Comparison of Arboreal Beetle Catches in Wet and Dry Collection Cups with Lindgren Multiple Funnel Traps

DANIEL R. MILLER[1] AND DONALD A. DUERR[2]

USDA Forest Service, Southern Research Station, 320 Green Street, Athens, GA 30602

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ABSTRACT We compared the effectiveness of a dry collection cup (with an insecticide killing strip) to a wet collection cup (containing antifreeze) for use with Lindgren multiple-funnel traps in catching several common species of bark and wood-boring beetles, and their associates in southern pine forests. All traps were baited with either the binary combination of ethanol and (−)-α-pinene or the quaternary combination of (±)-ipsenol, (±)-ipsdienol, ethanol, and (−)-α-pinene. We found that cup treatment had little, if any, effect on catches of *Ips avulsus* (Eichhoff) and *I. grandicollis* (Eichhoff) (Coleoptera: Scolytidae), *Alaus myops* (F.) (Elateridae), *Chalcophora* Solier species (Buprestidae), *Temnochila virescens* (F.) (Trogositidae), and *Lasconotus* Erichson species (Colydiidae). In contrast, catches of the following species were significantly less (by 40–97%) in traps with dry cups than in traps with wet cups: *Hylobius pales* Herbst and *Pachylobius picivorus* LeConte (Curculionidae); *Buprestis lineata* F. (Buprestidae); *Acanthocinus obsoletus* (Olivier), *Arhopalus rusticus nubilus* (LeConte), *Monochamus titillator* (F.) and *Xylotrechus sagittatus sagittatus* (Cerambycidae); *Hylastes porculus* Erichson and *Xyleborinus saxeseni* (Ratzeburg) (Scolytidae); and *Thanasimus dubius* (F.) (Cleridae). The same was true in at least one experiment for the following species: *Dendroctonus terebrans* (Olivier), *Hylastes salebrosus* Eichhoff, *Hylastes tenuis* Eichhoff, and *Xylosandrus crassiusculus* (Motschulsky) (Scolytidae). We conclude that cup treatment can have a significant impact on catches of some arboreal beetles in baited multiple-funnel traps. Anyone using multiple-funnel traps to capture arboreal beetles should evaluate the potential impacts arising from their choice of collection cup treatment to their trapping objectives and expectations. The issue of cup treatment may be particular important at low population levels when maximum trap efficiency is required such as in the detection of exotic insects at ports-of-entry and within quarantine and containment zones.

KEY WORDS Cerambycidae, Curculionidae, detection, multiple-funnel trap, Scolytidae

Lindgren multiple-funnel traps (Lindgren 1983) are used widely to trap bark and wood-boring beetles (Coyle et al. 2005, Bentz 2006, Campbell and Borden 2006, Fettig and Dabney 2006, Miller 2006). The multiple-funnel trap is a standard trap in operational programs to mass-trap ambrosia beetles in wood-processing areas in British Columbia (Borden et al. 2001); to monitor populations of the southern pine beetle, *Dendroctonus frontalis* Zimmermann (Coleoptera: Scolytidae) in the U.S. South (Clarke 2001); and to detect exotic and invasive species of bark and wood-boring beetles (USDA–Forest Service 2004, Brockerhoff et al. 2006). There are two types of collection cups used with multiple-funnel traps: dry and wet cups (Pherotech International 2006). The dry cup has a sieve located at the bottom of the cup that allows rainwater to drain out of the cup. In the wet cup, the bottom hole is plugged with a rubber stopper and a screened drainage hole is located half-way up the side of the cup. The dry cup can be used with or without a killing agent such as dichlorvos. The wet cup allows for the use of killing and preservation fluids such as soapy, salted water or solutions of glycols.

The choice of cup type and use of killing and preservation agent seems largely a personal choice by various researchers and managers. Dry-cup trapping has a distinct advantage in not requiring large amounts of fluid to be carried to traps. Under arid or dry conditions, catches in dry cups can be emptied into plastic bags and stored in a freezer until processed. In comparison, wet-cup trapping generally requires the transfer of catches in a solution into bottles, jars or whirl-pak bags before conveying them to an initial processing site. The catches are then typically sieved and transferred into alcohol solutions before final processing. In addition, the solutions used in the wet cups are often viscous and messy. There are at least three

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[1] Corresponding author, e-mail: dmiller@fs.fed.us.

[2] USDA Forest Service, Forest Health Protection, 1720 Peachtree St., Atlanta, GA 30309.

potential benefits in using wet-cup trapping over dry-cup trapping: 1) total avoidance of the cost and safety issues in using insecticides; 2) less decay, damage, and destruction of captured insects; and 3) easier servicing of traps under wet conditions. Considerable time can be spent scraping insects from the inside of a dry cup in moist environments.

Maximizing trap efficiency is a critical issue in survey and detection programs that deal with low population levels of insects (USDA–Forest Service 2004). At ports-of-entry, the goal of a detection program is to capture the first exotic insects that attempt to establish breeding populations in the country. Early detection of exotic insects allows for a greater number of options and higher probability of containment and eradication (Lodge et al. 2006). Within areas of quarantine, effective detection at low population levels can help ensure comprehensive treatment strategies and actions.

Recently in Nova Scotia, Sweeney et al. (2006) found that baited traps with wet cups containing a propylene glycol solution caught more *Tetropium fuscum* (F.) and *Rhagium inquisitor* L. (Cerambycidae) than baited traps with dry cups containing a dichlorvos strip. Our objective was to examine the issue of cup treatment on catches of beetles in multiple-funnel traps in a different ecosystem with a greater diversity of arboreal beetles that varied in size and morphology. In stands of southern pines, we compared catches of southern arboreal beetles in baited multiple-funnel traps with dry cups containing dichlorvos as a killing agent to those in baited traps using wet cups with a solution of propylene glycol as the killing and preservation agent.

The following diverse group of beetle species, commonly found in stands of southern pines, were monitored in our experiments: *Acanthocinus obsoletus* (Olivier), *Arhopalus rusticus nubilus* (LeConte), *Monochamus titillator* (F.), *Xylotrechus sagittatus sagittatus* (Germar) (Cerambycidae); *Buprestis lineata* F., *Chalcophora* Solier spp. (Buprestidae); *Hylobius pales* Herbst, *Pachylobius picivorus* LeConte (Curculionidae); *Alaus myops* (F.) (Elateridae); *Temnochila virescens* (F.) (Trogositidae); *Thanasimus dubius* (F.) (Cleridae); *Lasconotus* Erichson species (Colydiidae); and *Dendroctonus terebrans* (Olivier), *Hylastes porculus* Erichson, *H. salebrosus* Eichhoff, *H. tenuis* Eichhoff, *Ips avulsus* (Eichhoff), *I. grandicollis* (Eichhoff), *I. calligraphus* (Germar), *Xyleborinus saxeseni* (Ratzeburg), and *Xylosandrus crassiusculus* (Motschulsky) (Scolytidae). The group includes bark and ambrosia beetles as well as sapwood- and heartwood-boring species, root feeding weevils and several associated predators (USDA–Forest Service 1985).

Materials and Methods

Semiochemical-Releasing Devices. Pherotech International (Delta, BC, Canada) supplied the following types of lures: 1) (±)-ipsdienol bubblecap lure (chemical purity, 98%; in solution with 1,3-butanediol); 2) (±)-ipsenol bubblecap lure (chemical purity, 98%; in solution with 1,3-butanediol); 3) black, ultrahigh release rate ethanol pouch (chemical purity, 95%); 4) short, blue, ultrahigh release rate (−)-α-pinene pouch [chemical purity, 98%; enantiomeric purity, >95%-(−)]; and 5) regular, blue, ultrahigh release rate (−)-α-pinene pouch [chemical purity, 98%; enantiomeric purity, > 95%-(−)]. The short (−)-α-pinene pouch measured 20 cm in length, whereas the regular (−)-α-pinene pouch measured 40 cm in length.

The release rates of (±)-ipsenol and (±)-ipsdienol from the bubblecap lures were 0.1–0.2 mg/d at 25°C (Pherotech International). The release rate of ethanol from the ethanol pouch was ≈0.7 g/d at 23–27°C, whereas the release rates of (−)-α-pinene from the short and regular (−)-α-pinene pouches were 1–3 g/d and 2–5 g/d, respectively, at 23–27°C (determined gravimetrically).

Experiments. Three experiments were conducted in Georgia and Florida to test the effects of cup treatment on catches of arboreal beetles; experiments 1 and 2 in 2001 and experiment 3 in 2006. Black, eight-unit multiple-funnel traps (Pherotech International) were used in all three experiments. Each trap was suspended on rope strung between trees such that the collection cup of each trap was 0.2–0.5 m above ground level. No trap was within 2 m of any tree. Trap catches were collected at intervals of 2–3 wk. Voucher specimens were deposited in the Entomology Collection, Museum of Natural History, University of Georgia (Athens, GA).

Experiment 1 was conducted from 20 February to 5 June 2001 in a mature stand of slash pine, *Pinus elliottii* Engelmann, on the Osceola National Forest near Lake City, FL. Experiment 2 was conducted from 2 July to 29 August 2001 in a mature stand of loblolly pine, *P. taeda* L., on the Scull Shoals Experimental Forest (Oconee National Forest) near Greensboro, GA. Experiment 3 was conducted from 2 May to 19 June 2006 in a mature slash pine and shortleaf pine, *P. echinata* Mill., seed orchard on the Whitehall Forest (University of Georgia) in Athens, GA. In experiments 1 and 2, 10 funnel traps were deployed in a linear array of five replicate blocks of two traps per block. In experiment 3, twenty funnel traps were deployed in a linear array of ten replicate blocks of two traps per block. In each experiment, traps were spaced 10–15 m apart within and between blocks.

All traps in experiments 1 and 2 were baited with an ethanol lure and a short (−)-α-pinene lure. The combination of the host compounds, ethanol and (−)-α-pinene, is an effective attractant for various common species of large wood-boring beetles and reproduction weevils (Miller 2006). In experiment 3, all traps were baited with ethanol, (−)-α-pinene (regular lure), and the bark beetle pheromones (±)-ipsenol and (±)-ipsdienol; an effective blend for attracting a broad spectrum of arboreal beetles in the southeastern United States (Miller and Asaro 2005, Miller et al. 2005). In experiment 1, the lures were replaced after 8 wk.

Table 1. Effect of cup treatment on mean catches of Cerambycidae, Buprestidae, and Curculionidae in three southern pine stands (2001 and 2006) from multiple-funnel traps baited with ethanol and (−)-α-pinene (experiments 1 and 2; $n = 5$) or ethanol, (−)-α-pinene, (±)-ipsenol, and (±)-ipsdienol (experiment 3; $n = 10$)

Species	Exp	*N*	Mean ± SE no. of beetles per trap		*P* value (*t*-test)	Difference of catches in dry cups compared with wet cups (%)
			Wet cup	Dry cup		
Cerambycidae						
Acanthocinus obsoletus	1	67	9.4 ± 3.0	4.0 ± 2.1	0.066	−60.0
	3	68	5.9 ± 1.8	0.9 ± 0.3	<0.001	−84.7
Arhopalus r. nubilus	1	289	38.8 ± 8.3	19.0 ± 2.5	0.057	−52.1
Monochamus titillator	3	256	20.6 ± 1.8	5.0 ± 0.9	<0.001	−75.7
Xylotrechus s. sagittatus	1	489	75.6 ± 21.3	22.2 ± 5.1	0.020	−70.6
	2	193	25.8 ± 7.2	12.8 ± 5.9	0.072	−50.4
	3	177	11.5 ± 1.5	6.2 ± 1.5	0.006	−46.1
Buprestidae						
Buprestis lineata	3	25	2.3 ± 0.8	0.2 ± 0.1	<0.001	−91.3
Chalcophora spp.	1	56	6.4 ± 2.2	4.8 ± 0.6	0.394	−25.0
Curculionidae						
Hylobius pales	1	536	84.2 ± 13.9	23.0 ± 4.6	0.001	−72.7
	2	38	6.0 ± 0.9	1.6 ± 0.7	0.004	−73.3
	3	116	9.2 ± 2.2	2.4 ± 0.9	0.001	−73.9
Pachylobius picivorus	1	179	23.0 ± 5.8	12.8 ± 3.2	0.065	−44.3
	3	164	10.9 ± 1.6	5.5 ± 0.7	0.004	−49.5

N is total number of beetles captured.

In each experiment, the following treatments were assigned randomly within each replicate block: 1) wet cup and 2) dry cup. The wet cup treatment consisted of 150–200 ml of a pink solution of polypropylene glycol and water (25–30% propylene glycol by weight) (Peak RV and Marine Antifreeze, Old World Industries Inc., Northbrook, IL) in the wet-style cup. The dry cup treatment in experiments 1 and 2 consisted of a piece (20 by 20 mm) of dichlorvos-impregnated wax bar (Hot Shot No Pest Strip, Spectrum Group, St. Louis, MO) in a dry-style cup. In experiment 3, the dry cup treatment contained a dichlorvos insecticidal strip (2 by 20 by 95 mm) (Vaportape II, Hercon Environmental Company, Emigsville, PA).

Statistical Analyses. Data were analyzed using the SYSTAT statistical package version 11.00.01 (Systat Software, Inc. 2004b) and the SigmaStat statistical package version 3.1. Systat Software, Inc. 2004a). In all experiments, statistical analyses were conducted on total numbers of beetles caught per trap, transformed by $\ln(y + 1)$ to remove heteroscedasticity (Pepper et al. 1997). For each species in each experiment, reductions in mean trap catches in dry cups compared with mean trap catches in wet cups were determined by a *t*-test (1-sided) after testing for normality and homoscedasticity. Power analyses and sample size determinations (for power = 0.80) were conducted with SYSTAT when $P > 0.05$ to ensure that a lack of difference was not due simply to inadequate sample size. An expected 50% reduction level in trap catches was used arbitrarily in these analyses; we hypothesize that a 50% reduction likely would be of concern to those using multiple-funnel traps.

Results

Cup treatment had a significant effect on catches of four species of Cerambycidae with reductions of 46–86% in trap catches associated with the use of dry cups (Table 1). In experiment 3, catches of *M. titillator* were significantly lower in dry cups than in wet cups; only 30 *M. titillator* were captured in experiments 1 and 2. The reduction in catches of *A. obsoletus* in dry cups compared with wet cups was strongly significant in experiment 3, but weakly significant in experiment 1; only eight beetles were captured in experiment 2. The weak significance for catches of *A. obsoletus* in experiment 1 may be related to sample size as the power of the test to detect a 50% reduction in mean catches was only 0.41. A sample size of 14 would have been required to ensure a power = 0.80. Similarly, reductions in trap catches of *A. r. nubilus* in experiment 1 were only weakly significant at $P = 0.057$. With power = 0.437, a sample size of 13 would have been required to ensure power = 0.80. Trap catch reductions from using dry cups were strongly significant for *X. s. sagittatus* in experiments 1 and 3, but only weakly significant in experiment 2; power = 0.425 in experiment 2. A sample size of 13 in experiment 2 would have ensured power = 0.80.

As in other trapping studies in stands of southern pines (Miller and Asaro 2005, Miller 2006), Buprestidae were not abundant in the present studies (Table 1). Catches of *B. lineata* were reduced by 91% in dry cups compared with those in wet cups (Table 1). However, only 25 *B. lineata* were captured in experiment 3; none were caught in the other two experiments. Catches of *Chalcophora* spp. [*C. georgiana* (LeConte) and *C. virginiana* (Drury)] were not significantly affected by the cup treatments (Table 1) (power = 0.447).

A cup treatment effect was clearly apparent with *H. pales* with catches significantly lower in baited traps with dry cups than in those with wet cups in all three experiments (Table 1). The catch reductions were very consistent at 72–74% across the three experi-

Table 2. Effect of cup treatment on mean catches of bark beetles (Scolytidae) in three southern pine stands (2001 and 2006) from multiple-funnel traps baited with ethanol and (−)-α-pinene (experiments 1 and 2; n = 5) or ethanol, (−)-α-pinene, (±)-ipsenol, and (±)-ipsdienol (experiment 3; n = 10)

Species	Exp.	N	Mean ± SE no. of beetles per trap		P value (t-test)	Difference of catches in dry cups compared with wet cups (%)
			Wet cup	Dry cup		
Dendroctonus terebrans	1	482	69.8 ± 24.7	26.6 ± 8.0	0.034	−61.9
	2	75	8.4 ± 1.9	6.6 ± 1.0	0.300	−21.4
	3	271	17.4 ± 2.2	9.7 ± 1.2	0.002	−44.3
Dryoxylon onoharaensis	1	163	22.0 ± 3.5	10.6 ± 3.4	0.026	−51.8
Hylastes porculus	2	340	44.6 ± 9.9	23.4 ± 1.8	0.027	−47.5
Hylastes salebrosus	1	230	25.0 ± 5.5	21.0 ± 4.8	0.348	−16.0
	2	82	7.6 ± 1.9	8.8 ± 0.6	0.791	+21.1
	3	101	6.0 ± 0.8	4.1 ± 1.1	0.034	−31.7
Hylastes tenuis	2	180	24.8 ± 3.8	11.2 ± 1.9	0.016	−54.8
	3	490	26.5 ± 3.7	22.5 ± 3.6	0.058	−4.4
Ips avulsus	3	993	50.8 ± 6.2	48.5 ± 6.0	0.385	−4.5
Ips grandicollis	1	1,096	117.2 ± 19.2	102.0 ± 7.3	0.327	−13.0
	2	105	11.6 ± 2.9	9.4 ± 1.5	0.369	−19.0
	3	4,003	201.0 ± 3.5	199.3 ± 15.8	0.335	−0.8
Xyleborinus saxesenii	1	1,742	246.8 ± 9.2	101.6 ± 13.4	<0.001	−58.8
	2	81	13.8 ± 2.7	2.4 ± 0.7	0.001	−82.6
	3	243	15.2 ± 3.1	9.1 ± 1.4	0.070	−40.1
Xylosandrus crassiusculus	2	120	23.2 ± 5.7	0.8 ± 0.5	<0.001	−96.6
	3	782	35.6 ± 5.0	42.6 ± 8.2	0.644	+19.7

N is total number of beetles captured.

ments even though the total numbers of weevils captured in traps varied considerably between the experiments. The reduction in catches of *P. picivorus* from the use of dry cups was strongly significant in experiment 3 and weakly significant in experiment 1 with a fairly consistent reduction of 44–50% in the two experiments. As with three of the Cerambycidae, the power of the test in experiment 1 to detect a 50% reduction in catches of *P. picivorus* was low at only 0.623; a sample size of eight would have ensured power = 0.80. Only 12 *P. picivorus* were captured in experiment 2.

The lack of any cup treatment effect was consistent only for two species of common southern pine bark beetles (Table 2). There was no effect of cup type on catches of *I. avulsus* in experiment 3 with catches in dry cups not significantly different from those in wet cups; no *I. avulsus* was captured in experiments 1 and 2. The power of the test was high in experiment 3 (power = 0.993). Similarly, catches of *I. grandicollis* were unaffected by cup treatment in all three experiments. The power of the tests was high in experiments 1 and 3 (power = 0.808 and 1.000, respectively) although low in experiment 2 (power = 0.509). Only 30 *I. calligraphus* were captured in experiment 3; none in the other two experiments.

In contrast, catches of *H. porculus* in experiment 2 were significantly lower in traps with dry cups than in traps with wet cups by 48% (Table 2); there were only 21 *H. porculus* captured in the other two experiments. Similarly, the reduction in catches of *X. saxesenii* arising from the use of dry cups was strongly significant in experiments 1 and 2 and weakly significant in experiment 3. The power of the test in experiment 3 was high for detecting a 50% reduction in catches of *X. saxesenii* (power = 0.750).

The results for other species of bark and ambrosia beetles were inconsistent between experiments (Table 2). The treatment effect on catches of *D. terebrans* was strongly significant in experiments 1 and 3 with reductions of 62 and 44%, respectively, but insignificant in experiment 2. However, only 75 beetles were captured in experiment 2 and power = 0.596. In experiment 2, catches of *H. tenuis* were significantly lower in dry cups than in wet cups by 55%. However, the effect on *H. tenuis* in experiment 3 was weakly significant with a reduction of only 4% (power = 0.778). There was a significant treatment effect on catches of *H. salebrosus* in experiment 3, but not in experiments 1 and 2 (power = 0.478 and 0.377, respectively). There was a 97% reduction in catches of *X. crassiusculus* in experiment 2, but no significant effect in experiment 3 (power = 0.898).

There was no significant effect of cup treatment on catches of *T. virescens*, a common predator of bark and ambrosia beetles, in experiments 1–3 (Table 3) (power = 1.000, 0.931, and 0.900, respectively). Similarly, there was no treatment effect on catches of *A. myops* in experiment 3 (power = 0.627) or *Lasconotus* spp. in experiments 1 and 3 (power = 0.553 and 1.000, respectively). In contrast, catches of *T. dubius* in experiment 3 were significantly lower in traps with dry cups than those with wet cups by 63% (Table 3); no beetles were captured in experiments 1 and 2.

Incidental to the target species, 72 wood roaches, *Parcoblatta virginica* Brunner (Blattodea: Blatellidae), were caught in experiment 3. The mean ± SE number of roaches in traps with dry cups was 0.1 ± 0.1; significantly less than the mean ± SE trap catch of 7.1 ± 0.1 in traps with wet cups ($P < 0.001$).

Table 3. Effect of cup treatment on mean catches of some associates of bark and wood-boring beetles in three southern pine stands (2001 and 2006) from multiple-funnel traps baited with ethanol and (−)-α-pinene (experiments 1 and 2; $n = 5$) or ethanol, (−)-α-pinene, (±)-ipsenol, and (±)-ipsdienol (experiments 3; $n = 10$)

Species	Exp.	*N*	Mean ± SE no. of beetles per trap		*P* value (*t*-test)	Difference of catches in dry cups compared with wet cups (%)
			Wet cup	Dry cup		
Elateridae						
Alaus myops	3	40	1.7 ± 0.7	2.3 ± 0.7	0.759	+35.2
Trogositidae						
Temnochila virescens	1	422	41.4 ± 2.9	43.0 ± 7.6	0.474	+3.9
	2	94	8.4 ± 1.3	10.4 ± 2.7	0.650	+23.8
	3	490	26.5 ± 3.7	22.5 ± 3.6	0.243	−15.1
Cleridae						
Thanasimus dubius	3	93	6.8 ± 1.1	2.5 ± 0.5	0.002	−63.2
Colydiidae						
Lasconotus spp.	1	168	16.6 ± 4.3	17.0 ± 2.1	0.651	+2.4
	3	457	19.8 ± 1.8	25.9 ± 2.6	0.945	+30.8

N is total number of beetles captured.

Discussion

For some species, we found that the choice of collection cup had no significant effect on catches of adult beetles in baited multiple-funnel traps at our study sites. Catches of the bark beetles *I. avulsus* and *I. grandicollis* in traps with dry cups were not significantly different from those in traps with wet cups (Table 2). The power in these experiments was generally high (0.808–1.000), although the power was 0.509 in experiment 2 with *I. avulsus.* Similarly, there was little effect of cup treatment on catches of some common predators of bark beetles and woodborers (Table 3). In all three experiments, we found that catches of *T. virescens* in traps with dry cups were not significantly different from those in wet cups (power = 0.900–1.000). The same was true for *Chalcophora* spp. in experiment 1 (Table 1), *A. myops* in experiment 3, and *Lasconotus* spp. in experiments 1 and 3 (Table 3).

In our experiments, we identified one significant caveat to using dry-cup traps for bark beetles, relating to damage caused by predators. In several dry-cup traps, we found significant damage to *I. grandicollis.* Abdomens were severed or eaten, often with elytra as the only remains that could be tabulated. With frequently encountered species, such damage makes counting beetles a little more laborious, but not impossible. However, damage to rare beetles such as exotic species at ports-of-entry may be a significant obstacle to identification of the species by morphology alone. When collecting catches of beetles in dry-cup traps, we often found that a few *T. virescens* and the cerambycid *X. s. sagittatus* were alive and active, suggesting a differential tolerance for dichlorvos in comparison to the bark beetles and a chance for them to consume or damage prey before dying.

A second consideration in using dry-cup trapping relates to levels of rainfall. Although not an issue in our experiments, dry-cup trapping in areas of high and frequent rainfall, such as in northern Florida, can result in moisture saturation of insect material and decay in the cups, leading to the attraction of dung (Scarabaeidae) and carrion beetles (Silphidae). The resultant catch can be quite odiferous and pungent, making processing onerous, if not hazardous to your health (unpublished data from Hanula et al. 2002).

For many other species, we found that the use of dry cups with baited traps resulted in a significant reduction in trap catches relative to wet cups. Catches of four species of Cerambycidae were reduced by 46–86% with the use of dry cups, whereas catches of two root-feeding weevils, *H. pales* and *P. picivorus,* were reduced by 44–74% (Table 1). Similarly, catches of the bark beetle, *H. porculus,* and the ambrosia beetle, *X. saxesenii,* were reduced by 40–83% (Table 2). In experiment 3, we found that catches of a common bark beetle predator, *T. dubius,* were reduced by 63% (Table 3). We did not find any significant damage to beetles captured in wet cups.

We can think of five possible explanations for differences in catches between dry-cup traps and wet-cup traps (none of which are mutually exclusive). Moreover, the same explanations may not be applicable to each species equally. The first explanation may relate to variation in insecticide tolerance and susceptibility of beetles. Weevils and woodborers do not seem to die right away, likely giving them a greater opportunity to escape. Predatory species such as *T. virescens* may be able to escape, but the abundance of prey items may not give them much incentive to do so, hence the lack of treatment effect with this species.

Second, interspecific variation in agility may explain some of the differences. The bottom funnel of a funnel trap narrows to a diameter of 55 mm; significantly less than the diameter of the collection cup (95 mm), resulting in a weir effect designed to limit escape of bark and ambrosia beetles. Species such as weevils and longhorn woodborers seem much more agile than bark beetles and may be able to climb out of the dry cups. Species such as *I. grandicollis* and *T. virescens* do no seem able to climb the walls of a dry cup very well; much less navigate the weir at the top of the cup. Large beetles such as *A. myops* and *Chalcophora* species may simply be too awkward to manage the weir at the top of the cup.

A third possible explanation may relate to attraction or repellency of cup treatments. It is possible that vapors from the dichlorvos strips used in dry cups inhibited attraction of some species to baited funnel traps. Alternatively, some species may have been attracted by the volatiles emitted by propylene glycol solution used in wet-cup trapping. However, propylene glycol itself has low volatility (hence, its usefulness as antifreeze); the water in the glycol solution evaporates but glycol remains in the cup.

A fourth possibility may relate to searching mechanisms used by insects after they land on a funnel. Some beetles may search downwards in a funnel trap in response to the pink color of the propylene glycol solution. Or the use of a liquid in wet cups may create a minor down current of air within a funnel, resulting in accumulation of volatiles closer to the cup. Beetles landing on a funnel may explore this possible gradient, resulting in higher probability of capture in a wet cup. And fifth, variation in predation and competition between some species may account for some differences. It is possible that differences in catches of the beetle predator, *Th. dubius* (Table 3) may relate to predation or competition with the larger *Te. virescens.*

Predicting the species likely to be affected or unaffected by cup treatment is difficult as some species exhibited both types of responses. In experiment 2, the dry cup treatment resulted in a reduction of 97% in catches of *X. crassiusculus*, whereas there was no significant effect in experiment 3 (Table 2). Catches of *H. tenuis* were reduced by 55% in experiment 2, but only 4% in experiment 3. Similarly, catches of *H. salebrosus* were affected by cup treatment in experiment 3, but not experiments 1 and 2; catches of *D. terebrans* were affected in experiments 1 and 3, but not in experiment 2. One possible explanation for these inconsistencies might have been the occurrence of sporadic weather events such as a quick heavy rain (common in the southeastern United States), drowning beetles in dry cups soon after they were captured.

In spite of these inconsistencies, we found that differences in catches arising from cup treatment definitely occurred for some common species of arboreal beetles in at least some experiments. Managers should consider potential cup treatment effects on target species in any multiple funnel trap program for bark and wood-boring beetles along with the effects of climate on ease and efficiency in servicing funnel traps. The issue may be of particular concern for programs dealing with rare individuals. Because beetles likely enter and leave cups independently of each other, reductions in trap catches likely reflect reductions in probability of catching rare individuals. At ports-of-entry where numbers of invasive exotic insects are low, the reduction in probability of capture may be the difference between detection and nondetection. The effectiveness of rapid response programs for exotic invasive insects is wholly dependent on early detection, often of a single beetle. As trap efficacy is largely unknown for most species, we should attempt to maximize efficiency at all times. The same is likely true with leading edges of containment and quarantine zones. Inadequate detection may result in misdirected treatments or the need for larger treatment areas, and associated treatment costs. Managers should be encouraged to use the most effective technologies in all attempts to mitigate the effects of invasive species (Lodge et al. 2006). The simple practice of using wet cups rather than dry cups may enhance trap-based detection programs for exotic bark and wood-boring beetles.

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