Assessing capture techniques for ground beetles

Andrea Dávalos,[1] Bernd Blossey

Department of Natural Resources, Fernow Hall, Cornell University, Ithaca, New York 14853, United States of America

Abstract—We investigated the use of wooden boards to sample ground beetles (Coleoptera: Carabidae) and compared their efficacy with that of single pitfall traps and two modified pitfall traps (barrier and grouped traps). Carabid captures and species richness were similar between wooden boards and single pitfall traps, but higher in barrier and grouped traps. Although captures were higher in the modified pitfall traps, no method was consistently superior or capable of capturing all carabid species recorded at our study site. A distinct advantage of wooden boards is their ease of installation and maintenance and the fact that they can be left in remote areas for extended periods of time, eliminating the need to visit areas to open traps (if livetrapping is the desired outcome). These time savings and reduced site disturbance may make wooden boards an alternative to single pitfall traps.

Résumé—Nous avons évalué l'utilisation de planchettes pour l'échantillonnage des carabes (Coleoptera : Carabidae) et comparé leur efficacité à celle des pièges à fosse simples et de deux modifications de pièges à fosse doubles (piège avec barrière et pièges regroupés). Les captures de carabes et la richesse en espèces sont semblables avec les planchettes et les pièges à fosse simples, mais plus faibles qu'avec les pièges regroupés ou les pièges avec barrière. Bien que les captures soient plus importantes dans les pièges à fosse modifiés, aucune méthode ne s'avère constamment supérieure, ni capable de recueillir toutes les espèces de carabes signalées à notre site d'étude. La facilité d'installation et d'entretien des planchettes constituent des avantages certains; on peut aussi laisser les planchettes dans des sites éloignés pendant de longues périodes, ce qui élimine la nécessité de visiter à répétition ces sites pour relever les pièges, si l'on cherche à capturer des animaux vivants. Le temps sauvé et la réduction des perturbation dans les sites peuvent faire des planchettes une méthode de remplacement des pièges à fosse simples.

[Traduit par la Rédaction]

Pitfall trapping is the most common method used to capture ground beetles (Coleoptera: Carabidae). Although this method is widely used, inexpensive, and efficient, it has several shortcomings (Luff 1975; Spence and Niemelä 1994; Lövei and Sunderland 1996; Rainio and Niemelä 2003). Pitfall traps measure both carabid density and carabid activity, complicating comparisons across different habitats (Luff 1975; Thomas *et al.* 1998; Raworth and Choi 2001). In addition, the killing agent and the size, shape, and spatial arrangement of traps influence pitfall trap efficacy (Spence and Niemelä 1994; Weeks and McIntyre 1997; Koivula *et al.* 2003). Finally, collection efficiency in habitats with low ground beetle abundance is often inadequate, compromising the researcher's ability to draw inferences from the data. Therefore, it is important to develop alternative sampling methods that will increase sampling efficiency and allow density estimation, providing reliable data on carabid ecology, their responses to environmental changes, and their importance as biocontrol agents.

Collecting ground beetles underneath natural or artificial cover objects is a plausible but untested alternative to pitfall sampling. It is common for many ground beetle species to shelter underneath logs and rocks during the day (Larochelle and Larivière 2003), so handpicking carabids from these refuges may yield a good representation of carabid abundance and diversity. However, it is difficult to establish comparisons between habitats or treatments unless the amount, location, and quality of refuges searched at each site are standardized. A viable method for equalizing the refuge areas searched is the introduction of standardized artificial cover objects (hereafter called coverboards).

We evaluated four types of traps — coverboards, single pitfall traps, grouped pitfall traps, and barrier pitfall traps — at a deciduous

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[1]Corresponding author (e-mail: amd48@cornell.edu).

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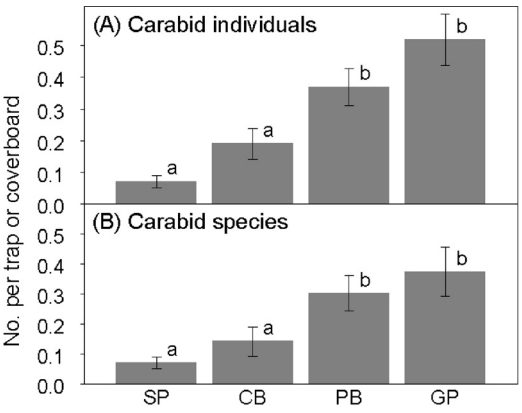
forest in central New York, United States of America (42°23.22′N, 76°14.44′W). Coverboards consisted of weathered, untreated sugar maple (*Acer saccharum* Marsh.; Aceraceae) boards approximately 50 cm long by 25 cm wide and at least 2.5 cm thick. We carefully removed leaf litter and rocks and flattened the terrain before placing each coverboard. Single pitfall traps were plastic containers (diameter 12 cm, depth 14 cm) placed in the ground with the top of the container flush with the soil surface. We placed a few stones and moist florist's foam in the bottom of each trap to provide refuge. Barrier pitfall traps consisted of a single pitfall trap with three guiding metal plates, 15 cm long, placed 120° apart from each other. Grouped pitfall traps consisted of three single pitfall traps arranged in a triangle, 25 cm apart from each other. The positions of the four trap types within the sampling grid (90 m × 90 m, 15 m intervals) were allocated randomly, for a total of 12 replicates per trap design. We sampled over a 2-year period; in 2001 we sampled once in August, once in October, and three times in September, while in 2002 we sampled once in mid-April, once in mid-May, and thereafter every 15 days until mid-September (nine times).

On each sampling date, we removed lids and left traps open for 24 h. We conducted checks from 0900 to 1100 by carefully lifting coverboards and hand-collecting all sheltering ground beetles. Carabids captured in pitfall traps were collected and traps were closed between sampling periods. Captured carabids were transported to the laboratory for species identification (Lindroth 1961, 1963, 1966, 1968, 1969*a*, 1969*b*). Reference specimens of each species were preserved, mounted, and deposited at the Cornell University Insect Collection, Ithaca, New York (lot No. 1249).

To determine trap efficacy we compared total carabid captures and species richness among collection methods using a one-way ANOVA followed by pairwise comparisons with Tukey's multiple comparison test (alpha = 0.05). Given that sampling effort and timing were different between 2001 and 2002, we pooled data from both years of the study and did not evaluate year effects. Data were log-transformed to correct for lack of normality and to reduce variance heterogeneity.

To test whether species captures differed among collection methods, we ran a χ^2 test of each species group *versus* method. Species

Fig. 1. Number (mean ± 2 SE) of carabids (A) and species (B) captured per collection method (SP, single pitfall traps; CB, coverboards; BP, barrier pitfall traps; and GP, grouped pitfall traps). Parameters were estimated from pooled data for both years of the study. Significant differences between means are indicated by different letters (Tukey's test, alpha = 0.05).



were placed in three groups corresponding to the three most abundant genera: *Platynus* spp., *Pterostichus* spp., and *Sphaeroderus* spp. Another χ^2 test was run to determine whether the average size of captured carabids was independent of collection method. Carabids were classified into three size categories: <8 mm, 8–12 mm, and >12 mm. Finally, a χ^2 test was performed to test whether carabid captures were consistent with those expected based solely on trap size, measured as the perimeter length of each trap (Luff 1975). We ran the test twice: first we evaluated the minimum effective perimeter of barrier traps (single trap diameter), and then we evaluated the maximum effective perimeter (single trap diameter + length of barrier).

Totals of 79 and 113 carabids belonging to 11 and 21 species were captured in 2001 and 2002, respectively. Our results showed that sampling techniques clearly differed in their efficacy. Ground beetle captures and species richness were significantly different among collection methods ($F_{3,668} = 12.62$, $P = 4.89 \times 10^{-8}$; $F_{3,668} = 12.43$, $P = 6.37 \times 10^{-8}$, respectively), with grouped and barrier pitfall traps capturing significantly more individuals and species than single pitfall traps and coverboards (Fig. 1). The increased efficacy of modified pitfall traps was expected because sampling effort was tripled with grouped traps, and the effective trapping area was increased by the incorporation of guiding plates in barrier traps. However,

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Table 1. Carabid species and number of individuals of each collected in single pitfall traps (SP), coverboards (CB), barrier pitfall traps (BP), and grouped pitfall traps (GP).

Species	Size (mm)	SP	CB	BP	GP
Amphasia interstitialis Say	8.5–10.2	—	1	—	—
Bembidion obtusum Audinet-Serville	2.6–3.2	—	1	—	4
Calathus gregarius Say	8.2–10.8	1	1	—	1
Carabus limbatus Say	20–25	—	—	—	3
Cymindis cribricollis Dejean	8.5–11	—	—	—	1
Dicaelus teter Bonelli	15–21.5	1	—	—	—
Notiophilus aeneus Herbst	2–4	—	—	1	—
Platynus decentis Say	9–14	1	4	9	22
Platynus hypolithos Say	13.5–15.5	—	—	1	2
Platynus parmaginatus Hamilton	9–14	—	—	1	1
Poecilus lucublandus Say	9–14	—	—	—	1
Pterostichus honestus Say	7–8.5	—	—	2	—
Pterostichus lachrymosus Newman	14.5–17	1	1	6	2
Pterostichus melanarius Illiger	12–19	2	1	2	1
Pterostichus mutus Say	9.5–13.5	—	7	6	26
Pterostichus novus Straneo	16–19.5	1	1	7	7
Pterostichus pensylvanicus LeConte	9.5–12	1	—	1	—
Pterostichus rostratus Newman	12.7–18	—	—	2	1
Pterostichus stygicus Say	12.5–18	—	15	3	5
Sphaeroderus lecontei Dejean	11.5–17	2	—	14	10
Synuchus impunctatus Say	8.7–11.2	2	—	2	—
Trichotichnus vulpeculus Say	9.0–10	—	—	4	—
Total no. of species		9	9	15	15

increased captures may be a function of more than just trap size. At our site, the observed capture rates in barrier and grouped pitfall traps were larger than expected based solely on trap size, whereas single pitfall traps and coverboards caught fewer carabids than expected ($\chi^2_3 = 42.73$, $P = 2.8 \times 10^{-9}$; $\chi^2_3 = 14.86$, $P = 0.0019$; minimum and maximum barrier pitfall trap perimeters, respectively). These results suggest that other factors, such as position and arrangement of traps, could also increase efficacy. Increasing the effective trapping area of coverboards may yield a result similar to that achieved for pitfall traps, where efficacy was significantly improved. Larger or grouped coverboards may be more likely to yield higher carabid captures; however, carabids are more likely to escape when larger coverboards are used.

As reported in other studies (Durkis and Reeves 1982; Spence and Niemelä 1994; Winder *et al.* 2001), we found that the relative abundance of carabid species and the species composition differed among sampling methods (Table 1). Captures of the most abundant genera were not independent of collection method ($\chi^2_6 = 17.34$, $P = 0.008$). The effect of collection method was genus-specific: more *Platynus* spp. than expected were captured in grouped pitfall traps, whereas more *Pterostichus* spp. than expected were captured under coverboards and more *Sphaeroderus* spp. than expected were captured in barrier traps. These differences in species captures among methods may indicate that the performance of each trapping method is associated with the natural history and morphology of different carabid species. For instance, species size can greatly influence capture probability ((Durkis and Reeves 1982; Spence and Niemelä 1994; Winder *et al.* 2001; Arneberg and Andersen 2003). Although carabid size distribution was independent of collection method ($\chi^2_6 = 9.471$, $P = 0.148$), single pitfall traps tended to capture large-bodied carabid species. However, abundance of small species was very low (mostly single individuals),

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so it is possible that differences are not entirely a function of the sampling method.

While the efficacy of coverboards was comparable to that of single pitfall traps, a qualitative assessment of the experimental limitations and benefits of both methods indicates that coverboards have several advantages over pitfall traps. Coverboards caused less disturbance associated with installation and maintenance than pitfall traps. In addition, coverboards are less likely to attract interference by predators such as raccoons and skunks (personal observation) and they eliminate captures of nontarget organisms that commonly fall into pitfall traps. When livetrapping is desired, coverboards may have a distinct advantage over pitfall traps (including modifications) because they do not require a visit to open traps before each sampling interval. These advantages may be especially important in studies where remote areas are under investigation for extended periods. However, coverboards, like pitfall traps, have inherent deficiencies that should be considered when data are interpreted. Carabid species active during the day or those that climb vegetation are less likely to be encountered under coverboards. In addition, coverboards provide a high-quality habitat that could attract beetles differentially according to environmental conditions (*i.e.*, temperature and moisture). Finally, at sites with high carabid densities it might be difficult to capture all beetles before they disperse, favoring captures of slower moving species. However, decreasing coverboard size could reduce this effect. Pitfall traps, on the other hand, may be more advantageous than coverboards when cumulative catch over a definite time period is desired (dead sampling) because pitfall traps catch all individuals that fall into a trap, whereas individuals can freely move in and out of coverboards.

Our results indicate that no method provides a universal representation of carabid assemblages. The efficacy of each collection method is affected by species-specific differences and habitat characteristics. Variations in pitfall design, such as the addition of guiding plates or the use of multiple traps, may significantly increase efficacy of pitfall traps. The reduced site disturbance and the time savings associated with coverboard sampling suggest that it is a preferable alternative to single pitfall trapping when livetrapping is desired. However, neither method is ideal, and further research is needed to develop a methodology that increases trap efficacy and allows proper estimation of carabid density at sites with low carabid abundance.

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Arneberg, P., and Andersen, J. 2003. The energetic equivalence rule rejected because of a potentially common sampling error: evidence from carabid beetles. Oikos, **101**: 367–375.

Durkis, T.J., and Reeves, R.M. 1982. Barriers increase efficiency of pitfall traps. Entomological News, **93**: 8–12.

Koivula, M., Kotze, D.J., and Hiisivuori, L. 2003. Pitfall trap efficiency: do trap size, collecting fluid and vegetation structure matter? Entomologica Fennica, **14**: 1–14.

Larochelle, A., and Larivière, M.C. 2003. A natural history of the ground-beetles (Coleoptera: Carabidae) of America north of Mexico. Pensoft Publishers, Sofia, Bulgaria.

Lindroth, C.H. 1961. The ground beetles (Carabidae, excl. Cicindelinae) of Canada and Alaska. Opuscula Entomologica Supplementum, **20**: 1–200.

Lindroth, C.H. 1963. The ground beetles (Carabidae, excl. Cicindelinae) of Canada and Alaska. Opuscula Entomologica Supplementum, **24**: 201–408.

Lindroth, C.H. 1966. The ground beetles (Carabidae, excl. Cicindelinae) of Canada and Alaska. Opuscula Entomologica Supplementum, **29**: 409–648.

Lindroth, C.H. 1968. The ground beetles (Carabidae, excl. Cicindelinae) of Canada and Alaska. Opuscula Entomologica Supplementum, **33**: 649–944.

Lindroth, C.H. 1969*a*. The ground beetles (Carabidae, excl. Cicindelinae) of Canada and Alaska. Opuscula Entomologica Supplementum, **34**: 945–1192.

Lindroth, C.H. 1969*b*. The ground beetles (Carabidae, excl. Cicindelinae) of Canada and Alaska. Opuscula Entomologica Supplementum, **35**: i–xlviii.

Lövei, G.L., and Sunderland, K.D. 1996. Ecology and behavior of ground beetles (Coleoptera: Carabidae). Annual Review of Entomology, **41**: 231–256.

Luff, M.L. 1975. Some features influencing the efficiency of pitfall traps. Oecologia, **19**: 345–357.

Rainio, J., and Niemelä, J. 2003. Ground beetles (Coleoptera: Carabidae) as bioindicators. Biodiversity and Conservation, **12**: 487–506.

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https://doi.org/10.4039/n05-018 Published online by Cambridge University Press

Raworth, D.A., and Choi, M.Y. 2001. Determining numbers of active carabid beetles per unit area from pitfall-trap data. Entomologia Experimentalis et Applicata, **98**: 95–108.

Spence, J.R., and Niemelä, J.K. 1994. Sampling carabid assemblages with pitfall traps: the madness and the method. The Canadian Entomologist, **126**: 881–894.

Thomas, C.F.G., Parkinson, L., and Marshall, E.J.P. 1998. Isolating the components of activity-density for the carabid beetle *Pterostichus melanarius* in farmland. Oecologia, **116**: 103–112.

Weeks, R.D., and McIntyre, N.E. 1997. A comparison of live versus kill pitfall trapping techniques using various killing agents. Entomologia Experimentalis et Applicata, **82**: 267–273.

Winder, L., Holland, J.M., Perry, J.N., Woolley, C., and Alexander, C.J. 2001. The use of barrier-connected pitfall trapping for sampling predatory beetles and spiders. Entomologia Experimentalis et Applicata, **98**: 249–258.

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