Catches of Longhorn Beetles (Coleoptera: Cerambycidae) in Traps Baited with Generic Pine Beetle Lure Blend Unaffected by *Ips* Pheromones Lanierone and *cis*-Verbenol in Georgia[1]

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Abstract A generic trap lure blend of host volatiles (ethanol + α-pinene) and *Ips* bark beetle pheromones (ipsenol + ipsdienol) is effective for detecting numerous species of longhorn beetles (Coleoptera: Cerambycidae) in pine forests of North America. In 2021, the potential benefits of adding two other *Ips* pheromones (lanierone and *cis*-verbenol) to traps baited with the pine beetle lure blend were determined in north Georgia. Lanierone and *cis*-verbenol had no effect on catches of the six cerambycid species captured in the study: *Acanthocinus nodosus* (F.), *A. obsoletus* (LeConte), *Astylopsis arcuata* (LeConte), *Monochamus titillator* (F.), *Neoclytus acuminatus* (F.), and *Xylotrechus sagittatus* Germar. Similarly, neither compound had any effect on catches of some common ambrosia and bark beetles and snout weevils nor on catches of some associated predators, all commonly caught in traps baited with the pine beetle lure blend. In contrast, catches of *Ips avulsus* Eichhoff and *I. grandicollis* (Eichhoff) were enhanced by the addition of lanierone, whereas those of *I. calligraphus* (Germar) and *Hylastes tenuis* Eichhoff (Curculionidae) were enhanced by the addition of *cis*-verbenol. The data do not support the addition of lanierone or *cis*-verbenol to the blend of ethanol + α-pinene + ipsenol + ipsdienol as a trap lure blend for the broad detection of pine longhorn beetles in north Georgia.

Key Words Cerambycidae, Curculionidae, Cleridae, Scolytinae, *Ips*

Detection programs for non-native species of bark and woodboring beetles require trap lure blends that can detect multiple species at the same time, thereby minimizing program costs (Fan et al. 2019, Hanks and Millar 2013, Poland and Rassati 2019, Rice et al. 2020). Lure combinations with the cerambycid pheromones 2,3-hexanediols and 3,2-hydroxyketones are successful in the detection of numerous species of cerambycids in eastern North America, particularly those that inhabit hardwood forests (Hanks and Millar 2013, 2016). Additionally, complex lure blends can provide opportunities for determining biodiversity of the woodboring guild (Dodds et al. 2015, Wickham et al. 2021).

In the southeastern United States, traps baited with ethanol + α-pinene are attractive to multiple species of longhorn beetles (Coleoptera: Cerambycidae) that inhabit pine forests (Miller 2006, 2020; Miller et al. 2015). The addition of the *Ips* bark beetle pheromones ipsenol and ipsdienol to traps baited with ethanol + α-

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pinene significantly enhances the abundance and diversity of cerambycid species captured in traps (Miller et al. 2011, 2013b, 2015). Ipsenol is used as a pheromone by *Ips grandicollis* (Eichhoff), whereas *Ips avulsus* (Eichhoff) and *Ips calligraphus* (Germar) use ipsdienol (Allison et al. 2012). Lanierone and *cis*-verbenol are two additional pheromones used by *I. avulsus* and *I. calligraphus*, respectively, in the southeastern United States (Allison et al. 2012; Miller et al. 2003, 2005). The goal of this study was to assess the benefit of adding lanierone and/or *cis*-verbenol to traps baited with the pine beetle lure blend of ethanol + α-pinene + ipsenol + ipsdienol. The primary focus of the study was on cerambycids; a secondary focus was on the responses of bark and ambrosia beetles, and associated predators.

Materials and Methods

A trapping study was conducted 7 May–17 June 2021 to determine the effects of lanierone and *cis*-verbenol (racemic) on catches of forest beetles in traps baited with the pine beetle lure blend (ethanol + α-pinene + ipsenol + ipsdienol). Ethanol and α-pinene [75%(–)] lures with release rates of 0.5 g/d and 1–6 g/d, respectively, were obtained from Scotts Canada (Victoria, BC, Canada). Synergy Semiochemicals Inc. (Burnaby, BC, Canada) supplied lures of ipsenol (racemic), ipsdienol (racemic), and lanierone, each with release rates of 0.1-0.2 mg/d, and *cis*-verbenol [87%(–)] released at 1–3 mg/d. All release rates were determined at 23°C by the respective manufacturer.

Six replicate blocks of four 10-unit black multiple-funnel traps (Synergy Semiochemicals) per block were set in a mature upland pine and hardwood forest at the Scull Shoals Experimental Forest (Greene Co.) in north Georgia, USA (33.7731°N, 83.2396°W). The primary tree species were *Pinus taeda* L., *P. echinata* Miller, Q*uercus alba* L, *Q. falcata* Michaux, *Liquidambar styraciflua* L., and *Carya tomentosa* Sargent. The holes at the bottom of each funnel within a trap were enlarged from 5 to 12 cm to allow lures to be hung within funnels (Miller et al. 2013a). Traps were hung on twine tied between trees and >2 m from any tree and spaced approximately 10 m apart within and between blocks. Approximately 200 ml of an aqueous solution of propylene glycol (Winter-Eez RV & Marine Antifreeze, Southwin Ltd., Greensboro, NC) was placed in each collection cup to kill and preserve captured beetles (Miller and Duerr 2008). A piece (2.5 × 5.0 cm) of VaporTape II (Hercon Environmental Corp., Emigsville, PA) was attached under the canopy of each trap to prevent nest building by paper wasps.

All traps were baited with the pine beetle lure blend of ethanol + α-pinene + ipsenol + ipsdienol (P). In a randomized complete block design, one of the following four treatments was allocated to each of the four traps within each block: (1) P alone; (2) P + lanierone (L); (3) P + *cis*-verbenol (cV); and (4) P + L + cV. Voucher specimens were deposited in the University of Georgia Collection of Arthropods (UGCA), Athens, GA, USA.

SYSTAT (ver. 13) and SigmaStat (ver. 3.01) statistical packages (SYSTAT Software Inc., Point Richmond, CA) were used to analyze trap catch data for species with total counts $\geq$ 30. As needed, data were transformed by $\ln(Y + 1)$ to obtain normality and homoscedasticity, verified by the Shapiro-Wilk and equal variance tests, respectively. Data were analyzed by a mixed-model analysis of variance (ANOVA) with treatment as the fixed factor, followed by the Holm-Sidak multiple-comparison test for species affected by the treatments ($\alpha = 0.05$). The Holm-Sidak test controls the overall experiment-wise error rate at 0.05 (Glantz 2005). For species affected by treatments, data were further analyzed by a mixed-model ANOVA using the following model factors: (1) L; (2) cV; and (3) L $\times$ cV.

Results

Cerambycidae. A total of 3,031 longhorn beetles were captured in the study, representing six cerambycid species (Table 1). Catches of cerambycids in traps baited with the pine beetle lure blend were not affected by lanierone and/or *cis*-verbenol for all six species: *Acanthocinus nodosus* (F.), *Acanthocinus obsoletus* (LeConte), *Astylopsis arcuata* (LeConte), *Monochamus titillator* (F.), *Neoclytus acuminatus* (F.), and *Xylotrechus sagittatus* (Germar) (Coleoptera: Cerambycidae) (Table 2).

Curculionidae. The ambrosia beetle *Cnestus mutilatus* (Blandford), the bark beetles *Dendroctonus terebrans* LeConte and *Hylastes porculus* Erichson, and the weevils *Hylobius pales* (Herbst), *Pachylobius picivorus* (Germar), and *Stenoscelis brevis* (Boheman) were unaffected by the lure treatments (Table 2). In contrast, four species of bark beetles were affected by lure treatments. Lanierone lures affected trap catches of *I. avulsus* and *I. grandicollis* (Table 3). Traps baited with lanierone (with or without *cis*-verbenol) caught more *I. avulsus* than those baited with pine beetle lure blend alone or the blend + cis-verbenol (Fig. 1A). Catches of *I. grandicollis* were greater in traps baited with the pine beetle lure blend + lanierone than in traps baited with the pine beetle lure blend alone (Fig. 1B). Catches of *I. calligraphus* were affected by all three factors, whereas catches of *H. tenuis* were affected by *cis*-verbenol and the interaction between *cis*-verbenol and lanierone (Table 3). Catches of *I. calligraphus* were highest in traps baited with the pine lure blend + *cis*-verbenol and lowest in traps baited with the pine beetle lure blend (with or without lanierone) (Fig. 1C). Lanierone significantly reduced catches of *I. calligraphus* in traps baited with the pine lure blend + *cis*-verbenol (Fig. 1C). Traps baited with the pine beetle lure blend + *cis*-verbenol caught more *H. tenuis* than traps baited solely with the pine beetle lure blend (Fig. 1D).

Predators. Catches of the predatory species *Temnoscheila virescens* (F.) (Coleoptera: Trogossitidae) and *Thanasimus dubius* (F.) (Coleoptera: Cleridae) were unaffected by lure treatments (Table 2). Although catches of *Enoclerus nigripes* (Say) (Coleoptera: Cleridae) were affected by the interaction between lanierone and *cis*-verbenol (Table 3), catches in traps baited with the pine beetle lure blend alone were not different from those in traps co-baited with lanierone and/or *cis*-verbenol (Fig. 1E). Catches of *Platysoma* spp. (Coleoptera: Histeridae) were affected by *cis*-verbenol (Table 3) with catches in traps baited with the pine beetle lure blend + *cis*-verbenol + lanierone greater than those in traps baited solely with the pine beetle lure blend (Fig. 1F). The lanierone trap treatment affected catches of *Lasconotus* spp. (Coleoptera: Zopheridae) (Table 3), with catches in traps baited with the pine beetle lure blend + lanierone (with or without *cis*-verbenol) greater than those in traps baited solely with the pine beetle lure blend (Fig. 1G). *Aulonium* spp.

Table 1. Numbers of beetles (Coleoptera) captured in multiple-funnel traps baited with ethanol + α-pinene + ipsenol + ipsdienol (P), with or without lanierone (L) and/or *cis*-verbenol (cV).

	Lure Treatments				
Family and Species	P	P + L	P + cV	P + L + cV	Total
Cerambycidae					
Acanthocinus nodosus (F.)	12	18	16	21	67
Acanthocinus obsoletus (Olivier)	171	197	159	215	742
Astylopsis arcuata (LeConte)	6	6	13	9	34
Monochamus titillator (F.)	409	433	400	404	1,646
Neoclytus acuminatus (F.)	14	17	9	16	56
Xylotrechus sagittatus (Germar)	105	127	111	143	486
Cleridae					
Chariessa pilosa (Forster)	3	13	8	13	37
Enoclerus ichneumonus (F.)	—	—	3	3	6
Enoclerus nigripes (Say)	25	15	17	44	101
Thanasimus dubius (F.)	49	61	68	78	256
Curculionidae					
Cnestus mutilatus (Blandford)	91	109	121	137	458
Dendroctonus terebrans (Olivier)	191	229	157	191	768
Hylastes porculus Erichson	38	16	6	4	64
Hylastes salebrosus Eichhoff	9	7	5	4	25
Hylastes tenuis Eichhoff	4	8	17	9	38
Hylobius pales (Herbst)	74	108	85	107	374
Ips avulsus (Eichhoff)	141	6,365	97	6,811	13,414
Ips calligraphus (Germar)	61	59	398	111	629
Ips grandicollis (Eichhoff)	1,000	1,510	1,125	1,315	4,950
Myoplatypus flavicornis (F.)	3	1	4	8	16
Pachylobius picivorus (Germar)	57	58	72	66	253
Stenoscellis brevis (Boheman)	31	18	19	29	97
Xyleborinus saxesenii (Ratzeburg)	9	4	5	2	20
Xylosandrus crassiusculus (Motschulsky)	5	3	14	6	28

Table 1. Continued.

Family and Species	Lure Treatments				Total
	P	P + L	P + cV	P + L + cV	
Elateridae					
Alaus myops (F.)	3	8	8	7	26
Histeridae					
Platysoma spp.	75	88	124	132	419
Passandridae					
Catogenus rufus (F.)	4	8	3	2	17
Tenebrionidae					
Corticeus spp.	13	8	12	16	49
Trogossitidae					
Temnoscheila virescens (F.)	262	319	373	392	1,346
Zopheridae					
Aulonium spp	—	20	4	12	36
Lasconotus spp	8	31	16	45	100

(Coleoptera: Zopheridae) were caught in all traps except those baited solely with the pine lure blend (Fig. 1H).

Discussion

The addition of lanierone and/or *cis*-verbenol had no effect on catches of all six species of cerambycids captured in traps baited with the pine beetle lure blend of ethanol + α-pinene + ipsenol + ipsdienol (Table 2). Similarly, there were no treatment effects on catches of reproduction and snout weevils, several species of bark and ambrosia beetles (Curculionidae), and some species of associated predators (Cleridae, Tenebrionidae, and Trogossitidae) (Table 2). The major exception to this pattern were the responses of *Ips* bark beetles, especially *I. avulsus* (Fig. 1A–C). Unless managers are targeting *Ips* species specifically, there is no obvious benefit in adding lanierone and/or *cis*-verbenol to the pine beetle lure blend for detecting bark and woodboring beetles, and associated predators. The abundance of *I. avulsus* in traps baited with lanierone would slow processing of collections focused on detections of other taxa.

Results in this study may provide some additional insights into the chemical ecology of *Ips avulsus*, *I. calligraphus*, and *I. grandicollis*, which breed in various species of southern pines, often in the same tree (Allison et al. 2012). In 2009, Allison et al. (2012) found that catches of *I. calligraphus* in Georgia and Louisiana

Table 2. Mean ± SE number per trap, and *F* and *P* values (ANOVA) for beetle species not affected by lure treatments.

Family and Species	Mean ± SE	$F_{3,21}$	*P*
Cerambycidae			
Acanthocinus nodosus	2.8 ± 0.5	0.419	0.742
Acanthocinus obsoletus	31.0 ± 2.8	0.631	0.606
Astylopsis arcuata	1.4 ± 0.3	0.724	0.553
Monochamus titillator	68.6 ± 4.6	0.232	0.873
Neoclytus acuminatus	2.3 ± 0.3	1.234	0.332
Xylotrechus sagittatus	20.3 ± 2.9	1.129	0.369
Cleridae *			
Chariessa pilosa	1.5 ± 0.4	1.186	0.348
Thanasimus dubius	10.7 ± 0.9	1.281	0.317
Curculionidae			
Cnestus mutilatus	19.1 ± 2.4	1.212	0.340
Dendroctonus terebrans	32.0 ± 2.4	1.336	0.300
Hylastes porculus	1.6 ± 0.3	1.904	0.172
Hylobius pales	15.6 ± 1.9	0.681	0.577
Pachylobius picivorus	10.5 ± 1.0	0.715	0.558
Stenoscellis brevis	4.0 ± 0.6	1.694	0.211
Tenebrionidae*			
Corticeus spp	2.0 ± 0.4	0.742	0.544
Trogossitidae*			
Temnoscheila virescens	56.1 ± 5.5	2.916	0.069

N, total number captured per species.
*Families of bark beetle and woodborer predators.

were highest in traps baited with ipsdienol + *cis*-verbenol, both pheromones of *I. calligraphus*, whereas catches were reduced with the addition of ipsenol, which is not a pheromone for *I. calligraphus* but is for *I. grandicollis*; lanierone was not tested. Similarly, I found that catches of *I. calligraphus* in traps baited with the pine beetle lure blend of ethanol + α-pinene + ipsenol + ipsdienol were significantly enhanced by the addition of *cis*-verbenol; an effect interrupted with the addition of lanierone (Fig. 1C). Miller et al. (2005) found that lanierone (pheromone for *I. avulsus*) reduced catches of *I. calligraphus* in traps baited with ipsdienol + *cis*-verbenol in Florida, Georgia, and Louisiana. These behaviors could minimize host competition interactions of *I. calligraphus* with *I. grandicollis* and/or *I. avulsus*.

Table 3. ANOVA results for effects of lanierone (L), *cis*-verbenol (cV), and the interaction of L $\times$ cV on catches of beetles in traps baited with ethanol + α-pinene + ipsenol + ipsdienol.

	L		cV		L $\times$ cV	
Family and Species	$F_{1,21}$	P	$F_{1,21}$	P	$F_{1,21}$	P
Cleridae*						
Enoclerus nigripes	2.322	0.148	3.543	0.079	11.00	0.006
Curculionidae						
Hylastes tenuis	0.635	0.438	7.778	0.014	5.714	0.030
Ips avulsus	186.4	<0.001	0.180	0.677	0.267	0.613
Ips calligraphus	21.28	<0.001	66.89	<0.001	14.27	0.002
Ips grandicollis	16.91	0.001	0.066	0.800	2.709	0.121
Histeridae*						
Platysoma spp.	0.959	0.343	12.98	0.003	0.177	0.680
Zopheridae*						
Lasconotus spp.	19.13	0.001	3.250	0.092	0.148	0.706

N, total number captured per species.
*Families of bark beetle and woodborer predators.

Similar to previous results in Florida, Georgia, Louisiana, and North Carolina (Miller et al. 2005), I found no effect of *cis*-verbenol on catches of *I. grandicollis* in traps baited with the pine beetle lure blend (Fig. 1B). In contrast, trap catches of *I. grandicollis* increased with the addition of lanierone (Fig. 1B). Similarly in a phenology study of *Ips* spp. in Georgia, Brownell (2014) found that catches of *I. grandicollis* in traps baited with ipsenol + ipsdienol + lanierone were twice those in traps baited with its pheromone ipsenol and the host volatile α-pinene. These data suggest the possibility of a positive association between *I. grandicollis* and *I. avulsus*, the latter using lanierone as a pheromone (Miller et al. 2003, 2005). Ipsenol is the pheromone for *I. grandicollis* and attracts *I. avulsus*, which does not use ipsenol as a pheromone (Miller et al. 2003, 2005). The relationship between these two species in host use and allocation deserves further study and clarification.

The magnitude of the effects of lanierone on catches of *I. avulsus* in this study was surprising. There was a 44-fold increase in catches of *I. avulsus* in traps baited with the pine lure blend + lanierone compared with those in traps baited with the pine lure blend alone and a 69-fold increase in traps baited with the pine lure blend + lanierone + *cis*-verbenol compared with those in traps baited with the pine lure blend + *cis*-verbenol (Fig. 1A). Miller et al. (2005) noted only a two- to fourfold increase in catches of *I. avulsus* in traps baited with ipsenol + ipsdienol by the addition of lanierone, which is more than an order of magnitude less than the

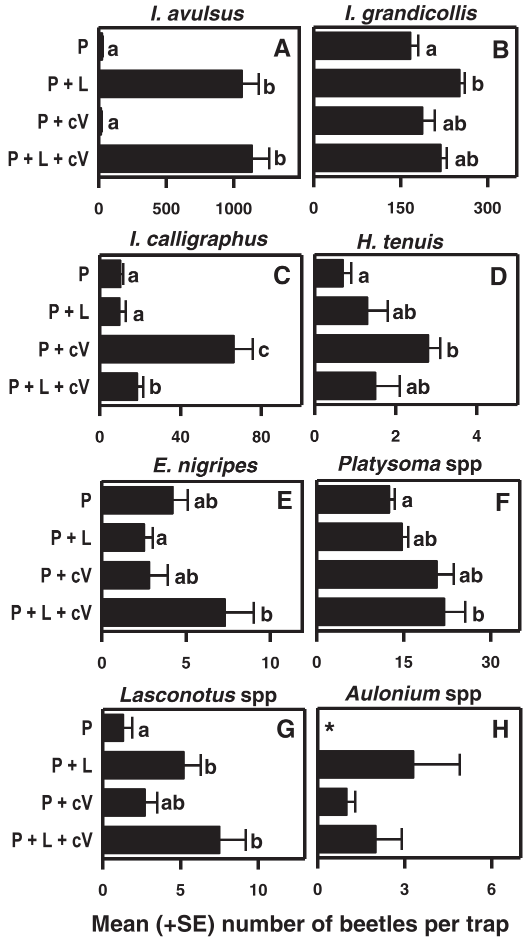

Fig. 1. Effects of lanierone (L) and *cis*-verbenol (cV) on catches of *Ips avulsus* (A), *Ips grandicollis* (B), *Ips calligraphus* (C), *Hylastes tenuis* (D), *Enoclerus nigripes* (E), *Platysoma* spp. (F), *Lasconotus* spp (G), and *Aulonium* spp. (H) in traps co-baited with ethanol + α-pinene + ipsenol + ipsdienol (P). Means for a species followed by the same letter are not significantly different at $P = 0.05$ (Holm-Sidak test). Treatment mean with an asterisk (*) had zero catch.

present study. The pine beetle lure blend does contain ethanol and α-pinene, a combination that reduces attraction of *I. avulsus* to traps baited with ipsenol + ipsdienol (Miller 2020, Miller and Crowe 2018, Miller et al. 2011). It may be that lanierone overrides the interruptive effect of host compounds by providing a species-specific indicator of host availability and mating opportunity for *I. avulsus*.

Species of *Platysoma* (Histeridae), *Lasconotus*, and *Aulonium* (Zopheridae) are thought to be predators of bark beetles (Dixon and Payne 1979, 1980; Goyer et al.

1980; Linit and Stephen 1983; Rohlfs and Hyche 1984; Steed and Wagner 2008; Stephen and Dahlsten 1976) and respond positively to pheromones produced by *Ips* spp. (Allison et al. 2013). The flight activity of *Platysoma* spp coincides with that of *Ips* spp in Louisiana (Shepherd and Goyer 2003). In a cage study with bolts of *Pinus taeda* L., Shepherd and Goyer (2005) found that brood mortality of *I. calligraphus* and *I. grandicollis* was significantly higher with the addition of *Platysoma parallelum* (Say) (Coleoptera: Histeridae) to the cages. In California, early-instar larvae of *Lasconotus subcostulatus* Kraus (Coleoptera: Zopheridae) feed on fungi under the bark of pine trees but switch to feeding on larvae of *Ips paraconfusus* (LeConte) as late-instar larvae (Hackwell 1973). In Israel, adult *Aulonium ruficorne* Olivier (Coleoptera: Zopheridae) feed on the eggs and larvae of the bark beetles *Orthotomicus erosus* (Wollaston) and *Pityogenes calcaratus* Eichhoff (Coleoptera: Curculionidae) (Podoler et al. 1990).

In this study, *Lasconotus* spp were most abundant in traps baited with lanierone (Fig. 1G), mirroring the response profile of *I. avulsus* (Fig. 1A). In contrast, the response profile of *Platysoma* spp was highest in traps baited with both compounds (Fig. 1F), suggesting generalist predation of *Ips* spp. Responses by *Aulonium* spp in our study also appear to be linked with those of lanierone and *cis*-verbenol as none were caught in traps without these compounds (Fig. 1H). The diversity of predators associated with bark and woodboring beetles underscores the need to understand their ecologies, particularly with the advent of non-native species of bark and woodboring beetles and climate change. This may be particularly important for trapping programs targeting pest species of bark beetles. Large captures of predators in such trapping programs may undermine the ability of predators to control populations of pest bark beetles.

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References Cited

Allison, J.D., J.L. McKenney, D.R. Miller and M.L. Gimmel. 2012. Role of ipsdienol, ipsenol, and *cis*-verbenol in chemical ecology of *Ips avulsus*, *Ips calligraphus* and *Ips grandicollis* (Coleoptera: Curculionidae: Scolytinae). J. Econ. Entomol. 105: 923–929.

Allison, J.D., J.L. McKenney, D.R. Miller and M.L. Gimmel. 2013. Kairomonal responses of natural enemies and associates of the southern *Ips* (Coleoptera: Curculionidae: Scolytinae) to ipsdienol, ipsenol and *cis*-verbenol. J. Insect Behav. 26: 321–335.

Brownell, K.A. 2014. Subcortical beetle communities in Georgia. MS Thesis. Univ. Georgia, Athens.

Dixon, W.N. and T.L. Payne. 1979. Sequence of arrival and spatial distribution of entomophagous and associate insects of southern pine beetle-infested trees. Texas Agric. Exp. Sen. Misc. Pub. MP-1432, College Station, TX.

Dixon, W.N. and T.L. Payne. 1980. Attraction of entomophagous and associate insects of the southern pine beetle to beetle- and tree-produced volatiles. J. Georgia Entomol. Soc. 15: 378–389.

Dodds, K.J., J.D. Allison, D.R. Miller, R.P. Hanavan and J. Sweeney. 2015. Considering species richness and rarity when selecting optimal survey traps: Comparisons of semiochemical baited flight intercept traps for Cerambycidae in eastern North America. Agric. For. Entomol. 17: 36–47.

Fan, J.-T., O. Denux, C. Courtin, A. Bernard, M. Javal, J.G. Millar, L.M. Hanks and A. Roques. 2019. Multi-component blends for trapping native and longhorn beetles at potential points-of-entry and in forests. J. Pest Sci. 92: 281–297.

Glantz, S.A. 2005. Primer of Biostatistics. McGraw-Hill Professional, New York.

Goyer, R.A., G.J. Lengard, T.E. Nebeker and L.D. Garrard. 1980. How to identify common insect associates of the southern pine beetle. U.S. Dept. Agric., Agriculture Handbook 563. Washington, DC.

Hackwell, G.A. 1973. Biology of *Lasconotus subcostulatus* (Coleoptera: Colydiidae) with special reference to feeding behavior. Ann. Entomol. Soc. Am. 66: 62–65.

Hanks, L.M. and J.G. Millar. 2013. Field bioassays of cerambycid pheromones reveal widespread parsimony of pheromone structures, enhancement by host plant volatiles, and antagonism from heterospecifics. Chemoecology 23: 21–44.

Hanks, L.M. and J.G. Millar. 2016. Sex and aggregation-sex pheromones of cerambycid beetles: Basic science and practical implications. J. Chem. Ecol. 42: 631–654.

Linit, M.J. and F.M. Stephen. 1983. Parasite and predator component of within-tree southern pine beetle (Coleoptera: Scolytidae) mortality. Can. Entomol. 115: 679–688.

Miller, D.R. 2006. Ethanol and (–)-α-pinene: Attractant kairomones for some large wood-boring beetles in southeastern USA. J. Chem. Ecol. 32: 779–794.

Miller, D.R. 2020. Effects of ethanol and α-pinene in a generic trap lure blend for pine bark and wood-boring beetles in southeastern United States. J. Entomol. Sci. 55: 310–320.

Miller, D.R., C. Asaro and C.W. Berisford. 2005. Attraction of southern pine engravers and associated bark beetles (Coleoptera: Scolytidae) to ipsenol, ipsdienol, and lanierone in southeastern United States. J. Econ. Entomol. 98: 2058–2066.

Miller, D.R., C. Asaro, C.M. Crowe and D.A. Duerr. 2011. Bark beetle pheromones and pine volatiles: Attractant kairomone lure blend for longhorn beetles (Cerambycidae) in pine stands of the southeastern United States. J. Econ. Entomol. 104: 1245–1257.

Miller, D.R. and C.M. Crowe. 2018. Effect of distance between baited multiple-funnel traps on catches of bark and woodboring beetles (Coleoptera: Curculionidae, Cerambycidae) and associates in north-central Georgia. J. Entomol. Sci. 53: 268–277.

Miller, D.R., C.M. Crowe, B.F. Barnes, K.J.K. Gandhi and D.A. Duerr. 2013a. Attaching lures to multiple-funnel traps targeting saproxylic beetles (Coleoptera) in pine stands: Inside or outside funnels? J. Econ. Entomol. 106: 206–214.

Miller, D.R., C.M. Crowe, K.J. Dodds, L.D. Galligan, P. de Groot, E.R. Hoebeke, A.E. Mayfield III, T.M. Poland, K.F. Raffa and J.D. Sweeney. 2015. Ipsenol, ipsdienol, ethanol, and α-pinene: Trap lure blend for Cerambycidae and Buprestidae (Coleoptera) in pine forests of eastern North America. J. Econ. Entomol. 108: 1837–1851.

Miller, D.R., K.J. Dodds, A. Eglitis, C.J. Fettig, R.W. Hofstetter, D.W. Langor, A.E. Mayfield, III, A.S. Munson, T.M. Poland and K.F. Raffa. 2013b. Trap lure blend of pine volatiles and bark beetle pheromones for *Monochamus* spp. (Coleoptera: Cerambycidae) in pine forests of Canada and the United States. J. Econ. Entomol. 106: 1684–1692.

Miller, D.R. and D.A. Duerr. 2008. Comparison or arboreal beetle catches in wet and dry collection cups with Lindgren multiple funnel traps. J. Econ. Entomol. 101: 107–113.

Miller, D.R., K.F. Raffa, M.J. Dalusky and C.W. Berisford. 2003. North-south variation in the response of the pine engraver (Coleoptera: Scolytidae) to lanierone and ipsdienol in eastern North America. J. Entomol. Sci. 38: 468–476.

Podoler, H., Z. Mendel and H. Livne. 1990. Studies on the biology of a bark beetle predator, *Aulonium ruficorne* (Coleoptera: Colydiidae). Environ. Entomol. 19: 1010-1016.

Poland, T.M. and D. Rassati. 2019. Improved biosecurity surveillance on non-native forest insects: a review of current methods. J. Pest Sci. 92: 37–49.

Rice, M.E., Y. Zou, J.G. Millar and L.M. Hanks. 2020. Complex blends of synthetic pheromones are effective multi-species attractants for longhorned beetles (Coleoptera: Cerambycidae). J. Econ. Entomol. 113: 2269–2275.

Rohlfs, W.M., III and L.L. Hyche. 1984. Observations on activity and development of *Lasconotus pusillus* and *L. referendarius* (Coleoptera: Colydiidae) following arrival at *Ips* spp. infested southern pines. J. Georgia Entomol. Soc. 19: 114–119.

Shepherd, W.P. and R.A. Goyer. 2003. Seasonal abundance, arrival and emergence patterns of predaceous hister beetles (Coleoptera: Histeridae) associated with *Ips* engraver beetles (Coleoptera: Scolytidae) in Louisiana. J. Entomol. Sci. 38: 612–620.

Shepherd, W.P. and R.A. Goyer. 2005. Impact of *Platysoma parallelum* and *Plegaderus transversus* (Coleoptera: Histeridae) predation on developing *Ips calligraphus* and *Ips grandicollis* brood. J. Entomol. Sci. 40: 80–87.

Steed, B.E. and M.R. Wagner. 2008. Seasonal pheromone response by *Ips pini* in northern Arizona and western Montana, U.S.A. Agric. For. Entomol. 10: 189–203.

Stephen, F.M. and D.L. Dahlsten. 1976. The arrival sequence of the arthropod complex following attack by *Dendroctonus brevicomis* (Coleoptera: Scolytidae) in ponderosa pine. Can. Entomol. 108: 283–304.

Wickham, J.D., R.D. Harrison, W. Lu, L.M. Hanks and J.G. Millar. 2021. Rapid assessment of cerambycid beetle biodiversity in a tropical rainforest in Yunnan Province, China, using a multicomponent pheromone lure. Insects 12: 277.