampling method (triangles) on community composition (arrows) of small mammals. The first two eigenvalues were 0.23 and 0.36, respectively.

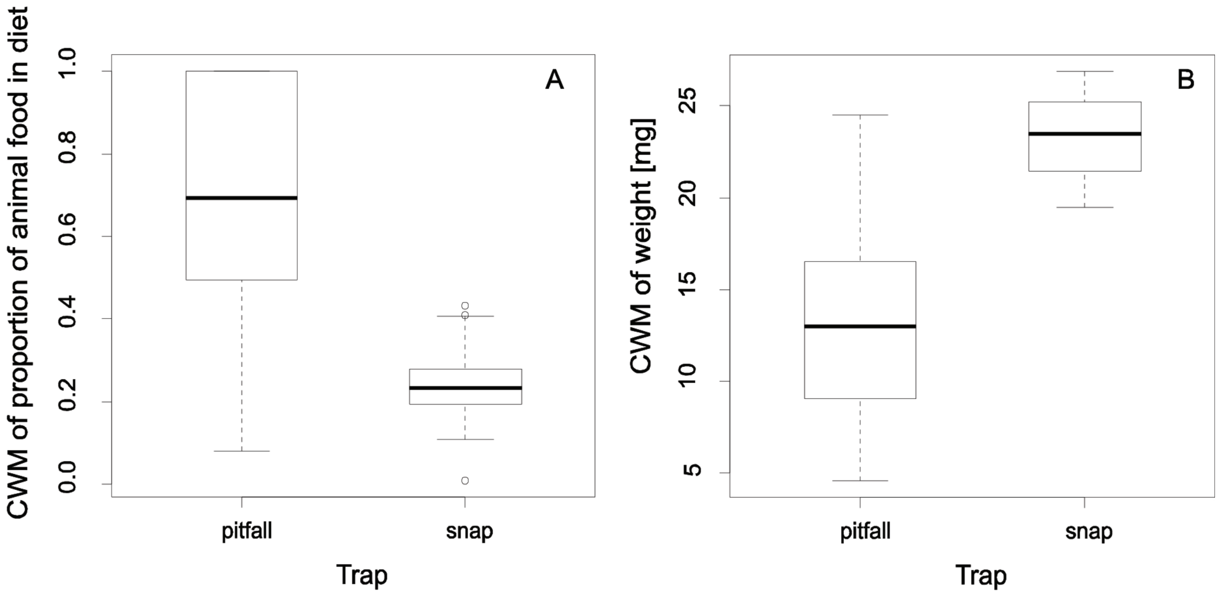

Figure 2. Comparison of community weighted means (CWM) of communities of small mammals caught by two types of sampling methods with regard to proportion of animal food in the diet (A) and body mass (B). Horizontal lines show medians, boxes are quartiles, whiskers reach 1.5 times the interquartile range, and the points are outliers.

require maintenance; they only need to be pulled out at the end of the monitoring period. Longer capture periods (usually tens of days) may slightly affect the results because of the short generation interval and fluctuations in the populations of some species of small terrestrial mammals.

Communities captured by snap traps and pitfalls differed in both species and functional composition. The Eurasian water shrew (*Neomys fodiens*) and Alpine shrew (*Sorex alpinus*) were missing in snap traps, while Striped field mouse (*Apodemus agrarius*), Edible dormouse (*Glis glis*), Common vole (*Microtus arvalis*), European pine vole (*Microtus subterraneus*), and Hazel dormouse (*Muscardinus avellanaraius*) were missing in pitfalls. Pitfalls caught lighter individuals of species with higher proportions of animal food (*Sorex araneus*, *Sorex minutus*; Table 1). Differing species spectra could be ascribed either to different trap attractiveness or to some threshold activation values. By attractiveness, we understand how a trap attracts organisms to itself. Threshold activation value means the limit value leading to trap activation, or

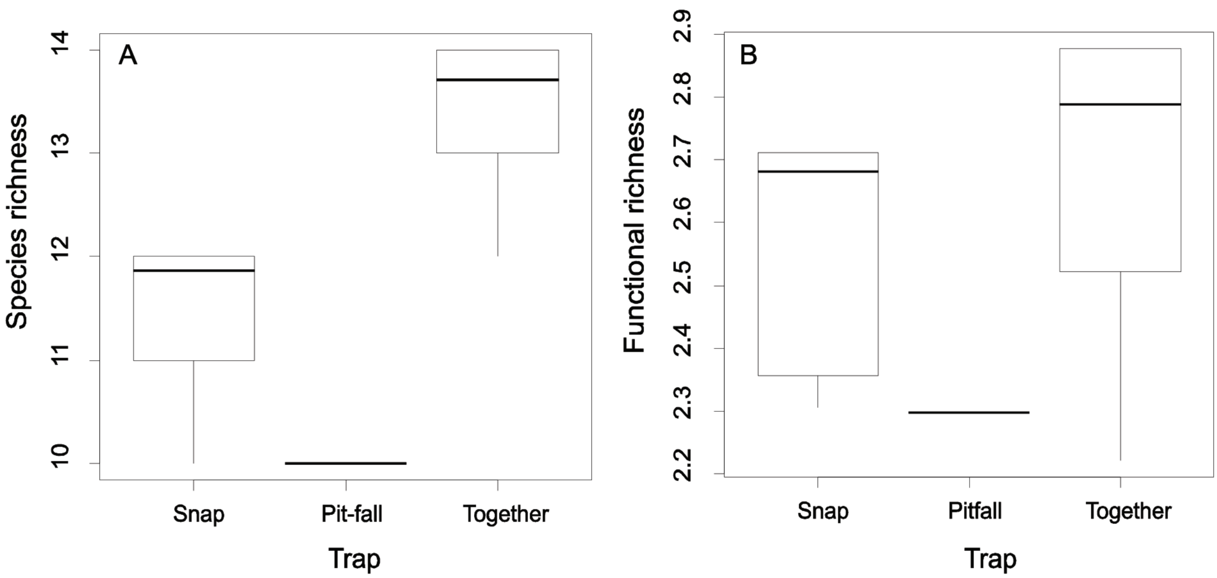

Figure 3. Comparison of species richness (A) and functional richness (B) of communities of small mammals when sampled by one of the two sampling methods or both methods together. Horizontal lines show means from 1000 permutations, boxes define 95% CI, and vertical lines show minimum values obtained during the permutations.

whether this value is sufficient to capture all key organisms or discriminates some of them (e.g., those too light, too large, too mobile). The effectiveness of traps depends on both their attractiveness and the threshold activation value.

The attractiveness of snap traps was influenced by the bait, which probably influenced the success of catching in snap traps and species composition of catches (peanut butter is much more appealing to omnivorous rodents than to shrews (Brosset, 1966)). Trapped insects acted as an attractant in the pitfalls, influencing the range of small terrestrial mammals in favor of species with higher proportions of animal food in the diet, especially for shrews (Kalko and Handley, 1993), but also for Northern birch mouse (*Sicista betulina*).

The threshold activation value of each type of trap can be understood in two ways: snap traps need a certain limit force to activate, i.e. they discriminate lighter and weaker animals (Nicolas and Colyn, 2006). The pitfalls (especially those smaller than about 0.7 L) may not catch "big small mammals", especially good jumpers (e.g., *Peromyscus* sp. (Williams and Braun, 1983) or *Apodemus* sp. (Adamczewska, 1959; Pelikan et al., 1977; Pankakoski, 1979)). However, these would not escape from the glass jars we used. One or both of those factors may be the cause of the higher representation of heavier individuals in snap traps. While the significance of weight (i.e. threshold activation values) for the different results of snap traps and pitfalls was repeatedly confirmed (Pelikan et al., 1977; Nicolas and Colyn, 2006; Torre et al., 2016), food composition (i.e. attractiveness) has not been yet directly described.

Snap traps captured a richer functional community (i.e. species with a wider ecological niche or more varied food composition). From this point of view, it would be sufficient to use only snap traps for the overall description of the small terrestrial mammal community.

A wider species spectrum was found in snap traps. This is not entirely common, as most studies describe richer or comparable species spectrum in pitfalls (Kalko and Handley, 1993; Stanko et al., 1999; Nicolas and Colyn, 2006; Santos-Filho et al., 2006). This is probably due to the high and long-term intensity of the use of snap traps, the low number of small species in the area, and the very low affinity of voles to pitfalls. However, since snap traps are selective for some species (they are ideal for mice and most voles but shrews are undervalued), pitfalls are irreplaceable. Therefore, it would be necessary to combine both types of traps to find a full species spectrum of small mammals.

In conclusion, each type of trap was more suitable for monitoring a different group of small terrestrial mammals. Snap traps proved to be better suited to capture larger species with a higher proportion of plant food, and they captured a wider species spectrum. To maximally cover the species spectrum of small mammals, it is necessary to use both types of traps; to monitor functional diversity, it is sufficient to use snap traps.

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