Factors Affecting Efficacy of Pitfall Traps For Beetles (Coleoptera: Carabidae and Tenebrionidae)[2, 2]

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ABSTRACT Numbers of trapped beetles in the field and a laboratory arena increased with pitfall trap size. Size and configuration of guides affected catch size. Beetles which moved rapidly were more likely to be captured. Non-captures resulted when beetles turned away from traps or pulled out of the trap cones. Plant debris in traps reduced catch size.

KEY WORDS Insect behavior, pitfall traps, trap efficacy, Carabidae, Tenebrionidae.

Ground beetles, (Coleoptera: Carabidae), called carabids hereafter, are soil-surface dwelling insects which are dominant in agricultural systems (Rivard 1966). Carabid activity density (a function of movement × population density) has been measured with pitfall traps (Southwood 1987). Although trap catches may not reflect population densities directly (Grenslade 1964, Scheller 1984), pitfall traps have been used extensively for ecological studies of carabids and *Eleodes* spp. (Coleoptera: Tenebrionidae) (Calkins and Kirk 1975, Faragalla and Adam 1985).

Pitfall traps have been made from buried cups, cans, jars, and troughs (Greenslade 1964; Luff 1975, 1978; Tyler and Ellis 1979; Lesiewicz et al. 1983; Hylton et al. 1985). Fences and guides have been added to increase catch numbers (Smith 1976, Wallin 1985). Other modifications included protective rain roofs (Frank 1971, Baars 1979), camouflaging, and baiting (Tardiff and Dindall 1980). Traps made from disposable cups (Morrill 1975) have been used effectively (Barney and Pass 1986, Lester and Morrill 1989).

Our study included field and laboratory experiments to determine effects of trap size and "guides" on catch sizes. We also evaluated behavior of carabids and *Eleodes extricata* (Say) when traps were encountered, and compared visual counts of *E. extricata* in field plots with trap catches.

Materials and Methods

The basic trap design (Morrill 1979) was improved by using stronger materials. Traps were made from plastic funnels with 9.5 cm top diameter which were

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inserted through holes in plastic jar lids. Bottoms of catch jars were removed and covered with aluminum wire screen. Traps rested in PVC pipe sections 20 cm long which were buried in the ground with the upper end level with the soil surfice (Fig. 1).

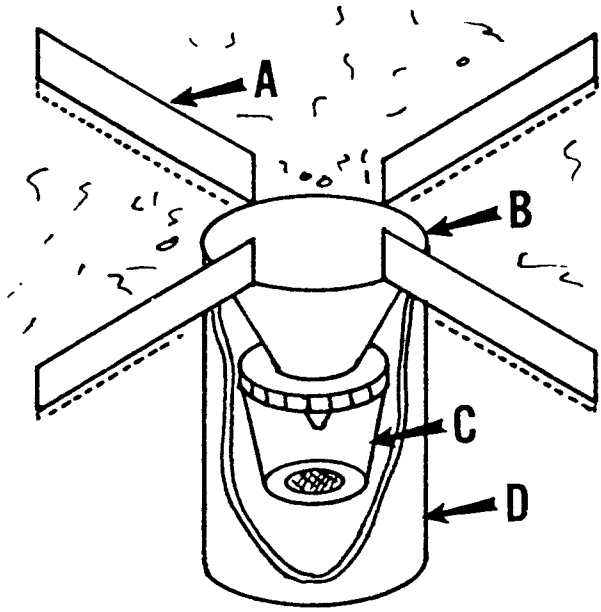

Fig. 1. Pitfall trap and guide configuration. A-aluminum guide, B-trap cone (funnel), C-catch container (jar with screw lid and screend bottom hole, and D-outer cylinder (pvc pipe section). The configuration of 4 guides is shown. Tests were also conducted with 1 guide and 2 guides at 180 degrees.

Laboratory trials were conducted in an arena made of a round plywood base (1.2 meter dia by 2 cm thick) surrounded by an upright plastic edge (20 cm high). Four equidistant holes were cut in the plywood base through which the PVC cylinders were inserted to support trap cones. The plywood base was supported by wooden blocks to permit extension of the traps below the arena. Soil was added (about 10 cm deep), and moistened periodically to maintain high relative humidity necessary for beetle survival. The arena was covered with a 7 mm thick sheet of plexiglass. Carabids were collected in the field and released in the arena at weekly intervals.

Traps with cone perimeters of 17.3 and 25.1 cm were tested in an alfalfa field in 1985 and 1986. There were four replications of four traps per size. Numbers of predominant species of carabids were counted for 17 days and averaged to carabids per day. Means were compared using ANOVA and LSD. A computerized statistical program, MSUSTAT, was used for all comparisons.

Laboratory traps were made from coffee cup liners (buried in the soil without catch jars) which were cut to obtain the desired size. Trap perimeters were 14, 16,

18, 20, and 22 cm. One trap of each size was placed in the soil, and numbers of *Pterostichus melanarius* Illiger captured after 24 hours were recorded. Carabids were released, and the trial was repeated 3 times.

The effects of guides on numbers of beetles captured was tested in the field and in the laboratory. In 1985, traps were installed in a wheat field (about 40 ha) which was heavily infested with *E. extricata* adults. Guides (0, 1, 2, or 4 per trap) made from thin aluminum sheet (5.5 by 25 cm) were used. There were four replications consisting of four traps of each configuration. *Eleodes extricata* were counted at weekly intervals for 3 weeks. Guides of the same length and configuration were also tested in alfalfa in 1985 and 1986. Mean numbers of predominant species of carabids/day captured in a 20 days were compared by using ANOVA and LSD.

The effect of guide length was tested in the laboratory. A single guide representing a ¼, ½, ¾ and 1x of the trap perimeter (20 cm) was used. Traps were operated for 24 hr, and tests were repeated four times. Mean numbers of four species of caribids captured were compared by using ANOVA and LSD.

Behavior of *Pterostichus corvus* LeConte and *Harpalus amputatus* Say which encountered trap perimeters in the arena were categorized as 1) - avoidance (turning away), 2) - escape (entered cone of trap, but pulled out), or 3) - capture (fell into the trap). Forty observations were made. Numbers within each category were expressed as percentages.

Movement of *P. corvus* was either very rapid or slow. Trap encounters by "rapid" and "slowly" moving beetles were recorded as "capture" or "escape" in 13 observations. Observations of *H. amputatus, P. melanarius,* and *P. corvus* were recorded in 30 encounters as "escape" or "capture."

Numbers of carabids captured in traps with cones flush with the soil surface were compared with traps in which the cones were raised about 3 mm above the soil.

Carabid response to voids was tested on a 21 by 30 cm platform constructed from corrugated cardboard covered with fine sandpaper. A cross section of a pitfall trap was glued into a circular notch cut into the side of the platform. The platform rested on blocks 60 cm above the bench top. Field-collected *E. extricata, Amara farcta* LeConte, and *P. corvus* were placed under clear plastic boxes on top of the platform. After they had quieted, the boxes were removed carefully, and carabid behavior was observed for several minutes.

To determine if pitfall trap catches would accurately indicate beetle activity, three replications of plots (45 by 45 m) of winter wheat which was heavily infested with *E. extricata* were treated with permethrin emulsifiable concentrate (0.11 kg/ha) or malathion emulsifiable concentrate 1.12 kg/ha). There were untreated check plots. Chemicals were applied with a backpack sprayer pressurized with CO^2 delivering 20 l/ha. One pitfall trap was placed in the center of each plot. Numbers of *E. extricata* captured at approximately weekly intervals were counted. Numbers of living and dead beetles visible on the soil surface were counted between eight rows of wheat across each plot. Means were compared by using ANOVA and LSD.

Some problems which were encountered during the project included: plant stems fell into cones, cones broke away from the jar lids, and jars were unscrewed from lids. To determine the effect of these problems on catch sizes, these

conditions were simulated in trials over a 5-week sampling period in alfalfa. There were four replications, and means were compared by using ANOVA and LSD.

Results and Discussion

In the field, significantly more carabids were captured as trap size increased for 3 out of 5 species (Table 1). The increase in catch size was influenced by factors in addition to the trap perimeter, for some catches increased up to 76% while perimeters increased only 31%. Therefore, we established laboratory trials to examine beetle behavior and trap configuration.

Table 1. Numbers of predominant species of ground beetles (Coleoptera: Carabidae) captured in various sizes of pitfall traps in alfalfa, Gallatin County, MT.

	Mean catch/day				
	1985		1986		
Trap perimeter	*Harpalus amputatus*	*Pterostichus melanarius*	*Stenolophus comma*	*Harpalus amputatus*	*Amara farcta*
17.3 cm	0.7a	1.2a	0.5a	1.2a	2.9a
25.1 cm	1.8b	1.1a	2.1b	2.2b	3.8a

* Numbers are means of 4 replications, adjusted to daily catches for 17 days. Number within columns followed by the same letter are not significantly different, LSD, $P < 0.05$.

In the laboratory arena, *P. melanarius* catches significantly increased as trap perimeters increased from 18 to 20 and 22 cm (Table 2). These traps consisted only of a cone, and after carabids accumulated in the small cone, some were able to reach the top and escape. Also, in the 16 cm diameter cone, carabids on the soil surface were attracted to trapped carabids in bottom of the cone, resulting in unusally high catch numbers. This attraction was never observed in traps which retained carabids in the catch jar rather than in the cone. Again, the increase in catch size was greater than what would be expected from increased trap size.

Table 2. Numbers of *Pterostichus melanarius* Illiger (Coleoptera: Carabidae) captured in pitfall trap cones in a laboratory arena.

Cone perimeter, cm	Mean number carabids	Carabids/cm of trap perimeter	Notes
14	4.3	0	escaped*
16	10.7	0	jumped in†
18	2.0a	0.111	fell in
20	7.3b	0.365	fell in
22	10.0c	0.454	fell in

Numbers followed by the same letter are not significantly different, LSD, $P < 0.05$.

* Carabids were able to escape by climbing on top of each other and reaching the edge of the cone.

† Carabids were attracted to those which were already captured, thereby biasing the results.

Assuming carabids move in a nondirectional, or Brownian fashion (Jansen and Metz 1979), catch size should be function of trap perimeter. In the "perimeter model," the likelihood of a carabid being caught depends upon the probability of it arriving at any point of the perimeter of the trap (Luff 1975). Therefore, catch sizes are positively correlated with trap size. However, if carabid movement is directional, catches are more likely to be represented by the "diameter model," for it represents an obstacle in the path of the movement (Luff 1975).

Various elements of carabid behavior influenced catch numbers in the laboratory arena. These elements were: turning to avoid the edge of the trap which represented a change in the topography, retreating after sensing a "void" represented by the interior of the cone, and escape after entering the cone. Some foliage-dwelling insects probably can sense voids, an adaptation which prevents falling from plants. Although carabids are generally soil dwelling insects, they also occur in plants. We occasionally captured *Harpalus* spp. during sweep net sampling in alfalfa. Cone avoidance was shown by 43% and 32% of *P. corvus* and *H. amputatus,* respectively.

Further observations of a carabid void avoidance were made in the laboratory with *P. melanarius* and *P. corvus.* Individual carabids were released on the elevated platform. They did not jump or fall from the edge. However, it was necessary to confine them under a container until they had quieted.

Other beetles were able to escape after they began to fall into the cones. The escape behavior of *E. opaca* (Say) followed an orderly sequence (Fig. 2). When the beetle began to fall into the cone, the edge was grasped with one or both metathoracic legs, and the downward movement was stopped. If the cone was grasped with both legs, one released, and the body was pushed sideways with free legs. When the cone edge could be grasped by the prothoracic leg, the body was pulled upward and the beetles escaped. Escape was recorded in 29% and 46% of the *P. corvus* and *H. amputatus,* respectively.

The speed movement of carabids on the soil surface influenced catch numbers. In the arena, *P. corvus* displayed two distinct types of movement. "Rapid" movement was associated with erect heat position (parallel to the soil surface), and movement was in a straight line. "Slow" movement was associated with the head directed downward, and there was frequent examination of objects encountered on the soil. There were frequent changes in direction. We observed that 31% of the "rapid" and 8% of the "slow" moving *P. corvus* were captured when they encountered the cones.

Field conditions may determine movement (slow vs rapid) of beetles. For example, unfavorable conditions (hot, bare ground) resulting from alfalfa foliage harvesting would encourage rapid dispersion of beetles. This dispersion for ground moving species would be by rapid movement, and in a single direction as was shown in the laboratory arena. Conversely, carabid survival in favorable environments with adequate hosts, suitable moisture, and moderate temperature would require comparatively little movement. Probably this movement would be slow and occur for a minimum amount of time. Obviously, pitfall traps operated in these two situations would produce different catch sizes, even though the population densities were similar.

Rapid movement sometimes changed to slow movement when obstacles such as guides or protruding trap edges were encountered. Cones which rested on cylinders which protruded 3 mm above the soil surface were avoided by 71, 75,

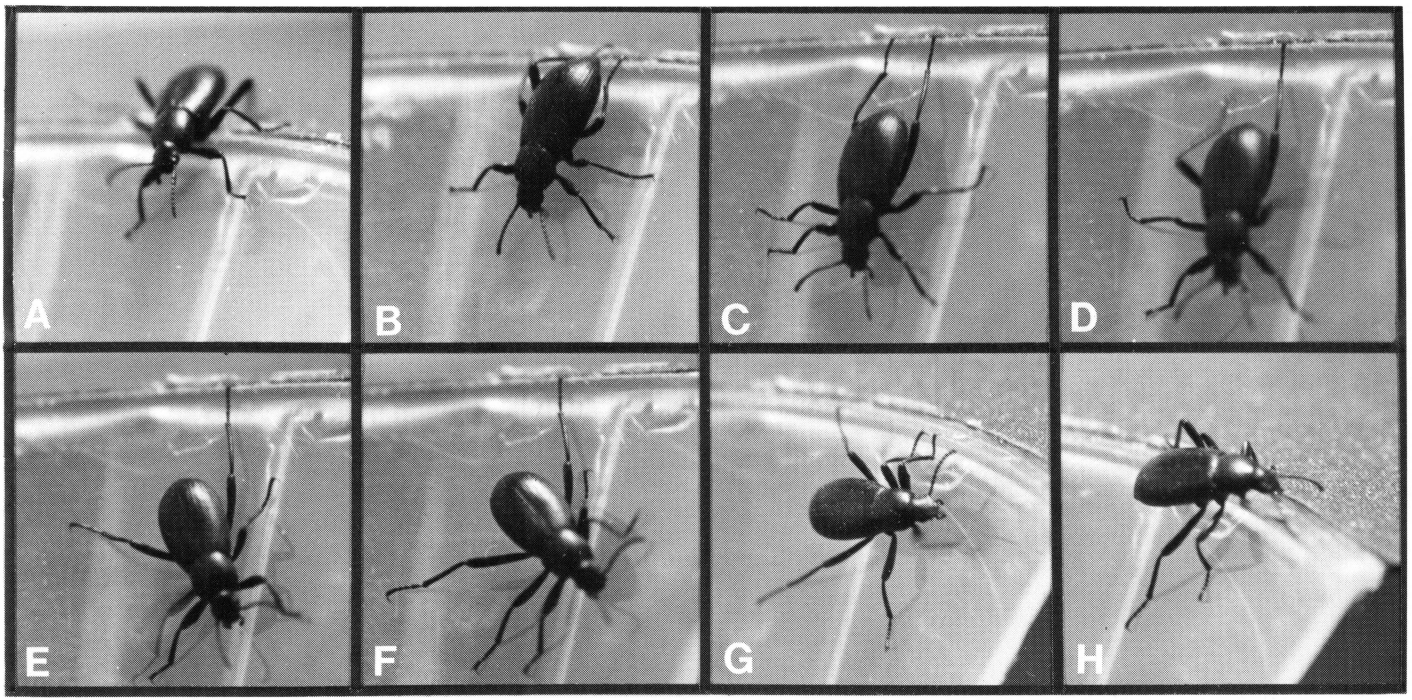

Fig. 2. Escape of *Eleodes opaca* (Say) (Coleoptera: Tenebrionidae) from the cone of a pitfall trap. A-entrance into the cone, B-body completely into cone, edge of cone grasped by right meso and both metathoracid legs; C-edge of cone grasped by metathoracic legs, D-release of cone edge with right mesothoracic leg, E-use of right legs to move body to the left, F-continued movement of body toward the left, G-grasping cone edge with left legs, and H-pulling body up out of the cone.

and 100% of the *P. melanarius, P. corvus,* and *H. amputatus,* respectively. This illustrates the importance of careful installation and maintenance of traps in the field.

In the field, guides are easily installed, should increase trap catches. Use of four guides in a "X" configuration significantly increased catch size of *E. extricata* in the field in two out of three sample periods (Table 3). Catches were not significantly increased by the use of one or two guides during any sample period. The use of four guides in alfalfa increased carabid catches for two out of five instances (Table 4).

Table 3. Effect of various numbers of guides on pitfall trap catches of *Eleodes extricata* (Say) (Coleoptera: Tenebrionidae) in wheat, 1985, Broadwater County MT.

Number of guides	Sample period		
	May 14 - 21	May 21 - 28	May 28 - 13
None	0.75a	0.50a	0.75a
1	2.25ab	2.50a	0.25a
2	1.25ab	2.00a	0.75a
4	3.50b	2.00a	2.25b

* Numbers within columns followed by the same letter are not significantly different, LSD, $P < 0.05$. Numbers are means of 4 replications.

Table 4. Effects of numbers of guides on catches of predominant species of ground beetles in alfalfa, Gallatin County, MT, 1985-86.

	Mean number carabids/day				
	1985		1986		
Number guides	*Harpalus amputatus*	*Pterostichus melanarius*	*Stenolophus comma*	*Harpalus amputatus*	*Amara farcta*
0	1.2a	1.2a	2.2a	3.9a	2.2a
1	2.1ab	2.1ab	2.0a	3.8a	2.8a
2	2.2b	2.4ab	1.5a	3.3a	2.7a
4	2.5b	3.8b	1.8a	3.9a	2.5a

Numbers are standardized means of carabid catches for at least 20 days for 4 replications. Numbers within columns for each trap style followed by the same letter are not significantly different, LSD, $P < 0.05$.

Guide length should also be a factor which affects catchs. In the laboratory arena, a single guide with a length ¼ the trap perimeter (5 cm) did not significantly increase catch size (Table 5). A guide length equal to the trap perimeter (20 cm) significantly increased trap catches in 3 out of 4 species. The catch increases for significant species ranged from 100 to 251%. Inconsistent response to guides by carabid species may be a result of different behavioral responses, such as chances in speed of movement which in turn affects the percent of escapes or avoidances.

Table 5. Effect of various guide sizes on pitfall trap catches in a laboratory arena.

Guide length	Number of carabids captured			
	Pterostichus melanarius	*Harpalus amputatus*	*Pterostichus corvus*	*Amara farcta*
None	8.25a	4.25a	4.00a	3.50a
5 cm	10.25ab	2.75a	5.25ab	2.00a
10 cm	14.00bc	4.25a	6.75ab	4.25ab
15 cm	18.00c	6.75a	11.00ab	4.50ab
20 cm	29.00d	4.00a	11.25b	7.00b

Numbers within columns followed by the same letter are not significantly different, LSD, $P < 0.05$. Numbers represent means of 4 replications.

Analysis of effects of a guide on capture/escape of six carabids in hypothetical trap with a guide can be made in the following fashion (Fig. 3). Carabids "B" and "D" approach the guide, turn toward the trap, and are captured. Carabids "C" and "E" turn away from the trap and escape. Beetles "A" and "F" encounter the perimeter of the trap and are captured. The guide length equals the cone perimeter, and the probability of beetles encountering the trap perimeter is equal to that of encountering the guide. Beetles have an equal probability of turning right or left. The number of beetles captured is therefore doubled by the use of a guide.

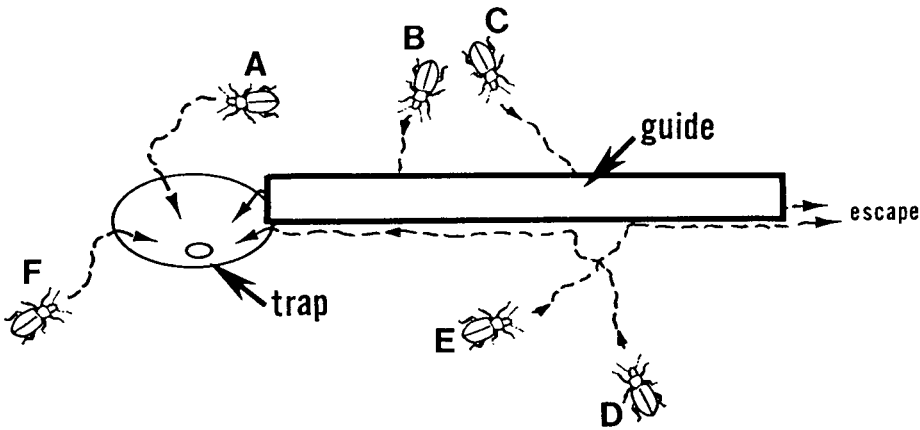

Fig. 3. Hypothetical movement and subsequent capture or escape of 6 carabids, assuming non-directional movement and equal probability of turning right or left when the guide is encountered. Guide length equals the cone perimeter, and the guide doubles the catch size.

Numbers of living *E. extricata* were significantly lower three days after treatment with insecticide (Table 6), and correspondingly there were more dead beetles on the soil surface, indicating that there was a reduction in the population. There were fewer beetles captured in pitfall traps in the permethrin treated plots during the following two sample periods. After 16 days, there was no significant differences in catch sizes, apparently due to movement of beetles into the treated plots. Data indicate that trap catches represented changes in beetle populations in the field.

Table 6. Effect of insecticide treatments on numbers of adult *Eleodes extricata* (Say) (Coleoptera: Tenebrionidae) visible on the soil surface and captured in pitfall traps in wheat, Broadwater County, MT, 1985.

	Beetles on soil		Mean number of beetles in traps			
Treatment*	Alive†	Dead	May 23	May 29	June 4	July 14
Untreated	43.7a	1.0a	28.33b	33.33b	25.00a	19.50a
Permethrin	20.0b	12.7c	7.00a	7.67a	15.00a	23.33a
Malathion	24.7b	4.7d	17.67ab	32.67b	23.67a	22.00a

* Permethrin applied at 0.11 kg/ha and malathion was applied at 1.12 kg/ha on May 19.
† Mean no. beetles seen in an area measuring 2.4m × 30m in each plot on May 23.
Numbers are means of 3 replications. Numbers within columns followed by the same letter are not significantly different, LSD, $P < 0.05$.

Numbers of *H. corvus* were reduced in malfunctioning traps, and in most cases, carabids were able to escape when an alfalfa stem extended from the cup to the top of the cone (Table 7).

Table 7. Effect of trap malfunction on numbers of *Harpalus corvus* LeConte (Coleoptera: Carabidae) captured in pitfall traps in alfalfa, 1987.

	Sample period				
Trap condition	June 30-Aug. 3	Aug. 3-Aug. 6	Aug. 6-Aug. 11	Aug. 11-Aug. 15	Aug. 15-Aug. 31
Complete	12.25b	4.25b	5.25a	4.75b	9.75b
Cone removed	5.75ba	0.50a	4.50a	5.00b	5.75ab
Jar unscrewed	4.00a	1.00a	2.00a	5.00b	4.00ab
Stem in trap	0.50a	1.25ab	0.75a	1.25a	0.50a

Numbers within columns followed by the same letter are not significantly different, LSD, $P < 0.05$. Numbers represent means of 4 replications.

In conclusion, pitfall traps were effectively used to capture beetles. Catch numbers increased when guides were used. However, species showed different behavioral responses to traps, resulting in biased numbers. Traps must be maintained carefully, for cones which protrude above the soil or contain plant debris will catch and retain fewer beetles. Under our conditions, predation in traps was not an important factor. In fact, occasionally cutworms were captured, and were not eaten during the collection periods.

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