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COMPARING THREE LIVE TRAPPING METHODS FOR SMALL MAMMAL SAMPLING IN CULTIVATED AREAS OF NE SPAIN

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ABSTRACT - We aimed to investigate trap efficiency and specificity of three widely used live trapping methods (Sherman, mesh, and pitfall traps) in an agricultural landscape of NE Spain. We trapped 243 small mammals of 8 different species. Sherman traps yielded more species (6) than mesh (5) and pitfall (3) traps. Log-linear analysis for contingency tables showed that the three trapping methods used were species-specific and the analysis of the standardized residuals pointed out that *Apodemus sylvaticus* and *Mus spretus* were under-sampled by pitfall traps, whereas *Suncus etruscus* and *Microtus duodecimcostatus* were significantly over-sampled by pitfall traps. Finally, *Suncus etruscus* was significantly under-sampled by Sherman and mesh traps. The composition of the small mammal community studied was rather similar when using Sherman and mesh traps, but differed strongly from the community sampled by pitfall traps. As previously pointed out by many authors, a combination of trapping techniques is necessary to assess the composition of small mammal communities.

Key words: Sampling methods, live trapping, small mammals, cultures, trapping efficacy

RIASSUNTO - ***Confronto di tre metodi di trappolaggio dei micromammiferi in aree coltivate della Spagna nord-orientale***. In un'area agricola della Spagna nord-orientale, abbiamo testato l'efficienza e la specificità di tre metodi di cattura "a vivo" (trappole Sherman, in maglia di rete e a caduta) utilizzati per i micromammiferi. Sono stati catturati 243 piccoli mammiferi, appartenenti a 8 diverse specie. Le trappole Sherman hanno permesso la cattura di un maggior numero di specie (rispettivamente 6, 5 e 3 specie). I modelli log-lineari per tabelle di contingenza multidimensionali hanno mostrato che la frequenza di cattura di ciascuna specie è dipesa dal metodo utilizzato. Le trappole a caduta hanno sotto-stimato la frequienza di *Apodemus sylvaticus* e *Mus spretus,* mentre hanno sovra-stimato quelle di *Suncus etruscus* e *Microtus duodecimcostatus*. Infine, *Suncus etruscus* è stato sottostimato sia dalle trappole Sherman che da quelle in maglia di rete. Nel complesso, la composizione della comunità ottenuta tramite l'uso delle trappole Sherman e di quelle in maglia di rete è risultata differente da quella stimata tramite le trappole a caduta. Si conferma quindi che per ottenere un quadro preciso della composizione delle comunità di micromammiferi è consigliabile utilizzare più di un metodo di campionamento.

Parole chiave: campionamento, trappolaggio "a vivo", micromammiferi, aree coltivate, efficacia del trappolaggio

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INTRODUCTION

Agricultural landscapes are important habitats for mammals across Europe (Macdonald *et al.*, 2007) and some areas, such as the Mediterranean basin, hold interesting endemic species (Rodríguez and Peris 2007, and references therein). However, changes in farming practices during the last decades, such as increased pesticide use, have resulted in the decline of a number of mammalian species (Love *et al.*, 2000; Macdonald *et al.*, 2007). Small mammals are key species since they have an intermediate position along the food chain (Tew *et al.*, 2000), and the decline in their numbers may have serious consequences for the predators than rely on them (Love *et al.*, 2000). Pseudo-steppes of NE Spain are important areas for the conservation of some endangered birds of prey (Blanco *et al.*, 1998), of which some are generalist predators whose diet is based on small mammals, like the barn owl (*Tyto alba*) and Montagu's harrier (*Circus pygargus*).

Assessing the composition of small mammal communities is difficult because small mammals are mainly nocturnal and elusive species, due to their role as a prey for many predators (Luiselli and Capizzi, 1996). Many authors suggested that a combination of different methods (either direct or indirect methods) is needed in order to obtain accurate and unbiased estimates of the composition and structure of small mammal communities at different spatial scales (Garden *et al.*, 2007; Torre *et al.*, 2004).

Live trapping has been considered as the key technique for monitoring small mammal populations (Flowerdew *et al.*, 2004). However, live trapping encompasses different techniques which differ in their efficiency (Anthony *et al.*, 2005; Lambert *et al.*, 2005) and may even account for variations in the estimated population structure of single species (Burger *et al.*, 2009). Sherman traps (H.B. Sherman Inc., Tallahassee, USA) are amongst the most used models for small mammals sampling. Nonetheless, Sherman traps are considered to be less efficient for small mammal sampling than mesh live traps (O'Farrell *et al.*, 1994; Lambert *et al.*, 2005; Burger *et al.*, 2009). Pitfall traps are interception or passive traps, and animals are caught randomly (Nicolas and Colin, 2006). Pitfall traps have been shown to be efficient in capturing small mammals with semi-fossorial habits (Umetsu *et al.*, 2006), which may be difficult to trap by commercial live traps. Advantages and limitations of the different trapping methods have been reviewed by Sibbald *et al.* (2006). Biases in the success of the different traps used may yield erroneous estimates of small mammal community composition, species density, survival, sex ratio and age structure (O'Farrell *et al.*, 1994; Burger *et al.*, 2009).

In this study we aimed to investigate the efficiency and specificity of three widely used live trapping methods in an agricultural landscape of NE Spain.

STUDY AREA AND METHODS

The study area was set in the Catalan Central Depression (Lleida province, Catalonia, NE Spain). It covers 60,160 ha and elevation ranges from 113 to 465 m a.s.l. Landscape consists of 3 main habitats: 1) flat, dry areas with cereal cultivations, mainly barley and wheat, 2) irrigated land with fruit trees and crops of alfalfa and maize, and 3) valleys and plains with almond and olive trees and small holm-oak forest patches.

During 2003 we sampled small mammal communities by trap-lines. The four main crops of the area were sampled according to their availability, laying three trap-lines each on cereal and alfalfa crops, and one each on irrigated land and dry orchards. These 8 lines were replicated once a month from May to July (three times). Three kinds of small mammal traps were used: Sherman traps (23 x 7.5 x 9 cm; Sherman Co., USA, N = 812 trap-nights), mesh live traps (29 x 12 x 9.5 cm, charged by CENMA to the Andorra Penitentiary Centre, N = 1114 trap-nights), and pitfall traps (1.5 L. water bottle that was cut 17 cm tall, N = 789 trap-nights). Traps were spaced 10 m apart and brought into operation for three consecutive nights. Every trap-line consisted in a similar proportion of traps of the three models that were intercalated, starting with a Sherman, followed by mesh and pitfall, and repeating the sequence up to the end of the line (O'Farrell *et al.*, 1994; Lambin and MacKinnon, 1997; Nicolas and Colin, 2006). Average number of traps per trap-line was 64.45 ± 4.29 (n = 24, range 58-73). In order to control for sampling differences among trapping methods, trapping success was expressed as number of captures per 1000 trap-nights (*i.e.*, number of catches of a species divided by the number of traps brought into operation for every sampling method along the study period x 1000, see Tellería *et al.*, 1987 and Nicolas and Colin, 2006 for a similar approach). In order to increase sample size to perform the analysis, the results of the three sampling sessions were accumulated for each trap-line. All traps were baited with a mixture of tuna, flour and oil, and, whenever possible, were set under the cover of shrubs or dense herbs to conceal them and to provide some thermal insulation. Small mammals caught were identified to the species, marked by fur-clipping (Gurnell and Flowerdew, 1990) and released at the place of capture.

Statistical log-linear analysis for contingency tables (Zar, 1996) was used to test for variation in the frequency of occurrence of small mammal species between trap-models and trap-lines. First we tested a three-way log-linear model including species (N = 7), trap (N = 3), and trap-line (N = 8), as main factors. Due to large number of empty cells (122 out of 168), we collapsed cells and excluded "trap-line" as a factor (see O'Farrell *et al.*, 1994, for a similar approach). Then we tested a two-way log-linear model including species (N = 7) and trap model (N = 3). Statistical significance was verified examining the components of maximum likelihood, comparing these values with the critical level of significance for 1 degree of freedom (χ^2 =3.84, $P < 0.05$, df = 1; Flaquer *et al.*, 2007). Standardized residuals (after log-linear analysis) higher than ± 2 were used to verify which frequencies deviated from the null model of no association between variables (Anthony *et al.*, 2005).

Since the total number of individuals collected varied between methods, we used rarefaction to compare species richness between sampling methods (Ecosim 7.0 software, Gotelli. and Entsminger, 2001; see Flaquer *et al.*, 2007 for details). The individual-based datasets were obtained after pooling replicated samples in single ones for each sampling method (Gotelli and Colwell, 2001). Wilcoxon's matched pairs test was performed to compare recapture rates between Sherman and mesh traps.

RESULTS

On the whole, 256 small vertebrates of 13 species were trapped during the study period: 8 different species of small mammals (243 individuals and 313 captures), two reptiles (*Podarcis*

Table 1 - Number of captures and relative frequencies of occurrence (controlling for sampling effort) of small vertebrates in three different live-traps along the study period. Sampling effort was unevenly distributed among trapping methods (Pitfall: 789 trap-nights; Sherman: 812 trap-nights; Mesh: 1114 trap-nights), so relative frequencies (Rf) were expressed as captures per 1000 trap-nights.

Species	Pitfall		Sherman		Mesh		Total
	N	Rf	N	Rf	N	Rf	N
Amphibians							
Alytes obstetricans	1	1.27	0	0.00	0	0.00	1
Bufo bufo	1	1.27	0	0.00	0	0.00	1
Reptiles							
Podarcis hispanica	1	1.27	0	0.00	0	0.00	1
Timon lepida	1	1.27	3	3.69	0	0.00	4
Mammals							
Crocidura russula	3	3.80	14	17.24	7	6.28	24
Suncus etruscus	19	24.08	1	1.23	0	0.00	20
Erinaceus europaeus	0	0.00	0	0.00	1	0.90	1
Apodemus sylvaticus	0	0.00	51	62.81	77	69.12	128
Eliomys quercinus	0	0.00	4	4.93	9	8.08	13
Mus musculus	0	0.00	5	6.16	3	2.69	8
Mus spretus	0	0.00	46	56.65	70	62.84	116
Microtus duodecimcostatus	3	3.80	0	0.00	0	0.00	3
Mustela nivalis	0	0.00	2	2.46	3	2.69	5
Total	29	36.76	126	155.17	170	152.60	325

hispanica and *Timon lepida*), two amphibians (*Alytes obstetricans* and *Bufo bufo*) and one small carnivore (*Mustela nivalis*). The Algerian mouse (*Mus spretus*) and the wood mouse (*Apodemus sylvaticus*) were the dominant species (Tab. 1).

Sherman traps yielded more species (6) than mesh (5) and pitfall (3) traps (Tab. 1). Correcting for the sampling effort performed, that was unevenly distributed among trapping methods, Sherman traps (11.82%), and mesh traps (10.95%) were more efficient than pitfall traps (3.16%) in capturing individuals (respectively, $\chi^2 = 38.7$, $P < 0.001$, df = 1 and $\chi^2 = 37.7$, $P < 0.001$, df = 1). Rarefaction analysis showed that Sherman traps displayed higher species richness irrespective of the number of individuals sampled, followed by mesh traps and pitfall traps (Fig. 1).

Frequencies of occurrence of small mammal species differed depending on the sampling methods used (Tab. 1). Only one species was sampled by all methods (*Crocidura russula*), whereas

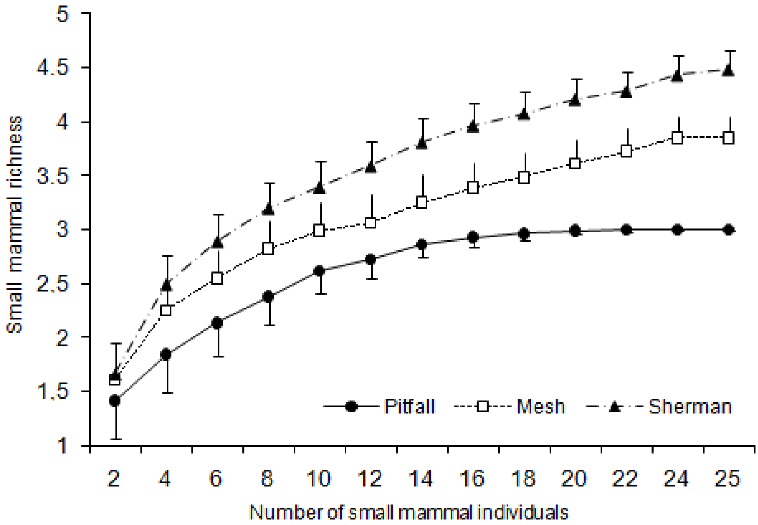

Figure 1 - Individual-based rarefaction curves showing small mammal species richness rarefied to the same number of individuals sampled by each trapping method. Coefficients of variation of the mean are shown.

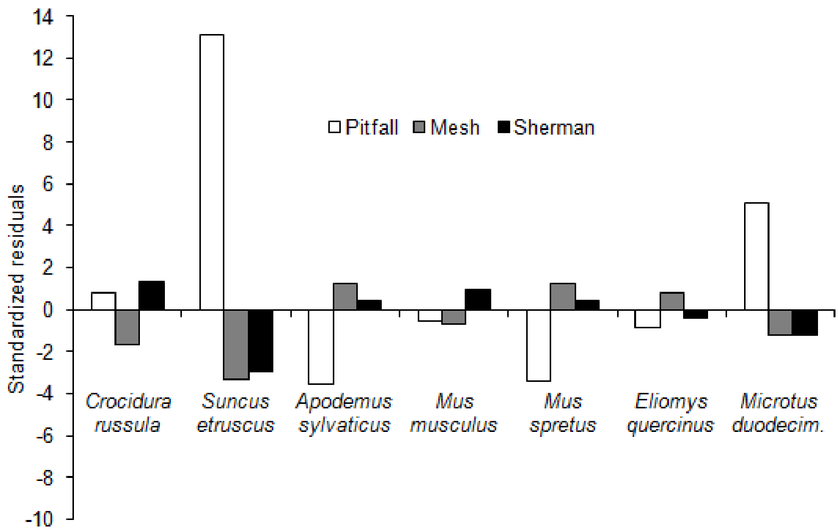

Figure 2 - Standardized residuals after the log-linear analysis performed with the frequencies of occurrence of the seven small mammal species as obtained by the three sampling methods (G^2_{12} = 168.41, P < 0.0001). Standardized residuals greater than ± 2 are significantly different from zero.

almost all species were sampled by two methods, and only one species was sampled by only one method (*Microtus duodecimcostatus* by pitfall traps). *Apodemus sylvaticus* and *Mus spretus* showed higher frequencies of occurrence by mesh traps ($\chi^2 = 25.00$, $P < 0.001$, df = 2, and $\chi^2 = 22.40$, $P < 0.001$, df = 2, respectively), while *Suncus etruscus* and *Microtus duodecimcostatus* were mainly sampled by pitfall traps ($\chi^2 = 97.38$, $P < 0.001$, df = 2, and $\chi^2 = 14.60$, $P < 0.001$, df = 2, respectively).

The statistical log-linear model showed that the three trapping methods used were species-specific (interaction Species x Method: $G^2_{12} = 168.41$, $P < 0.0001$), and the analysis of the standardized residuals (Fig. 2) pointed out that pitfall traps under-sampled *Apodemus sylvaticus* and *Mus spretus* while over-sampled *Suncus etruscus* and *Microtus duodecimcostatus*. Finally, *Suncus etruscus* was significantly under-sampled by both Sherman and mesh traps.

Recapture rate was higher for mesh than Sherman traps (Z = 2.02, P = 0.043, N = 5), whilst no recaptures were obtained from pitfall traps.

DISCUSSION

The small mammal community that inhabits cultivated areas of NE Spain was composed by 8 species. Rats (*Rattus norvegicus* and *R. rattus*), were not trapped maybe due to their different habitat associations (*i.e.*, human buildings) or lower densities, since both species were trapped by these methods in other areas of NE Spain (authors' unpublished data). So, we considered that almost all the small mammal species present in cultivated areas were sampled by the three methods used.

Our results agree with those reported by previous authors who claimed that a combination of trapping techniques is necessary to have a good picture of the composition of small mammal communities (Garden *et al.*, 2007). Furthermore, trapping methods should be combined with indirect methods to have complete information at larger spatial scales (Torre *et al.*, 2004).

Pitfall traps were, by far, the live-trapping method that provided less small mammal species and individuals (Laurance, 1992). Despite this method needing much more effort to set traps than the other methods used, the results obtained are considered as valuable as those obtained by other trapping methods (Walters, 1989; Laurance, 1992; Umetsu *et al.*, 2006). Two species of shrews and a fossorial vole were trapped, whilst none of the common rodent species found in this study was trapped by pitfall traps (*e.g. Apodemus sylvaticus* and *Mus spretus*). Accordingly, these traps are considered to be efficient for catching shrews (Nicolas and Colin, 2006), but do not seem to be as effective for trapping mice (Andrzejewski and Rajska, 1972; Nicolas and Colin, 2006; Stanko *et al.*, 1999). As Walters (1989) pointed out, pitfall traps are ineffective for sampling species that are good climbers and jumpers such as wood mice, unless they are partially filled with water (Tellería *et al.,*1987). Capture success in pitfalls may depend on the size of traps (Umetsu *et al.*, 2006) and, in our case, the low depth of the trap may have been responsible for the lack of captures of mice. Otherwise, *Suncus etruscus* was over-sampled by pitfall traps and was trapped only on one occasion with conventional live traps (Sherman) in this study. This small shrew (1-3 g, Gosàlbez, 1987) rarely can trigger the treadle to close the door of the trap, and can be under-represented by using this kind of live traps (Torre *et al.*, 2004). *Microtus duodecimcostatus* was rarely trapped during the study. This fossorial vole is more abundant in the area than trapping actually reflects, as suggested by the large number of mounds counted (up to 600 / km near to a trap-line), a consequence of the burrowing activity of the voles (Borghi *et al.*, 1994). So, the relative frequency of the Mediterranean pine vole was probably under-estimated by all trapping methods used. *Microtus duodecimcostatus* can be trapped with Sherman traps (Borghi *et al.*, 1994), but traps need to be placed within the tunnels after digging out the ground (Guedon *et al.*, 1992).

The low efficiency of pitfall traps contrasts with other studies which found higher species richness by using pitfall than Sherman traps (Umetsu *et al.*, 2006). Pitfall traps design affects trapping efficiency, and the use of drift fences can increase significantly the trapping success of these traps in relation to commercial baited traps (Kalko and Handley, 1993; Umetsu *et al.*, 2006).

We did not find evidence of mesh traps being more efficient than Sherman traps, as was noticed by many authors (O'Farrell *et al.*, 1994; Lambert *et al.*, 2005; Burger *et al.*, 2009). Interestingly, recapture rates were higher for mesh than Sherman traps. Mesh, being transparent, may encourage small mammals to be more confident with these traps (O'Farrell *et al.*, 1994; Burger *et al.*, 2009). No recaptures were obtained from pitfall traps, confirming that small mammals tended to avoid the traps after first exposure (Twigg, 1975). Umetsu *et al.* (2006) also reported lower recapture rates in pitfall than in Sherman traps.

According to our results, and in agreement with other authors (Garden *et al.*, 2007), a combination of live-trapping methods would be appropriate for sampling almost all the species present in the agricultural landscapes of NE Spain.

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