Effects of Ethanol and α-Pinene in a Generic Trap Lure Blend for Pine Bark and Wood-Boring Beetles in Southeastern United States[1]

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Abstract Managers of detection programs for bark and wood-boring beetles require cost-effective trap lure combinations that maximize species detections. A trapping study was conducted in 2012 to determine the effects of ethanol and α-pinene lures on beetle catches in traps baited with ipsenol and ipsdienol lures in a stand of *Pinus taeda* L. in north-central Georgia. Traps with all four compounds worked well for 20 of 25 species of bark and wood-boring beetles, and associated predators. Catches of *Acanthocinus obsoletus* (LeConte) and *Monochamus titillator* (F.) (Cerambycidae), *Hylastes porculus* Erichson, *Hylastes salebrosus* Eichhoff, *Hylobius pales* (Herbst), *Orthotomicus caelatus* (Eichhoff) (Curculionidae), *Thanasimus dubius* (F.) (Cleridae), and *Temnoscheila virescens* (F.) (Trogossitidae) in baited traps increased with the addition of ethanol and α-pinene with maximum catches in traps baited with all four compounds. Catches of *Ips avulsus* (Eichhoff) (Curculionidae) decreased with the addition of both compounds; the lowest numbers of *I. avulsus* and *Ips grandicollis* (Eichhoff) were caught in traps baited with all four compounds. α-Pinene increased catches of *Buprestis lineata* F. (Buprestidae), *Ips calligraphus* (Germar), *Pachylobius picivorus* (Germar) (Curculionidae), *Corticeus* spp. (Tenebrionidae), *Lasconotus* spp., and *Pycnomerus sulcicollis* LeConte (Zopheridae); ethanol had no effect on these species. Ethanol increased trap catches of *Curius dentatus* Newman (Cerambycidae), *Dryoxylon onoharaense* (Murayama) (Curculionidae) and *Platysoma* spp. (Histeridae); α-pinene reduced catches. The data suggest that ethanol and α-pinene should be retained with ipsenol and ipsdienol as a generic trap lure blend for pine bark and wood-boring beetles in southeastern United States.

Key Words *Ips avulsus*, *Ips grandicollis*, *Acanthocinus obsoletus*, *Monochamus titillator*, kairomones

The quaternary blend of ipsenol + ipsdienol + ethanol + α-pinene shows promise as a generic trap lure blend for the detection of bark and wood-boring beetles (Coleoptera) in pine stands of southeastern United States (Miller et al. 2011, 2013b, 2015). Ipsenol and ipsdienol are pheromones for *Ips grandicollis* (Eichhoff) and *Ips avulsus* (Eichhoff) (Curculionidae), respectively (Allison et al. 2012, Birgersson et al. 1995, Smith et al. 1990, Vité and Renwick 1971, Vité et al. 1972). The combination of ipsenol + ipsdienol is attractive to *I. avulsus* and *I. grandicollis* (Allison et al. 2012, Hedden et al. 1976), as well as the wood-borers *Monochamus*

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titillator (F.) and *Acanthocinus obsoletus* (Olivier) (Cerambycidae) (Miller and Asaro 2005).

Ethanol, a common fermentation product of sugars in the resin and phloem tissues of dead, injured, or dying trees (Kelsey and Westlind 2017, Madden et al. 2018), is an attractant for many species of bark and ambrosia beetles in the Southeast (Miller and Rabaglia 2009). The monoterpene α-pinene is a major resin component of pines in the United States (Gansel and Squillace 1976, Mirov 1961, Smith 2000, Squillace and Wells 1981) and is attractive to the bark beetles *Dendroctonus terebrans* (Olivier), *I. grandicollis*, and *Hylastes tenuis* Eichhoff (Curculionidae) (Miller and Rabaglia 2009). The combination of ethanol + α-pinene is the most attractive trap lure for the bark beetles *Hylastes porculus* Erichson and *Hylastes salebrosus* Eichhoff (Curculionidae), and the woodborers *Xylotrechus sagittatus* (Germar), *M. titillator* and *A. obsoletus* (Cerambycidae) (Miller 2006, Miller and Rabaglia 2009).

Adding the binary blend of ethanol + α-pinene to traps baited with the binary blend of ipsenol + ipsdienol increases catches of *M. titillator* and *A. obsoletus*, and the bark beetle *Orthotomicus caelatus* (Eichhoff) (Curculionidae), but reduces catches of *I. avulsus and I. grandicollis* (Miller et al. 2011, 2013b, 2015). However, the individual effects of ethanol and α-pinene on catches of bark and wood-boring beetles in traps baited with ipsenol + ipsdienol are unknown. Therefore, my goal was to evaluate the cost and benefit of retaining both ethanol and α-pinene as part of a generic trap lure blend with ipsenol + ipsdienol to maximize catches of bark and wood-boring beetles in southeastern United States.

Materials and Methods

A trapping study was conducted 22 March–17 May 2012 at Rock Eagle, Putnam Co., GA (N 33.4351°, W 83.3798°) in a mature stand of loblolly pine, *Pinus taeda* (L.). The following lures were obtained from Contech Enterprises Inc. (Delta, British Columbia, Canada): black ethanol pouch lure, blue α-pinene pouch lure, white racemic ipsenol bubblecap lure, and white racemic ipsdienol bubblecap lure. The release rates of these lures were 0.5 g/d, 1–6 g/d, 0.2 mg/d, and 0.1 mg/d, respectively (determined by the manufacturer at 23–25°C).

Multiple-funnel (10-unit) traps (Synergy Semiochemicals Inc., Burnaby, British Columbia, Canada), modified to allow lures to hang within the funnels (Miller et al. 2013a), were hung on twine strung between trees at a height of 0.5–1.0 m from ground level to bottom of collection cups. Forty traps were spaced 8–15 m apart in randomized complete block design with 10 replicate blocks of four traps per block. In each block, one of the following lure combinations was randomly allocated to each trap: ipsenol + ipsdienol, ipsenol + ipsdienol + ethanol, ipsenol + ipsdienol + α-pinene, or all four lures. Each collection cup contained approximately 150 ml of propylene glycol and water solution (SPASH RV & Marine Antifreeze, SPLASH Products Inc., St. Paul, MN) to kill and preserve captured beetles (Miller and Duerr 2008). Catches were retrieved every 2 weeks with new solution added to each cup. Voucher specimens for each species were deposited in the University of Georgia Collection of Arthropods, Athens, GA, and retained at the USDA Forest Service, Southern Research Station, Athens, GA.

Analyses were conducted with the SYSTAT (ver. 13) and the SigmaStat (ver. 3.01) statistical packages (SYSTAT Software Inc., Point Richmond, CA) for each species caught in sufficient numbers ($n \geq 30$). Trap catch data were transformed as needed by $\ln(Y + 1)$ to ensure normality and homoscedasticity (Pepper et al. 1997), verified by the Shapiro–Wilk and Levene's tests, respectively. Data were analyzed by mixed-model analysis of variance using the following model factors: (a) replicate block, (b) ethanol treatment, (c) α-pinene treatment, and (d) ethanol x α-pinene treatments. The Holm–Sidak multiple comparison test was used to compare treatment means. The Holm–Sidak test controls the experiment-wise error rate at 0.05 (Glantz 2005). Paired *t*-tests were used to compare treatment means for species with only two treatment means.

Results

More than 46,000 bark and wood-boring beetles (Buprestidae, Cerambycidae, and Curculionidae) were captured in the study (Table 1). There was a significant effect of α-pinene ($F = 13.120$; df = 1, 27; $P = 0.001$) but not ethanol ($F = 0.509$; df = 1, 27; $P = 0.482$) on catches of *Buprestis lineata* F. (Buprestidae) in traps baited with ipsenol + ipsdienol ($F = 13.120$; df = 1, 27; $P = 0.001$). Mean catches of *B. lineata* were greater in traps baited with all four compounds than those baited solely with ipsenol + ipsdienol (Table 2).

Four species of Cerambycidae were captured in sufficient numbers for analyses (Table 1). Both ethanol and α-pinene had significant effects on catches of *A. obsoletus* ($F = 15.455$; df = 1, 27; $P = 0.001$; and $F = 161.992$; df = 1, 27; $P < 0.001$, respectively) and *M. titillator* (F.) ($F = 12.925$; df = 1, 27; $P = 0.001$; and $F = 100.846$; df = 1, 27; $P < 0.001$, respectively) with a significant treatment interaction for *A. obliquus* ($F = 6.059$; df = 1, 27; $P = 0.021$) but not *M. titillator* ($F = 1.147$; df = 1, 27; $P = 0.704$). For both species, the greatest catches were in traps baited with all four compounds (Table 2). Catches of *Curius dentatus* Newman were greatest in traps baited with ethanol although the effect was negated by the addition of α-pinene (Table 2). Only traps baited with α-pinene caught *Xylotrechus sagittatus* (Table 2) with no treatment effect between the two means (paired *t*-test, $P = 0.165$, df = 9).

Trap treatments had significant effects on catches of eight species of bark beetles (Curculionidae: Scolytinae) (Table 2). Responses of *Dendroctonus terebrans* and *Hylastes tenuis* were affected by α-pinene ($F = 354.919$; df = 1, 27; $P < 0.001$; and $F = 408.391$; df = 1, 27; $P < 0.001$, respectively) but not ethanol ($F = 3.885$; df = 1, 27; $P = 0.059$; and $F = 0.270$; df = 1, 27; $P = 0.607$, respectively). There was a significant treatment interaction for *H. tenuis* ($F = 4.806$; df = 1, 27; $P = 0.037$) but not *D. terebrans* ($F = 3.132$; df = 1, 27; $P = 0.088$). Catches of *D. terebrans* and *H. tenuis* were greatest in traps baited with α-pinene, with the addition of ethanol increasing catches for *D. terebrans* but not *H. tenuis* (Table 2). In contrast, *H. salebrosus* and *H. porculus* were affected by both ethanol ($F = 81.989$; df = 1, 27; $P < 0.001$; and $F = 10.960$; df = 1, 27; $P = 0.003$, respectively) and α-pinene ($F = 382.816$; df = 1, 27; $P < 0.001$; and $F = 225.237$; df = 1, 27; $P < 0.001$, respectively) with significant interactions between treatments ($F = 14.1452$; df = 1, 27; $P = 0.001$; and $F = 4.708$; df = 1, 27; $P = 0.039$, respectively). Catches of both

Table 1. Total catches of beetles (Coleoptera) in traps baited with ipsenol + ipsdienol (SD), ipsenol + ipsdienol + α-pinene (SDA), ipsenol + ipsdienol + ethanol (SDE), and ipsenol + ipsdienol + ethanol + α-pinene (ALL) at Rock Eagle, GA, in 2012 ($n = 10$).

Family Species	Trap Treatments				
	SD	SDA	SDE	ALL	Total
Buprestidae					
Buprestis lineata F.	5	23	9	29	66
Cerambycidae					
Acanthocinus nodosus (F.)	–	2	–	22	24
Acanthocinus obsoletus (Olivier)	6	109	27	145	287
Aegomorphus modestus (Gyllenhal)	–	–	1	–	1
Anelaphus villosus (F.)	–	–	3	–	3
Arhopalus rusticus (L.)	–	5	–	4	9
Astylopsis arcuatus (LeConte)	1	5	4	18	28
Astylopsis sexguttata (Say)	–	–	7	4	11
Curius dentatus Newman	–	1	42	1	44
Cyrtophorus verrucosus (Olivier)	–	–	3	–	3
Ecyrus dasycerus (Say)	–	–	1	–	1
Elaphidion mucronatum (Say)	–	–	5	1	6
Eupogonius tomentosus (Haldeman)	–	–	1	–	1
Monochamus titillator (F.)	65	315	122	547	1,049
Obrium maculatum (Olivier)	–	–	1	–	1
Orthosoma brunneum (Forster)	1	–	–	1	2
Prionus imbricornis (L.)	1	1	–	–	2
Prionus pocularis Dalman	–	2	1	3	6
Strangalia bicolor (Swederus)	–	–	–	1	1
Strangalia luteicornis (F.)	1	1	1	1	4
Typocerus zebra (Olivier)	–	1	–	–	1
Xylotrechus colonus (F.)	–	1	2	4	7
Xylotrechus sagittatus (Germar)	–	22	–	44	66

Table 1. Continued.

Family Species	Trap Treatments SD	SDA	SDE	ALL	Total
Cleridae					
Chariessa pilosa (Forster)	–	1	3	1	5
Enoclerus nigripes (Say)	3	5	2	5	15
Thanasimus dubius (F.)	2	109	27	226	364
Curculionidae					
Ambrosiophilus atratus (F.)	–	–	2	–	2
Cnestus mutilatus (Blandford)	–	–	11	7	18
Cyclorhipidion bodoanum (Reitter)	–	1	8	–	9
Dendroctonus terebrans (Olivier)	107	1,030	107	1,600	2,844
Dryoxylon onoharaense Murayama	–	–	88	43	131
Euwallacea interjectus (Blandford)	1	–	–	–	1
Gnathotrichus materiarius (Fitch)	10	11	55	45	121
Hylastes porculus Erichson	12	151	18	388	569
Hylastes salebrosus Eichhoff	4	106	18	558	686
Hylastes tenuis Eichhoff	61	1,274	81	841	2,257
Hylobius pales Herbst	31	203	36	485	755
Hypothenemus spp.	–	–	5	2	7
Ips avulsus (Eichhoff)	8,208	917	3,487	1,136	13,748
Ips calligraphus (Germar)	253	411	189	455	1,308
Ips grandicollis (Eichhoff)	6,502	5,994	5,027	3,519	21,042
Orthotomicus caelatus (Eichhoff)	–	28	168	232	428
Monarthrum fasciatum (Say)	–	–	2	1	3
Monarthrum mali (Fitch)	–	–	3	2	5
Myoplatypus flavicornis (F.)	1	3	–	3	7
Pachylobius picivorus (Germar)	41	155	75	269	540
Xyleborinus saxesenii (Ratzeburg)	–	–	68	72	140
Xyleborus bispinatus Eichhoff	–	–	2	4	6
Xyleborus pubescens Zimmermann	–	1	7	9	17
Xylosandrus crassiusculus (Motschulsky)	–	–	10	14	24

Table 1. Continued.

Family Species	Trap Treatments				
	SD	SDA	SDE	ALL	Total
Xylosandrus germanus (Blandford)	–	–	–	1	1
Elateridae					
Alaus myops (F.)	3	5	4	16	28
Histeridae					
Platysoma spp.	1,045	745	3,434	2,053	7,277
Tenebrionidae					
Corticeus spp.	137	439	147	370	1,093
Trogossitidae					
Temnoscheila virescens (F.)	487	860	753	1,368	3,468
Tenebroides spp.	17	19	26	28	90
Zopheridae					
Namuria guttulata (LeConte)	1	4	–	4	9
Lasconotus spp.	752	4,560	1,427	5,649	12,388
Pycnomerus sulcicollis LeConte	–	32	3	25	60
Total	17,758	17,552	15,523	20,256	71,089

species as well as *Orthotomicus caelatus* (Eichhoff) were greatest in traps baited with all four lures (Table 2).

The α-pinene treatment affected the trap responses of *I. avulsus*, *I. calligraphus* (Germar), and *I. grandicollis* ($F = 303.073$; df = 1, 27; $P < 0.001$; $F = 24.693$; df = 1, 27; $P < 0.001$; and $F = 6.632$; df = 1, 27; $P = 0.016$, respectively), whereas the ethanol treatment affected catches of *I. avulsus* and *I. grandicollis* ($F = 10.007$; df = 1, 27; $P = 0.004$; and $F = 22.990$; df = 1, 27; $P < 0.001$, respectively) but not *I. calligraphus* ($F = 0.055$; df = 1, 27; $P = 0.816$). There was a treatment interaction for *I. avulsus* ($F = 35.872$; df = 1, 27; $P < 0.001$) but not *I. calligraphus* or *I. grandicollis* ($F = 1.602$; df = 1, 27; $P = 0.216$; and $F = 3.162$; df = 1, 27; $P = 0.087$, respectively). The addition of ethanol and/or α-pinene significantly reduced catches of *I. avulsus* in traps baited with ipsenol + ipsdienol, whereas catches of *I. grandicollis* were reduced by the combination of ethanol and α-pinene (Table 2). In contrast, catches of *I. calligraphus* were greatest in traps baited with α-pinene, regardless of the addition of ethanol (Table 2).

Ethanol and α-pinene affected trap catches of the root-feeding weevils *Hylobius pales* Herbst ($F = 13.037$; df = 1, 27; $P = 0.001$; $F = 203.041$; df = 1, 27; $P < 0.001$, respectively) and *Pachylobius picivorus* (Germar) (Curculionidae) ($F = 6.042$; df = 1, 27; $P = 0.021$; and $F = 60.525$; df = 1, 27; $P < 0.001$, respectively). There were no

Table 2. Mean (± SE) catches of beetles (Coleoptera) in traps baited with ipsenol + ipsdienol (SD), ipsenol + ipsdienol + α-pinene (SDA), ipsenol + ipsdienol + ethanol (SDE), and ipsenol + ipsdienol + ethanol + α-pinene (ALL) at Rock Eagle, GA, in 2012 ($n = 10$). *

Family and Species	SD	SDA	SDE	ALL
Buprestidae				
Buprestis lineata	0.5 ± 0.2 a	2.3 ± 0.6 ab	0.9 ± 0.3 ab	2.9 ± 0.7 b
Cerambycidae				
Acanthocinus obsoletus	0.6 ± 0.2 a	10.9 ± 1.2 c	2.7 ± 0.4 b	14.5 ± 2.5 d
Curius dentatus	–	0.1 ± 0.1 a	4.2 ± 0.9 b	0.1 ± 0.1 a
Monochamus titillator	6.5 ± 0.9 a	31.5 ± 2.5 c	12.2 ± 2.0 b	54.7 ± 7.8 d
Xylotrechus sagittatus	–	2.2 ± 0.8	–	4.4 ± 1.0
Cleridae				
Thanasimus dubius	0.2 ± 0.1 a	10.9 ± 1.1c	2.7 ± 0.5 b	22.6 ± 1.8 d
Curculionidae				
Dendroctonus terebrans	10.7 ± 1.5 a	103.0 ± 12.9 b	10.7 ± 1.6 a	160.0 ± 15.4 c
Dryoxylon onoharaense **	–	–	8.8 ± 1.4 b	4.3 ± 0.8 a
Gnathotrichus materiarius	1.0 ± 0.4 a	1.1 ± 0.3 a	5.5 ± 0.7 b	4.5 ± 0.5 b
Hylastes porculus	1.2 ± 0.4 a	15.1 ± 1.6 b	1.8 ± 0.5 a	38.8 ± 5.3 c
Hylastes salebrosus	0.4 ± 0.2 a	10.6 ± 1.7 c	1.8 ± 0.4 b	55.8 ± 3.3 d
Hylastes tenuis	6.1 ± 1.0 a	127.4 ± 17.7 b	8.1 ± 1.5 a	84.1 ± 7.8 b
Hylobius pales	3.1 ± 0.8 a	20.3 ± 1.9 b	3.6 ± 0.7 a	48.5 ± 5.7 c

Table 2. Continued.

Family and Species	SD	SDA	SDE	ALL
Ips avulsus	820.8 ± 77.8 c	91.7 ± 10.7 a	348.7 ± 40.3 b	113.6 ± 7.0 a
Ips calligraphus	25.3 ± 2.2 a	41.1 ± 6.2 ab	18.9 ± 2.7 a	45.5 ± 4.7 b
Ips grandicollis	650.2 ± 56.6 b	599.4 ± 45.0 b	502.7 ± 42.1 b	351.9 ± 28.8 a
Orthotomicus caelatus	–	2.8 ± 0.6 a	16.8 ± 2.6 b	23.2 ± 2.5 c
Pachylobius picivorus	4.1 ± 0.8 a	15.5 ± 2.0 b	7.5 ± 2.9 a	26.9 ± 2.8 b
Xyleborinus saxesenii	–	–	6.8 ± 1.1	7.2 ± 0.8
Histeridae				
Platysoma spp.	104.5 ± 7.2 b	74.5 ± 7.8 a	343.4 ± 48.5 d	205.3 ± 24.7 c
Tenebrionidae				
Corticeus spp.	13.7 ± 2.2 a	43.9 ± 5.5 b	14.7 ± 3.7 a	37.0 ± 4.4 b
Trogossitidae				
Temnoscheila virescens	48.7 ± 4.7 a	86.0 ± 6.2 b	75.3 ± 8.6 b	136.8 ± 15.5 c
Tenebroides spp.	1.7 ± 0.5	1.9 ± 0.4	2.6 ± 0.6	2.8 ± 0.8
Zopheridae				
Lasconotus spp.	75.2 ± 4.3 a	456.0 ± 37.7 c	142.7 ± 17.4 b	564.9 ± 36.9 c
P. sulcicollis	–	3.2 ± 0.7 b	0.3 ± 0.3 a	2.5 ± 0.6 b

* Means in row followed by different lowercase letters are significantly different at $P < 0.05$ (Holm-Sidak test).
** Means are significantly different at $P < 0.05$ (Paired *t*-test).

interactions between treatments for *H. pales* or *P. picivorus* ($F = 3.726$; df = 1, 27; $P = 0.064$; and $F = 0.521$; df = 1, 27; $P = 0.477$, respectively). The greatest catches of *H. pales* were in traps baited with all four compounds, whereas all traps baited with α-pinene, regardless of the addition of ethanol, caught the most *P. picivorus* (Table 2).

Ambrosia beetles (Curculionidae: Scolytinae) were not abundant in this study although three species were caught in sufficient numbers for analyses (Table 1). Catches of *Gnathotrichus materiarius* (Fitch) were affected by ethanol ($F = 65.473$; df = 1, 27; $P < 0.001$) but not α-pinene ($F = 0.077$; df = 1, 27; $P = 0.783$) with no interactions between the treatments ($F = 0.471$; df = 1, 27; $P = 0.498$). Traps baited with ethanol caught the most *G. materiarius* regardless of the addition of α-pinene (Table 2). *Xyleborinus saxesenii* (Ratzeburg) and *Dryoxylon onoharaense* (Olivier) were only caught in ethanol-baited traps (Table 2). The addition of α-pinene reduced catches of *D. onoharaense* (paired *t*-test, $P = 0.006$, df = 9) but not *X. saxesenii* (paired *t*-test, $P = 0.787$, df = 9) (Table 2).

More than 24,000 known or suspected predators of bark and wood-boring beetles (Cleridae, Histeridae, Tenebrionidae, Trogossitidae, and Zopheridae) were caught in the study with sufficient numbers of seven species for analyses (Table 1). Catches of *Thanasimus dubius* (F.) (Cleridae), *Platysoma* spp. (Histeridae), *Temnoscheila virescens* (F.) (Tenebrionidae), and *Lasconotus* spp. (Zopheridae) were affected by ethanol ($F = 70.531$; df = 1, 27; $P < 0.001$; $F = 95.745$; df = 1, 27; $P < 0.001$, $F = 23.640$; df = 1, 27; $P < 0.001$; and $F = 11.504$; df = 1, 27; $P = 0.002$, respectively) and α-pinene ($F = 407.804$; df = 1, 27; $P < 0.001$; $F = 15.774$; df = 1, 27; $P < 0.001$, $F = 46.565$; df = 1, 27; $P < 0.001$; and $F = 238.392$; df = 1, 27; $P < 0.001$, respectively) with no treatment interactions ($F = 2.759$; df = 1, 27; $P = 0.108$; $F = 0.380$; df = 1, 27; $P = 0.543$, $F = 0.002$; df = 1, 27; $P = 0.962$; and $F = 0.634$; df = 1, 27; $P = 0.433$, respectively). Traps baited with all four compounds caught the most *Thanasimus dubius*, *Platysoma* spp., *Temnoscheila virescens*, *Lasconotus* spp., and *Pycnomerus sulcicollis* LeConte (Zopheridae) (Table 2). In contrast, catches of *Corticeus* spp. (Tenebrionidae) were affected by α-pinene ($F = 51.256$; df = 1, 27; $P < 0.001$) but not ethanol ($F = 0.597$; df = 1, 27; $P = 0.446$) with no interaction between treatments ($F = 0.152$; df = 1, 27; $P = 0.700$). All traps baited with α-pinene caught the most *Corticeus* spp., regardless of the addition of ethanol (Table 2). Catches of *Tenebroides* spp. (Trogossitidae) were unaffected by trap treatments ($F = 0.887$; df = 3, 27; $P = 0.460$) (Table 2).

Discussion

Recent introductions of exotic invasive species of woodborers and ambrosia beetles have demonstrated our inability to predict the next pest species to invade North America. Detection programs that attempt to detect introductions on nonnative species need to target numerous species across multiple guilds. Managers are beginning to consider the use of multiple-species blends of trap lures rather than multiple single-species lures in order to be cost effective in detection programs. However, managers need to verify the benefits of all components in such blends and consider the potential trade-offs between species. No one blend will be perfect for all species.

Results from this study suggest that both ethanol and α-pinene should be retained with ipsenol + ipsdienol as a general trap lure for pine bark and wood-boring beetles. Traps baited with ethanol + α-pinene worked well for 20 of 25 species analyzed in the study (Table 2). Catches in traps baited with ipsenol + ipsdienol were maximized by the addition of both ethanol and α-pinene for *M. titillator*, *A. obsoletus*, and *Hylobius pales* as well as four species of bark beetles and two species of predators. Ethanol enhanced catches of *G. materiarius*, *Xyleborinus saxesenii*, and *Platysoma* spp. with no adverse effect from the addition of α-pinene. Catches of *Xylotrechus sagittatus*, *Hylastes tenuis*, *I. calligraphus, Pachylobius picivorus*, *Corticeus* spp., *Lasconotus* spp., and *Pycnomerus sulcicollis* were enhanced by the addition of α-pinene but unaffected by the addition of ethanol. Ethanol and α-pinene had no effect on catches of *Tenebroides* spp.

However, managers of detection programs should consider the trade-offs in using this lure combination. The addition of ethanol + α-pinene minimized catches of *I. avulsus* and *I. grandicollis* in traps baited with ipsenol + ipsdienol (Table 2), reducing trap catches by 86.2% and 45.8%, respectively. Significant mortality of pines has been attributed to *I. avulsus* and *I. grandicollis* in the southern United States (McNichol et al. 2019, USDA 1985). Similarly, attraction of *C. dentatus*, *Dryoxylon onoharaense*, and *Platysoma* spp. to ethanol-baited traps was countered by the addition of α-pinene, reducing trap catches by 97.6, 51.1, and 40.2%, respectively. Maximizing catches of these species would require additional traps baited with other lure combinations: ipsenol + ipsdienol for *I. avulsus* and *I. grandicollis*, ethanol for *C. dentatus* and *D. onoharaense*, and ipsenol + ipsdienol + ethanol for *Platysoma* spp.

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