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Monitoring arthropods in protected grasslands: comparing pitfall trapping, quadrat sampling and video monitoring

J. G. Zaller[1], G. Kerschbaumer[1], R. Rizzoli[1], A. Tiefenbacher[1], E. Gruber[1], and H. Schedl[2]

[1]Institute of Zoology, University of Natural Resources and Life Sciences, Vienna, Austria
[2]Institute of Integrative Nature Conservation Research, University of Natural Resources and Life Sciences, Vienna, Austria

Correspondence to: J. G. Zaller (johann.zaller@boku.ac.at)

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Abstract. When monitoring the activity and diversity of arthropods in protected areas it is ethically advisable to use non-destructive methods in order to avoid detrimental effects on natural populations and communities. The aim of this study was to compare the efficiency of three methods for potential use for arthropod monitoring in a protected grassland: pitfall trapping, quadrat sampling and video monitoring. Pitfall trapping was conducted either during the day or over night (cup diameter 6.5 cm, unfenced, without preservation fluid). Quadrat sampling was conducted within a metal frame (width × length × height: 50 × 50 × 30 cm). Video monitoring was done on a 68 × 37 cm area using a digital high-density video camera mounted on a tripod. The study site was located in a semi-dry grassland northwest of Vienna, Austria (305 m a.s.l., 48°27′ E, 16°34′ N); the three methods were replicated five times. Across the sampling methods a total of 24 arthropod orders were observed with Hymenoptera being the most abundant, followed by Diptera and Coleoptera. The sampling methods differed considerably in number of arthropods recorded: video monitoring (2578 individuals) followed by quadrat sampling (202 individuals), nocturnal (43 individuals) and diurnal pitfall trapping (12 individuals). Diversity of arthropod assemblages varied highly significantly among the tested methods with quadrat sampling yielding the highest diversity 0.70 ± 0.22 (Gini–Simpson index, mean ±SD) followed by video monitoring (0.57 ± 0.15), diurnal pitfall sampling (0.35 ± 0.28) and nocturnal pitfall sampling (0.17 ± 0.24). Video surveillance of the pitfall traps showed that out of a total of 151 individuals crawling in the vicinity of pitfall traps none of them were actually trapped. A tabular comparison listing the advantages and disadvantages of the sampling methods is presented. Taken together, our results suggest that video monitoring has a great potential as a supplementary method for quantitative and qualitative assessments of arthropod activity and diversity in grasslands.

1 Introduction

Monitoring the activity and diversity of arthropods often requires a certain amount of disturbance or even killing of the studied animals depending on the methods employed. Hence, ecologically sensitive and cost-effective monitoring techniques are required to assess whether conservation measures are sufficient, especially for protected areas (Work et al., 2002).

One of the most often used technique to assess the activity and diversity of ground-dwelling arthropods is pitfall trapping (Barber, 1931) which has been utilized in various terrestrial ecosystems (e.g. Schmidt et al., 2006; Drapela et al., 2008; Zaller et al., 2009; Cheli and Corley, 2010; Schirmel et al., 2010; Matalin and Makarov, 2011; Frank et al., 2012; Hancock and Legg, 2012). This method is very attractive because it works when the observer is absent, it is very simple and inexpensive and it has been used in numerous studies (e.g. Prasifka et al., 2007; Cheli and Corley, 2010; Schirmel et al., 2010; Matalin and Makarov, 2011). However, pitfall traps are commonly filled with liquid preservatives that kill the collected animals (e.g. Schmidt et al., 2006;

Calixto et al., 2007; Santos et al., 2007; Jud and Schmidt-Entling, 2008; Cheli and Corley, 2010; Schirmel et al., 2010; Matalin and Makarov, 2011) or lead to unwanted small mammal by-catch (Lange et al., 2011), which often prohibits the use of this method in protected areas where endangered species might get caught by this method. Alternatively, pitfall traps containing water only or no preservative at all were used (e.g. Zaller et al., 2009); however, this requires regular checks as trapped animals could escape from the sampling containers. Either way, insertion of traps also causes soil disturbance.

Another often used method in biodiversity monitoring is quadrat sampling, which is a non-destructive method in which the observer collects all taxa in a given area (e.g. Andersen, 1995; Schoenly et al., 2003; Corti et al., 2013). Ideally, collected animals could be identified in the field and subsequently released. However, for truly reliable arthropod identifications, the collection of material and the use of microscopes for identification by specialists are often necessary. Another advantage with quadrat sampling data is that absolute densities for a given area can be calculated in contrast to relative or activity densities from pitfall trapping without an area relation.

A so far only rarely utilized non-destructive method for assessing the activity and diversity of ground-dwelling arthropods is video monitoring. Similar to the classical methods video cameras are used for field surveillance of arthropods in quadrats or along transects or sometimes both (Dicks et al., 2002; Olesen and Jordano, 2002; Hegland and Totland, 2005). The majority of studies using video monitoring focused on pollinators and observed a few focal plant and pollinator species (Manetas and Petropoulou, 2000). One study observed pollinators every 2 weeks over a period of 12 weeks (Kaiser-Bunbury et al., 2010); observation intervals varied in length from 5 min (Dupont et al., 2003) to 1 h (Ladd and Arroyo, 2009). Another study surveyed the activity of invertebrate pollinators during 1 entire day with small digital cameras available in many mobile devices (e.g. in digital music players or smartphones; Lortie et al., 2012).

The aim of the current study was to compare the efficiency and suitability of pitfall trapping, quadrat sampling and video monitoring for assessing the activity and diversity of arthropods in a protected grassland.

2 Material and Methods

The study plots were established in a semi-dry grassland within the biosphere reserve Wienerwald (www.bpww.at) in the village of Nussdorf (305 m a.s.l., 48°27′ E, 16°34′ N) at the northwestern border of the city of Vienna (Austria). The study area covered a transect of 5 m width and 20 m length which was divided into 100 1×1 m quadrats. Within this matrix, five replicate plots for each of the three sampling methods (pitfall trapping, quadrat sampling and video monitoring) were randomly assigned. Data for all three methods were collected at similar weather conditions (air temperatures above 15 °C, only slight wind) on 10, 11 and 24 May 2012. At each date all three methods were applied.

2.1 Pitfall trapping

Two pitfall traps (plastic cups: diameter 6.5 cm, depth 10 cm) were installed flush with the soil surface in the centre of each assigned plot in a distance of about 30 cm from each other. The pitfall traps were not filled with a preservative liquid to avoid potential killing of protected arthropod species. Each pitfall trap was covered with a metal shield 3 cm above the soil surface to protect collected arthropods from predators while allowing surface arthropods to pass. Traps were emptied after 4 h of diurnal exposure or after 13 h nocturnal exposure. Catches of the three sampling dates were pooled for data analysis and expressed on an hourly basis to account for differences in sampling periods.

2.2 Quadrat sampling

For the quadrat sampling a $50 \times 50 \times 30$ cm (width $\times$ length $\times$ height) metal frame was inserted 3 cm deep into the soil surface in each of the designated sampling plot. Within this area all flying arthropods were collected using an insect net, all ground-dwelling arthropods were collected using a pair of tweezers. This was done for at least 30 min until all visible arthropods of the area were collected.

2.3 Video monitoring

We used a digital video camera (HDV Panasonic HDC-SD 600, Panasonic Inc., Tokyo, Japan) mounted on a tripod about 67 cm above the soil surface to survey arthropod activity. The filmed area was 68×37 cm (2516 cm^2), similar to that used for quadrat sampling. In order to facilitate the observation of ground-dwelling arthropods by video monitoring the vegetation was cut 3 cm above the ground. Filming started 20 min after setting up the tripod to make sure that the insects show their natural behaviour. Every plot was filmed for 45 min. Afterwards, the video material was analyzed twice on a computer screen by counting and identifying all arthropods.

To examine whether arthropods avoided a pitfall trap or escaped due to the missing preservative liquid, five pitfall traps were surveyed with video cameras for 45 min each.

Arthropods collected with pitfall traps and by quadrat sampling were counted and identified in the field and immediately released back to the field thereafter.

2.4 Statistical analyses

All measured parameters were tested for normal distribution and variance homogeneity using the Kolmogorov–Smirnov test and Levene test respectively. The Gini–Simpson index of arthropod assemblages collected with different sampling

Table 1. Total numbers of recorded arthropod taxa for the four sampling methods across all sampling dates. UFO (undetermined flying organism) and UCO (undetermined crawling organism) are not identified individuals that were recorded only by video monitoring.

Taxa	Pitfall traps day sampling	Pitfall traps night sampling	Quadrat sampling	Video monitoring	Total	ANOVA results of sampling method
Hymenoptera	5	25	76	1617	1723	$P < 0.001$
Myrmica ants	0	0	20	131	151	
Other Formicidae	5	25	53	1483	1566	
Bees	0	0	2	0	2	
Wasps	0	0	1	3	4	
Diptera	1	0	16	128	145	$P < 0.001$
Flies	0	0	10	100	110	
Fruit flies	1	0	5	0	6	
Hover flies	0	0	1	28	29	
Arachnida	4	7	40	16	67	$P = 0.007$
Wolf spiders	1	3	6	0	10	
Crab spider	2	1	4	0	7	
Other spiders	1	3	5	16	25	
Acari	0	0	25	0	25	
Coleoptera	2	8	14	27	51	$P = 0.001$
Leaf beetles	0	2	3	0	5	
Weevils	0	4	4	0	8	
Ground beetles	0	0	3	0	3	
Chafers	1	0	0	0	1	
Lady beetles	0	0	1	1	2	
Scarab beetles	0	1	0	0	1	
Other beetles	1	1	3	26	31	
Hemiptera	0	0	43	2	45	$P < 0.001$
Aphids	0	0	9	2	11	
Bugs	0	0	7	0	7	
Cicadas	0	0	22	0	22	
Cockroaches	0	0	5	0	5	
Orthoptera	0	1	11	24	36	$P = 0.026$
Locusts	0	1	11	24	36	
Lepidoptera	0	1	2	2	5	$P = 0.545$
UFO/UCO	0	0	0	600/162	600/162	$P < 0.001$
Total individuals	12	43	202	2578	2835	$P < 0.001$

methods was calculated (Ricklefs and Schluter, 1993; Guiasu and Guiasu, 2012). The effect of sampling method on the number of collected arthropods, the relative proportion of taxa and the diversity index was assessed by one-way analyses of variances (ANOVA). Relations between the arthropod numbers from the different sampling methods were tested using Pearson correlations. All statistical analyses were performed using "R" (version 3.0.2; www.R-project.org; R Core Team, 2013). Values within the text are mean ±SD.

3 Results

We found a total of 24 different arthropod taxa belonging to the orders Hymenoptera, Diptera, Arachnida, Coleoptera, Hemiptera, Orthoptera, other (mainly Lepidoptera and Blattodea) and unknown flying and crawling organisms (UFOs and UCOs respectively; Table 1). Overall, Hymenoptera were the most abundant followed by Diptera and Coleoptera (Table 1). The sampling methods differed significantly ($P < 0.001$) in their sampling efficiencies with highest total cumulative arthropod numbers observed by video monitoring (2578 individuals) followed by quadrate sampling (202

Table 2. Number of arthropods individuals in the vicinity of pitfall traps observed by video monitoring, passing through and actually collected through pitfall traps. UFO is an undetermined flying organism and UCO is an undetermined crawling organism.

Taxa	Observed by video in vicinity of pitfall traps	Transit through pitfall trap	Actually trapped with pitfall trap
Hymenoptera	118	19	0
Coleoptera	1	0	0
Orthoptera	1	0	0
UFO	23	0	0
UCO	8	1	0
Total	151	20	0

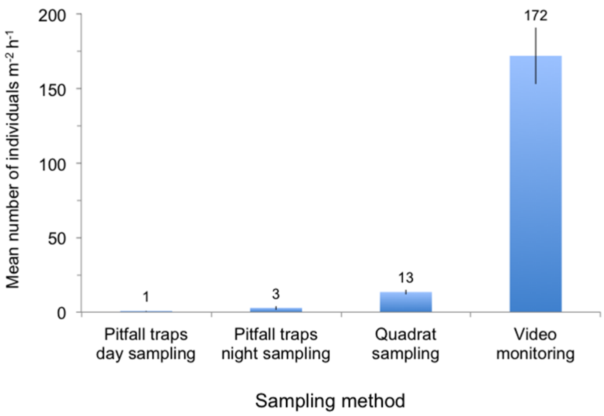

Figure 1. Total number of arthropods by pitfall traps exposed during the day, pitfall traps exposed during night, quadrat sampling and video monitoring. Mean ±SD pooled among measurement dates ($n = 5$). Note: for methodological reasons areal basis does not apply for pitfall trapping.

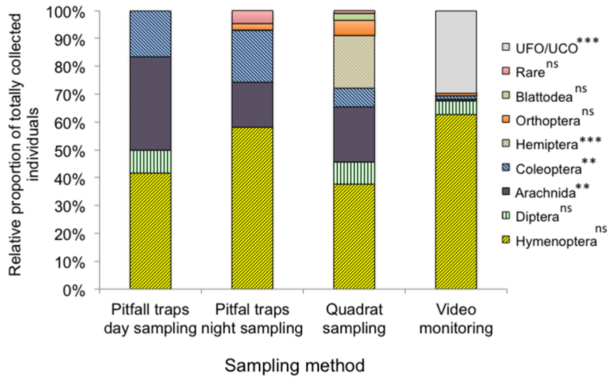

Figure 2. Proportion of arthropod taxa in the four tested monitoring methods. Means of three measurement dates ($n = 5$). Superscripts in the legend denote statistical differences between the sampling methods for each taxon: *** indicates $P < 0.001$; ** indicates $P < 0.05$; ns indicates $P > 0.05$.

individuals), nocturnal pitfall trapping (43 individuals) and diurnal pitfall trapping (12 individuals; Table 1). The same pattern was seen when data were expressed on an hourly basis (Fig. 1).

The diversity of arthropod assemblages collected with the different methods varied highly significantly from each other ($P < 0.001$). Arthropod assemblage collected with quadrat sampling was the most diverse (Gini–Simpson index, 0.70 ± 0.22, mean ±SD) followed by video monitoring (0.57 ± 0.15), diurnal pitfall sampling (0.35 ± 0.28) and nocturnal pitfall sampling (0.17 ± 0.24). Relative proportions of Hemiptera, UFOs and UCOs, Coleoptera and Arachnida differed significantly between sampling methods (Fig. 2). Relative proportions of rare taxa, Blattodea, Orthoptera, Diptera, and Hymenoptera were similar between sampling methods (Fig. 2). The most abundant animals recorded by all three methods were Formicidae; some taxa of Apoidea and Hemiptera were only observed by quadrat sampling (Table 1). Considering the time of pitfall trapping, Diptera were recorded only during diurnal sampling, whereas Orthoptera and a few other taxa (e.g. Chrysomelidae and Curculionidae) were only found during nocturnal pitfall trapping. Video monitoring captured a high number of Hymenoptera, mainly ants, while the other taxa such as spiders and beetles made up low proportions (Table 1). UFOs and UCOs observed by video monitoring made up to 30 % of the total counted individuals (Table 1, Fig. 2).

Video surveillance of pitfall traps showed that from a total of 151 arthropods crawling in the vicinity of the pitfall traps, 20 of them crawled through the trap but none were actually trapped (Table 2).

There were significant positive correlations between number of all taxa, Hymenoptera or Coleoptera observed with video monitoring and the numbers collected with nocturnal pitfall sampling (Table 3). For Coleoptera diurnal pitfall trapping correlated positively with nocturnal pitfall sampling (Table 3).

4 Discussion

Several studies compared the efficiency of methods assessing ground-dwelling arthropods (Andersen, 1995; Mesibov et al., 1995; Standen, 2000; Schmidt et al., 2006; Sabu et al., 2011; Corti et al., 2013). However, to our knowledge the

Table 3. Pearson correlation of number of individuals recorded with different methods.

Taxa		Sampling method Pitfall (day)	Pitfall (night)	Quadrat sampling
All taxa				
	Pitfall (day)	–	–	–
	Pitfall (night)	0.0919	–	–
	Quadrat sampling	−0.3462	0.1595	–
	Video monitoring	0.1066	0.688**	0.2783
Arachnida				
	Pitfall (day)	–	–	–
	Pitfall (night)	−0.1622	–	–
	Quadrat sampling	−0.2417	0.1249	–
	Video monitoring	−0.2764	−0.0982	−0.117
Coleoptera				
	Pitfall (day)	–	–	–
	Pitfall (night)	0.5617**	–	–
	Quadrat sampling	−0.16	0.2165	–
	Video monitoring	0.1995	0.5015*	0.3557
Hymenoptera				
	Pitfall (day)	–	–	–
	Pitfall (night)	−0.1152	–	–
	Quadrat sampling	−0.0434	−0.3123	–
	Video monitoring	−0.1559	0.7631***	−0.0806

* $P < 0.10$, ** $P < 0.05$, *** $P < 0.001$.

current study is among the first to compare video monitoring with more classical methods such as pitfall trapping or quadrat sampling.

We found great differences in the number and diversity of the recorded taxa among the tested sampling methods. Arthropod numbers recorded by video monitoring were 13 or 43 times higher than those gained with quadrat sampling or pitfall trapping respectively. The highest diversity of arthropod taxa, however, was recorded by quadrat sampling mainly due to the fact that almost 30 % of the arthropods on the videos could not be identified.

Our results corroborate earlier studies that methods for recording ground-dwelling arthropods are subject to multiple sources of bias due to behavioural and size differences among taxa and physical characteristics of the sampled habitats (Desender, 1985; Spence and Niemelä, 1994; Melbourne, 1999; Missa et al., 2009; Hancock and Legg, 2012). Moreover, variations in methods such as sizes of pitfall traps and quadrats showed different sampling efficiencies (Edwards, 1991; Standen, 2000; Work et al., 2002; Schmidt et al., 2006). Our data probably also reflect findings of others who found that the abundance of highly mobile invertebrates (e.g. Coleoptera, Arachnida) may be overestimated in pitfall traps due to higher catch probabilities (Topping and Sunderland, 1992) and underestimated in video monitoring or quadrat samples due to rapid movement out of or through the observation areas (Uetz and Unzicker, 1976). Laboratory experiments showed that species-specific behaviour was shown to bias results even between species of the same genus (e.g. the carabid beetle Poecilus; Mommertz et al., 1996). However, pitfall traps in comparison to quadrat sampling may underestimate the abundance of taxa that avoid traps (e.g. Hemiptera, Orthoptera; Halsall and Wratten, 1988; Corti et al., 2013), or pitfall traps in comparison to video monitoring may naturally underestimate flying arthropods. Video monitoring captured more taxa of Hymenoptera (mainly consisting of Formicidae) than the other methods. This is not surprising as the inefficacy of pitfall traps for sampling Formicidae is well known (Fisher, 1999), especially when pitfalls traps were without a preservation liquid as in our study. Although we did not explicitly measure body size of recorded arthropods in our study, there was no obvious relationship to the number of taxa recorded in different methods (Franke et al., 1988, Spence and Niemelä, 1994; Mommertz et al., 1996).

In an attempt to compare the advantages and disadvantages of the methods used in the current study, Table 4 was compiled. Pitfall trapping has one clear advantage over the spatially and temporarily limited quadrat sampling method: it enables collection of nocturnal and diurnal guilds of taxa. However, our video surveillance of pitfall traps also suggests that data from our pitfall trappings without preservation liquid have low sampling efficiency as 20 individuals actually crawled through the pitfall traps and were not caught. However, even when preservation liquid was used, studies found that male carabids could escape if they were not rapidly killed by formalin (Waage, 1985). As shown by specific studies, the type of fluid in the trap is very important, because it

Table 4. Advantages and disadvantages of using pitfall trap and quadrat samples to collect terrestrial invertebrates in dry riverbeds.

Method	Advantage	Disadvantage
Pitfall trapping	– Cheap equipment – Continuous sampling (days and nights) – Rigorous taxonomic identification is possible – Collected specimens are conserved for later identification – No disturbance of animals through observer presence	– Bias in favour of fast-moving, ground-dwelling taxa – Several visits are required to install and retrieve the pitfall traps – Measure of relative density (activity density, no area relation) – When preservation liquid is used, animals are killed (problem in conservation areas)
Quadrat sampling	– Cheap equipment – Measure of absolute density (area-based) – Ground-dwelling and flying taxa can be monitored – Potentially non-destructive	– Bias in favour of slow-moving taxa – Collect only taxa that are present at the sampling time – Coarse taxonomic identification level (morphospecies) – Disturbance of animals by observer presence – Dense vegetation affects observation of animals
Video monitoring	– Measure of absolute density (area-based) – Filmed specimens are conserved for later identification – Ground-dwelling and flying taxa can be monitored – Potentially non-destructive	– Potentially expensive equipment – Bias in favour of slow-moving taxa – Coarse taxonomic identification level (morphospecies) – Dense vegetation affects observation of animals – Double counts of animals possible

should be effective enough to paralyze and thus decrease the escape ability of arthropods (Schmidt et al., 2006; Jud and Schmidt-Entling, 2008; Hancock and Legg, 2012). Another advantage of pitfall trapping is that long periods (up to several weeks) can be sampled allowing for a better inventory of the arthropod assemblages since different species might be active at different times. In contrast, quadrat sampling and video monitoring record species that are active at a short time period only.

We found that none of the 151 arthropod individuals we observed in the vicinity of pitfall traps through video monitoring were actually trapped. This suggests that pitfall traps without a preservative liquid which are exposed for couple of hours only are not suitable for monitoring biodiversity of surface-dwelling arthropods in a given area. However, the use of deeper pitfall traps, using non-liquid lubricants on the inner sides of the trap or using funnels and a collection jar at the bottom, might yield better results than the type of traps used in the current study. Using these more sophisticated pitfall traps without preservative might then be more advisable in conservation areas in order to avoid potential killing endangered species through commonly used liquid preservatives (e.g. Schmidt et al., 2006; Calixto et al., 2007; Santos et al., 2007; Jud and Schmidt-Entling, 2008; Cheli and Corley, 2010; Schirmel et al., 2010; Matalin and Makarov, 2011). It has to be noted that due to the relatively short catching period in our study, slow-moving arthropods may be underrepresented (Topping and Sunderland, 1995). The accuracy with which the taxonomic richness and composition of terrestrial invertebrate assemblages are estimated by pitfall traps and quadrats have been previously compared in a range of habitats (Uetz and Unzicker, 1976; Andersen, 1995; Sabu et al., 2011; Tista and Fiedler, 2011; Corti et al., 2013).

An advantage of quadrate sampling over pitfall trapping is that also flying arthropods can be assessed. Considering that little equipment is needed and there is little time to spend performing arthropod assessments with quadrate sampling, it seems to be a valid method for getting a snapshot impression of the arthropod activity and diversity in protected areas. Although we found by far the highest arthropod numbers with video monitoring, it has to be noted that analyzing the memory card was time consuming, as the records had to be watched several times in order to properly count and identify the filmed arthropods (Table 4). A great advantage of video monitoring is also that the film material is conserved, can be repetitively watched at different speeds (e.g. slow motion) in order to identify fast-moving individuals and gives a real impression of actual arthropod activity. Moreover, movies could also be shown to specialists for clarifying species identification. It has to be considered, however, that high vegetation ideally needs to be removed in order to be able to film the arthropods crawling on the soil surface. Removing of vegetation might, however, also influence the results as shelter for arthropods has been removed and different volumes in which arthropods might live were compared. Recent developments in digital video techniques allow sampling of data on flower-visiting bumblebees (Steen and Thorsdatter Orvedal Aase, 2011), assessing the diversity and abundance of insect pollinators or observing their responses to predatory spiders (Lortie et al., 2012). Even when small mobile cameras (Apple iPod nanos with 2.1 megapixel) were used to observe invertebrate pollinators and associated plant species, subsequent analysis of the video material provided the means to identify taxonomic units and often species (Lortie et al., 2012). When a video system is equipped with motion detection storage memory for the video can be saved as demonstrated for monitoring bumblebees (Steen and Thorsdatter Orvedal Aase, 2011).

Although the rate of indeterminable arthropods (UFOs and UCOs) was relatively high, the number of determinable individuals, at least to genus, was comparable or even higher than results of pitfall traps or quadrate sampling in total. However, this also reflects the skills of the investigator in the field and the possibility to reiterate identification on video tapes. Thus, we assume that video monitoring is an appropriate method for recording arthropod activity and biodiversity in grasslands, especially in protected area where destructive methods are prohibited. However, to improve identification at lower taxonomic levels necessary for biodiversity assessments a combination with a further method like quadrate sampling seems to be advisable. When cost and time constraints dictate limiting of ground-dwelling arthropod sampling to one method, the video monitoring is ideal for quantitative estimation and the quadrat sampling is ideal for qualitative estimates in grasslands. Moreover, both video monitoring and quadrat sampling enable the calculation of real density per area, whereas the relative density or activity density from pitfall data have no direct relationship to land surface area.

Of course differences in the capture of taxa between the methods should be interpreted with caution as low frequency of occurrence and abundance, and the relatively short observation period can affect collection efficiencies. Among the three methods, video monitoring was most efficient for exhaustive quantitative data and quadrat sampling was most efficient for qualitative data of the diversity of ground-dwelling arthropods in our grassland. The finding that abundances of nearly all taxa were significantly different between the collection/observation methods suggests that more than one method should be combined in order to get a proper indication of the arthropod fauna of a grassland. Also, methods could also be selected depending on the specific group of arthropods the research is focused on. Based on our findings we suggest a combination of video monitoring either with pitfall trapping or quadrat sampling. However, clearly more in-depth investigations in various ecosystems should be made to be able to make suggestions for possible inclusion of video monitoring in biodiversity monitoring assessments. Especially for biodiversity monitoring assessments with restricted budgets this appears to be an important finding. One could also envisage including public participation using a citizen science approach in biodiversity assessments in which participants film grassland plots with video cameras/smart phones and leave the film document for entomologists to analyze (e.g. Cooper et al., 2012; Oberhauser, 2012). With decreasing prices for high-resolution digital camera systems this method may potentially become more important for non-destructive surveillance of a wide variety of animals (O'Connell et al., 2011).

Based on the current results we suggest that video monitoring should more often be combined with classical methods such as pitfall trapping or quadrat sampling. Although identification at the species level will not always be possible by video monitoring in many cases a rapid biodiversity assessment at the level of parataxonomic units (i.e. morphospecies) or activity has been shown to be an appropriate and sufficient measure (Obrist and Duelli, 2010).

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References

Andersen, J.: A comparison of pitfall trapping and quadrat sampling of Carabidae (Coleoptera) on river banks, Entomol. Fennica, 6, 65–77, 1995.

Barber, H. S.: Traps for cave-inhabiting insects, J. Elisha Mitch. Sci. S., 46, 259–266, 1931.

Calixto, A. A., Harris, M. K., and Dean, A.: Sampling ants with pitfall traps using either propylene glycol or water as a preservative, Southwest. Entomol., 32, 87–91, 2007.

Cheli, G. H. and Corley, J. C.: Efficient sampling of ground-dwelling arthropods using pitfall traps in arid steppes, Neotrop. Entomol., 39, 912–917, 2010.

Cooper, C. B., Hochachka, W. M., and Dhondt, A. A.: The opportunties and challenges of citizen science as a tool for ecological research, in: Citizen Science. Public Participation in Environmental Research, edited by: Dickinson, J. L., and Bonney, R., Cornell University Press, Ithaca, New York, USA, 99–113, 2012.

Corti, R., Larned, S. T., and Datry, T.: A comparison of pitfall-trap and quadrat methods for sampling ground-dwelling invertebrates in dry riverbeds, Hydrobiologia, 717, 13–26, doi:10.1007/s10750-013-1563-0, 2013.

Desender, K. R.: A simple device and technique for quantitative sampling of riparian beetle populations with some Carabid and Staphylinid abundance estimates on different riparian habitats (Coleoptera), Rev. Ecol. Biol. Sol., 22, 497–506, 1985.

Dicks, L. V., Corbet, S. A., and Pywell, R. F.: Compartmentalization in plant-insect flower visitor webs, J. Anim. Ecol., 71, 32–43, 2002.

Drapela, T., Moser, D., Zaller, J. G., and Frank, T.: Spider assemblages in winter oilseed rape affected by landscape and site factors, Ecography, 31, 254–262, 2008.

Dupont, Y. L., Hansen, D. M., and Olensen, J. M.: Structure of a plant-pollinator network in the high altitude sub-alpine desert of Tenerife, Canary Islands, Ecography, 26, 301–310, 2003.

Edwards, C. A.: The assessment of popula soil inhabiting invertebrates, Agr. Ecosyst. Environ., 34, 145–176, 1991.

Fisher, B. L.: Improving inventory efficiency: a case study of leaf-litter ant diversity in Madagascar, Ecol. Appl., 9, 714–731, 1999.

Frank, T., Aeschbacher, S., and Zaller, J. G.: Habitat age affects beetle diversity in wildflower areas, Agr. Ecosyst. Environ., 152, 21–26, 2012.

Franke, U., Friebe, B., and Beck, L.: Methodisches zur Ermittlung der Siedlungsdichte von Bodentieren aus Quadratproben und Barberfallen, Pedobiologia, 32, 253–264, 1988.

Guiasu, R. C. and Guiasu, S.: The weighted gini-simpson index: revitalizing an old index of biodiversity, Int. J. Ecol., 2012, 478728, 10 pp., doi:10.1155/2012/478728, 2012.

Halsall, N. B. and Wratten, S. D.: The efficiency of pitfall trapping for polyphagous predatory Carabidae, Ecol. Entomol., 13, 293–299, 1988.

Hancock, M. H. and Legg, C. J.: Pitfall trapping bias and arthropod body mass, Insect Conserv. Diver, 5, 312–318, 2012.

Hegland, S. J., and Totland, O.: Relationships between species' floral traits and pollinator visitation in a temperate grassland, Oecologia, 145, 586–594, 2005.

Jud, P. and Schmidt-Entling, M. H.: Fluid type, dilution, and bitter agent influence spider preservation in pitfall traps, Entomol. Exp. Appl., 129, 356–359, 2008.

Kaiser-Bunbury, C. N., Muff, S., Memmott, J., Müller, C. B., and Caflisch, A.: The robustness of pollination networks to the loss of species and interactions a quantitative approach incorporating pollinator behaviour, Ecol. Lett., 13, 442–452, 2010.

Ladd, P. G. and Arroyo, M. T.: Comparisons of breeding systems between two sympatric species, Nastanthus spathulatus (*Calyceraceae*) and Rhodophiala rhodolirion (*Amaryllidaceae*), in the high Andes of central Chile, Plant Spec. Biol., 24, 2–10, 2009.

Lange, M., Gossner, M. M., and Weisser, W. W.: Effect of pitfall trap type and diameter on vertebrate by-catches and ground beetle (Coleoptera: Carabidae) and spider (Araneae) sampling, Methods Ecol. Evol., 2, 185–190, 2011.

Lortie, C. J., Budden, A. E., and Reid, A. M.: From birds to bees: applying video obseration techniyues to invertebrate pollinators, J. Pollin. Ecol., 6, 125–128, 2012.

Manetas, Y. and Petropoulou, Y.: Nectar amount, pollinator visit duration and pollination success in the mediterranean shrub Cistus creticus, Ann. Bot.-London, 86, 815–820, 2000.

Matalin, A. V. and Makarov, K. V.: Using demographic data to better interpret pitfall trap catches, Zookeys, 100, 223–254, 2011.

Melbourne, B. A.: Bias in the effect of habitat structure on pitfall traps: an experimental evaluation, Aust. J. Ecol., 24, 228–239, 1999.

Mesibov, R., Taylor, R. J., and Brereton, R. N.: Relative efficiency of pitfall trapping and hand-collecting from plots for sampling of millipedes, Biodivers. Conserv., 4, 429–439, 1995.

Missa, O., Basset, Y., Alonso, A., Miller, S. E., Curletti, G., Meyer, M. D., Eardley, C., Mansell, M. W., and Wagner, T.: Monitoring arthropods in a tropical landscape: relative effects of sampling methods and habitat types on trap catches, J. Insect Conserv., 13, 103–118, 2009.

Mommertz, S., Schauer, C., Kösters, N., Lang, A., and Filser, J.: A comparison of D-Vac suction, fenced and unfenced pitfall traps sampling of epigeal arthropods in agroecosystems, Ann. Zool. Fenn., 33, 117–124, 1996.

Oberhauser, K.: Monitoring monarchs: citizen science and a charismatic insect, in: Citizen Science. Public Participation in Environmental Research, edited by: Dickinson, J. L. and Bonney, R., Cornell University Press, Ithaca, New York, USA, 35–42, 2012.

Obrist, M. K. and Duelli, P.: Rapid biodiversity assessment of arthropods for monitoring average local species richness and related ecosystem services, Biodivers. Conserv., 19, 2201–2220, 2010.

O'Connell, A. F., Nichols, J. D., and Karanth, K. U.: Camera Traps in Animal Ecology, Methods and Analyses, Springer, Tokyo, Japan, 271 pp., 2011.

Olesen, J. M. and Jordano, P.: Geographic patterns in plant-pollinator mutualistic networks, Ecology, 83, 2416–2424, 2002.

Prasifka, J. R., Lopez, M. D., Hellmich, R. L., Lewis, L. C., and Dively, G. P.: Comparison of pitfall traps and litter bags for sampling ground-dwelling arthropods, J. Appl. Entomol., 131, 115–120, 2007.

R Core Team: R: A language and environment for statistical computing, R Foundation for Statistical Computing, Vienna, Austria, http://www.R-project.org/ (last access: May 2015), 2013.

Ricklefs, R. E. and Schluter, D.: Species diversity in ecological communities, Chicago University Press, Chicago, USA, 1993.

Sabu, T. K., Shiju, R. T., Vinod, K., and Nithya, S.: A comparison of the pitfall trap, Winkler extractor and Berlese funnel for sampling ground-dwelling arthropods in tropical montane cloud forests, J. Insect Sci., 11, 1–19, doi:10.1673/031.011.0128, 2011.

Santos, S. A. P., Cabanas J. E., and Pereira, J. A.: Abundance and diversity of soil arthropods in olive grove ecosystem (Portugal): Effect of pitfall trap type, Euro. J. Soil Biol., 43, 77–83, 2007.

Schirmel, J., Lenze, S., Katzmann, D., and S., B.: Capture efficiency of pitfall traps is highly affected by sampling interval, Entomol. Exp. Appl., 136, 206–210, 2010.

Schmidt, M. H., Clough, Y., Schulz, W., Westphalen, A., and Tscharntke, T.: Capture efficiency and preservation attributes of different fluids in pitfall traps, J. Arachnol., 34, 159–162, 2006.

Schoenly, K. G., Domingo, I. T., and Barrion, A. T.: Determining optimal quadrat sizes for invertebrate communities in agrobiodiversity studies: A case study from tropical irrigated rice, Environ. Entomol., 32, 929–938, 2003.

Spence, J. R. and Niemelä, J. K.: Sampling carabid assemblages with pitfall traps: the madness and the method, Can. Entomol., 126, 881–894, 1994.

Standen, V.: The adequacy of collecting techniques for estimating species richness of grassland invertebrates, J. Appl. Ecol., 37, 884–893, 2000.

Steen, R. and Thorsdatter Orvedal Aase, A. L.: Portable digital video surveillance system for monitoring flower-visiting bumblebees, J. Pollin. Ecol., 5, 90–94, 2011.

Tista, M. and Fiedler, K.: How to evaluate and reduce sampling effort for ants, J. Insect Conserv., 15, 547–559, 2011.

Topping, C. J. and Sunderland, K. D.: Limitations to the use of pitfall traps in ecological studies exemplified by a study of spiders in a field of winter wheat, J. Appl. Ecol., 29, 485–491, 1992.

Topping, C. J. and Sunderland, K. D.: Methods for monitoring aerial dispersal by spiders, in: Arthropod natural enemies in arable land, edited by: Toft, S. and Riedel, W., Aarhus University Press, Aarhus, Denmark, 245–256, 1995.

Uetz, G. W. and Unzicker, J. D.: Pitfall trapping in ecological studies of wandering spiders, J. Arachnol., 3, 101–111, 1976.

Waage, B. E.: Trapping efficiency of carabid beetles in glass and plastic pitfall traps containing different solutions, Fauna Norv. Ser. B., 32, 33–36, 1985.

Work, T. T., Buddle, C. M., Korinus, L. M., and Spence, J. R.: Pitfall trap size and capture of three taxa of litter-dwelling arthropods: implications for biodiversity studies, Environ. Entomol., 31, 438–448, doi:10.1603/0046-225X-31.3.438, 2002.

Zaller, J., Moser, D., Drapela, T., and Frank, T.: Ground-dwelling predators can affect within-field pest insect emergence in winter oilseed rape fields, Biocontrol, 54, 247–253, doi:10.1007/s10526-008-9167-8, 2009.