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Comparative efficacy of five types of trap for woodborers in the Cerambycidae, Buprestidae and Siricidae

R. L. McIntosh, P. J. Katinic, J. D. Allison, J. H. Borden and D. L. Downey

Centre for Environmental Biology, Department of Biological Sciences, Simon Fraser University, 8888 University Drive, Burnaby, British Columbia V5A 1S6, Canada

Abstract

1. Traps of four new designs were tested against the conventionally used multiple-funnel trap to determine whether trapping of large wood-boring insects can be improved in western Canada. All four new traps used a large collecting receptacle containing detergent-laced water, and three presented a prominent visual silhouette above the receptacle.
2. In total, 27 336 large woodborers were captured from 10 June to 30 September in an experiment in the southern interior of British Columbia, and 4737 from 6 June to 27 July in an experiment in northern Alberta. The woodborers captured in the British Columbia experiment were mainly beetles in the families Cerambycidae (79%) and Buprestidae (15%), and woodwasps in the family Siricidae (6%). Most woodborers, e.g. three *Monochamus* spp. and *Xylotrechus longitarsus* (the predominant cerambycids), were captured throughout the summer, with peak captures in August.
3. Cross-vane, pipe and stacked-bottomless-flower-pot traps were generally superior to pan and multiple-funnel traps for insects in nine taxa, but cross-vane traps were the most effective overall, trapping 32% of all insects captured.
4. The large number of target insects captured in a relatively small number of traps in the two experiments suggests that employment of an efficacious trap with a large vertical silhouette and a wide, escape-proof collecting receptacle could make mass trapping of large woodborers in timber processing areas operationally feasible.
5. Because the most effective traps were unstable in the wind, and the detergent-laced water captured unacceptably high numbers of small mammals, design modifications are necessary. We are currently developing a wind-firm trap, with a prominent vertical silhouette, a wide collecting surface, and an escape-proof, but dry collecting receptacle.

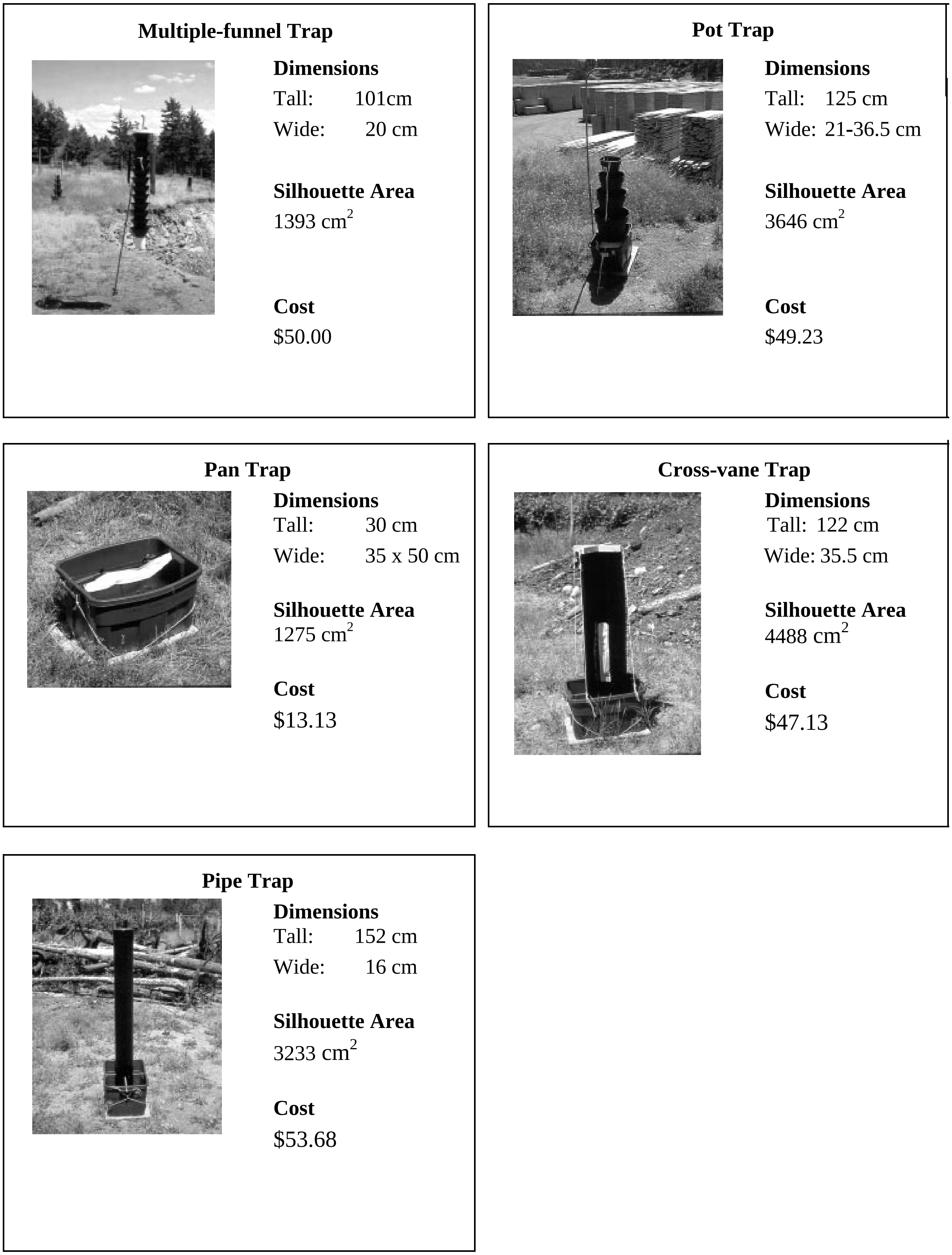
Keywords Buprestidae, Cerambycidae, pest management, silhouette, Siricidae, trapping.

Introduction

Wood-boring insects fill an important niche in forest ecosystems. Trees that have been recently killed by insects, disease and fire (Belyea, 1952; Gardiner, 1957; Ross, 1960), as well as newly felled green logs (Cerezke, 1977) are attacked by adult woodborers, which oviposit in the bark. Larvae mine first in the phloem, and in some species they then bore deeply into the wood, leaving large holes and creating infection courts for wood-rotting fungi and access for other wood-boring insects. In initiating the process of decomposition, wood-boring insects serve a role as 'nature's recyclers' (Borden, 1984). However, this same action can result in significant economic loss (Orbay *et al*., 1995).

Woodborers in the families Cerambycidae, Buprestidae (Coleoptera) and Siricidae (Hymenoptera) reduce the value of logs by leaving large holes in the wood (Vallentgoed, 1991). Because some cerambycid beetles (*Monochamus* spp.) are

Correspondence: Dr Rory McIntosh, Saskatchewan Environment and Resource Management, PO Box 3003, Prince Albert, Saskatchewan S6V 6G1, Canada. Tel.: +1 306 953 3617; fax: +1 306 953 2360; e-mail: mcintosh@derm.gov.sk.ca



Multiple-funnel Trap

Dimensions
Tall: 101cm
Wide: 20 cm

Silhouette Area
1393 cm^2

Cost
$50.00

Pot Trap

Dimensions
Tall: 125 cm
Wide: 21-36.5 cm

Silhouette Area
3646 cm^2

Cost
$49.23

Pan Trap

Dimensions
Tall: 30 cm
Wide: 35 x 50 cm

Silhouette Area
1275 cm^2

Cost
$13.13

Cross-vane Trap

Dimensions
Tall: 122 cm
Wide: 35.5 cm

Silhouette Area
4488 cm^2

Cost
$47.13

Pipe Trap

Dimensions
Tall: 152 cm
Wide: 16 cm

Silhouette Area
3233 cm^2

Cost
$53.68

Figure 1 Specifications of all five traps tested for large woodborers in British Columbia and Alberta. The silhouette area includes the collecting receptacle expressed as a mean of the side and end-exposed areas. Cost of multiple-funnel traps is the retail price. Costs of other traps include materials and an estimate of labour required for manufacturing. All costs are in Canadian dollars.

Table 1 Proportional representation of taxa among 27 336 large woodborers captured at Gorman Bros. Mill Yard, Westbank, British Columbia from 16 June to 30 September 1999.

Order and family	Percent of total insects captured	Genus and species	Percent of total insects captured
Coleoptera			
Cerambycidae	78.8	*Monochamus scutellatus* (Say)	20.8
		M. obtusus Casey	17.9
		M. clamator LeConte	1.1
		Arhopalus spp.	3.8
		Asemum spp.	6.2
		Xylotrechus longitarsus Casey	28.8
		Other cerambycids	0.2
Buprestidae	15.1	*Buprestis laeviventris* (LeConte)	2.2
		B. adjecta LeConte	0.7
		B. aurulenta L.	1.5
		Chalcophora virginiensis (Drury)	1.7
		Dicerca tenebrosa Kirby	0.3
		Chrysobothris spp.	6.7
		Other buprestids[a]	2.0
Hymenoptera			
Siricidae	6.1	*Sirex* spp.	1.5
		Urocerus spp.	4.5
		Xeris spp.	0.1

[a] *Buprestis lyrata* Casey and *B. subornata* LeConte are included in this category and are not reported in Fig. 2 because we were unable to separate them by species until after all counts were completed.

vectors of the pinewood nematode *Bursaphalenchus xylophilus* (Steiner and Buhrer) Nickle, logs attacked by *Monochamus* spp. have been rejected from the marketplace (Dwinell & Nickle, 1989). Infested lumber is unsuitable for value-added manufacturing, is downgraded or rejected from certain markets, and shipments of milled products may be quarantined or returned to the port of origin (Shore, 1985).

Safranyik & Raske (1970) attributed 30% degrade loss in Alberta to damage by cerambycid larvae. More recently, surveys conducted in sawmills in the interior of British Columbia disclosed an estimated annual economic impact of US$43 million caused by large woodborers, excluding ambrosia beetles (Phero Tech Inc., Delta, British Columbia, Canada, unpublished report, 1997). As wood resources have become increasingly scarce, there is a corresponding need to manage woodborer pests so as to facilitate the manufacture of value-added and speciality products from uninfested wood, and thus to maximize the utility of wood harvested from the forest.

Many wood-boring beetles utilize volatiles from their hosts, e.g. monoterpene components of resin, and ethanol, as host-finding cues (Ikeda *et al.*, 1980; Phillips *et al.*, 1988; Chénier & Philogène, 1989a). In pyrophilous species, attractive cues include smoke (Cerambycidae) and heat (Buprestidae) (Evans, 1971). For many bark beetles and woodborers, long-distance chemical stimuli are apparently augmented by the close-range visual stimulus provided by the tree silhouette (Tilden *et al.*, 1983; Wyatt *et al.*, 1997).

There are numerous trap designs for capturing insects (Marshall *et al.*, 1994). Many traps have been designed to exploit the host-selection response by particular target species. The multiple-funnel trap (Lindgren, 1983; Phero Tech, 1994) exploits the insects' host-selection response to a silhouette. It was initially designed and tested for ambrosia beetles but is also used extensively to trap bark beetles and (with lesser efficacy) large wood-boring beetles. Chénier & Philogène (1989b) compared sticky stovepipe, flight interception, and multiple-funnel traps for efficacy in catching conifer feeding beetles and other forest Coleoptera. Of the 953 cerambycids and buprestids trapped, 79% were found on sticky stovepipe traps, 14% in multiple-funnel traps and 7% in flight interception traps. The sticky stovepipe traps were judged to be superior because of their distinct vertical silhouette.

Although many insects can be captured by a sticky trap, such traps are not feasible for use in large-scale operational trapping programmes. We hypothesized that for large woodborers the silhouette presented by the multiple-funnel trap may be too narrow, that the close spacing of the funnels may prohibit entry of many large insects into the trap, and that the trapping receptacle, with its sole entry point at the centre of the lowest funnel, may miss capturing insects that fall outside of the funnel column. The latter hypothesis arose from personal communication with P. de Groot (Canadian Forest Service, Sault Ste. Marie, Ontario, Canada), who reported success in capturing large wood-boring beetles in an open pan containing detergent-laced water. Our objective was to test the efficacy of four trap designs, all with a large, open, water-filled trapping receptacle, and three with different prominent silhouettes for trapping large woodborers. Our research was carried out in British Columbia and Alberta, and a similar study was completed in Ontario (de Groot & Nott, 2001).

Methods and materials

Traps of four designs (Fig. 1) with different silhouettes were tested against 12-unit multiple-funnel traps. The pan trap comprised a blue Rubbermaid^{TM} 53 L tote box. All other experimental traps used identical tote boxes as catching

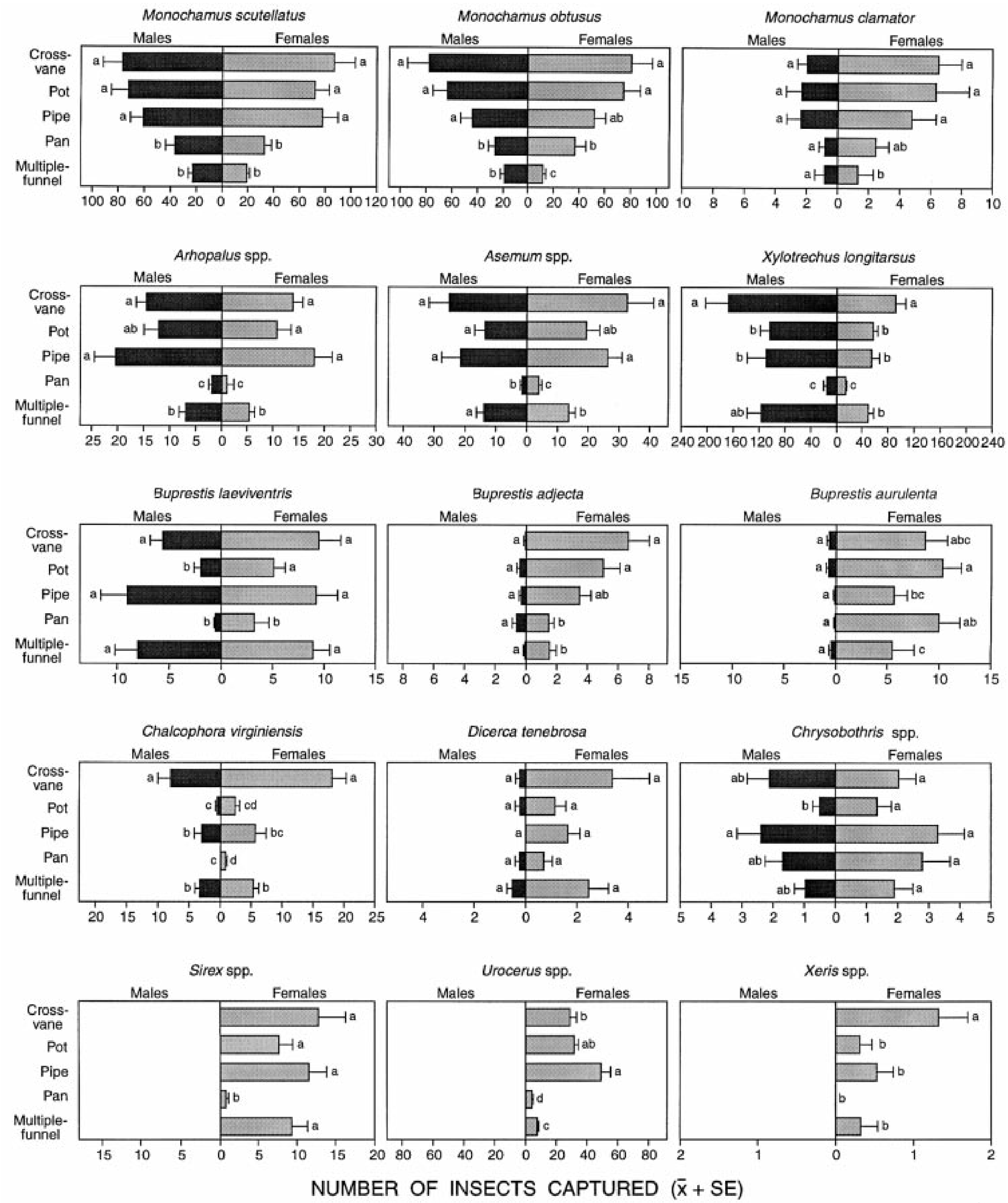


Figure 2 Mean numbers of large woodborers captured in traps of five different designs from 16 June to 30 September 1999 at Gorman Bros. Mill Yard, Westbank, British Columbia. Bars within a taxon and sex with the same letter are not significantly different, REGW test, $P < 0.05$. Results of ANOVA are as follows: *M. scutellatus* males $P = 0.0001$, d.f. = 4, $F = 8.5$, females $P = 0.0001$, d.f. = 4, $F = 19.01$; *M. obtusus* males $P = 0.0001$, d.f. = 4, $F = 17.15$, females $P = 0.0001$, d.f. = 4, $F = 22.06$; *M. clamator* males $P = 0.0333$, d.f. = 4, $F = 2.94$, females $P = 0.0003$, d.f. = 4, $F = 7.11$; *Arhopalus* spp. males $P = 0.0001$, d.f. = 4, $F = 20.17$, females $P = 0.0001$, d.f. = 4, $F = 34.61$; *Asemum* spp. males $P = 0.0001$, d.f. = 4, $F = 29.40$, females $P = 0.0001$, d.f. = 4, $F = 35.91$; *Xylotrechus longitarsus* males $P = 0.0001$, d.f. = 4, $F = 75.53$, females $P = 0.0001$, d.f. = 4, $F = 52.12$; *Buprestis laeviventris* males $P = 0.0001$, d.f. = 4, $F = 10.95$, females $P = 0.0001$, d.f. = 4, $F = 8.20$; *Buprestis adjecta* males $P = 0.4588$, d.f. = 4, $F = 0.93$, females $P = 0.0001$, d.f. = 4, $F = 9.53$; *Buprestis aurulenta* males $P = 0.1103$, d.f. = 4, $F = 2.03$, females $P = 0.0036$, d.f. = 4, $F = 4.73$; *Chalcophora virginiensis* males $P = 0.0001$, d.f. = 4, $F = 17.92$, females $P = 0.0001$, d.f. = 4, $F = 22.79$; *Dicerca tenebrosa* males $P = 0.3435$, d.f. = 4, $F = 1.16$, females $P = 0.1672$, d.f. = 4, $F = 1.72$; *Chrysobothris* spp. males $P = 0.0269$, d.f. = 4, $F = 3.11$, females $P = 0.1891$, d.f. = 4, $F = 1.63$; *Sirex* spp. females $P = 0.0001$, d.f. = 4, $F = 17.37$; *Urocerus* spp. females $P = 0.0036$, d.f. = 4, $F = 4.73$; *Xeris* spp. females $P = 0.0004$, d.f. = 4, $F = 6.63$.

Table 2 Catches of wood-boring beetles in traps of five different designs in Lesser Slave Lake, Alberta, 6 June–27 July 1999, $N = 10$. Only species for which $\geqslant 250$ specimens in total were captured are listed.

Family and species	Trap type	Number of beetles captured (mean ± SE)[a]	
		Male	Female
CERAMBYCIDAE			
Monochamus scutellatus	Cross-vane	3.0 ± 0.4 a	4.4 ± 0.4 a
	Pot	2.9 ± 0.5 ab	4.1 ± 1.5 a
	Pipe	1.4 ± 0.5 bc	2.4 ± 0.7 ab
	Pan	2.8 ± 0.4 ab	3.0 ± 0.6 a
	Multiple funnel	1.0 ± 0.4 c	1.1 ± 0.4 b
Xylotrechus undulatus (Say)	Cross-vane	7.8 ± 1.6 a	2.3 ± 0.5 a
	Pot	6.3 ± 0.8 a	3.0 ± 0.6 a
	Pipe	5.1 ± 0.9 a	2.2 ± 0.5 a
	Pan	0.2 ± 0.1 b	0.5 ± 0.2 b
	Multiple funnel	1.0 ± 0.4 b	0.5 ± 0.2 b
Asemum spp.	Cross-vane	60.9 ± 19.9 a	26.7 ± 6.2 a
	Pot	50.2 ± 0.5 a	19.2 ± 5.3 a
	Pipe	51.0 ± 10.1 a	21.3 ± 4.1 a
	Pan	2.8 ± 0.9 b	3.0 ± 1.0 b
	Multiple funnel	30.8 ± 7.6 a	17.4 ± 4.1 a
Tetropium spp.	Cross-vane	4.0 ± 0.06 a	8.0 ± 2.0 a
	Pot	3.5 ± 0.5 a	5.3 ± 0.7 a
	Pipe	2.1 ± 0.5 ab	3.2 ± 0.7 ab
	Pan	0.4 ± 0.2 c	0.3 ± 0.2 c
	Multiple funnel	1.6 ± 0.5 bc	2.7 ± 0.7 b
BUPRESTIDAE			
Dicerca tenebrica (Kirby)	Cross-vane	2.8 ± 1.1 ab	23.8 ± 6.1 a
	Pot	2.5 ± 0.5 a	14.3 ± 2.6 a
	Pipe	1.3 ± 0.4 ab	8.5 ± 1.4 a
	Pan	1.2 ± 1.1 b	0.3 ± 0.2 b
	Multiple funnel	2.7 ± 0.7 a	11.7 ± 2.1 a

[a] Means within a species and sex followed by the same letter are not significantly different, REGW test, $P < 0.05$. Results of ANOVA are as follows: *Monochamus scutellatus* males $P = 0.0008$, d.f. = 4, $F = 5.99$, females $P = 0.0015$, d.f. = 4, $F = 5.47$; *Xylotrechus undulatus* males $P = 0.0001$, d.f. = 4, $F = 37.45$, females $P = 0.0001$, d.f. = 4, $F = 8.59$; *Asemum* spp. males $P = 0.0001$, d.f. = 4, $F = 31.68$, females $P = 0.0001$, d.f. = 4, $F = 16.22$; *Tetropium* spp. males $P = 0.0001$, d.f. = 4, $F = 9.92$, females $P = 0.0001$, d.f. = 4, $F = 14.05$; *Dicerca tenebrica* males $P = 0.0334$, d.f. = 4, $F = 2.94$, females $P = 0.0001$, d.f. = 4, $F = 15.90$.

receptacles. The pipe trap was constructed using a 1.5-m long by 16.0 cm diameter polyvinyl chloride (PVC) drainage tile pipe. The pipe had three equally spaced rows of 12.7 mm diameter holes, 12.7 cm apart, drilled along its length, and was painted with black gloss enamel paint. It was secured vertically inside a tote-box using 1.3 cm diameter threaded redi-rod placed through the pipe at right angles and secured to each edge of the box. The pot trap was constructed from a linear vertical array of four bottomless plastic flower pots, with diameters from the top down measuring 21.0, 25.9, 31.5 and 36.6 cm, respectively. The pots were joined with lengths of 6 mm diameter cord attached through four holes drilled at equidistant positions on the upper lip of each pot. The bottom pot was secured to the top edge of a tote box. The pots were suspended from a section of bent 1.9 cm diameter conduit tubing. The cross-vane trap was constructed from two interlocking 1.3 m tall by 35.5 cm wide black acrylic panels, 3 mm thick. The cross-panels were fixed at right angles to each other at the top and bottom using grooved 5.1 cm square wood supports into which the panels slotted. Specifications are listed adjacent to each trap shown in Fig. 1.

A season-long trapping experiment was run from 16 June to 30 September 1999 at the Gorman Bros Ltd Sawmill, Westbank, British Columbia. An identical experiment was run from 6 June to 27 July 1999 at the Vanderwell Contractors Ltd mill site in Lesser Slave Lake, Alberta. Ten replicates of five traps each were deployed, with traps 10 m apart, in randomized complete blocks, around the perimeter of the mill yards. Each trap was baited with a commercial bait comprised of (–)-α-pinene and 95% ethanol in separate polyethylene pouches releasing (at 30 °C) 2190 and 1160 mg/day, respectively (Phero Tech Inc.). The baits were hung with monofilament line across the opening of the pan traps and at the mid-point of the other traps. Baits were replaced at 6-week intervals. All tote boxes contained ≈ 30 L of water, and multiple-funnel traps were fitted with commercially available 'wet cup' containers containing ≈ 300 mL of water. Insect escape was restricted in all traps by adding ≈ 5% (v:v) unscented hypo-allergenic detergent to the water to act as a surfactant.

Traps were maintained and all insects were collected from each trap at weekly intervals. Insects were placed in labelled plastic bags in a portable cooler for transport to the laboratory, and were

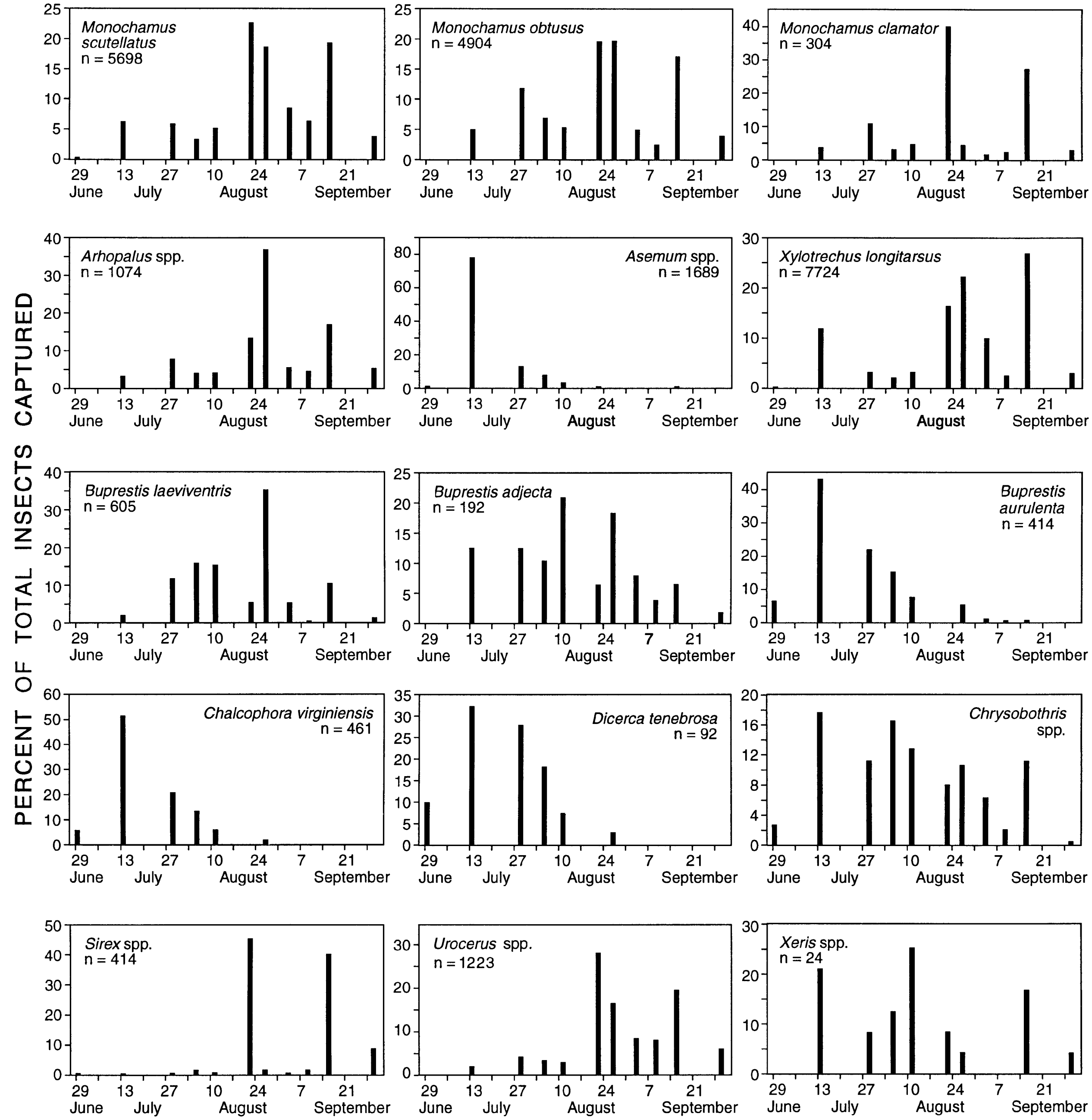


Figure 3 Seasonal distribution of captures of large woodborers at Gorman Bros. Mill Yard. Relative abundance is expressed as the percentage of total insects within a given taxon captured in 50 traps throughout the 16 June to 30 September, 1999 trapping period. Total numbers of each taxon captured are shown in each subgraph.

then stored at – 3 °C. Captured insects were identified to species and sex if possible according to published keys and descriptions as follows: Cerambycidae (Linsley, 1961, 1962, 1964; Linsley & Chemsak, 1984; Chemsak, 1996; Yanega, 1996), Buprestidae (Bright, 1987) and Siricidae (Goulet, 1992). Following identification, insects were stored by species in sealed glass jars filled with 95% ethanol. Voucher specimens were confirmed and deposited in the reference collection maintained by the Canadian Forest Service, Pacific Forestry Centre, Victoria, British Columbia, Canada.

Data for all woodborer species for which ⩾ 250 insects were captured over an entire experiment were included in statistical analysis. If one or more traps in a replicate failed in some way to perform in a given week (e.g. through tipping or leaking) the entire catch for that replicate in that week was discounted. To correct for non-normal distribution and heteroscedasticity (Zar, 1984), mean trap catches were transformed by $\log_{10}(x + 1)$ and analysed using ANOVA (PROC, ANOVA; Schlotzhauer & Littell, 1987). Multiple comparisons between means were made using the Ryan Einot, Gabriel, Welsh (REGW) test (PROC MEANS/REGWQ, SAS, 1988; Day & Quinn, 1989). In all analyses $\alpha = 0.05$.

Results

In total, 27 336 wood-boring insects were trapped in British Columbia and 4737 in Alberta. For the season-long experiment in British Columbia, the majority of captured insects were in the family Cerambycidae, followed by Buprestidae and Siricidae (Table 1). *Monochamus* spp., *Xylotrechus longitarsus* and *Buprestis* spp. represented 73% of all captured insects. The most abundant siricids were *Urocerus* spp.

The cross-vane, pipe, pot, multiple-funnel and pan traps captured 32.0, 24.2, 21.9, 14.2 and 7.7%, respectively, of the tabulated insects in British Columbia, and 32.7, 22.3, 25.4, 15.7 and 3.9%, respectively, of the insects in Alberta. Cross-vane traps caught the highest number of woodborers (8758), followed by the pipe (6630) and pot (6009) traps, respectively. In British Columbia, the cross-vane, pot and pipe traps were not significantly different in their superior ability to capture either sex of the three *Monochamus* spp., *Arhopalus* spp., *Asemum* spp., *Buprestis adjecta*, *Dicerca tenebrosa* and *Sirex* spp. (Fig. 2). Cross-vane traps were clearly the best for *Chalcophora virginiensis*. Multiple-funnel traps were among the top rank only for *Buprestis laeviventris*, *D. tenebrosa* and *Chrysobothris* spp. Both pot and pipe traps fell out of the statistically highest rank several times, while cross-vane traps did so only for *Urocerus* spp. Pan traps caught the lowest numbers in nine of 15 instances. No male siricids were captured in any trap. In Alberta, the cross-vane, pot and pipe traps were generally statistically superior for four of the five species tabulated (Table 2). As in British Columbia, they were joined in the top rank for *D. tenebrica*, but also were in the top rank for *Asemum* spp. Pan traps were among the top rank for female *M. scutellatus* and replaced pipe traps in the top rank for males.

The seasonal abundance of many species was erratic (Fig. 3). In general, most species were captured throughout the summer, with peak catches of *Chrysobothris* spp. in July, all three *Monochamus* spp., *Arhopalus* spp., *B. laeviventris*, *B. adjecta*, *Urocerus* spp., and *Xeris* spp. in August and *X. longitarsus* in September. *Asemum* spp., *B. aurulenta, C. virginiensis* and *D. tenebrosa* were caught predominantly in the early summer, with peak catches in July. *Sirex* spp. were caught only in August and September.

Discussion

The capture of 27 336 large woodborers in a 15-week period in 50 traps at a mill yard in British Columbia suggests that suppression of woodborer populations through mass-trapping for diverse species over the entire duration of the flight season is operationally feasible. Efficacious mass-trapping programmes using semiochemical-baited multiple-funnel traps for ambrosia beetles have been commercially implemented in British Columbia since 1981 (Lindgren & Fraser, 1994; Borden, 1995).

The superiority of the cross-vane, pot and pipe traps over the currently used multiple-funnel trap indicates that great improvements in operational efficacy could be achieved with adoption of a trap of a modified design. The slightly greater overall catches in the cross-vane than the other types of trap suggests that it may have the most potential for operational development.

We do not know at this point whether presentation of a prominent visual silhouette, large vertical trapping surface, difficulty of landing by incoming insects, or use of a large, escape-proof collecting receptacle contributed most to improved catches. However, our results with non-sticky traps suggest that high catches achieved by Chénier & Philogène (1989b) were because of the prominent silhouette presented by the stovepipe traps rather than their sticky surface. Landing behaviour is also likely to play a role in catching efficacy. In a characteristic landing behaviour also observed in other insects (Goodman, 1960), incoming *M. scutellatus* and *M. obtusus* were observed to fan the elytra to a forward position, apparently causing the beetle to slow down its approach to a large vertical object, and at the same time to force the legs forward in preparation for landing. We observed that on multiple-funnel traps, this landing behaviour often resulted in an imperfect landing with a beetle falling away outside the trap, but not entering it. Had the multiple-funnel traps been suspended over large collecting receptacles they might have been competitive with the cross-vane, pot and pipe traps. Unlike de Groot & Nott (2001), we did not catch more *Monochamus* spp. in open pan than in multiple-funnel traps. This may have been because we used the 'wet cup' option which would have prevented escape by any beetles we did catch in multiple-funnel traps.

Despite its inferiority for large woodborers, the multiple-funnel trap is the only one of the five traps tested that is operational at present. It is light, compacts into a small size for storage and transport, is affected little by strong winds, and presents a strong visual target. In contrast, the cross-vane and pipe traps blew over in strong winds requiring them to be fixed to the ground. The pipe trap is bulky, and unlike the pot and cross-vane traps, cannot be disassembled for compact storage and light-weight transport. The water-filled tote box collecting receptacles were easily punctured when placed over rocks and stones and were surprisingly prone to develop leaks as they were shifted around on rough surfaces during the collections. Worst of all, they captured unacceptably high numbers of small mammals.

We are currently exploring the development of an operational trap for large woodborers that incorporates the following features: a prominent silhouette with a large surface area on which large insects have difficulty landing; a collecting surface that is at least twice as wide as the silhouette above it; and an escape-proof, but dry, collecting receptacle.

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