# Using Malaise traps to sample ground beetles (Coleoptera: Carabidae)

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Pitfall traps provide an easy and inexpensive way to sample ground-dwelling arthropods (Spence and Niemela 1994; Spence *et al.* 1997; Abildsnes and Tommeras 2000) and have been used exclusively in many studies of the abundance and diversity of ground beetles (Coleoptera: Carabidae). Despite the popularity of this trapping technique, pitfall traps have many disadvantages. For example, they often fail to collect both small (Spence and Niemela 1994) and "trap-shy" species (Benest 1989), eventually deplete the local carabid population (Digweed *et al.* 1995), require a species to be ground-dwelling in order to be captured (Liebherr and Mahar 1979), and produce different results depending on trap diameter and material, type of preservative used, and trap placement (Greenslade 1964; Luff 1975; Work *et al.* 2002). Further complications arise from seasonal patterns of movement among the beetles themselves (Maelfait and Desender 1990), as well as numerous climatic factors, differences in plant cover, and variable surface conditions (Adis 1979).

Because of these limitations, pitfall trap data give an incomplete picture of the carabid community and should be interpreted carefully. Additional methods, such as use of Berlese funnels and litter washing (Spence and Niemela 1994), collection from lights (Usis and MacLean 1998), and deployment of flight intercept devices (Liebherr and Mahar 1979; Paarmann and Stork 1987), should be incorporated in surveys to better ascertain the species composition and relative numbers of ground beetles. Flight intercept devices, like pitfall traps, have the advantage of being easy to use and replicate, but their value to carabid surveys is largely unknown. Here we demonstrate the effectiveness of Malaise traps for sampling ground beetles in a bottomland hardwood forest.

This is part of a larger study investigating the response of insects to the creation of canopy gaps in a bottomland hardwood forest in the southeastern United States. The gaps were created within a 120-ha stand of 75-year-old bottomland hardwoods at the Savannah River Site (near Aiken, South Carolina), a nuclear production facility and Environmental Research Park of 80 269 ha owned and operated by the United States Department of Energy. For a detailed description of the study site, including the dominant plant species present, consult Ulyshen *et al.* (2004).

We established 72 trapping locations in and around canopy gaps of varying size (0.13, 0.26, and 0.50 ha) and age (1 or 7 years). The gaps were located throughout the forest and were separated by at least 200 m. We placed one Malaise trap and two pitfall traps (all three spaced approximately 5 m apart) at the center and edge of each gap as well as 50 m into the surrounding forest. We sampled at the following intervals during 2001: 17–23 May, 10–16 July, 7–13 September, and 3–9 November.

The Malaise traps used in this study (canopy trap, Sante Traps, Lexington, Kentucky) have a collecting jar at the bottom of each trap in addition to one at the top. They were suspended from 3 m tall hangers constructed from metal tubing. The pitfall traps consisted of 480-mL plastic cups with 8.4 cm diameter funnels. The funnels directed beetles into 120-mL specimen cups containing preservative. Each trap was positioned at the intersection of four 0.5 m long metal drift fences to increase trap catch. The two pitfall traps were combined at each location prior to analysis. The preservative used in both the Malaise and the pitfall traps was a 2% formaldehyde and saturated NaCl solution with a few drops of detergent added to reduce surface tension (New and Hanula 1998).

Samples were stored in 70% ethanol, sorted to morphospecies, and identified using a key to the carabids of South Carolina (Ciegler 2000). This reference was also used to assign our

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**Table 1.** List of ground beetles (Carabidae) collected by Malaise (Mal) and pitfall (Pit) traps in a bottomland hardwood forest (South Carolina, United States of America).

| Tribe | Species | Number (Mal/Pit) | Habitat | Wing structure |
|---|---|---|---|---|
| Bembidiini | *Bembidion affine* Say | 7/1 | Ground | Macropterous |
| | *Elaphropus granarius* (Dejean) | 3/12 | Ground | Dimorphic |
| | *Micratopus aenescens* (LeConte) | 424/0 | Ground | Macropterous |
| | *Mioptachys flavicauda* (Say) | 5/4 | Ground, under bark | Macropterous |
| | *Paratachys* spp. | 100/25 | Ground | Macropterous |
| | *Polyderis laevis* (Say) | 24/0 | Ground | Macropterous |
| | *Tachyta nana inornata* (Say) | 6/0 | Ground, under bark | Macropterous |
| Brachinini | *Brachinus alternans* Dejean | 1/727 | Ground | Macropterous |
| Carabini | *Carabus sylvosus* Say | 0/47 | Ground | Brachypterous |
| Chlaenini | *Chlaenius aestivus* Say | 0/374 | Ground | Dimorphic |
| | *Chlaenius erythropus* Germar | 0/73 | Ground | Macropterous |
| | *Chlaenius laticollis* Say | 6/0 | Ground | Macropterous |
| | *Chlaenius pusillus* Say | 0/4 | Ground | Macropterous |
| | *Chlaenius* sp. 5 | 0/151 | Ground | Macropterous |
| Cicindelini | *Cicindela punctulata* Olivier | 0/5 | Ground | Macropterous |
| | *Cicindela sexguttata* Fabr. | 2/0 | Ground | Macropterous |
| | *Megacephala* sp. | 0/1 | Ground | Macropterous |
| Clivinini | *Clivina bipustulata* (Fabr.) | 29/171 | Ground | Macropterous |
| | *Clivina dentipes* Dejean | 15/0 | Ground | Macropterous |
| | *Clivina rubicunda* LeConte | 32/0 | Ground | Dimorphic |
| | *Dyschirius* sp. | 0/4 | Ground | Macropterous |
| | *Semiardistomis viridis* (Say) | 6/1258 | Ground | Macropterous |
| Ctenodactylini | *Leptotrachelus dorsalis* (Fabr.) | 1/0 | Ground, vegetation | Macropterous |
| Cychrini | *Scaphinotus* sp. | 0/7 | Ground | Brachypterous |
| | *Sphaeroderus* sp. | 0/3 | Ground | Brachypterous |
| Cyclosomini | *Tetragonoderus intersectus* (Germar) | 3/1 | Ground | Macropterous |
| Galeritini | *Galerita* spp. | 0/47 | Ground | Macropterous |
| Harpalini | *Acupalpus testaceus* Dejean | 77/1 | Ground | Macropterous |
| | *Acupalpus* sp. 2 | 172/7 | Ground | Macropterous |
| | *Acupalpus* sp. 3 | 0/8 | Ground | Macropterous |
| | *Amblygnathus iripennis* (Say) | 1/0 | Ground | Macropterous |
| | *Amerinus linearis* LeConte | 6/0 | Ground | Dimorphic |
| | *Anisodactylus furvus* LeConte | 0/3 | Ground | Macropterous |
| | *Anisodactylus rusticus* (Say) | 1/0 | Ground | Macropterous |
| | *Harpalus pennsylvanicus* (De Geer) | 5/28 | Ground | Macropterous |
| | *Notiobia terminata* (Say) | 28/0 | Ground | Macropterous |
| | *Selenophorus ellipticus* Dejean | 2/2 | Ground | Macropterous |
| | *Selenophorus opalinus* (LeConte) | 8/4 | Ground | Macropterous |
| | *Selenophorus palliatus* (Fabr.) | 3/0 | Ground | Macropterous |
| | *Stenolophus ochropezus* (Say) | 40/16 | Ground | Macropterous |
| | *Stenolophus spretus* Dejean | 9/1 | Ground | Macropterous |
| Helluonini | *Helluomorphoides* sp. | 2/5 | Ground | Macropterous |
| Lachnophorini | *Euphoroticus pubescens* (DeJean) | 0/2 | Ground | Macropterous |

**Table 1** (*continued*).

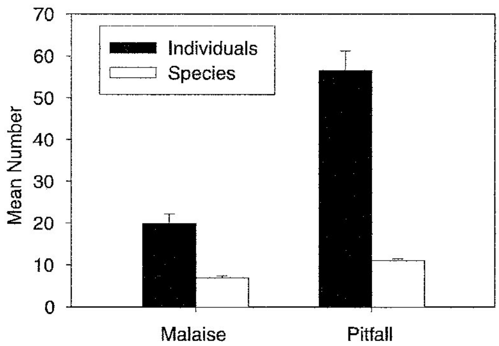
| Tribe | Species | Number (Mal/Pit) | Habitat | Wing structure |
|---|---|---|---|---|
| Lebiini | *Apenes sinuatus* (Say) | 2/3 | Ground | Macropterous |
| | *Calleida decora* (Fabr.) | 2/0 | Vegetation | Macropterous |
| | *Calleida virdipennis* (Say) | 3/0 | Vegetation | Macropterous |
| | *Coptodera aerata* Dejean | 4/0 | Vegetation | Macropterous |
| | *Cymindis* sp. | 60/0 | Ground? | Macropterous |
| | *Dromius piceus* Dejean | 1/0 | Vegetation | Macropterous |
| | *Lebia lobulata* LeConte | 16/0 | Vegetation | Macropterous |
| | *Lebia marginicollis* Dejean | 5/0 | Vegetation | Macropterous |
| | *Lebia tricolor* Say | 7/0 | Vegetation | Macropterous |
| | *Lebia viridis* Say | 22/0 | Vegetation | Macropterous |
| | *Lebia vittata* (Fabr.) | 1/0 | Vegetation | Macropterous |
| | *Philorhizus atriceps* (LeConte) | 0/2 | Ground | Brachypterous |
| Licinini | *Badister maculatus* LeConte | 8/0 | Ground | Macropterous |
| | *Badister ocularis* Casey | 12/0 | Ground | Macropterous |
| | *Dicaelus dilatatus* Say | 0/44 | Ground | Brachypterous |
| | *Dicaelus elongatus* Bonelli | 0/46 | Ground | Brachypterous |
| | *Diplocheila assimilis* (LeConte) | 0/71 | Ground | Macropterous |
| Loxandrini | *Loxandrus rectus* (Say) | 5/3 | Ground | Macropterous |
| | *Loxandrus* sp. 1 | 10/161 | Ground | Macropterous |
| | *Loxandrus* sp. 2 | 3/0 | Ground | Macropterous |
| Morionini | *Morion monilicornis* (Latr.) | 2/0 | Under bark | Unknown |
| Notiophilini | *Notiophilus* sp. | 0/3 | Ground | Dimorphic |
| Oodini | *Anatrichus minuta* (Dejean) | 2/1 | Ground | Macropterous |
| | *Oodes amaroides* Dejean | 42/30 | Ground, vegetation | Macropterous |
| | *Oodes* sp. 2 | 0/37 | Ground | Macropterous |
| Panagaeini | *Panagaeus fasciatus* Say | 0/1 | Ground | Macropterous |
| Pentagonicini | *Pentagonica flavipes* (LeConte) | 6/0 | Vegetation | Macropterous |
| Platynini | *Agonum aeruginosum* Dejean | 27/0 | Ground | Macropterous |
| | *Agonum decorum* Say | 0/83 | Ground, vegetation | Macropterous |
| | *Calathus opaculatus* LeConte | 11/4 | Ground | Macropterous |
| | *Olisthopus* sp. 1 | 2/0 | Ground | Macropterous |
| | *Olisthopus* sp. 2 | 137/12 | Ground | Macropterous |
| | *Platynus decentis* (Say) | 6/0 | Ground, vegetation | Submacropterous |
| Pterostichini | *Cyclotrachelus brevoorti* (LeConte) | 0/44 | Ground | Brachypterous |
| | *Cyclotrachelus spoliatus* (Newman) | 0/3 | Ground | Brachypterous |
| | *Cyclotrachelus* sp. 3 | 0/23 | Ground | Brachypterous |
| | *Lophoglossus gravis* LeConte | 0/310 | Ground | Macropterous |
| | *Piesmus submarginatus* (Say) | 9/93 | Ground | Macropterous |
| | *Poecilus chalcites* (Say) | 0/31 | Ground | Macropterous |
| | *Pterostichus* sp. 1 | 0/2 | Ground | Brachypterous |
| Scaritini | *Scarites* sp. | 5/67 | Ground | Macropterous |
| Zabrini | *Amara* sp. | 0/2 | Ground | Macropterous |
| Zuphiini | *Thalpius pygmaeus* (Dejean) | 1/0 | Ground | Macropterous |
| Unknown | Unidentified sp. | 1/0 | | |

**Table 1** (*concluded*).

| Tribe | Species | Number (Mal/Pit) | Habitat | Wing structure |
|---|---|---|---|---|
| Total no. of individuals | | 1430/4068 | | |
| Total no. of species | | 58/54 | | |
| No. of species unique to trap | | 33/29 | | |

**Note:** Information on the habits and wing morphology of each species was taken from Larochelle and Lariviere (2001, 2003).

**Fig. 1.** Mean numbers of individuals and species of carabids collected in Malaise and pitfall traps in a bottomland hardwood forest (South Carolina, United States of America) in 2001.




species to size classes (<5 mm, 5–10 mm, 10–15 mm, and >15 mm).

We collected a total of 5498 individuals representing 87 carabid species (including *Amerinus linearis* LeConte, a new state record) (Table 1). Although the average pair of pitfall traps collected more species and individuals than did the average Malaise trap (Fig. 1), Malaise traps collected more species overall (Table 1). Furthermore, 33 of the species captured in Malaise traps were not collected in pitfall traps (Table 1). Pitfall traps also collected many unique species (29). Of these, 10 were brachypterous and incapable of flight (Table 1).

Although smaller carabid species were better represented in Malaise than in pitfall trap samples, pitfall traps collected a greater proportion of the larger species (Fig. 2). Relatively few carabids above 10 mm in length were collected in Malaise traps, but large numbers of such carabids were collected in pitfall traps (Fig. 2). Similarly, while pitfall traps captured few species under 5 mm in length, many species of this size class were captured in Malaise traps (Fig. 2).

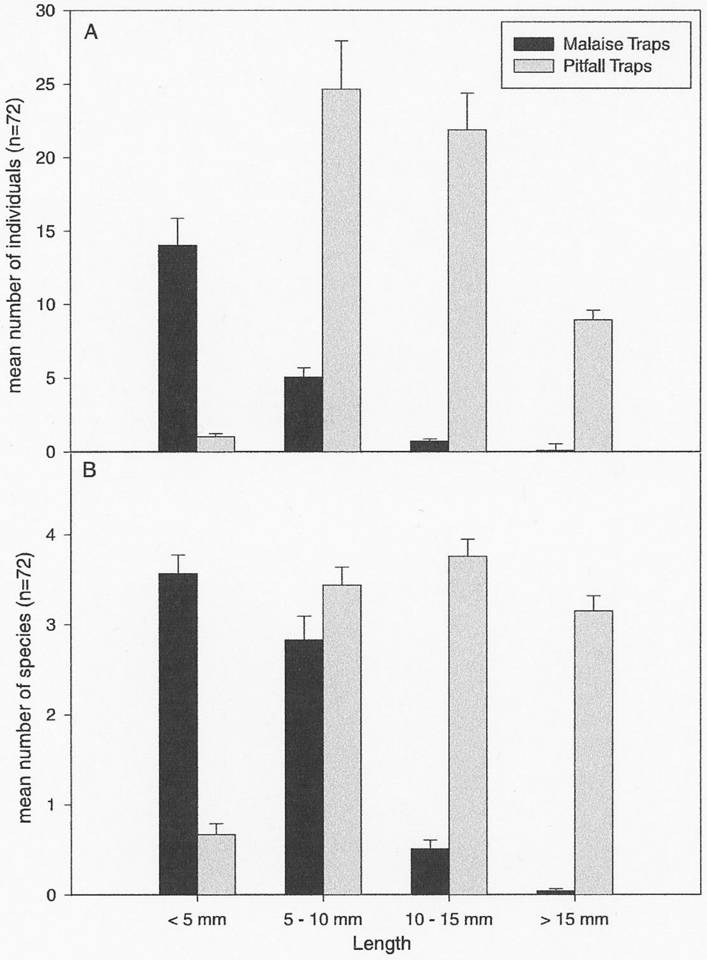
Many of the carabid species (11) captured exclusively in Malaise traps live primarily on vegetation. For example, we collected 12 species of Lebiini (the "colorful foliage ground beetles"), a group of primarily plant-dwelling species. Nine of these were captured only in Malaise traps (Table 1).

Malaise traps greatly increased the number and diversity of carabids sampled in this study. If only pitfall traps had been used, the numbers of individuals and species collected would have been reduced by 26% and 38%, respectively. These results emphasize the importance of using more than one trapping method when conducting ground beetle surveys. Despite their success in this study, the efficacy of Malaise traps in different habitats remains uncertain.

Past researchers have recognized the importance of flight to the dispersal of carabids and the prevalence of macropterous species in unstable habitats (Darlington 1943; Boer 1970; Cardenas and Bach 1992). Cardenas and Bach (1992) found a frequently flooded site to contain predominantly macropterous carabid species, while a nearby stable environment had many apterous and brachypterous forms. Because our forest was flooded seasonally, and because many of the low-lying areas were under water throughout the study, flight may be a more important mode of dispersal here than in other, more stable habitats. Further studies are needed to elucidate the value of Malaise traps to carabid surveys in different habitats and regions before any general recommendations on their use can be made.

Trap design is another important consideration. The collecting jar at the base of our traps was of particular value because beetles often fall upon encountering a barrier during flight. We recently set out Malaise traps of the same

**Fig. 2.** Mean numbers of individuals (A) and species (B) of carabids by size class collected in Malaise and pitfall traps in a bottomland hardwood forest (South Carolina, United States of America) in 2001.




design in the Oconee National Forest (Greene Co., Georgia) to compare the numbers of beetles captured in the upper and lower collecting jars. We ran 12 traps for a month and collected 275 carabids. Of these, 223 (81.1%) were collected in the lower chamber (unpublished data).

We have demonstrated the value of one Malaise trap design to carabid surveys in a bottomland hardwood forest. The expense of these traps, as well as the inability of alternative designs to capture specimens that fall upon contact, may limit the use of Malaise traps by many researchers. Other less expensive flight intercept devices (such as window-pane traps) are specifically designed to capture fallen insects and may prove similarly useful to future carabid surveys.

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Abildsnes, J., and Tommeras, B.A. 2000. Impacts of experimental habitat fragmentation on ground beetles (Coleoptera, Carabidae) in a boreal spruce forest. Annales Zoologici Fennici, **37**: 201–212.

Adis, J. 1979. Problems of interpreting arthropod sampling with pitfall traps. Zoologischer Anzeiger, **202**: 177–184.

Benest, G. 1989. The sampling of a carabid community. I. The behavior of a carabid when facing the trap. Revue d'Ecologie et de Biologie du Sol, **26**: 205–211.

Boer, P.J., den. 1970. On the significance of dispersal power for populations of carabid beetles (Coleoptera, Carabidae). Oecologia, **4**: 1–28.

Cardenas, A.M., and Bach, C. 1992. The influence of environmental changes on wing development in carabids (Col. Carabidae) in the Guadiato River basin (SW Spain). Vie Milieu, **42**: 277–282.

Ciegler, J.C. (*Editor*). 2000. Ground beetles and wrinkled bark beetles of South Carolina (Coleoptera: Geadephaga: Carabidae and Rhysodidae). Clemson University, Clemson, South Carolina.

Darlington, P.J. 1943. Carabidae of mountains and islands: data on the evolution of isolated faunas and on atrophy of wings. Ecological Monographs, **13**: 37–64.

Digweed, S.C., Currie, C.R., Carcamo, H.A., and Spence, J.R. 1995. Digging out the "digging-in effect" of pitfall traps: influences of depletion and disturbance on catches of ground beetles (Coleoptera: Carabidae). Pedobiologia, **39**: 561–576.

Greenslade, P.J.M. 1964. Pitfall trapping as a method for studying populations of Carabidae (Coleoptera). Journal of Animal Ecology, **33**: 301–310.

Larochelle, A., and Lariviere, M.-C. 2001. Natural history of the tiger beetles of North America north of Mexico. Cicindela, **33**: 41–162.

Larochelle, A., and Lariviere, M.-C. 2003. A natural history of the ground-beetles (Coleoptera: Carabidae) of America north of Mexico. Pensoft Series Faunistica No. 7. Pensoft Publishers, Sofia and Moscow.

Liebherr, J., and Mahar, J. 1979. The carabid fauna of the upland oak forest in Michigan: survey and analysis. Coleopterists Bulletin, **33**: 183–197.

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

Maelfait, J.P., and Desender, K. 1990. Possibilities of short-term carabid sampling for site assessment studies. *In* The role of ground beetles in ecological and environmental studies. *Edited by* N.E. Stork. Intercept, Andover, Hampshire, United Kingdom. pp. 217–225.

New, K.C., and Hanula, J.L. 1998. Effect of time elapsed after prescribed burning in longleaf pine stands on potential prey of the Red-Cockaded Woodpecker. Southern Journal of Applied Forestry, **22**: 175–183.

Paarmann, W., and Stork, N.E. 1987. Seasonality of ground beetles (Coleoptera: Carabidae) in the rain forests of N. Sulawesi (Indonesia). Insect Science and its Application, **8**: 483–487.

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

Spence, J.R., Langor, D.W., Hammond, H.E.J., and Pohl, G.R. 1997. Beetle abundance and diversity in a boreal mixed-wood forest. *In* Forests and insects. *Edited by* A.D. Watt, N.E. Stork, and M.D. Hunter. Chapman and Hall, London. pp. 287–301.

Ulyshen, M.D., Hanula, J.L., Horn, S., Kilgo, J.C., and Moorman, C.E. 2004. Spatial and temporal patterns of beetles associated with coarse woody debris in managed bottomland hardwood forests. Forest Ecology and Management, **199**: 259–272.

Usis, J.D., and MacLean, D.B. 1998. The ground beetles (Coleoptera: Carabidae) of Stillfork Swamp Nature Preserve, Carroll County, Ohio. Ohio Journal of Science, **98**: 66–68.

Work, T.T., Buddle, C.M., Korinus, L.M., and Spence, J.R. 2002. Pitfall trap size and capture of three taxa of litter dwelling arthropods: implications for biodiversity studies. Environmental Entomology, **31**: 438–448.