SCIENTIFIC NOTE

A pheromone-baited pitfall trap for monitoring *Agriotes* spp. click beetles (Coleoptera: Elateridae) and other soil-surface insects

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Pheromone traps have been developed specifically for the survey, research and management of click beetles (Coleoptera: Elateridae) in temperate North America (NA), Europe and Asia (Ritter and Richter 2013; Vernon and van Herk 2013; Traugott *et al*. 2015). These include: 'Estron Traps' for survey of *Agriotes* species in the former USSR (Oleshchenko *et al*. 1987); 'Yatlor Traps' for survey and scientific study of *Agriotes* in Europe (Furlan *et al.* 2001), and; 'Vernon Beetle Traps' for survey and integrated pest management (IPM) of invasive *Agriotes* in NA, i.e., *A. obscurus* (AO), *A. lineatus* (AL) and *A. sputator* (AS; Vernon 2004). Although effective, these traps are no longer available commercially, although the Yatlor Trap has been re-designed as a funnel trap to better intercept various flying *Agriotes* in Europe (Csalomon, Budapest, Hungary). The loss of the Vernon Beetle Trap (VBT) and customized lures for AO, AL and AS [formerly produced by Contech Enterprises Inc., Delta, British Columbia (BC), Canada] necessitated the development of a new trap for use in *Agriotes* IPM program development in Canada. Based on the authors' experience with earlier *Agriotes* traps, the new trap was designed to: provide trapping efficacy comparable to the VBT; reduce the time required for assembly, installation and inspection; exclude insectivorous vertebrates and water, and; be consistent, reliable, inexpensive, small, easy to transport, and durable.

The new trap, named the Vernon Pitfall Trap® (VPT) (Fig. 1), is constructed of durable polypropylene, and is formed from three custom injection molds (Exact Molds Ltd, Abbotsford, BC). Two essential components are an in-ground pitfall chamber for specimen collection (Fig. 1A) and a protective cover containing a pheromone-bait holder and vertebrate-exclusion cage (Fig. 1B). The pitfall chamber forms a tapered cup that is 10 cm high from base to apex of the trap, with a 5.8-cm-diameter base (inside diameter, ID) and a 9-cm-diameter opening (ID) (Fig. 1A). The inside of the cup, three centimetres from the apex, is molded to receive a commercially available specimen cup (specifically, Fisherbrand™ 4.5-oz. Polypropylene Graduated Specimen Container). These removable containers, which can be filled with a preserving liquid such as propylene glycol or used without, and accompanying lids are used for labelling and storing collected specimens. Surrounding the apex of the chamber is a rounded collar that slopes gradually away from the opening (3 cm outward and 1 cm downward), with a steeper decline 0.5 cm from the outermost edge. The collar has raised ridges (0.1 mm high) spaced 1–2 mm apart to enable climbing by walking insects (Fig. 1A and D). Beneath the collar are four evenly spaced supports that link the collar to the chamber to provide rigid stability to the trap. At the apex of the collar are two 1.2-cm-diameter (outside diameter, OD) x 2-cm-high hollow wells, spaced 8.5 cm apart, which receive and secure the trap lid (Fig. 1A and D). The shape of the pitfall chamber is similar to typical hand-held or upright bulb planters, which can be used to quickly remove exact soil cores for tight trap insertion. Moreover, overlapping traps can be conveniently stacked for transport. When the base is inserted into the cored soil, foot pressure on the reinforced collar seals the base tightly to the

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ground (Fig. 1D). This process does not require the clearing of surface grass or excavation, as is typically required for other pitfall traps, and the raised collar helps reduce water entry into the base.

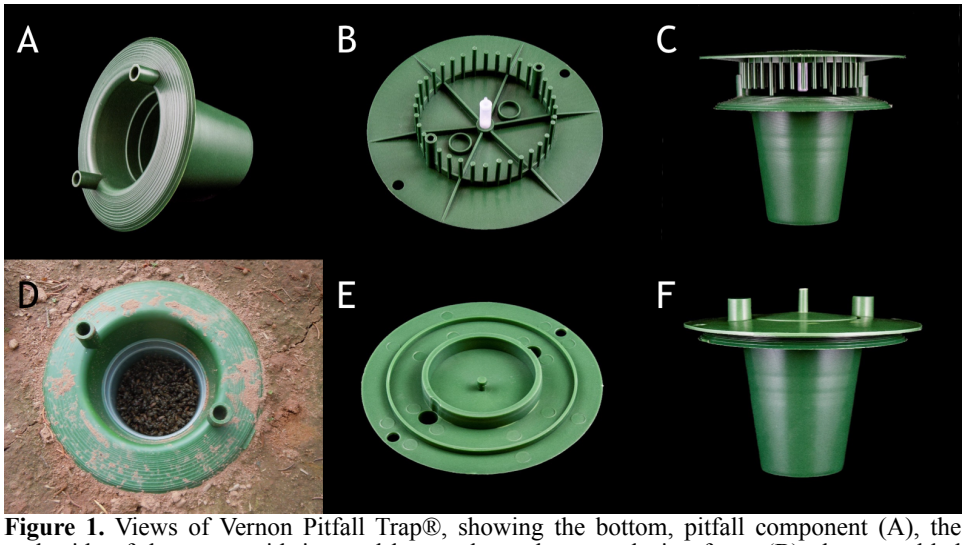

Figure 1. Views of Vernon Pitfall Trap®, showing the bottom, pitfall component (A), the underside of the cover with inserted lure and vertebrate exclusion fence (B), the assembled trap (C), the trap installed in soil with collected *A. sputator* (D), the optional cover for winterizing (E), and the assembled trap with winterizing cover (F). Photo credits: Warren Wong. Individual, high-resolution images are available as supplementary files on the journal website.

The second component is an easily detached cover, 16.5 cm in diameter, that tapers slightly downward as a shallow cone 0.5 cm from base to apex to shed rain (Fig. 1B). The cover contains a circular (1.2 cm diameter by 3 cm high, OD) downward-projecting well that is centred on the underside to hold 0.75-cm-diameter cylindrical *Agriotes* spp. pheromone baits (AO, AL and AS lures available from Csalomon, Budapest, Hungary), and two pegs (0.75-cm-diameter (OD) by 3 cm high) that are located 8.8 cm apart to fit into the corresponding wells on the base (Fig. 1A, B, and C). On the underside of the lid (Fig. 1B), six evenly spaced supports (0.5 cm high) that radiate from the projected pheromone lure well to the outside of the lid provide stability and prevent warping of the cover. To exclude insectivorous vertebrates (e.g., mice, voles, shrews, snakes) a circular fence of downward-projecting pins (3 mm diameter) is present on the underside of the lid. The pins are spaced 0.5 cm apart and range in length from 2.5 cm (30 pins) to 3 cm (4 pins). The longest pins just touch the base's collar section at four sites when base and lid are joined, lending stability to the assembled trap (Fig. 1C). The shorter pins leave a 0.5-cm-high passage above the collar to permit entry by click beetles or other walking insects.

The traps are manufactured in brown (used in Canada for AL), black (used for AO) and green (used for AS) to help avoid pheromone cross-contamination between species.

An optional trap component is a 16.5-cm-diameter winter lid (Fig. 1E) that replaces the main lid at the end of the trapping season. The winter lid is designed to snugly fit flush with the trap base (Fig. 1 F), so that the trap can remain *in situ* overwinter, protected from entry of debris, insects and water.

Should a need arise in the future, the cover's downward-projecting well for holding *Agriotes* pheromone lures could be replaced by a ring for hanging lures or a removable lure-holding basket, as in the Unitrap, for deploying lures for other target soil-surface

species. This would require the mold to be restructured. Alternatively, such lure-holders could be constructed as separate components that fit into the well.

The new trap offers a number of improvements to monitoring AO, AL and AS, relative to the former Vernon Beetle Trap. The VPT requires less time to assemble, install and inspect, and is more durable and transportable than the VBT. The VPT is similar to the VBT in catch of AO, AL and AS (van Herk, unpublished data). It has proven highly effective, with or without pheromone baits, in monitoring programs for AO and AL in BC and for AS in Prince Edward Island (PEI) (Table 1). The highest catch recorded to date for a single trap is 6,955 AS over a 5-day period in Orwell, PEI (27 May–1 June, 2015) (Fig. 1D). The trap has also been used, without pheromone baits, to successfully trap other elaterid species in other provinces of Canada, including *A. mancus* (Say), *Aeolus mellillus* (Say), *Hypnoidus abbreviatus* (Say), *H. bicolor* (Eschscholtz), *Limonius californicus* (Mannerheim), *Melanotus communis* (Gyllenhal), and *Selatosomus destructor* (Brown) (van Herk, unpublished data). It has also been used successfully to trap other walking insects, including carabids and weevils (e.g., *Sitona lineatus* L.; St. Onge *et al.* 2018).

Table 1

Catch of three *Agriotes* species in baited *versus* unbaited Vernon Pitfall Traps® (VPT) in field surveys in BC (AO and AL) and PEI (AS). N = number of traps.

Year	*Agriotes* Species[1]	Trapping period	Baited VPT		Unbaited VPT	
			N	Mean (SD)	N	Mean (SD)
2015	AO	26 Mar–16 July	22	977.7 (451.5)	33	10.2 (12.2)
2016	AL	21 Mar–11 July	22	171.0 (92.7)	33	0.8 (1.0)
2015	AS	20 May–13 Aug	44	7,797.1 (2,783.9)	38	71.6 (53.0)

[1]AO = *A. obscurus*; AL = *A. lineatus*; AS = *A. sputator*

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