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Effect of the colour of pitfall traps on their capture efficiency of carabid beetles (Coleoptera: Carabidae), spiders (Araneae) and other arthropods

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Abstract. Pitfall trapping is one of the most commonly used methods of sampling ground-dwelling arthropods. There are many studies on the effect of design of pitfall traps on their capture efficiency but, so far, none on the influence of the colour of the pitfall trap. In this study the abundances of seven invertebrate groups (Apidae, Araneae, Carabidae, Diptera, Formicidae, Isopoda, Vespinae) caught in pitfall traps of different colours (white, yellow, green, brown) at a dense and dry grassland site in Northwestern Germany were determined. White and yellow pitfall traps caught by far the highest numbers of individuals of Apidae, Araneae, Carabidae, Diptera and Formicidae. Isopoda were most abundant in the catches of green and brown traps. Differences among numbers caught were significant for Apidae, Araneae, Carabidae and Diptera. The effect of colour on the catches did not differ significantly between sites. Knowledge of the variation in the catching efficiency of differently coloured pitfall traps is important for designing invertebrate surveys, both from a scientific and ethical point of view.

INTRODUCTION

Pitfall traps, first described by Barber (1931), are a very frequently used for sampling in terrestrial ecology (New, 1998). Despite criticisms (e.g. Bombosch, 1962; Halsall & Wratten, 1988; Lang, 2000; Topping & Sunderland, 1992; Topping, 1993), pitfall traps are suitable for studying the occurrence and relative abundance of ground-dwelling arthropods such as carabid beetles (Coleoptera: Carabidae) and spiders (Araneae) (Adis, 1979; Luff, 1975; Müller, 1984; Tretzel, 1955; Uetz & Unzicker, 1976). Generally, pitfall traps consist of containers that are embedded flush with the ground surface and filled with a liquid that both preserves and kills any animals falling into the traps (Balogh, 1958; Barber, 1931; Grell, 1997). This self-sampling method is time-efficient, easy to use, inexpensive and results in catches rich in both species and individuals (Spence & Niemelä, 1994).

In many studies the effect of different pitfall designs (e.g. size, diameter, fluid type, spacing, trap type) on the capture efficiency has been analysed (Borgelt & New, 2005; Brennan et al., 1999; Buchholz & Hannig, 2009; Curtis, 1980; Digweed et al., 1995; Jud & Schmidt-Entling, 2008; Pekár, 2002; Santos et al., 2007; Schmidt et al., 2006; Waage, 1985; Ward et al., 2001). However, the effect of pitfall trap colour on the efficiency with which invertebrates are caught by these traps has not been studied. In some studies plastic cups (often white coloured) were used (e.g. Finch et al., 2007; Sroka & Finch, 2006) in others glass jars (transparent) (e.g. Lövei et al., 2006; Magura et al., 2001; Negro et al., 2009; Sadler et al., 2006). The colour of a pitfall trap could be important in the context of species protection, animal welfare and ethical considerations in science, as it is important to reduce unintentional by-catches (Putman, 1995; New, 1999). Pitfall traps are a non-selective sampling method and normally catch many different organisms (sometimes in high numbers). When white coloured traps (e.g. many kinds of plastic jars) are used mainly flower-seeking Diptera (e.g. Syrphidae) and Hymenoptera (e.g. bees), which are attracted to bright, striking colours (Kirk, 1984; Kratochwil, 1984; Ssymank, 1991), are caught. Often, these by-caught organisms are not the subject of the study and are not determined or the data can not be analysed statistically because of the unsuitability of pitfall trapping as a sampling method for these species (Bombosch, 1962; Buchholz et al., 2008). A knowledge of how the design of a pitfall trap affects its catching efficiency and the species composition of the invertebrates it catches is important not only from a scientific but also from an ethical point of view (cf. New, 1999; Ward et al., 2001). The aim of this study is to compare the capture efficiency of arthropods of differently coloured traps. We used the inconspicuous and earthy colours brown and green and attractive colours white and yellow to investigate possible differences. The following research questions were addressed: (i) Do different coloured pitfall traps differ in their capture efficiency? Which arthropods are affected? (ii) Can the right choice of colour reduce the incidence of by-catches when pitfall traps are used for studying ground-dwelling arthropods (mainly carabid beetles and spiders)?

MATERIAL AND METHODS

Study area and sampling design

This study was performed near the city of Münster (51°57′46.6″N, 7°37′43.3″E) North Rhine-Westphalia Germany. The climate in this region is sub-oceanic with mean annual temperature of 7.9°C and annual precipitation of 758 mm (MURL, the Ministry for the Environment, Spatial Planning and Agriculture of NRW, 1989). Two sites with homogeneous vegetation structure were selected: a sparsely vegetated dry grassland (Corynephoretum; coverage of herbaceous plants [CH] = 20%, height of herbaceous plants [HH] = 15 cm) and a densely vegetated grassland site (Lolio-Cynosuretum; CH = 100%, HH = 50–60 cm).

At the two sites a total of 60 coloured pitfall traps (plastic jar, diameter = 9 cm, height = 12 cm) filled with a 3% formalin solution and detergent were set. Traps were either brown, green,

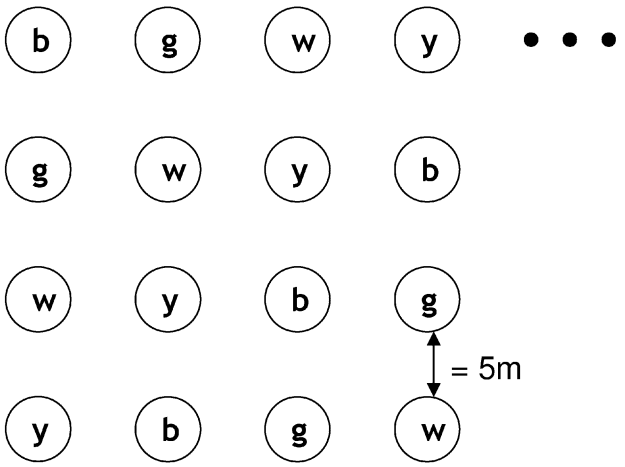

Fig. 1. Arrangement of the differently coloured pitfall traps at the dry grassland site (16 traps, 4 rows and 4 columns) and grassland site (44 traps, 11 rows and 4 columns). b – brown, g – green, w – white and y – yellow.

white or yellow and arranged in a grid in rotational order (distance between traps = 5 m). At the dry grassland site 16 pitfall traps (4 traps per colour) were set and at the densely vegetated grassland site 44 (11 traps per colour) (Fig. 1). These traps were used to catch arthropods from 24 April to 6 June 2009 and emptied fortnightly.

Analysis

After each emptying, arthropods were sorted and preserved in ethyl alcohol. Arthropods were determined as Araneae, Carabidae, Diptera, Formicidae, Apidae, Vespinae and Isopoda. For the analysis the numbers of individuals caught were used. To assess whether there were significant differences in capture efficiency between the four pitfall colours (explaining variables: brown, green, white, yellow) we used generalized linear models (GLM) and included "site" (dry grassland, grassland) as a second predictor. All statistics were performed in R 2.9.0.

RESULTS

Altogether, pitfall trapping yielded 6,436 Araneae, 1,122 Carabidae, 603 Diptera, 3,689 Formicidae, 50 Apidae, 92 Vespinae and 5,069 Isopoda (overall catch = 17,061).

Overall catches decreased from white > yellow > green > brown, however, differences were not significant ($P = 0.10$; Table 1). Differences among numbers caught were significant for Apidae ($P < 0.001$), Araneae ($P < 0.001$), Carabidae ($P < 0.01$) and Diptera ($P < 0.001$). More of these taxa were caught in white traps followed by yellow traps.

There were no significant differences in the numbers of Formicidae ($P = 0.08$), Isopoda ($P = 0.20$) and Vespinae ($P = 0.61$) caught by the different coloured traps. The effect of colour on the catches did not differ significantly between sites.

DISCUSSION

Our results indicate that in open grassland habitats the most common arthropods of conservation interest that are caught by pitfall traps, carabid beetles and spiders (e.g. Kratochwil & Schwabe, 2001; Lambeets et al., 2008, 2009; Negro et al., 2009), were most frequently caught in white and yellow coloured traps. Thus, carabid beetles and spiders in open habitats seem to be attracted by bright colours, maybe due to the sharp contrast between the trap and surrounding vegetation/ground and between the trap and possible prey (shown for Cicindelidae by Faasch, 1968; Gebert, 1991). This accords with both Van der Drift's (1951) observation that the carabid *Notiophilus* is a visual hunter and Foelix's (1992) that hunting spiders like the Thomisidae, Salticidae and Lycosidae have a well developed ability to see, which may allow these species to perceive colours or contrasts in colour.

As expected, the catches of winged arthropods such as Diptera and Apidae were greater in white and yellow traps, which are common flower colours (cf. Kirk, 1984; Mühlenberg, 1993). In contrast the catches of Vespinae were not affected by trap colour. Species of this taxon are not typical pollinators and therefore less likely to be attracted by flower colours. Similarly the colour of the pitfall traps did not affect the catches of Isopoda. The high catch of Isopoda in the dark coloured traps can be explained by the fact that most woodlice seek dark shelters in order to avoid light and dry sites (Abbott, 1918; Sutton, 1980; Sutton & Holdich, 1984). The Formicidae also showed no clear response to the pitfall colour: the clustered occurrence of ants near their nests and roads might have had a strong affect on the numbers caught by the traps (Laeger & Schultz, 2005; Seifert, 1990). In this context, one has to keep in mind the general problems associated with using pitfall traps as census method for ants (cf. Agosti et al., 2000; Majer, 1997; Schlick-Steiner et al., 2006; Steiner et al., 2005).

In conclusion, if the objective is to increase the capture efficiency of carabid beetles and spiders then the use of white coloured pitfall traps is recommended. In most studies large numbers of individuals result in higher levels of precision and completeness of species inventories (e.g. Brose, 2002; Brose et al., 2003; Cardoso et al., 2008; Perner, 2003; Shen et al., 2003). Nevertheless, when using white (or yellow) pitfall traps coleopterologists and arachnologists should be aware that it is inevitable that there will be large numbers of by-catches of most taxa (e.g. Apidae, Diptera). Hence, when utilizing such traps it is strongly recommended that all the by-catches are analysed as

TABLE 1. Standardized individual numbers (mean individuals per day ± SD) caught in the different coloured pitfall traps (per colour n = 15).

	Pitfall trap colour				F_{colour}	F_{site}	$F_{colour \times site}$
	brown	green	white	yellow			
Overall catch	217.3 ± 43.5	266.1 ± 47.9	328.5 ± 45.6	307.6 ± 59.1	2.20	72.97**	0.50
Apidae	0.3 ± 0.2	0.3 ± 0.2	2.0 ± 0.9	0.5 ± 0.3	12.85***	122.42***	1.10
Araneae	68.1 ± 9.9	86.4 ± 11.8	155.8 ± 22.8	113.7 ± 16.6	20.13	159.24***	0.22
Carabidae	15.5 ± 2.1	14.7 ± 2.6	26.8 ± 4.5	17.0 ± 3.3	4.22**	2.86***	0.68
Diptera	7.6 ± 1.5	6.0 ± 1.2	14.3 ± 1.5	8.9 ± 1.1	7.33***	2.65	2.35
Formicidae	36.1 ± 9.2	43.1 ± 12.3	68.3 ± 22.6	93.7 ± 33.3	2.35	12.66***	0.29
Isopoda	88.5 ± 31.3	114.6 ± 30.3	59.6 ± 13.5	72.6 ± 20.2	1.6	37.90***	0.01
Vespinae	1.2 ± 0.5	0.9 ± 0.2	1.8 ± 0.9	1.1 ± 0.4	0.62	0.24	2.59

suggested by Buchholz et al. (2008), for example, by exchanging the by-catches with other experts.

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