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	*Euphorticus pubescens* (DeJean)	0/2	Ground	Macropterous

Table 1 (*continued*).

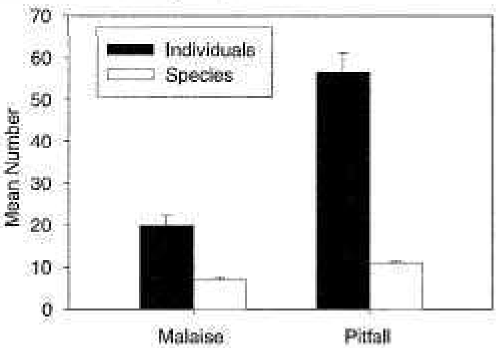
Tribe	Species	Number (Mal/Pit)	Habitat	Wing structure
Lebiini	*Apenes sinuatus* (Say)	2/3	Ground	Macropterous
	Calleida decora (Fabr.)	2/0	Vegetation	Macropterous
	Calleida virdipennis (Say)	3/0	Vegetation	Macropterous
	Coptodera aerata Dejean	4/0	Vegetation	Macropterous
	Cymindis sp.	60/0	Ground?	Macropterous
	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 Larivière (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).

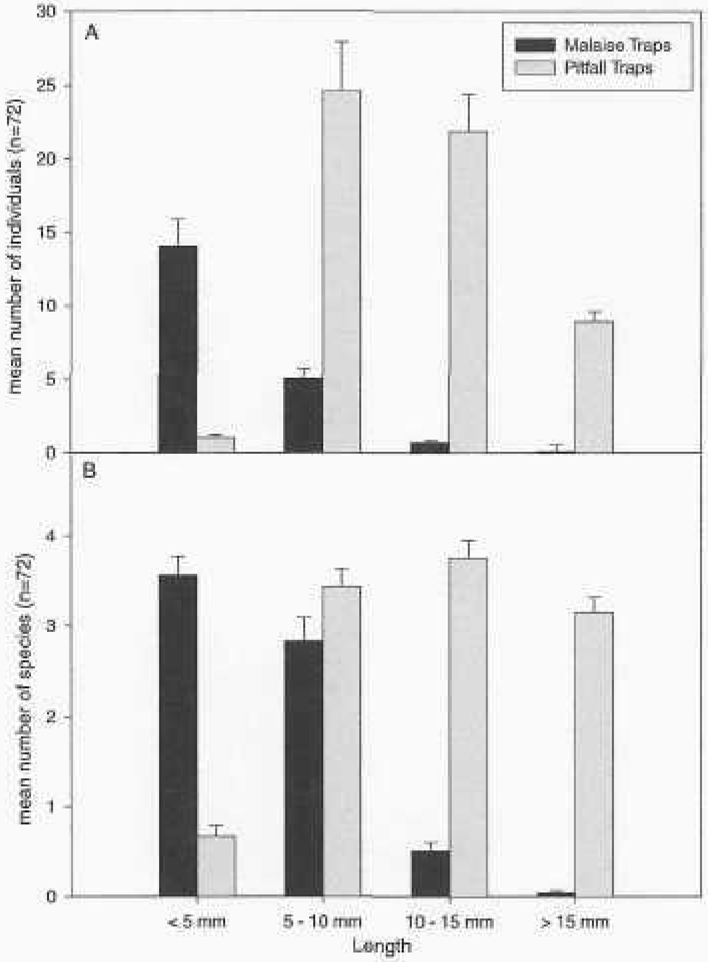
Many of the carabid species (11) captured exclusively in Malaise traps live primarily on vegetation. For example, we collected 12 species of Lebiini (the "colorful foliage ground beetles"), a group of primarily plant-dwelling species. Nine of these were captured only in Malaise traps (Table 1).

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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