BIOTROPICA 37(2): 322–325 2005 10.1111/j.1744-7429.2005.00042.x

Trap Spacing and Transect Design for Dung Beetle Biodiversity Studies[1]

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ABSTRACT

Standardized sampling methods are essential for comparing species diversity and abundance patterns across different studies and sites. Although dung beetles are widely used as a focal taxon in biodiversity studies, nothing appears to be known about the effective sampling area of dung-baited traps. Mark-recapture experiments using *Canthon acutus* showed that at least 50 m between traps should minimize trap interference, and that wind affects trap detectability. Consequently, we propose a standardized dung beetle sampling design.

RESUMEN

Los métodos de muestreo estandarizados son esenciales para comparar patrones de la diversidad de especies y abundancia entre diferentes estudios y sitios. Aunque los escarabajos coprófagos son utilizados ampliamente como taxon focal en los estudios de biodiversidad, aparentemente no hay conocimientos sobre el area efectiva de muestreo con trampas de caída cebadas. Utilizando experimentos de marca-recaptura con *Canthon acutus* como modelo, demostramos que una separación de por lo menos 50 metros puede ser requerida para minimizar la interferencia entre trampas, y que el viento afecta la detectabilidad de las mismas. En base a los resultados, proponemos un diseño estandarizado de muestreo de escarabajos coprófagos.

Key words: biodiversity monitoring; Canthon acutus; *dung beetles; tropical semi-deciduous forest; Venezuela.*

DUNG BEETLES (COLEOPTERA: SCARABAEIDAE: SCARABAEINAE) ARE BROADLY RECOGNIZED as a useful focal taxon for describing and monitoring spatial and temporal patterns of biodiversity (Favila & Halffter 1997, Spector & Forsyth 1998, Davis *et al.* 2001). By burying dung on which adults and larvae feed, dung beetles act as secondary seed dispersers, accelerate nutrient recycling rates, increase plant yield, and regulate parasites of vertebrates (Mittal 1993, Andresen 1999). Tropical dung beetle communities are usually very abundant and show high Alpha, Beta, and Gamma diversity (Hanski 1989, Spector 2002). Over 80 species of dung beetles can often be found locally in tropical forests and savannahs across the world (Cambefort 1991, Spector & Forsyth 1998, Davis 2000). Species composition changes distinctly across habitat types, and complete species turnover has been observed across a natural ecotone spanning as little as 100 m (Spector & Ayzama 2003).

Dung beetle species composition and abundance show a rapid, graded response to various kinds of disturbance. Habitat fragmentation, hunting, logging and other changes in vegetation usually cause a reduction in dung beetle species richness, abundance, and biomass as compared to undisturbed habitat (Howden & Nealis 1975, Hanski 1989, Klein 1989). Dung beetles are especially useful for understanding these patterns because of the ease with which they can be sampled. Because dung beetles are excellent fliers and actively forage for food by smell, they can be efficiently sampled using baited pitfall traps. Pitfall transects provide a fast, inexpensive, and relatively unbiased method for obtaining data on species diversity and abundance distributions (Spector & Forsyth 1998). Accurate abundance data are often difficult to obtain, but are much more powerful than presence-absence data for analyzing diversity patterns and for exploring the ecological factors that influence community structure (DeVries *et al.* 1997).

Despite the usefulness of dung beetles in biodiversity studies, nothing appears to be known about the effective sampling area (ESA) of baited dung beetle traps. If the ESAs of two adjacent traps overlap, the traps will interfere with each other, causing total beetle abundance and possibly species richness to be underrepresented. Furthermore, insufficient trap spacing will skew the distribution of species abundance across traps, since traps placed near the outside or ends of the transect will be subject to less trap interference and will consequently capture more individuals than those placed on the inside. Trap ESA must also be known in order to calculate absolute population densities (Turchin 1998). Because trap spacing can affect the results, a lack of standardized transect design has hampered comparisons among dung beetle diversity studies. We tested the ESA of a standard type of baited pitfall trap using the dung beetle *Canthon acutus* Harold. Based on the results, we propose a standardized dung beetle sampling design that should minimize trap interference and be simple to employ at almost any field site.

The study was conducted during May of 2002 and May of 2003 in a semi-deciduous tropical forest in the state of Bolivar, Venezuela (7°21′N, 62°52′W). The most abundant species at the site, *Canthon acutus*, was used for the experiment. *C. acutus* is a small diurnal ball-rolling beetle (mean body width = 4.1 ± 0.3 mm). We used a trap design frequently used to sample dung beetle communities (see Spector & Forsyth 1998). Each pitfall trap consisted of two stacked 16 oz (473 cm^3) plastic cups

[1] Received 4 February 2004; revision accepted 27 September 2004.

buried in the ground so that the top rim was flush with the soil surface. Two cups were used so that the top cup containing the sample could be easily removed and replaced again after each collection. The top cup was half-filled with water and a small amount of unscented liquid detergent to reduce surface tension. We wrapped a *ca* 20 g human dung bait in nylon tulle and tied it with string to a short stick. We placed the stick into the ground so that the bait was suspended above the cups, and covered the bait with a plastic plate (large leaves can also be used) to protect the trap from sun and rain and to help prevent beetles from landing on the bait. Favila and Halffter (1997) describe some other types of pitfall traps that can be used to capture dung beetles without killing them. However, we have found that it is difficult or impossible to accurately count and identify live beetles captured at sites with extremely high beetle diversity and abundance, especially when sympatric sister species appear almost identical externally.

In general, when using this sampling method, beetles are collected from each trap every 24 h for at least 4 d, a time period in which species accumulation curves show is usually adequate for sampling the majority of Alpha diversity (Spector & Forsyth 1998, T. Larsen pers. obs.). Human dung is used to standardize collecting methods because it is readily available at any study site in the world and is among the most attractive types of dung to most species of dung beetles (Howden & Nealis 1975). In forests, baits are replaced every 2 d after which they rapidly become less attractive, although baits set in more arid environments may need to be replaced daily (Spector & Ayzama 2003).

To collect live *C. acutus* for mark-recapture experiments, we set the same dung-baited pitfall traps described above, but did not add water to the cup. We also placed an inverted 2-liter bottle top on the rim of the cup to act as a funnel and prevent beetles from escaping. Traps for live beetles were placed on different days. We collected the live beetles after 24 h and placed them into 12 × 12 × 12 in collapsible field cages made of polyester netting. We immediately began marking beetles using a silver Sharpie® pen (Sanford Corp, Shelbyville, TN). Beetles were separated into groups of 100, and each group was marked with a unique combination of spots on the elytra and pronotum. We then released 100 beetles at each of five distances, 0, 12.5, 25, 50, and 100 m, measured along a linear transect from a freshly baited pitfall trap between 1045 and 1215 h. A total of six transects were set on different days and at different locations. For each transect, beetles were only released once, but the trap was collected every 24 h for 4 d and was rebaited after 2 d. We recorded wind speed and direction at the time of release using a Kestrel® 2000 wind meter (Nielsen-Kellerman, Boothwyn, PA).

In order to determine attraction distances, we divided the number of beetles recaptured from each release distance by the number of beetles recaptured from release at 0 m for each transect. We used this proportion in order to control for differences between transects, since not all released beetles were likely to be searching for dung, and because differences in weather, hunger, and other factors may have affected beetle behavior. We used paired sample *t*-tests to compare beetle recaptures after 1 d and after 4 d. In further analysis and discussion, we focus on the total number of beetles recaptured over 4 d, since this represents a typical minimum sampling period for dung beetle studies. We conducted nonlinear regression analyses of beetle recaptures versus release distance using SigmaPlot 8.0 software. We took the definite integral of this nonlinear regression equation to determine the distance corresponding to 95 percent of the area under the curve. This distance represents the effective sampling radius from which 95 percent of recaptured beetles were attracted.

TABLE 1. *Mean percent of* Canthon acutus *recaptured following releases at various distances from a baited trap. Values are normalized by dividing the number recaptured from each release distance by the number recaptured from 0 m. Results are shown from 1 d of trapping and 4 d of trapping. Probability (*P*) from paired sample* t*-test comparing number of beetles recaptured from 4 d and 1 d of sampling.*

Distance released from trap (m)	Actual 4 d mean ± SE	Normalized 4 d mean ± SE	Normalized 1 d mean ± SE	*P*
0	58.3 ± 29.1	100	100	–
12.5	13.3 ± 6.6	21.7 ± 9.0	21.6 ± 9.3	0.47
25	5.5 ± 2.2	10.0 ± 3.0	9.3 ± 3.3	0.27
50	1.7 ± 0.7	2.9 ± 1.0	2.0 ± 0.7	0.36
100	0.2 ± 0.1	0.4 ± 0.4	0	0.71

Over the 4-d period, slightly over half of the beetles released at 0 m were recaptured (mean = 58 ± 8.2 SE). The proportion of recaptured beetles decreased rapidly with increasing distance from the trap (Table 1), fitting the exponential decay regression $y = 0.997e^{(-0.11x)}$ (Fig. 1). Taking the definite integral of this regression from 0 to 25 m and from 0 to 100 m shows that 94.3 percent of the total beetles recaptured had been released within 25 m of the trap. Ninety-five percent of the recaptured beetles were attracted from within 26.2 m of the trap (Fig. 1, dashed line). There was a consistent east wind with a speed varying from 0.3 to 0.6 m/sec. The direction of the transect relative to the wind affected the proportion of beetles recaptured (Fig. 2). Beetles released upwind of the trap were less likely to find the bait than beetles released downwind of the trap. Beetles released along a transect perpendicular to the wind

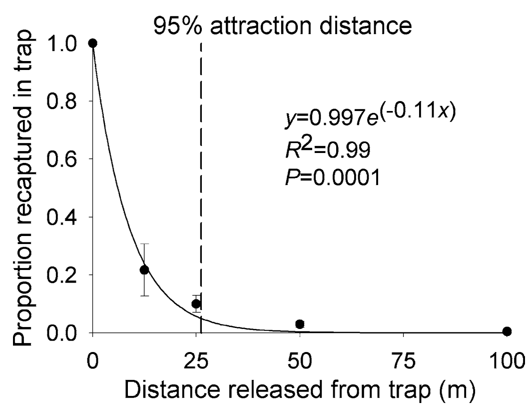

FIGURE 1. The mean proportion of *C. acutus* recaptured from releases at increasing distance from a baited trap (N = 6 transects). Each proportion is normalized by the number of recaptured beetles that had been released at 0 m. Traps were collected every 24 h for 4 d after release. Dashed line represents the trap attraction radius for 95 percent of recaptured beetles.

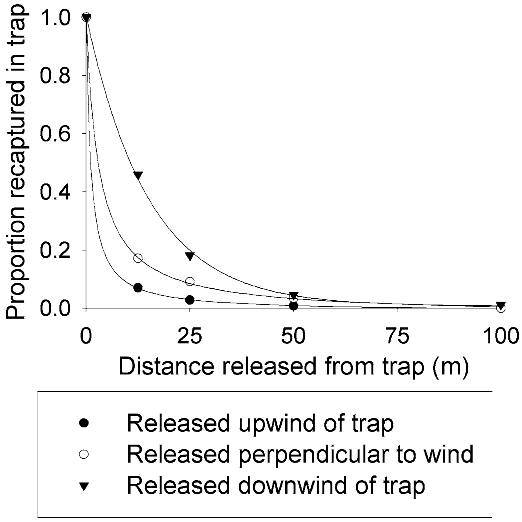

FIGURE 2. The effect of wind direction on the ability of *C. acutus* to detect the bait.

direction were recaptured in intermediate numbers. The results did not differ significantly between 1 and 4 d of trapping (Table 1).

Standardized sampling methods facilitate urgently needed comparisons of independently conducted diversity studies across the world. Species abundances are more powerful than species lists for understanding community dynamics and distributional patterns. Taxa that can be attracted with baited traps are excellent candidates for cross-study comparisons of composition and abundance because they can greatly reduce collector bias. However, proper transect design and trap placement requires knowledge of ESA, which, until now, has not been investigated for dung beetles. The results of this study indicate that at least 50 m spacing between traps is required to minimize trap interference in dung beetle studies. However, species differ in their foraging behavior, and this study only focused on a single small species. While small species, such as *C. acutus*, frequently perch on leaves, large beetles tend to use cruise flight to search for dung, and may be able to detect dung from larger distances (Peck & Forsyth 1982). For example, the large Neotropical species *Megathoposoma candezei* may be able to locate dung from 50 to 75 m away (Wille *et al.* 1974). The size and type of dung bait used during beetle sampling, as well as the openness of the habitat type, may also have a strong effect on attraction distance. Since this study was based on a small leaf-perching beetle species in a closed forest environment, 50 m may represent a minimum estimate for trap spacing using this type of pitfall trap.

A standardized design for sampling dung beetles should be usable in a wide variety of field situations. In selecting the optimal transect design, it is important to take into account that transect placement can be constrained by physical characteristics of the site. Gridded transects provide more complete area coverage than linear transects but can be difficult and/or destructive to set at many field sites because of the lack of trails or steep terrain. A linear transect with very widely spaced traps should eliminate trap interference, but the number of traps may be limited by the size of the study site or trail system. Therefore, we recommend using a linear transect of ten replicated traps with a minimum of 50 m trap separation. This transect design satisfies several requirements; it provides an adequate sample size, it can be easily installed at any site with 500 m or more of reasonably straight walking trail and, based on the results of this study, it should minimize or eliminate trap interference. Our results also indicate that changes in wind could affect trapping results. If there is a predominant wind direction at a site, the trap transect should be placed as perpendicularly to the wind as possible.

If the aim of the study is to sample the entire dung beetle community, additional types of traps should also be placed. Since many species of Scarabaeine dung beetles use other types of resources, traps baited with vertebrate carrion, invertebrate carrion, rotting fruit, and rotting fungus are often effective in capturing species that are not collected with dung. In some places, particularly in the African savannahs, trapping with various kinds of animal dung may increase the number of species collected, although human dung appears to be sufficient in the neotropics (T. Larsen, pers. obs.). Unbaited flight intercept traps provide an effective method for passively sampling species that are not attracted to any of these bait types (see Davis 2000).

Although several factors may affect the ESA of dung-baited pitfall traps, this study provides the first recommendation for trap spacing and transect design based on biological data. When properly sampled, dung beetles provide an excellent focal taxon for understanding and monitoring biodiversity patterns. They are especially useful because tropical dung beetle communities are usually diverse, abundant, highly varied in species traits including habitat specificity, respond rapidly and unambiguously to many kinds of environmental change, and most importantly, beetle composition and abundance can be quickly and quite thoroughly sampled in a relatively unbiased manner. In addition, their many functional roles in the ecosystem make dung beetles ideal for studying the interactions between human disturbances, biodiversity, and ecosystem function. Standardized and well-tested sampling methods are critical for providing the information necessary to conserve biodiversity and the long-term processes that sustain ecosystems.

ACKNOWLEDGMENTS

We thank Luis Balbas and EDELCA for permission to work in the Guri Impoundment; the Princeton Program in Latin American Studies, the Princeton Department of Ecology and Evolutionary Biology, and The Explorer's Club for financial support; John Terborgh and the Guri team for assistance in the field.

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