A test on the effectiveness and selectivity of three sampling methods frequently used in orthopterological field studies

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To obtain unbiased data in entomological samplings the selectivity and effectiveness of methods should be known. Sweepnetting, direct search and dish trap, which are frequently used in orthopterology, were tested to get data on selectivity and effectiveness. Based on the number of collected individuals, sweepnetting was the most labour efficient, while the highest number of species was collected by direct search. Dish traps were most selective to ground-dwelling species. Sweepnetting and direct search were sensitive to grass-dwelling species. Our results underlines that none of the methods is universal, and a combination of sweepnetting and direct search provides the greatest benefits.

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1. Introduction

The study of species distributions and community composition are essential elements in biodiversity assessment, monitoring and adaptive management (Colwell & Coddington 1994). In Hungary, grasslands represent a major and frequent habitat type, in which orthopterans constitute an important group of herbivorous insects. Herbivorous insects such as Orthoptera are often involved in 'bottom-up' resource control (Andersen *et al.* 2001) which makes them sensitive to changes of habitat structure (Bock & Bock 1991, Chambers & Samways 1998, Gebeyehu & Samways 2002). Based on their sensitivity, relatively high species richness (i.e. 120 species in Hungary, Nagy 2003), and easy sampling and identification, orthopterans are commonly used as indicators of habitat heterogeneity, ecosystem biodiversity and environmental stress (Andersen et *al*. 2001).

Ideally, unbiased data on both species richness and relative abundances of species in communities are necessary for the inventory and monitoring of biological diversity. Sampling methods for the estimation of the abundance of individual populations (e.g. distance sampling and capture-mark-recapture methods) are often impractical and too expensive to implement for all species of a community. Therefore indices of population abundance (e.g. number of individuals caught, heard or seen) are used in most studies. Utilization of these indices in statistical analyses and translation of them into estimates of species diversity assumes that ratios of indices estimate relative abundances; that is individuals of all species are equally detectable and all species are detected (Yoccoz *et al*. 2001). In order to reduce bias in the data as much as possible, the selectivity, effectiveness and accuracy of methods in different conditions should be known and sampling strategies should be developed.

Here we compare three sampling methods (sweepnetting, direct search and dish traps), that are widely used in orthopterological studies (Balogh 1958, Ausden 1996, Murkin *et al*. 1996, Gardiner *et al*. 2005). We compare the effectiveness and the selectivity of these methods with respect to habitat structure. Whereas the limits of application of these methods are known (Southwood 1978), we focus on fine scale differences among the methods, that can modify the outcome of the sampling. Based on the results we provide practical recommendation on the optimal use and combination of these methods in orthopterological research.

2. Materials and methods

2.1. Study sites and sampling procedure

The effectiveness and selectivity of three sampling methods (sweepnetting, direct search and dish trap) with respect to vegetation structure were compared. Twelve sampling sites of different habitat structure were studied in the Aggtelek Karst region (NE Hungary), which is part of the Aggtelek National Park, near Jósvafő village (48°28'59"N, 20°33'03"E). We sampled two 25 × 25 m quadrats per site, 10–15 meters apart. In one of these quadrats direct search was carried out first, followed by sweepnetting two days later. In the second quadrat at each site, dish trapping was running continuously for ten days. In this manner we essentially made a repeated measures analysis, where each sampling method was used on each subject but care was taken to ensure that use of any one sampling method did not influence the results of any other sampling method. Each sampling was made by A. N. The study was conducted from 4.–14.VIII.2004.

Direct search (searching) is appropriate for collecting presence/absence data and can be used parallel with sweepnetting (Kruess & Tscharntke 2002, Batáry *et al*. 2007). The samples were taken by walking along parallel transects in the sampling quadrate for 30 minutes. The width of the transects was 1.5 m and the distance between transect was at least 2 m. The total length of transects depended on vegetation structure, and density of Orthoptera-assemblages. All observed specimens were recorded in units of two minutes, and each specimen was recorded only once.

Sweepnetting (netting) is the most common method for collecting presence/absence and abundance data on orthopterans (Southwood 1978, Evans *et al*. 1983, Dunwiddie 1991, Cigliano *et al*. 2000, Gardiner *et al*. 2005). A total of 300 sweeps were taken per site using a sweep-net of 40 cm in diameter. The net was emptied after every 25 sweeps. Both search and netting were carried out between 9 am and 5 pm, in calm and sunny weather.

Sampling by traps (trapping) is less widely used in orthopterological studies than sweepnetting and direct search (Gardiner *et al*. 2005). Pitfall traps are generally used for sampling ground-dwelling crickets (e.g. Grylloidea, Rebek *et al*. 1995, Sperberg *et al*. 2003) and for simultaneous sampling of different arthropod taxa (e.g. Poulin & Lefebvre 1997). Landsberg *et al*. (1997) and Clayton (2002) used small traps (7 and 8 cm in diameter and 12 and 11 cm deep) to quantify abundance but these are preferably useful to estimate incidence of species but not abundances of Orthoptera (Bieringer & Zulka 2003). To sample Orthoptera (Acrididae, Tettigoniidae and Gryllidae) traps with larger diameter can be used e.g. funnel and dish traps (Duelli *et al*. 1999, Rácz *et al*. 2003). In this study, dish traps (a kind of large pitfall trap) were used, which are appropriate for sampling both grass-dwelling and ground-dwell-

Table 1. Mean abundance ranks and life forms of the orthopterans collected in 12 sampling sites of the Aggtelek Karst by three sampling methods. Species are sorted according to increasing mean abundance rank. Life forms: ch: chortobiont, fi: fissurobiont, g: geobiont, th: thamnobiont, transitional life form types are in parentheses (Rácz 1998).

Species	Sampling type			Life forms
	search	net	trap	
Chorthippus parallelus (Zetterstedt, 1821)	3	1	1	ch
Pholidoptera fallax (Fischer, 1853)	1	2	3	ch
Euthystira brachyptera (Ocskay, 1826)	2	3	6	ch
Metrioptera bicolor (Philippi, 1830)	4	5	5	ch
Chorthippus apricarius (Linnaeus, 1758)	7	8	4	ch
Stenobothrus crassipes (Charpentier, 1825)	5	6	9	ch
Omocestus haemorrhoidalis (Charpentier, 1825)	10	4	7	g (ch–g)
Calliptamus italicus (Linnaeus, 1758)	6	7	8	g (g–ch)
Leptophyes albovittata (Kollar, 1833)	8	9	16	th
Gryllus campestris Linnaeus, 1758	14	18.5	2	fi
Stenobothrus lineatus (Panzer, 1796)	12	13	11	ch
Phaneroptera falcata (Poda, 1761)	9	11	23	th
Decticus verrucivorus (Linnaeus, 1758)	11	22.5	10	th (ch–th)
Stauroderus scalaris (Fischer de Waldheim, 1846)	16.5	18.5	12	ch
Poecilimon fussi Brunner von Wattenwyl, 1878 *	21.5	12	–	th
Chorthippus dorsatus (Zetterstedt, 1821)	18.5	18.5	13.5	ch
Chorthippus brunneus (Thunberg, 1815)	18.5	14.5	18	ch
Pachytrachys gracilis (Brunner von Wattenwyl,1861)	20	18.5	13.5	th
Psophos stridulus (Linnaeus, 1758)	13	24	15	g (g–ch)
Chorthippus mollis (Charpentier, 1825) **	–	–	18	g (ch–g)
Tetrix bipunctata (Linnaeus, 1758)	24	10	20.5	ch
Metrioptera brachyptera (Linnaeus, 1761)	16.5	22.5	20.5	ch
Pseudopodisma nagyi Galvani et fontana, 1996	15	18.5	28	ch
Gomphocerippus rufus (Linnaeus, 1758)	23	14.5	28	ch
Platycleis albopunctata (Goeze, 1778)*	26.5	–	18	g (ch–th)
Isophya kraussii Brunner von Wattenwyl, 1878	21.5	18.5	28	ch
Omocestus rufipes (Zetterstedt, 1821)*	–	25.5	23	ch
Pholidoptera griseoaptera (DeGeer, 1763)	25	25.5	23	th
Arcyptera fusca (Pallas, 1773) *	26.5	28	–	g (ch–g)
Paracaloptenus caloptenoides (Brunner von Wattenwyl,1861)**	–	28	–	g
Chrysocraon dispar (Germar, [1834])	28	28	28	ch
Chorthippus biguttulus (Linnaeus, 1758)	33	28	28	ch
Saga pedo (Pallas, 1771)*	33	28	–	th (ch–th)
Tettigonia viridissima Linnaeus, 1758 **	33	–	–	th
Ruspolia nitidula (Scopoli, 1786)**	33	–	–	th
Mecostethus parapleurus (Hagenbach, 1822) **	33	–	–	ch
Omocestus petraeus (Brisout de Barneville, 1856)**	33	–	–	g (ch–g)
Oedipoda coerulescens (Linnaeus, 1758) **	33	–	–	g
Oecanthus pellucens (Scopoli, 1763)**	33	–	–	th (ch–th)
Chorthippus oschei Helversen 1986**	33	–	–	ch

* species that are missing from only one method out of the three
** species that are unique to only one method

ing Orthoptera. We used brown coloured flower-pots (20 cm in diameter and 20 cm deep) as traps. The traps were dug into the soil, and the vegetation was left intact. A mixture of ethylene-glycol (25 v/v%), detergent, formaldehyde (5 v/v%) and water was used as killing liquid and preservative. The ethylene-glycol slowly evaporates and the detergent decreases the probability of specimens

Table 2. Vegetation structure, number of Orthoptera species (S_{total}) and individuals (N_{total}) in the studied sites (1–12).

Sites	Height (cm)		Cover (%)		S_{total}	N_{total}
	lower	upper	lower	upper		
1	32.8±4.2	75.8±17.5	95	1	16	234
2	33.4±3.7	82.4±11.2	85	12	20	342
3	34.5±4.4	84.5±10.4	85	10	20	381
4	34.4±6.1	79.9±9.3	95	15	17	521
5	30.1±5.2	72.2±9.4	95	40	14	357
6	18.6±3.8	68.9±14.2	60	2	20	262
7	26.1±4.9	59.5±10.9	55	5	19	229
8	19.2±2.9	63.0±15.5	80	1	18	258
9	29.5±3.9	65.1±13.5	60	5	13	217
10	30.7±3.3	65.5±11.5	60	5	20	255
11	23.7±5.3	51.8±13.7	95	15	18	638
12	25.8±4.6	70.9±8.1	70	12	19	257

escaping from the traps. Traps were exposed for ten days and were emptied every two days.

For identification of the collected specimens, keys of Harz (1957, 1969, 1975) were used. For nomenclature, we followed Heller *et al*. (1998).

2.2. Data analysis

Species were grouped into life form types, based on the classification by Rácz (1998). Based upon their body shape, habitat preference and physiology, orthopterans can be classified into four primary life form types (Rácz 2001). Thamnobionts live in the canopy and dense grass, chortobionts are grass-dwelling, geobionts prefer sparse and open grasslands, and fissurobionts dwell on the ground. According to their behaviour, there are further, transitional types, i.e. chorto-thamno-, thamno-chorto-, chorto-geo- and geo-chortobiont (Rácz 1998, 2001). In this study only primary types were used because of insufficient number of cases of transitional types. In this case thamnobionts also include thamno-chorto- and chorto-thamnobionts, while geobionts also include geo-chorto-, and chorto-geobionts (Table 1).

Vegetation was characterised by mean heights of the lower and upper grass layer, calculated from measurements made in ten random points of the 25 × 25 m quadrates and by cover of the two grass layers estimated in field (Table 2). Parameters of the vegetation structure were subjected to principal component analysis (PCA). Along the first principal axis, two groups of sites were separated. The first group is characterised by short grasses (sites 6–12, short type), while the second by dense and tall grasses (sites 1–5, tall type). We used these two grass types in further analyses (Table 2, Fig. 1).

We were concerned about the abundance

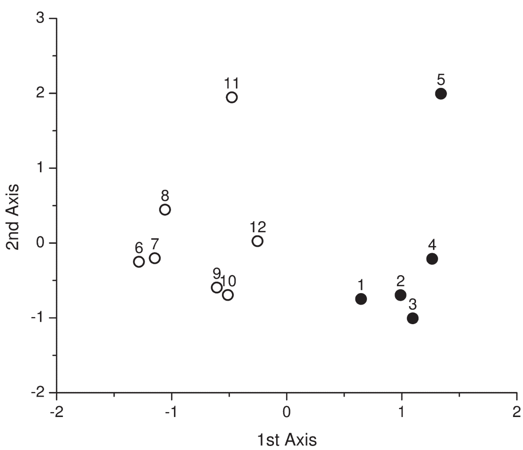

Fig. 1. Groups of sites according to principal component analysis based on four variables of vegetation structure (see Table 2). Empty dots: short grasses, filled dots: tall grasses. Labels of the dots refer to the numbers of sites in Table 2.

ranks of the species and not about their absolute abundance or relative frequency values. Thus we used Kendall's concordance based on ranks (Zar 1984) to test within-group agreement of abundance ranks of the species in samples collected with the same method for each grass type. The between-groups agreement of the species' abundance ranks was tested by two group concordance (Schucany & Frawley 1973).

To analyse the effectiveness of the three methods, we compared species accumulation curves specific to each method. For the estimation of the parameters of the species accumulation curves we used the Clench equation (Soberón & Llorente 1993):

$$S(n)=an/(1+bn)$$

where S is the number of species, n is the number of sampling units, and a and b are constants estimated from the data. As Willott (2001) suggests, we used the number of individuals in the subsequent samples – not sampling units (i.e. time intervals and net samples) alone – as the measure of sampling effort to use uniformly scaled independent variable in the extrapolation of the species accumulation curves. The sample orders were not randomized because sampling units were taken continuously in time.

For each method in each sampling site, we determined the observed number of species (S_{obs}), the estimated maximum number of species ($S_{max}=a/b$; Soberón & Llorente 1993), the expected number of species associated to the minimum number of individuals observed in samples (33 individuals) (S_{N33}), and the estimated number of individuals necessary to detect the minimum number of species observed in all samples (5 species) (N_{S5}). These dependent variables were log-transformed. We used the values of species richness, effectiveness and selectivity (described above) of the 12 sites as subjects, and compared by general linear models (GLM) with repeated measures. Methods were treated as repeated measures and grass type as fixed factor. Significance levels for multiple comparisons were adjusted by the Bonferroni method (Motulsky 1995). The error covariance matrices of the orthonormalized transformed dependent variables were proportional to the identity matrices respectively (Mauchy's test of sphericity, $p>0.2$).

To analyse the selectivity of the methods, we determined the number of unique species for each method (S_{diff}) and the proportion of life forms in the samples. Because these variables were not distributed normally even after a logarithmic transformation (Shapiro-Wilk test, $p<0.05$), we used nonparametric two-way analysis of variance (Zar 1984) with number of unique species for each method and the proportion of life forms as dependents, and method and grass type as factors. We excluded two short type sites (11 and 12) characterised by intermediate PCA scores (Table 2, Fig. 1) to get equal number of replicates ($n=5$) within each treatment combination. Because samples taken by the three methods in the same site are not independent, they can be considered as repeated measures. Therefore, we performed Friedman's nonparametric analysis of variance with method as repeated measures separately for the two grass types when the method × grass type interaction was not significant. We used the Wilcoxon signed rank test for pairwise comparisons of related samples.

We further tested the association between method-specific presence ("unique species" sampled by only one of the three methods in a given site) and absence (species not sampled by only one of the three methods in a given site) of species and life form categories by multinomial logistic regression. Method-specific presences and absences of species were treated as multinomial dependent variables (categories indicated the method by which the species was caught or not caught) and were analysed separately. Trapping was treated as the reference category. Life form categories of the species caught were factors in the model. Species identity as independent variable was not evaluated due to inadequate sample size and unbalanced species distribution among the levels of factors.

3. Results

A total of 40 Orthoptera species (16 Ensifera: 14 Tettigonioidea, 2 Grylloidea and 24 Caelifera) were found (Table 1). When all data were summarised according to methods, the five highest ranking species were *Chorthippus parallelus*,

Table 3. Results of repeated measures General Linear Models analysing the effect of method and grass type on species richness, effectiveness and selectivity on each of 12 sites (subjects). Method types were treated as repeated measures and grass type as a fixed factor. Dependent variables were the observed number of species (S_{obs}), estimated maximum number of species (S_{max}), the expected number of species associated to the minimum number of individuals observed in the samples (S_{N33}), and the estimated number of individuals necessary to catch the minimum number of species observed (N_{S5}).

Source of variation		S_{obs}	S_{max}	S_{N33}	N_{S5}
Within-subjects effects					
Method (*df*=2)	*F*	6.334	1.466	3.121	3.963
	p	0.007	0.255	0.066	0.035
Method × Grass (*df*=2)	*F*	0.192	0.460	0.421	1.391
	p	0.827	0.638	0.662	0.272
Between-subjects effects					
Intercept (*df*=1)	*F*	3224.881	4398.958	1594.529	686.214
	p	<0.001	<0.001	<0.001	<0.001
Grass (*df*=1)	*F*	0.074	0.094	0.605	0.285
	p	0.792	0.766	0.455	0.605

Pholidoptera fallax, *Euthystira brachyptera*, *Metrioptera bicolor* and *Chorthippus apricarius*, based on mean ranks of species. Seven species occurred only by the search method, which were the lowest ranking based on mean ranks of species. Only one unique species was caught each by netting and trapping. (Table 1).

In site-by-site analysis of the abundance ranking of the species, rank order was highly and significantly (p<0.001) concordant among the sites within both grass types (in short grasses, df=39: W_{search}=0.536, $W_{netting}$=0.510, $W_{trapping}$=0.559; in tall grasses, df=39: W_{search}=0.548, $W_{netting}$=0.498, $W_{trapping}$=0.492; p<0.001 for all groups). The two group agreement was lowest between netting and trapping (in short and tall grasses, W=0.247 and W=0.178, respectively) intermediate between search and trapping (in short and tall grasses, W=0.298 and W=0.262, respectively) and highest between search and netting (in short and tall grasses, W=0.311 and W=0.297, respectively).

Significantly more species were observed (S_{obs}) by searching than by either of the two other methods (Table 3, p<0.05, Bonferroni correction; Fig. 2) while the estimated maximum number of species (S_{max}) did not differ significantly (Table 3, Fig. 2). The effect of method was marginally significant (p<0.1) on the estimated number of species based on 33 individuals (S_{N33}) (Table 3), and it was highest in netting (Fig. 2). The estimated number of individuals based on five species (N_{S5}) showed significant differences among the me-

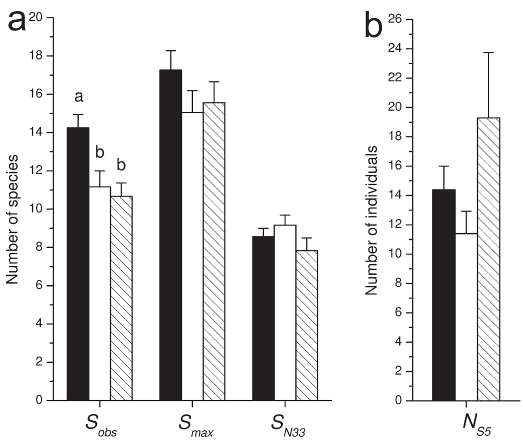

Fig. 2. Mean ± SE of the studied variables quantifying species richness and effectiveness of the three studied methods (search: filled, net: empty, trap: dashed columns) in 12 sampling sites. – a. Observed number of species (S_{obs}), estimated maximal number of species (S_{max}), expected number of species associated to the minimal number of individuals observed in the samples (S_{N33}). – b. Estimated number of individuals necessary to catch the minimal observed number of species (N_{S5}). Variables are grouped according to measurement scale. Different letters indicate significant (p<0.05) differences according to pairwise comparisons.

Table 4. Results of the two-way nonparametric analysis of variance analysing the effect of method and grass type on the number of unique species (S_{diff}) and the proportion of life forms (*Th*: thamnobionts, *Ch*: chorthobionts, *Geo:* geobionts, *Fi*: fissurobionts) on 10 sites (equal number of replicates, i.e. 5 + 5, were needed within each treatment combination; Zar 1984).

		S_{diff}	Proportion of life forms			
			Th	*Ch*	*Geo*	*Fi*
Total MS		77.5	77.5	77.5	77.5	77.5
Method (*df*=2)	*SS*	817.4	45.1	84.2	60.2	1376.6
	H	10.55**	0.58ns	1.09ns	0.78ns	17.76***
Grass (*df*=1)	*SS*	132.3	19.2	340.0	381.6	64.5
	H	1.71ns	0.25ns	4.39*	4.92*	0.83ns
Interaction (*df*=2)	*SS*	46.6	18.1	101.7	77.3	15.3
	H	0.60ns	0.23ns	1.31ns	1.00ns	0.20ns

SS: sum of squares of ranks.
MS: mean square
ns: not significant, *: $p<0.05$, **: $p<0.01$, ***: $p<0.001$.

thods (Table 3). Effectiveness increased from trapping through search to netting and netting performed marginally better than trapping ($p<0.1$, Bonferroni correction; Fig. 2). Grass type and the interaction of the two factors had no significant effect on the independent variables in either comparison (Table 3).

The number of unique species (S_{diff}) differed significantly among the methods, whereas the effects of grass type and interaction were not significant (Table 4). The effect of method in tall grasses was significant (Friedman test, $\chi^2=6.0$, $df=2$, $n=5$, $p<0.05$) and the number of unique species increased from netting through trapping to searching. Searching performed marginally better than netting ($p<0.1$, Bonferroni correction). In short grasses, the difference among methods was marginally significant (Friedman test, $\chi^2=4.73$, $df=2$, $n=7$, $p<0.1$), and pairwise comparisons revealed a tendency to that in tall grasses (Fig. 3).

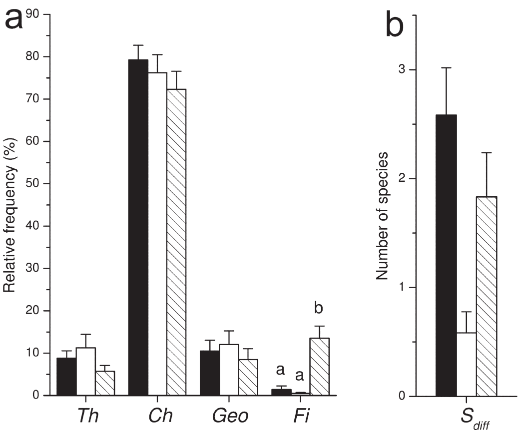

Fig. 3. Mean ± SE of the studied variables quantifying selectivity of the three studied methods. – a. Proportion of thamnobiont (*Th*), chortobiont (*Ch*), geobiont (*Geo*) and fissurobiont (*Fi*) life form. – b. Number of unique species (S_{diff}). Variables are grouped according to measurement scale. Different letters indicate significant ($p<0.05$) differences according to pairwise comparisons.

The sampling methods were roughly equally effective in detecting thamnobiont, chortobiont and geobiont species. The only exception was the detection of fissurobionts because the proportion of fissurobiont life form differed significantly among the methods (Table 4). Trapping outperformed the other two methods in both short (Friedman test, $\chi^2=12.0$, $df=2$, $n=7$, $p<0.01$; for post-hoc tests: $p<0.05$, Bonferroni correction) and tall grasses (Friedman test, $\chi^2=9.294$, $df=2$, $n=5$, $p<0.01$; for post-hoc tests: $p<0.1$, Bonferroni correction) (Fig. 3). The proportion of thamnobiont, chortobiont and geobiont life forms did not differ among methods and the grass × method interaction was also not significant although the proportion of chortobiont and geobiont life forms differed significantly between short and tall grasses (Table 4). Chortobionts were more abundant (mean proportion in short grasses 70.6 ± 13.3 SD, in tall grasses 83.5 ±

Table 5. Association between life forms and the selectivity of the methods studied by multinomial logistic regression. Table includes counts of individual catches and beta coefficients for presences and absences that were specific to each method[a].

Life form[b]	Chortobiont		Fissurobiont		Geobiont		Thamnobiont	
	Count	Beta	Count	Beta	Count	Beta	Count	Beta
Presence								
Searching	13	0.26ns	–	–20.15na	7	1.95+	11	0.61ns
Netting	4	–0.92ns	–	–20.15na	1	0.00ns	2	–1.10ns
Trapping	10	ref.	5	ref.	1	ref.	6	ref.
Absence								
Searching	7	–1.15**	1	19.08***	–	–19.82na	2	–2.20**
Netting	10	–0.79*	4	20.47na	3	–0.29ns	6	–1.10*
Trapping	22	ref.	–	ref.	4	ref.	18	ref.

a Method specific presences and absences of species were treated as multinomial dependent variables and were analysed sep arately (trapping was treated as reference category).
b Life form categories of the species caught were included as factors in the model.
ref.: reference category.
na: significance not assessed due to the lack of variance or low sample size, ns: not significant, +: $p<0.1$, *: $p<0.05$, **: $p<0.01$, ***: $p<0.001$.

10.9 SD), while geobionts were less abundant in tall grasses (mean proportion in short grasses 14.8 ± 10.0 SD, in tall grasses 4.1 ± 3.1 SD).

Analysis of between method-specific presences and life forms revealed that searching was selective for geobionts (χ^2=30.52, *df*=8, $p<0.001$). The association was also significant (χ^2=37.07, *df*=8, $p<0.001$) for method-specific absences. Fissurobionts were highly likely to be missed by search method and netting. Species, that were absent by either netting or searching, were likely not chortobionts or thamnobionts (Table 5).

4. Discussion

A great deal of work has been published on improvement (eg. Falkenbury & Verner 1970, Wrubeski & Rosenberg 1984, Sperberg *et al*. 2003) and comparison (eg. Morgan *et al*. 1963, Evans *et al*. 1983, Sparrow *et al*. 1994) of sampling methods used to estimate species richness, abundances and population size of insects. Gardiner *et al*. (2005) reviewed the methods for population estimates of Orthoptera, particularly grasshoppers (Orthoptera: Acrididae). The authors critically reviewed 112 publications and provided useful suggestions for researchers on the use of eight sampling methods. They highlighted the need for development of standardised sampling methods and strategies that can provide comparable data on abundances and species richness. In the present study we compared three of the most frequently used methods in Orthoptera assessments. We focused on the effectiveness and selectivity of these methods with regard to fine scale effect of habitat structure. Our study also included two groups of Orthoptera that have not been extensively studied, namely bush-crickets (Tettigonioidea) and crickets (Grylloidea).

Among the three studied methods, search provides the most complete list of observed Orthoptera species, because it is more sensitive to rare species than netting and trapping. However, considering sampling effort in terms of the number of individuals sampled, netting is the most effective. Although trapping is not a common method for sampling orthopterans and it is less effective than the other two methods, it can be useful when more, mainly ground-dwelling invertebrate taxa (e.g. Myriapoda, Opiliones, Orthoptera, Coleoptera: Carabidae, Silphidae, Geotrupidae, Scarabaeidae etc.) are sampled simultaneously. Another advantage of trapping is that this method is easier to standardise (Murkin *et al*. 1996), an important requirement to get unbiased data (Duelli *et al*. 1999). Since in case of trapping the distribution of thamno-, chorto-, and geobionts were similar and abundance ranks were positively correlated according to the between group concordance values, larger traps, as used in this study, can be useful in quantitative data collection. The diameter of the trap may have significant effect on effectiveness and selectivity as well.

To detect a minimum number of species (five species in this study), it is necessary to collect more individuals when using traps than with the other methods in short grasses. In tall grasses, sampling effort (number of individuals sampled to get the same species richness) increases from netting through searching to trapping, out of which trapping is the most labour-intensive and time-consuming, especially in the field.

In this study, searching was selective to rare species and the number of unique species was highest in this method. Consequently, trapping overestimated the proportion of fissurobiont life form in the assemblages. Based on specific absences, direct search and netting were less sensitive to fissurobionts, while both search and netting were more sensitive to chorthobionts and thamnobionts than dish trapping. The similar selectivity of sweep netting and direct search makes the comparison between samples and combination of these two methods more feasible. When trapping is combined with other methods, methods may complement each other's selectivity.

Sampling effort consists of two important components: manual-labour (e.g. collection of individuals, setting, checking and emptying traps) and intellectual achievement (identification of specimens). Although manual-labour can be carried out by both specialists and volunteers, the intellectual achievements needs specialists' knowledge. In case of netting and trapping these two parts can be carried out by different persons, however, direct search can only be done by specialists. The participation of volunteers or professional staff assisting in monitoring and inventory programs increases public awareness and reception of the research project and reduces the costs of manual-labour, although it comes with some shortcomings. On the one hand, volunteers cannot conduct efficient direct search, which is most sensitive to rare species, thus they usually have to collect more individuals than specialists to detect the same species richness. On the other hand, specialists can identify most of the individuals in field, while all individuals collected by volunteers need to be stored or killed and subsequently identified in the laboratory, which increases the disturbance associated with sampling.

Sampling methods also differ in their applicability in different habitats. Although in this study the effect of vegetation structure could not be detected, standard sweep net is not applicable in extremely dense or sparse vegetation (Southwood 1978).The applicability of trapping strongly depends on quality and depth of soil and bedrock, because relatively large traps can not be dug into rocky surface or shallow soil. Search can be used in a wide range of habitats but it is difficult to standardise because it is highly subjective. This effect decreases in the search-netting-trapping direction.

Our results suggest that none of the methods can be used universally thus one has to choose among methods based on the goals of the given study, its data requirements and the advantages and disadvantages of possible methods. In order to collect rare species and make complete checklists searching is the most appropriate. If we need a well standardised and effective method to collect quantitative data we should use sweep-netting. When the aim is to gain data on more ground-dwelling taxa simultaneously dish-trapping has the most advantages. Considering the different selectivity and restrictive applicability of methods, overall sampling bias can be decreased by combining them, because methods can complement each other. Since the abundance ranks showed significant positive correlations, the combination of methods can be used in both quantitative and qualitative studies. Combination of netting and direct search appears to provide the most advantages. Such a combination can be used in a wider range of habitats, it requires less manual labor and identification skills and volunteers can participate in field work. This combination provides the most complete list of species, it is the most cost effective and causes less disturbance to habitats and insect communities than other combinations of methods.

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