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A simple trap to study small-scale movement by walking arthropods

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Introduction

Movement is a key element of animal biology, and thus is of central importance to many studies of animal behavior and ecology. The study of insect movement at either small or large spatial scales remains technically challenging, although important progress has recently been made in quantifying movement, and especially aerial movement, using a variety of mark-release-recapture techniques (Hagler & Jackson, 2001). Here we describe a simple trapping technique that can be used to study small-scale movement by walking arthropods. The traps may be especially useful for studying patch leaving rules employed by arthropods foraging on plants.

Materials and methods

Trap design. Our technique uses a sticky material to create barriers that funnel walking insects into a holding area from which it is difficult for them to exit. To facilitate movement into the holding area and impede movement out of the holding area, we use the same concept that is employed in minnow traps and many crab and lobster traps: a funnel-shaped opening is easy to enter from the wide end, but difficult to enter from the narrow end. Thus, funnels create a 'one-way door' effect that can be exploited to trap moving animals.

We were interested in creating a trap for predatory larvae that were leaving a patch of prey by walking off a papaya leaf. The traps (Figure 1a) were deployed on the petioles of papaya leaves, and consisted of three streaks of a sticky material, Tanglefoot®, a product made of castor oil, natural gum resins, and vegetable wax (The Tanglefoot Company, Grand Rapids, Michigan, USA), which we applied to the petiole with a blunt-tipped syringe. Finely ground corn starch ($\approx 40\%$ by volume) was added to the Tanglefoot to make it more opaque, and thus easier to see, and less 'stringy', and thus easier to apply. Tanglefoot is a waterproof material that is designed to prevent insects from walking up tree trunks. Our use of this material rests on the ability of many arthropods to detect the sticky surface and avoid walking on it. First, we applied a circular ring of material at the base of the petiole near the junction with the plant trunk to create a total block to walking arthropods. Second, we applied two horseshoe-shaped streaks of Tanglefoot near the mid-point of the petiole, with the narrow opening pointing away from the leaf. These horseshoe-shaped streaks create the funnel effect that makes the trap work; we offset the openings of the horseshoes to reduce the likelihood that an arthropod walking towards the leaf would pass through both openings.

Efficacy of the trap. We performed a trial on 18 May, 2001 to evaluate the efficacy of the trap. Our objective was to determine if the trap would act as an absorbing barrier, allowing insects to enter and be retained damage-free within the trap once inside.

We used larvae of the predatory beetle, *Stethorus siphonulus* Kapur (Coleoptera: Coccinellidae), which are important consumers of carmine spider mites, *Tetranychus cinnabarinus* (Boisduval) (Acari: Tetranychidae), found on papaya in Hawaii. Our experimental plot was located at the University of Hawaii Poamoho Experimental Station. Leaves of the papaya tree are held on long ($\approx$ 55 cm), tubular petioles with a mean diameter of 13.7 $\pm$ 0.2 (SE) mm

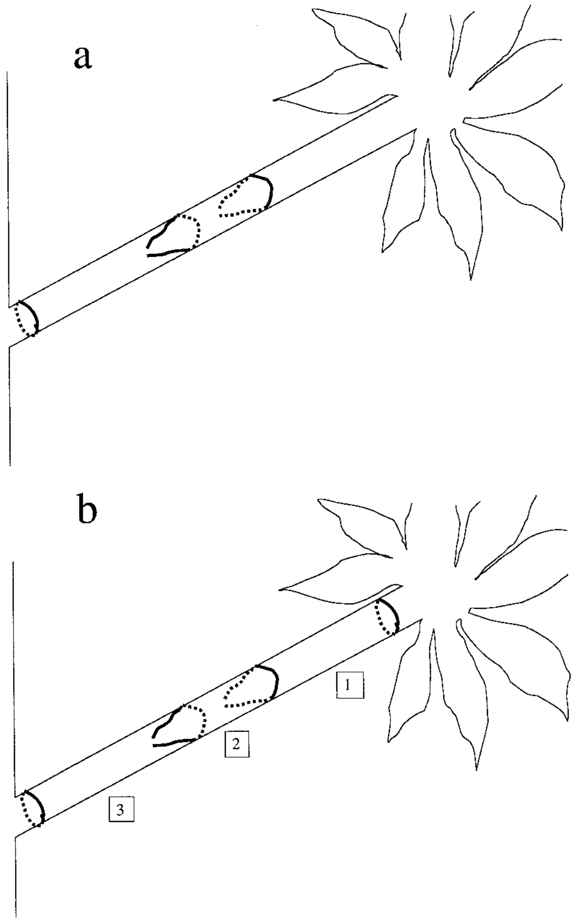

Figure 1. (a) Trap design for arthropods walking off a leaf and towards the trunk of a papaya tree. The trap was set up on the petiole, and consisted of a complete ring of sticky material, which created a total block to movement, and two horseshoe-shaped incomplete rings, which created a funnel effect. The black lines indicate lines of a sticky material (Tanglefoot) that were applied to the petiole. (b) Experimental arena used to test the trap. Larvae of *Stethorus siphonulus* were released in either zone 1 or 3 and their positions monitored for 8 h.

(n = 16). To test the approach, we created an experimental arena on each of 16 petioles (Figure 1b). The arenas were identical to the basic trap, except that we added a second complete ring of sticky material just below the leaf. Thus, the arena consisted of a single petiole with two complete rings at either end ('blocking rings') and two horseshoe-shaped incomplete rings in the middle ('funnel rings') with narrow openings (3.5 ± 0.1 mm). The rings defined three regions of the petiole: zone 1, out of the trap (mean length = 23.1 ± 0.4 cm), zone 2, in the trap but between the two funnel rings (length = 5.5 ± 0.4 cm), and zone 3 inside the trap and within both funnel rings (length = 23.3 ± 0.6 cm). In half of the replicates the openings of the funnel rings pointed towards the leaf, and in the other half of the replicates the openings pointed towards the trunk of the plant. In half of the replicates we released a single *S. siphonulus* larva (third or fourth instar) in zone 1 and in the other half in zone 3. We then checked the larvae at 5, 10, 20, 60, 120, and 640 min post-release to record their location and behavior (walking versus resting). One larva disappeared from the petiole after 1 h, so we re-initiated that replicate with a new larva. Two other larvae did not move after being placed on the experimental petioles (we suspect that they were preparing to molt), so we also re-initiated these replicates with new *S. siphonulus* larvae. For the trap design to be judged successful, our criteria were that (a) larvae should not become stuck in the barriers and (b) larvae should accumulate in the trap (in zones 2 and 3). We sought to create a completely symmetrical design, so that our statistical criterion for successful trapping would be a significant excess of larvae present in zone 3 compared to zone 1.

We also used the trap to study movement of *S. siphonulus* off papaya leaves in an experiment conducted 26 April – 18 May, 2001. Individual first instar *S. siphonulus* larvae (N = 68) were placed on papaya leaves and their position monitored for up to ten days throughout their four larval instars with daily checks at approximately 08:00, 10:00, 13:00, 15:00, and 17:00 h (*S. siphonulus* larvae are active only during daylight hours).

Results

The traps performed well with larvae of *S. siphonulus. Stethorus siphonulus* larvae foraged actively, and moved rapidly into the traps where they were effectively retained (Figure 2). We did not see any larvae move completely out of the traps once they had entered, despite the fact that larvae continued to walk throughout the experiment (15 of the 16 larvae were walking on all checks). None of the larvae ever became mired in the sticky barriers. Between the 120 and 640-min samples, we had a rainfall event, and six of the 16 larvae disappeared from the petioles. During dry periods, however, the larvae persisted in the traps for long periods (five of six larvae survived in the traps for 23 h in an earlier trial).

In our longer-term study of *S. siphonulus* movement, we observed a total of ten instances in which

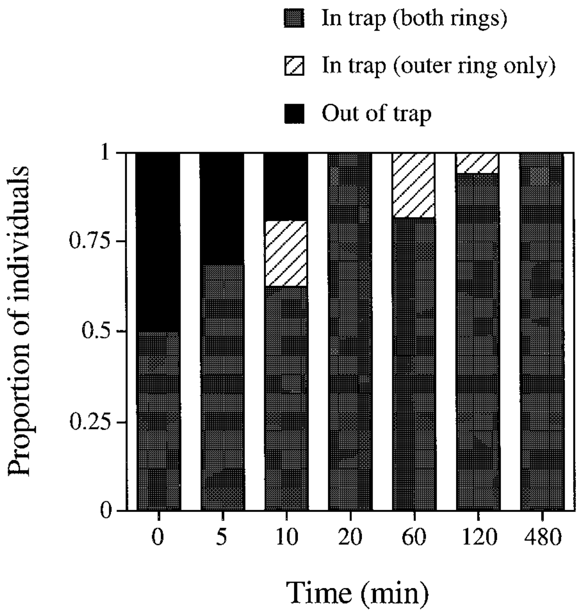

Figure 2. Field test of the efficacy of the trap. Shown are the proportions of *Stethorus siphonulus* larvae located in each of the three zones on a papaya leaf petiole, viz., out of the trap, in the trap between the inner and outer rings, and in the trap within both rings. Fisher's exact test contrasting the number of larvae out of the trap versus within both rings of the trap: 0 min, $P = 1.00$ (N.S.); 5 min, $P = 0.31$ (N.S.); 10 min, $P = 0.22$ (N.S.); 20 min, $P = 0.0002$; 60 min, $P = 0.0006$; 120 min, $P = 0.0002$; 640 min, $P = 0.008$. Sample sizes are $N = 16$ for all sample times except the last sample, when $N = 10$.

larvae moved off papaya leaves and into the traps, involving eight of the 68 larvae in the study. No larvae ever became mired in the sticky barriers that comprised the traps. We were able to move larvae out of the traps and onto new leaves to continue observations on their behavior and development. Only minor repairs to the traps were typically required over the 10-day duration of the experiment, in a few cases in response to birds landing on the petioles and disrupting the barriers. The barriers were not disrupted by several light rainfalls. Thus, the trap allowed us to identify reliably when during its larval development a *S. siphonulus* moved off a papaya leaf.

Discussion

Our purpose here has been to introduce a very simple, easily used technique for reliably detecting movements of walking insects among plant parts. The approach uses a trap to identify moving individuals, and as such is similar to other traps used by insect ecologists to study insect movement, such as malaise traps for flying insects and pitfall traps used for ground dwelling arthropods (Southwood & Henderson, 2000), but will be particularly useful in studying very small-scale movement on plants or in other settings where these other techniques cannot be used. For walking insects that forage in patchy environments, as is the case for *S. siphonulus* foraging for spider mite prey on papaya plants, our trap should be useful for studying patch-leaving behavior. Our informal observations in the papaya system suggest that the technique may have broad but not universal applicability: spider mites were also retained effectively in the traps without getting stuck, whereas a common group of predatory mites, *Phytoseiulus* spp., sometimes got stuck in the barriers and sometimes walked right over the barriers.

Our technique might be modified in several ways. For example, to increase the reliability with which arthropods are retained in the trap, additional horseshoe-shaped rings can be added, the size of the opening in the horseshoes can be reduced, and the distance between the horseshoes and the stopping ring can be increased. The long petioles of the papaya plant allowed us to deploy the trap on the petiole; for plants with smaller petioles, the traps might usefully be placed on stems, branches, or other structures. In some cases, it may be useful to place food in the space between the inner horseshoe and the stopping ring to sustain the trapped arthropod, especially if traps are to be checked infrequently.

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