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Pitfall trapping as the basis for studying ground beetle *(Carabidae)* predation in spring barley

Fangst i faldgruber som metode til belysning af løbebillers (Carabidae) *konsumering af bladlus i vårbyg*

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Summary

The influence of preservatives, trap spacing and trap size upon pitfall catches of *Carabidae* was studied. The experiments were carried out in a spring barley field and a fallow.

Traps with 2.5% benzoic acid, 0.5% formaldehyde and a solution containing 5% acetic acid and 2% formaldehyde caught respectively 18%, 25% and 39% more beetles than traps with plain water, but the influence varied between species. The proportion of *Bembidion lampros* containing detectable aphid remains was equal in traps with different preservatives.

Traps placed at 14 m intervals caught significantly more *Agonum dorsale* than traps placed at 6 m intervals. Central traps in a grid with 6 m trap intervals caught significantly less *Loricera pilicornis* than peripheral traps.

Catch rates for traps with diametres of 100 mm, 144 mm and 210 mm deviated from the values expected from trap sizes. The influence of trap size varied between species.

It is concluded that, provided that trap dimensions and preservatives are carefully standardized, pitfalls may be used for the study of *Carabidae* as aphid predators in spring barley fields.

Key words: Methods, trap preservatives, trap spacing, trap size, cereal aphids.

Resumé

Faldgrubefælder kan være et nyttigt værktøj, og i mange tilfælde den eneste praktisk anvendelige metode til indsamling af løbebiller (*Carabidae*). Imidlertid er fangsten ikke blot et udtryk for populationstætheden, men i lige så høj grad for billernes aktivitetsniveau. Endvidere indvirker en række fældefaktorer på fangsterne. I økologiske undersøgelser er det af særlig betydning, at denne indvirkning kan være forskellig for dyr af forskelligt køn eller udviklingsstadium. Også prædationseffektiviteten kan variere mellem dele af populationen. Som følge af disse forhold er der en risiko for, at fældefangsterne giver et forvrænget billede af populationssammensætning og prædatoreffektivitet. Derfor er det af betydning at begrænse en sådan fældeindvirkning, ligesom det bør undgås, at fælderne bevirker en væsentlig formindskelse af populationstætheden.

Formålet med undersøgelsen var at sikre anvendelse af en relevant fangstmetode i et studium af løbebillers betydning som bladlusprædatorer i vårbyg.

I et forsøg blev 4 fældevæsker sammenlignet. I alle fælder var der tilsat detergent for at forhindre dyrene i at undslippe. Fælder med 2,5% benzoesyre, 0,5% formaldehyd og en opløsning indeholdende 5% eddikesyre + 2% formaldehyd fangede henholdsvis 18%, 25% og 39% flere løbebiller end fælder med vand, men de enkelte arter reagerede forskelligt på fældevæskerne. Udeladelse af konserveringsmiddel vanskeliggjorde i visse tilfælde sortering og optælling af fangsterne. Procentdelen af *Bembidion lampros,* hvori bladlusrester kunne identificeres i tarmkanalen, kunne ikke vises at være afhængig af konserveringsmidlerne.

I den samme forsøgsopstilling blev der anvendt fælder med 14 m og 6 m indbyrdes afstand. Fangsterne i fælder med forskellig afstand var kun signifikant forskellige for *Agonum dorsale* (ud af 8 arter). Fælderne med 6 m afstand var placeret i 2 felter, hver med 4 × 4 fælder. I de inderste 8 fælder (4 i hvert felt) blev der fanget signifikant færre *Loricera pilicornis* end i randfælderne, hvorimod der ikke kunne vises nogen forskel for de øvrige arter. Antagelig mindskede randfælderne indvandringen til felternes centre med en større udtynding af populationen til følge.

Fældestørrelsen blev undersøgt i et andet forsøg. Der blev anvendt fælder med diametre på 100 mm, 144 mm og 210 mm. Fangsterne blev påvirket på en måde, som var forskellig arterne imellem og ikke i overensstemmelse med den forventede direkte proportionalitet mellem fangst og fældediameter. Dette må antages at skyldes utilsigtede forskelle mellem fælderne, f.eks. i randstruktur.

Det blev konkluderet, at faldgrubefælder kan benyttes til studier af løbebillers bladlusprædation, forudsat at fældedimensioner og fældevæske er omhyggeligt standardiserede. Specielt er fældedimensioner af betydning. Fældevæske og fældeafstand vil som oftest betyde mindre set i relation til den betydelige variation i fangsten pr. fælde. Det anbefales, at fælder placeres mindst 10 m fra hinanden.

Nøgleord: Metoder, fældevæsker, fældetæthed, fældestørrelse, bladlusprædatorer.

Introduction

Pitfall trapping is the most widely used method for sampling *Carabidae.* This is probably because it is the easiest way of sampling beetles. The main drawback of the method is that the catches monitor activity rather than population levels (*Grüm,* 1959; *Briggs,* 1961; *Mitchell,* 1963; *Greenslade,* 1964). Furthermore, catches are influenced by trap-dependent properties such as trap material and size (*Novàk,* 1969; *Luff,* 1975; *Hsin et al.,* 1979), preservatives (*Luff,* 1968; *Skuhravý,* 1970; *Adis & Kramer,* 1975; *Ericson,* 1979; *Feoktistov,* 1980) and distance between traps (*Luff,* 1975). The effects of these factors may vary not only between species but also within a species according to the sex or age of the individual (*Luff,* 1968; *Skuhravý,* 1970; *Adis & Kramer,* 1975; *Ericson,* 1979) as may predator efficiency (*Jones,* 1969; *Sunderland,* 1975). These circumstances may be the explanation for contradicting results obtained by different workers, e.g. as regards the influence of trap spacing (*Greenslade,* 1964; *Ericson,* 1978).

The present study of the influence of trap spacing, of trap sizes, and of preservatives on carabid catch and on gut contents of aphid remains, was therefore carried out to ensure the use of a relevant methodology in a study of the role of carabids as aphid predators in Danish spring barley fields.

Materials and methods

Traps

The traps consisted of black plastic flowerpots burried in the soil with rims flush with soil level. A removable cup of clear plastic was fitted tightly into the pot. This type of trap was described by *Münster-Swendsen* (1973). Three sizes of traps were used, with inside diameters of 100 mm, 144 mm and 210 mm, respectively.

At the weekly inspections, the plastic cup was replaced, and the soil around traps was smoothed. The trap contents of *Carabidae* were transferred to 70% alcohol for later identification and counting.

Preservatives

The influence on catch of 4 different trap liquids was examined. The liquids used were:

1: water + 0.05% detergent.
2: 2.5% benzoic acid + 0.05% detergent.
3: 0.5% formaldehyde + 0.05% detergent.
4: 2% formaldehyde + 5% acetic acid + 0.05% detergent.

Benzoic acid was used because of low toxicity to humans and low vapour pressure.

0.5% formaldehyde was suggested as preservative for a joint IOBC/WPRS study of carabid catches in relation to aphid densities in wheat fields (*Basedow,* 1981). As the effect of this preservative was not compared with the effect of other preservatives, it has been incorporated in the present study.

The solution containing formaldehyde and acetic acid had been used previously at the National Research Centre for Plant Protection and was known to be a very effective preservative.

The detergent used was unscented dish washing agent.

The influence of preservatives on the proportion of beetles containing aphid remains was examined by dissection. Dissections were carried out as described in *Sunderland* (1975).

Experimental areas and design

One field experiment was carried out in May–September 1982 in a spring barley field at Dyrehavegård, North Zealand. Two experimental areas with identical design were set out 30 m apart on 28 May. The distance from the edges of the field was more than 100 m. In both areas 16 traps were placed at intervals of 6 m, and 4 traps at intervals of 14 m. The traps with 6 m intervals were placed in 4×4-grids. All traps were medium-sized. Preservatives were rotated between traps as described in Fig. 1.

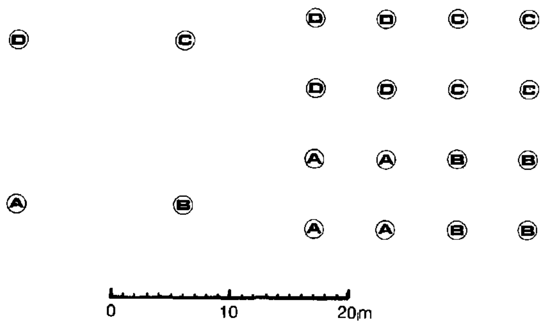

Fig. 1. Design of one of two experimental areas with identical design at Dyrehavegård, 1982. The first week 0.5% formaldehyde was used in traps indicated with A, 2.5% benzoic acid in traps indicated with B, formaldehyde/acetic acid solution in traps indicated with C, and water in traps indicated with D. The next week the 4 preservatives were used in traps indicated with B, C, D and A, respectively, etc.

Skitse af et af de to ens forsøgsarealer på Dyrehavegård i 1982. Den første uge blev der brugt 0,5% formaldehyd i fælder angivet med A, 2,5% benzoesyre i fælder angivet med B, formaldehyd/eddikesyre-opløsning i fælder angivet med C og vand i fælder angivet med D. Ugen efter blev de 4 konserveringsmidler brugt i fælder angivet med henholdsvis B, C, D og A osv.

With the purpose of examining the influence of trap size, another field experiment was carried out in August–October 1982 in a fallow with very little weed cover at Virumgård, North Zealand. Five traps of each size were set out in a randomized block design. Row intervals were 12 m, and within rows trap intervals were 6 m. 0.5% formaldehyde + detergent was used in all traps.

Statistical methods

For each species, the influences of preservatives, trap spacing and trap position in the grids (central vs. peripheral) were examined by means of analyses of variance on ln(x+l)-transformed catches.

The influence of preservatives was examined by means of 2-way analysis of variance as the dependence of the date was included. The influence of preservatives was also examined by means of pairwise comparisons in similar 2-way analyses of variance.

The influence of trap spacing was examined by means of 3-way analysis of variance as the dependence of the date and the preservative was included.

The influence of trap position was examined by means of similar 3-way analysis of variance.

Results

The species

At Dyrehavegård, 95% of the total catch consisted of *Bembidion lampros* Hbst., *Pterostichus melanarius* Illig., *Trechus quadristriatus* Schrank, *Synuchus nivalis* Panz., *Calathus melanocephalus* L., *Agonum dorsale* Pontopp., *Loricera pilicornis* Fabr. and *Amara spp.* At Virumgård, 94% of the total catch consisted of *Pt. melanarius, Tr. quadristriatus, Nebria brevicollis* Fabr., *B. lampros* and *B. quadrimaculatum* L.

Influence of preservatives

An overall difference between preservatives in their influence on catch was shown for 5 of the 8 most abundant species (Table 3).

In Table 1, the result of the pairwise comparisons of preservatives is shown. The influence of benzoic acid could be distinguished from the influence of water for 1 species and from the influence of 0.5% formaldehyde for 1 species. 0.5% formaldehyde was shown for 4 species to be more attractive than water. The dilute mixture of acetic acid and formaldehyde was shown for 5 species to be more attractive than water and in 4 cases to be more attractive than 0.5% formaldehyde.

In pairwise comparisons of species (2x4-contingency tables), there was, in most cases, a significant association between the influence of different preservatives and the species. However, it was possible to divide species into 4 groups with the same relation between catch and preservatives (Fig. 2).

The total catch in traps with benzoic acid, 0.5% formaldehyde, and formaldehyde/acetic acid was 18%, 25% and 39% higher, respectively, than the total catch in traps with water.

No significant effect of preservatives on the proportion of *B. lampros* containing detectable aphid remains in guts could be shown (2×4-contingency table, X^2=2.24, df=3, p>0.5) (Table 2).

Table 1. Total catch of carabids at Dyrehavegård in traps with different preservatives.
Totalfangsten af løbebiller på Dyrehavegård i fælder med forskellige konserveringsmidler.

Species	Water	2.5% benzoic acid	0.5% formaldehyde	5% acetic acid + 2% formaldehyde	Total catch
B. lampros	1049 a	1308 ab	1351 b	1368 ab	5075
Pt. melanarius	395 a	428 ab	487 b	492 b	1801
Tr. quadristriatus	266 a	255 a	280 a	310 a	1111
S. nivalis	193 a	181 a	203 a	357 b	934
C. melanocephalus	71 a	123 b	79 a	172 c	445
A. dorsale	47 a	67 ab	93 b	49 a	256
L. pilicornis	47 a	47 a	50 a	102 b	246
Amara spp.	28 a	43 ab	56 b	45 b	171
All species	2199 a	2600 b	2745 b	3067 c	10612

Numbers in the same row followed by the same letter are not significantly different (p>0.05). The influence of preservatives was examined by analyses of variance on ln(x+l)-transformed catches. Refer to 'Statical methods' for details on the analyses.

Tal i samme række efterfulgt af samme bogstav er ikke signifikant forskellige (p>0,05). Konserveringsmidlernes indflydelse blev undersøgt ved variansanalyse på ln(x+l)-transformerede fangster. Ved analyserne blev der taget højde for datoens betydning for forskelle i fangsten.

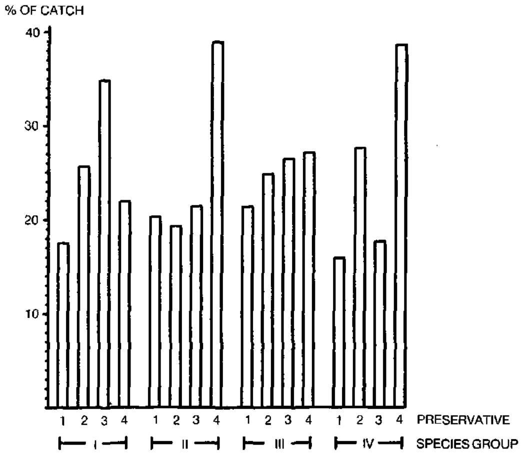

Fig. 2. Relation between different preservatives and catch of 4 groups of carabids at Dyrehavegård. The numbers of specimens in each group are given in brackets. I: *A. dorsale* and *Amara spp.* (428); II: *L. pilicornis* and *S. nivalis* (1180); III: *B. lampros, Pt. melanarius* and *Tr. quadristriatus* (7989); IV: *C. melanocephalus* (445). Preservatives are indicated as: 1: water; 2: 0.5% formaldehyde; 3: 2.5% benzoic acid; 4: 2% formaldehyde + 5% acetic acid.

Sammenhængen mellem forskellige fældevæsker og fangst af 4 grupper af løbebiller på Dyrehavegård. Antallet af dyr i hver gruppe er givet i parentes. I: A. dorsale *og* Amara spp. *(428); II:* L. pilicornis *og* S. nivalis *(1180); III:* B. lampros, Pt. melanarius *og* Tr. quadristriatus *(7989); IV:* C. melanocephalus *(445). Fældevæskerne er betegnet med: 1: vand; 2: 0,5% formaldehyd; 3: 2,5% benzoesyre; 4: 2% formaldehyd + 5% eddikesyre.*

Table 2. The percentage of *B. lampros* containing detectable aphid remains. The beetles were caught at Dyrehavegård in June, 1982.

Procentdelen af B. lampros, *hvori det var muligt at identificere bladlusrester i tarmkanalen. Billerne blev fanget på Dyrehavegård i juni 1982.*

Preservative	Number dissected	% containing aphids
Water	105	34.3
2.5% benzoic acid	153	26.1
0.5% formaldehyde	117	31.6
5% acet.ac. + 2% formaldeh.	187	31.6

Trap spacing

The influence of different trap spacing and of different trap positions in the grids of traps is shown in Table 3.

Only for *A. dorsale,* a significant influence of spacing could be established. The catch of *A. dorsale* was 36% lower in traps with 6 m intervals than in traps with 14 m intervals.

Only for *L. pilicornis,* a significant influence of position in the grids could be established. The catch of *L. pilicornis* was 38% lower in central traps than in peripheral traps.

Table 3. The results of analyses of variance on ln(x+1)-transformed catches from Dyrehavegård.

Resultaterne af variansanalyser på ln(x+1)-transformerede fangsttal fra Dyrehavegård.

	Source of variance: Preservatives		trap spacing		Pos. in grids	
	F(df=3)	p	F(df=1)	p	F(df=1)	p
B. lampros	1.8	0.15	3.2	0,08	2.2	0.14
Pt. melanarius	2.6	0.05	0.1	0.77	0.6	0.44
Tr. quadristriatus	0.4	0.77	0.4	0.55	0.04	0.85
S. nivalis	12.8	0.0001 ***	1.3	0.25	0.5	0.49
C. melanocephalus	12.1	0.0001 ***	2.4	0.12	0.1	0.76
A. dorsale	4.8	0.003 **	8.7	0.003 **	3.0	0.09
L. pilicornis	8.7	0.0001 ***	0.8	0.38	5.1	0.02 *
Amara spp.	2.7	0.04 *	0.5	0.49	1.2	0.27
All species	14.8	0.0001 ***	2.0	0.16	2.1	0.15

Refer to Statistical methods for details on the analyses. Levels of significance in this and the following table: *: $p<0.05$, **: $p<0.01$, ***: $p<0.001$.

*Ved undersøgelsen af konserveringsmidlernes indflydelse blev der taget højde for datoens betydning for forskelle i fangsten. Ved undersøgelsen af fældeafstandens betydning og ved undersøgelsen af fældeplaceringens betydning blev der taget højde for datoens og konserveringsmidlets betydning for forskelle i fangsten. Signifikansniveauer i denne og den følgende tabel: *: p<0,05; **: p<0,01; ***: p<0,001.*

Trap size

Results from the trap size experiment at Virumgård (Table 4) show that the catch rate of *Tr. quadristriatus, B. lampros* and *N. brevicollis* deviated significantly from the values expected on the basis of a linear proportionality between catch and trap diameter. (X^2=24, df=2, p<0.001; X^2=50, df=2, p<0.001 and X^2=7.6, df=2, p<0.05, respectively).

Table 4. Comparison of catch in traps of three different sizes at Virumgård in Aug.–Oct., 1982.
Sammenligning af fangsten i fælder af tre forskellige størrelser på Virumgård i august–oktober 1982.

Species	Trap diameter (mm) 100	144	210	
Pt. melanarius	245	379	490	
B. quadrimaculatum	40	76	100	
Tr. quadristriatus	107	286	249	***
B. lampros	36	102	78	***
N. brevicollis	46	73	143	*

The species in Table 4 can be divided into 3 groups within which the species could not be distinguished in the relationship between catch and trap size (2×3-contingency tables) (Fig. 3).

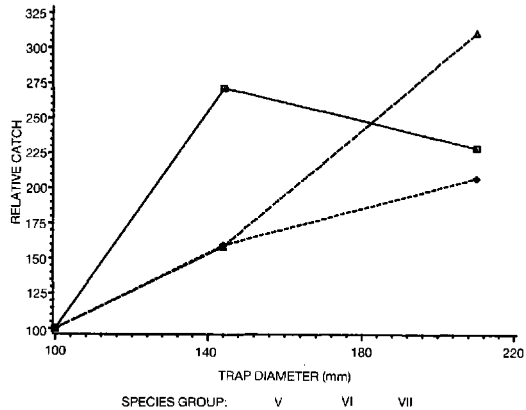

Fig. 3. Relation between trap diameter and relative catch of 3 groups of carabids at Virumgård. The numbers of specimens in each group are given in brackets. V: *B. lampros* and *Tr. quadristriatus* (858); VI: *Pt. melanarius* and *B. quadrimaculatum* (1330); VII: *Nebria brevicollis* (262).
Sammenhængen mellem fældediameter og den relative fangst af 3 grupper af løbebiller på Virumgård. Antallet af dyr i hver gruppe er givet i parentes. V: B. lampros *og* Tr. quadristriatus *(858); VI:* Pt. melanarius *og* B. quadrimaculatum *(1330); VIII:* Nebria brevicollis *(262).*

Discussion

Influence of preservatives

In this investigation traps with formaldehyde solution were shown to have different degrees of attraction to different species. This was also found by other workers (*Luff,* 1968; *Feoktistov,* 1980). On an average, the catch rate was 25% higher in traps with 0.5% formaldehyde than in traps with water. *Luff* (1968) found 100% higher catches of his (other) species in traps with 5% formaldehyde, and *Skuhravý* (1970) and *Feoktistov* (1980) found 20–50% higher catches in traps with 4% formalin (presumably equivalent to 1.6% formaldehyde). Generally, traps with the solution containing formaldehyde and acetic acid were particularly attractive to most species, while benzoic acid traps only exerted a slight attraction. The grouping of species according to the influence of preservatives (Fig. 2) could not be related to taxonomic groups, daily rhythms of activity, size or food preferences. (Information on activity rhythms was obtained from *Luff* (1978) and information on food preferences was obtained from *Thiele* (1977).

It might be argued that low catches in water traps is not a proof of attraction to traps with preservatives. In water traps, there could be a repellent effect or a higher escape. A repellent effect of decomposing contents in water traps seems unlikely as the use of meat or carrion baits does not influence catches (*Greenslade,* 1964; *Novák,* 1969; *Petruska,* 1969).

Carabids can escape from water traps (own observation during rain) and from formalin traps (*Petruska,* 1969) when detergent is not used. Individuals of different sex or age may have unequal capability of escape (*Petruska,* 1969), and this will be a further source of inconsistent results. Therefore, detergent should not be omitted. In the present investigation trapped beetles usually drowned readily.

The results from the dissections (Table 2) show that the use of preservatives is not essential for predator studies involving visual examination of gut contents of chitinous remains. However, the contents of water traps sometimes become very difficult and laborious to sort.

Although a significant influence of preservatives could be demonstrated, the catch in traps with benzoic acid and 0.5% formaldehyde was not very different from the catch in water traps, considering the high standard deviation of pitfall catches. Hence, it seems reasonable to use 0.5% formaldehyde (as suggested by *Basedow* (1981)) or benzoic acid for pitfall trapping of carabids. Benzoic acid is less toxic to humans, but more expensive, and the dissolving demands laborious heating prior to use.

Trap spacing

Only for *A. dorsale* there was a significant difference in catch between areas with 14 m trap intervals and areas with 6 m trap intervals. This difference was probably an effect of a relatively greater depletion of the populations in the areas with the smallest trap intervals. In central traps in the grids, catch rate was significantly lower than in peripheral traps for *L. pilicornis*. This was probably because the peripheral traps reduced migration into the center of the grids.

Even in the few cases where significant effects could be established, the difference in catch was only 36–38%. In an experiment in spring barley in 1983 with the same traps placed 10–12 m apart, *B. lampros* was caught in a number equivalent to 2 specimens per m^2 in 9 weeks in May–June while the population was estimated to be 60 specimens per m^2 (*Scheller,* in prep.). Thus, the population was not seriously depleted. It is possible that populations of species known to move over greater distances are more depleted (*Baars,* 1979), but then immigration into the depleted area will also be more extent. In the present results there is no indication that depletion effects were more severe for larger species.

Trap size

A trap without any attractive or repellent effect should catch soil-surface animals approximately proportionally to the diameter of the trap (*Greenslade & Greenslade,* 1971; *Baars,* 1979). It has been suggested that deviations from a direct proportionality indicate attraction (or repulsion) as is apparently true for some invertebrates (not including *Carabidae*) studied by *Greenslade* and *Greenslade* (1971). For some species, catch rates in traps of different sizes were far from expected values. The grouping of species (Fig. 3) was apparently unrelated to taxonomic groups, daily rhythms of activity, size or the grouping in relation to preservatives. (Information on activity rhythms was obtained from *Luff* (1978)). The catches of *Pt. melanarius, Tr. quadristriatus* and *B. lampros* had very similar relations to different preservatives. The relation to trap size, however, was markedly different between *Pt. melanarius* and the two remaining species. Therefore, it seems impossible to use departures from a direct proportionality between pitfall catches and trap diameter as an indication of attraction of *Carabidae.*

Altogether, it seems that catch efficiency may be very different between rather similar traps. The trap material may influence catch rate to a great extent (*Luff,* 1975; *Hsin et al.,* 1979), but in this experiment, traps were similar in colour and material. Other properties differed, however, as for instance the thickness of rims.

Conclusion

Trap dimensions seems to be the most important of the pitfall properties studied. For the study of carabid predators this property must be carefully standardized.

Secondly, a preservative and a detergent should be used. A 0.5% formaldehyde solution is apparently a good choice.

Depletion effects are not of great importance when trap intervals are more than about 10 m.

The high standard deviation of trap data indicates that a reasonably accurate estimate of population indices is impossible with a few traps.

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