Trapping efficiency of funnel- and cup-traps for epigeal arthropods

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Trapping efficiency of funnel- and cup-traps for epigeal arthropods

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Catches of six different groups of arthropods, collected in four habitat types, were analysed for the efficiency of two types of pitfall traps: plastic cups and plastic funnels. An ANOVA indicates influences of trap type, habitat and systematic group (spiders stand out) on capture success (Tab. 2). Correlation analysis of numbers captured per cm trap diameter shows significant dependence of catches in cup and funnel traps. A regression analysis confirms linear correlation of the number of specimens caught in cup and funnel traps (Tabs. 3+4, Fig. 2). The Linyphiidae (spiders) and the Formicidae differ significantly from all other investigated groups in the slopes of their regression lines. Both trap types catch these two groups about equally efficiently. However, all other groups (including lycosid spiders) are caught 2–3 times more efficiently per cm trap diameter with funnel traps. Potential reasons for the differential capture success of the two trap-types are discussed. We recommend funnel traps for the collection of epigeal arthropods.

Keywords: pitfall traps, efficiency, epigeal arthropods

INTRODUCTION

Pitfall traps of varying designs are commonly used to catch epigeal arthropods (SOUTHWOOD, 1978). The trapping efficiency for different species depends on a variety of parameters (ADIS, 1979), which complicates the comparison of data presented by different authors (TOPPING & SUNDERLAND, 1992). The initiative for this study evolved from a dispute between two experts: Our specialist for Araneae was convinced that cup traps of 7 cm diameter would catch better and more representatively than our funnel traps with 15 cm diameter. Our expert on Coleoptera defended the opposite idea. As the results show, both have some justification for their opinion.

If we assume random movements of arthropods on a surface, then the probability of an animal to make contact with the border of a circular trap is a linear function of the trap's diameter, but a multitude of further parameters influence the efficiency of pitfall traps (LUFF, 1975; ADIS, 1979). LUFF (1975) investigated several of these effects experimentally and found only partial correspondence between the expected linear relationship of trap diameter and trap efficiency. This, and our expert's controversial opinions, motivated us to test the efficiency of the two types of pitfall traps, which differ mainly in diameter and angle of the container walls. We predicted that the number of individuals caught per cm diameter of a cup trap (N/cmCTø) would correlate linearly with the number of individuals caught per cm diameter of a funnel trap (N/cmFTø).

MATERIAL AND METHODS

We analysed data from a large investigation on the dispersal of insects and spiders (DUELLI *et al.*, 1992; DUELLI & OBRIST, 1995). The field work was conducted between the 26.3.1987 and 22.10.1987 in the Limpach-valley, an elongated plain bordered by two hill-ranges in the Swiss central plateau. The traps were set along a 5 km long transect extending from a wetland area (Wengimoos, canton of Bern) through heavily cultivated agricultural areas (pasture, winterweat and maize) to a semi-arid meadow (Balm, canton of Solothurn). The wetland area had earlier been used to make peat. It now consisted of open water, reed beds, litter meadows, tall-sedge swamps and brushy areas. The semi-arid area was a meadow with south-east exposition on a slope bordering a mixed forest. The pastures had been used as such for several years and the wheat and maize fields had also been cultivated with similar crops (potatoes, sugar beets, barley, wheat or maize) in previous years. After the wheat harvest (last capture date 23.7.87) the traps from the wheat fields were moved to an adjacent maize field. As both crops included intensive treatement of the soil, the data were pooled for the analysis under one category: «heavily cultivated agricultural areas». It thus allowed us to compare data collected in natural areas with those collected in agricultural areas on an identical seasonal time-frame. Two types of ground traps were used; In 21 locations, spread in four biotope types, we set funnel traps (FT) and cup traps (CT; Fig. 1). In 16 trap positions we set two funnel traps and one cup trap. In the semi-arid area we used two traps of each type, in the wetland we used 4 cup- and 6 funnel-traps, summing up to a total of 40 FT and 22 CT. The distance between traps was always more than 10 m. Both traps were made of plastic. The cup trap had an outer diameter of 68 mm and a depth of 70 mm, while the funnel trap measured 153 mm in diameter and 110 mm in depth. The two traps therefore differed not only in diameter but also in the slope of the trap-border, which amounted to 89° in the cup traps and 46° in the funnel traps. A 0.75 liter bottle was screwed to the funnel as a holding container. To improve handling, the whole capture device was hung from a 5 mm rim into a PVC-tube, which was sunk into the

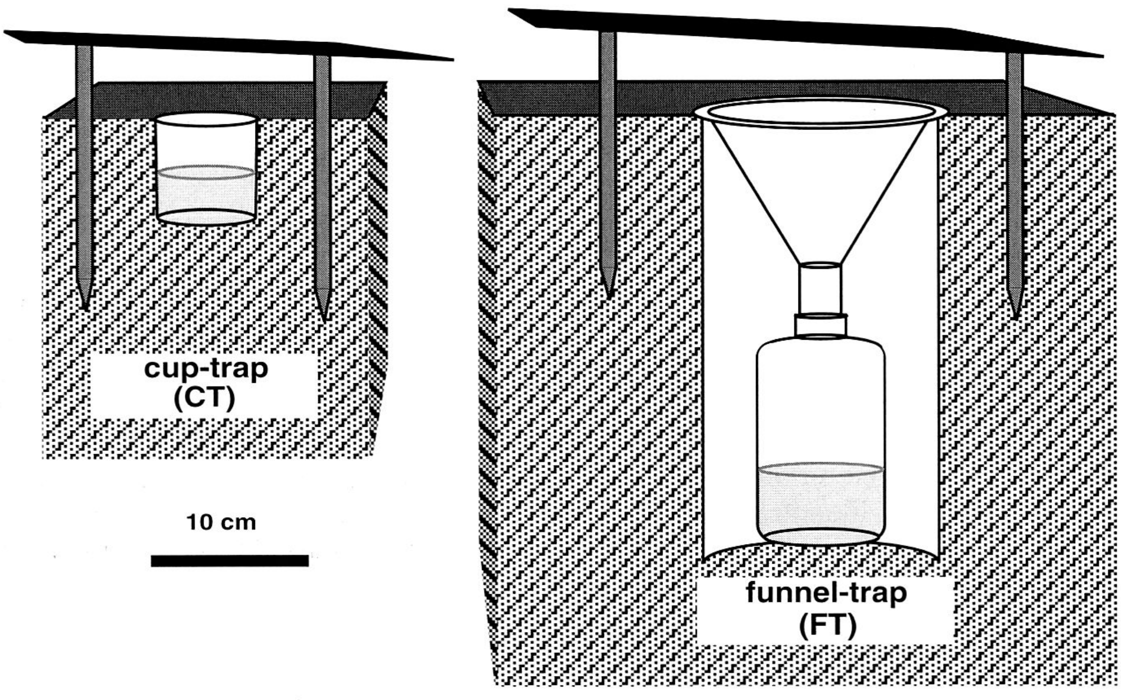

Fig. 1. – Construction of the two trap setups: The cup traps were sunk directly into the soil. To improve handling, the funnel traps where fit into a PVC-tube sunk previously into the soil.

soil with its end flush with the surface. A wire mesh (1.5 cm opening) inserted in the funnel-end prevented the capture of small mammals and amphibians. A transparent roof of 30x30 cm, set on woody-poles 10 cm above the traps provided protection from the rain. The cup trap was sunk directly into the soil and covered with a grey PVC-roof (30x30 cm). Both trap types were filled to ⅓ with a conserving mixture of 2 % formaldehyde, water and soap to decrease the surface tension. The weekly sampling of the catches included cleaning of the devices and careful levelling of the immediate surrounding of the trap-rims.

Data Desk-software (Data Description Inc., Ithaca, NY, U.S.A.) was used to perform statistical tests. We tested for the effects of habitat types, trap types and arthropod groups on the trapping efficiency in terms of number of species and number of individuals with an analysis of variance (ANOVA). Correlation- and regression analyses were performed to investigate dependencies of numbers of individuals caught in cup- or funnel traps.

RESULTS

The results presented here include data from 114’031 animals comprising 439 species of the following six arthropod groups: Araneae, Coleoptera, Diplopoda, Hymenoptera, Saltatoria and Isopoda. The 40 funnel traps caught a total of 428 species, the 22 cup traps only 251 species. 11 species were not caught with funnel traps, the cup traps missed 188 species (Tab. 1).

Do both trap types catch equal numbers of arthropod species per cm trap diameter? 1.7 species were caught per cm cup trap ø (251 species in 22 CT of 6.8 cm ø), while one cm of funnel trap ø caught 0.7 species (428 species in 40 FT of 15.3 cm ø) (Tab. 1). This suggests higher trapping success with CTs. However, with increasing number of individuals caught, numbers of species do not increase linearly, but rather approach a plateau at the maximum number of species occurring in the sampled area (Simberloff, 1978). This explains the seemingly higher species counts per cm ø in CT, which caught less individuals. As the number of species increases with total capture numbers of individuals (Simberloff, 1978; Samu & Lovel, 1995), we concentrated on the analysis of the latter.

Tab. 1. – Number of species and individuals caught with the two trap types. Numbers for families with large catches are shown separately. The total adds only lines indicated with ° as others are included therein. CT = cup traps, FT = funnel traps, Nsp = number of species, Nind = number of individuals, Nexcl =number of species caught exclusively in the respective trap type.

		Total (CT + FT)		CT			FT		
Group		Nsp	Nind	Nsp	Nexcl	Nind	Nsp	Nexcl	Nind
Araneae	°	128	49'727	92	5	13'382	123	36	36'345
Linyphiidae		64	33'645	44	1	11'113	63	20	22'532
Lycosidae		20	12'011	16	0	1'723	20	4	10'288
Coleoptera	°	241	41'748	116	5	3'475	236	125	38'273
Carabidae		86	30'909	47	0	2'345	86	39	28'564
Staphylinidae		136	9'317	58	3	1'020	133	78	8'297
Diplopoda	°	19	1'744	9	0	73	19	10	1'671
Hymenoptera	°	26	12'979	20	0	1'645	26	6	11'334
Formicidae		26	12'979	20	0	1'645	26	6	11'334
Isopoda	°	13	7'411	6	1	1'269	12	7	6'142
Saltatoria	°	12	422	8	0	42	12	4	380
TOTAL	(Σ°)	439	114'031	251	11	19'886	428	188	94'145

Tab. 2. – Results of a multiple comparison (Scheffé's test) of mean catching numbers per cm trap ø. Groups with identical symbols do not differ significantly in their mean trapping numbers ($p < 0.05$).

Trap type		
cup trap	○	
funnel trap		•

Habitat	Condition		
pasture	cultivated	○	
wheat/corn	cultivated	○	
semi-arid field	natural		•
wetland	natural		•

Group				
Araneae	○			
Coleoptera		•		
Diplopoda		•		+
Hymenoptera			*	
Isopoda			*	
Saltatoria				+

Analysis of variance (ANOVA)

Do both trap types catch equal numbers of individual arthropods per cm trap diameter? 19'886 individuals caught in 22 CT of 6.8 cm ø = 132.9 individuals per cm cup trap ø stand against 94'145 individuals caught in 40 FT of 15.3 cm ø = 153.8 individuals per cm funnel trap ø (Tab. 1). This suggests higher numeric trapping success of FT and deserves further analysis. As the two traps were differing in trap diameter, we first normalized the capture numbers by dividing by trap diameter and log transformed the results to achieve a normal distribution of the data.

We then performed an analysis of variance (ANOVA) to test the hypothesis, that capture success is influenced by trap type, by systematic group and by type of habitat (model: LogN.individuals/cmø = const + trap_type + order + habitat). The ANOVA indicated significant influences of trap type ($F=63.8$, $df=1$, $p \leq 0.001$), systematic group ($F=41.2$, $df=5$, $p \leq 0.001$) and habitat ($F=26.9$ $df=3$, $p \leq 0.001$) on the number of trapped individuals. In a multiple comparison we performed a post hoc test (Scheffé's test) to find differences between specific habitats or systematic groups (Tab. 2). Interestingly enough, capture success for habitats does only differ between cultivated and natural ones, but not between wet and dry or between grass and crops. The result for systematic groups is more complex, but the spiders catch attention, as they differ from all other groups.

Trapping success is therefore influenced by the trap type, the habitat under examination and the systematic group captured.

Correlation- and regression analyses

The ANOVA included all captured species, even when captured only in one of the two trap types. One might argue, species that selectively avoid a specific trap type bias the capture numbers and therefore the ANOVA. To reveal such an effect, we performed a correlation- and a regression analysis on only those species, that were captured in both trap types (240 species, see Tab. 1). From our hypothesis we expected that the numbers caught in any species with cup traps should correlate (linearly) with the number of individuals caught in the same species with funnel traps.

Cup traps and funnel traps differed in diameter and in numbers of sets used (68 mm*22 CT;153 mm*40 FT). We therefore normalized capture numbers by dividing by diameter and number of traps used. The log-transformed data where then used for the following steps.

The correlation analysis showed high values of the Pearson Product-Moment correlation coefficients (Tab. 3; Pearsons) for the total (All species) as well as for single systematic groups, except for the Isopoda.

A subsequent regression analysis confirmed the linear correlation between N/cmCTø and N/cmFTø with high significance (except in the Isopoda; Tab. 3). However, the slopes of the regression lines differed conspicuously (Fig. 2). Slopes reached 0.54 to 0.73 in most groups, but in the Formicidae and Linyphiidae they were close to 1 (Tab. 3).

To test if the slopes are all identical, we performed an analysis of covariance (ZAR, 1984; p. 300 ff.). The results suggested, that the slopes for Linyphiidae, Lyco-

Tab. 3. – Results of the correlation- and regression analysis testing if numbers caught per cm CT ø are correlated linearly with numbers caught per cm FT ø. For the total and for specifc systematic groups (orders or families) Pearsson Product-Moment correlation coefficients, and regression results are given.

Group	Pearsons correlation coefficient	Regression slope	Regression R^2	Regression prob
All species	0.801	0.737	64%	≤ 0.0001
Araneae	0.890	0.890	79%	≤ 0.0001
Linyphiidae	0.935	1.038	87%	≤ 0.0001
Lycosidae	0.806	0.579	65%	0.0002
Coleoptera	0.826	0.660	68%	≤ 0.0001
Carabidae	0.818	0.599	67%	≤ 0.0001
Staphylinidae	0.824	0.725	68%	≤ 0.0001
Diplopoda	0.806	0.645	65%	0.0088
Hymenoptera				
Formicidae	0.932	0.936	87%	≤ 0.0001
Isopoda	-0.147	-0.081	2%	0.8135
Saltatoria	0.772	0.543	60%	0.0246

Tab. 4. – Multiple comparison of slopes of regression lines shown in Fig. 2. Groups differing significantly in regression slopes are indicated with •.

	Saltatoria	Diplopoda	Staphylinidae	Carabidae	Lycosidae	Linyphiidae	Formicidae
Formicidae				•	•		
Linyphiidae	•	•	•	•	•		
Lycosidae							
Carabidae							
Staphylinidae							
Diplopoda							
Saltatoria							

sidae, Carabidae, Staphylinidae, Diplopoda, Formicidae and Saltatoria, are not identical (F = 5.38, Fkrit[0.05(1),6,184] = 2.15). Finally, in a multiple comparison, we tested each regression against all others for equality of slopes (ZAR, 1984; p. 302 ff.; Tab. 4).

As Fig. 2 suggests and Tab. 4 summarizes, significant differences exist between slopes of the Linyphidae and all other groups, as well as between the Formi-

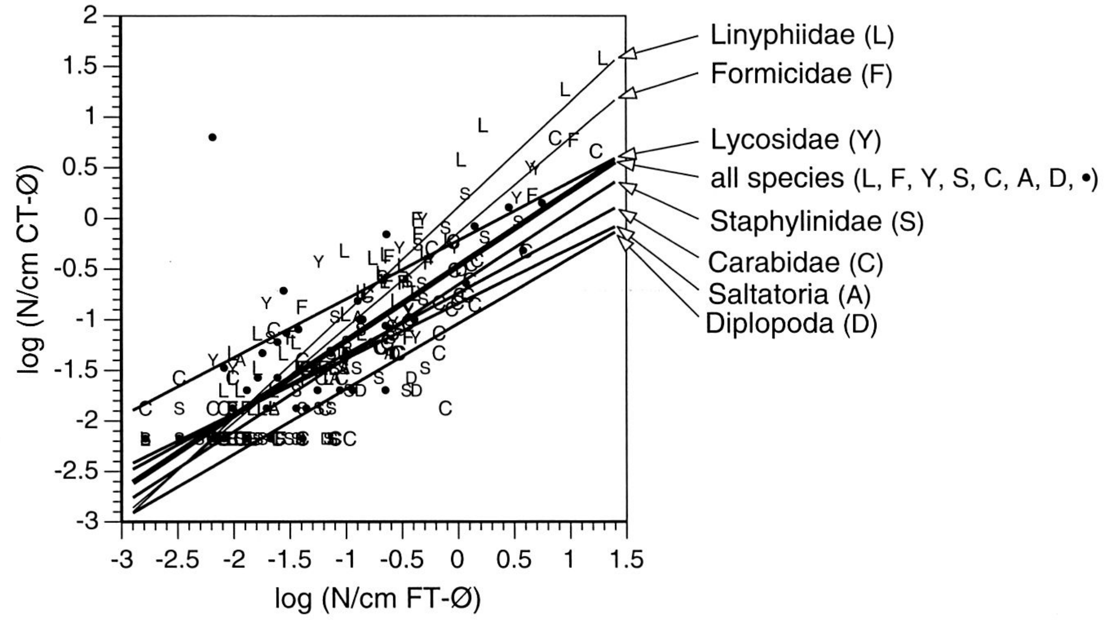

Fig. 2. – Regression analysis of arthropod catches. For every species that was caught in both trap types, the log of the normalized number of individuals caught per cm cup trap diameter was plotted in function of the log of the normalized number of individuals caught per cm funnel trap diameter. Regression lines and corresponding symbols used in the scatterplot are marked with arrows.

cidae on one side and the Carabidae and Lycosidae on the other. If we transform the slopes of the log-transformed numbers back on a linear base again, we find that cup traps and funnel traps catch roughly equally efficiently in the Linyphiidae and the Formicidae. However, funnel traps are 2 to 3 times more efficient per cm trap diameter in catching all other groups.

DISCUSSION

Our analysis clarified the effect of trap type, habitat and systematic group on the efficiency of pitfall traps. Catching numbers do differ between the two trap types and also between natural and cultivated habitats. The family of linyphiid spiders and the Formicidae are captured equally efficient with both trap types, revealing a behaviour which differs from that of other arthropods, which were clearly caught more efficiently with the funnel traps.

Theoretically, a linear relationship exists between the trap diameter or its circumference (LUFF, 1975) and the number of epigeal arthropods caught in the trap, provided the animals move randomly (JANSEN & METZ, 1979). As circumference and diameter are proportional (π) in circular traps, we used the diameter as a convenient measure for the size of the obstacle obtruding the way of an approaching arthropod.

This hypothesis of linear relationship may serve well for otherwise completely controlled experiments, but field experiments deviate from the ideal experimental situation. A wealth of external influences affecting the efficiency of traps were compiled by ADIS (1979). Some of these effects were also documented experimentally by other authors: SCHELLER (1984) found clear differences in capture success due to differing conserving fluids in the traps (formaldehyde, acetic acid, water) and SEIFERT (1990) observed a highly species specific startle behaviour of five ant species against a watery solution of 4 % formaldehyde. Both trap types used in our experiment contained identical conserving fluid.

In SCHELLER'S (1984) experiments with three different trap diameters the counts of captured carabids deviated significantly from the expected linear dependence with the trap diameter. Even negative linear correlation of trap diameter and trapping success were reported (BENEST, 1989). However, in these experiments highly unnatural trap surroundings (broad aluminum rim around the trap opening) were used. Both trap types used in our experiments were made of comparable plastics, which excludes any influence of the make of the material on the trapping success (LUFF, 1975).

The species specific behavioural response of animals to small differences in the trap setup probably accounts for most of the differential capture success (LOHSE, 1981; TOPPING, 1993). An unexpected crossing of the trap rim followed by a loss of adhesion likely explains the multitude of the catches. Many foraging species will enter the trap out of curiosity. Swift runners are certainly caught more often than more sedentary species (ADIS, 1979), a fact which certainly differentiates the two spider families Lycosidae (wolf spiders) and Linyphiidae (sheet-web weaver spiders). How skilful a carabid beetle escapes from a funnel, to which rim it clings to with only one leg, was very impressively photographed by MORRILL *et al.* (1990). In this light, our cup traps certainly offered more opportunities to escape than the funnel traps, as the sharp rim of the cups presented a better hold for arthropod legs than the transition of the funnel rim to the funnel itself. Arthropods capable of flight can flee cup traps even after contact with the conserving fluid, which is less likely in the case of funnel traps.

The free opening of a trap determines its retaining efficacy for flying arthropods (KUSCHKA *et al.*, 1987). This area amounted to 36 cm^2 in our cup traps, but the funnel traps' opening at the funnel-neck was only 7 cm^2. This difference in holding efficiency may explain the better trapping success of the funnel traps in Lycosidae, Carabidae, Staphylinidae, Saltatoria and Diplopoda.

Finally, a species specific difference in the readyness to risk walking on vertical surfaces could further have influenced the divergence between the capture results: species that primarily hunt on more or less horizontal surfaces are more likely to avoid the vertical walls of a cup trap (89° slope) compared to the less inclined funnel walls (46° slope). For species which are used to climb on leaves and at the underside of leaves (Formicidae) or which secure themselves with threads (Linyphiidae), the opposite may be true.

In most groups, between 8% and 18% of the catches were done with cup traps. However, in the spiders 27% were caught in this trap type, which splits up in 14% for the Lycosidae and 33 % for the Linyphiidae. These linyphiid spider species, which make up for 67 % of all spiders collected and where caught about equally efficiently in the cup traps, seem to have convinced our spider expert of the superiority of this trap type. The opinion of our carabid beetle expert was confirmed by our analysis. To summarize, we are convinced that funnel traps catch considerably more efficiently per centimeter trap diameter than do cup traps.

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ZUSAMMENFASSUNG

Fangzahlen von sechs Arthropodengruppen aus einem grösseren Feldversuch in vier Habitattypen wurden hinsichtlich der Fangeffizienz von kleinen Becherfallen (BF) und grösseren Trichterfallen (TRF) untersucht. Die Ansichten über die Effizienz divergierten zwischen unserem Spinnen- und dem Laufkäferspezialisten und widersprachen der theoretischen Erwartung einer linearen Zunahme der Individuenzahlen mit dem Durchmesser der runden Fallen. Eine Varianzanalyse zeigte einen Einfluss von Fallentyp, Habitatzustand (natürlich oder bewirtschaftet) sowie der Tiergruppe auf die Fangzahlen, wobei vor allem die Spinnen hervorstechen (Tab. 2 +3). Eine Korrelationsanalyse der Anzahl gefangener Tiere pro cm Fallendurchmesser zeigt eine klare Abhängigkeit zwischen den Fangzahlen der Becher- und Trichterfallen. Die Regressionsanalyse bestätigt eine lineare Korrelation der Fangzahlen (Tab. 3+4, Abb. 2). Die Spinnenfamilie der Linyphiidae sowie die Formicidae unterscheiden sich aber signifikant in der Steigung der Regressionsgeraden von den anderen Gruppen. Dies bedeutet, dass diese beiden Gruppen mit beiden Fallen etwa gleich gut gefangen werden, während alle anderen Gruppen (auch die Lycosidae) pro cm Fallendurchmesser 2–3 mal häufiger mit Trichterfallen gefangen werden. Gründe für die unterschiedliche Fangeffizienz der Fallentypen werden diskutiert. Für Fänge epigäischer Arthropoden sind Trichterfallen nach unserer Meinung Becherfallen vorzuziehen.

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