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EVALUATION OF THREE TRAP TYPES AND FIVE LURES FOR MONITORING *HYLURGUS LIGNIPERDA* (COLEOPTERA: SCOLYTIDAE) AND OTHER LOCAL SCOLYTIDS IN NEW YORK

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ABSTRACT

Hylurgus ligniperda (Coleoptera: Scolytidae) is a pine (*Pinus* spp.) pest native to Eurasia and northern Africa. In December 2000, an established population of *H. ligniperda* was discovered in Monroe County, New York. When surveys were initiated to determine the distribution of *H. ligniperda*, questions arose regarding the most effective trap and lure for survey purposes. We conducted a study in April-May 2001 to compare the effectiveness of commercially available scolytid traps and lures for attracting and capturing *H. ligniperda*. Traps tested included: 1) 12-unit Lindgren funnel trap, 2) Intercept panel trap, and 3) Theysohn slot-trap. Lures tested included: 1) α-pinene high release (750 mg/day) and ethanol (280 mg/ day), 2) α-pinene low release (300 mg/day) and ethanol, 3) β-pinene high release (2000 mg/day) and ethanol, 4) α-pinene low release, and 5) the "exotic bark beetle lure" [ipsdienol (0.15 mg/day), cis-verbenol (0.35 mg/day), and methylbutenol (10 mg/day)]. All three trap designs captured *H. ligniperda*, however, the Lindgren funnel trap caught significantly higher numbers. Capture rates of *Tomicus piniperda* (Coleoptera: Scolytidae) and *Hylastes opacus* were highest in Lindgren funnel traps; whereas *Orthotomicus caelatus* collections were highest in Theysohn traps. Capture rates of *Ips grandicollis* and *Xyleborinus saxeseni* did not vary significantly among trap types. Behavioral differences among scolytid species such as visual stimuli, flight and landing behavior, and host selection may explain some of these differences. Lures containing α-pinene or β-pinene and ethanol were most attractive to *H. ligniperda* adults, with ethanol and high-release α-pinene attracting the highest numbers in absolute terms. The exotic bark beetle lure was the least attractive lure to *H. ligniperda*. Attractiveness of the lures tested varied significantly for other Scolytidae, including *Dendroctonus valens*, *H. opacus, Ips calligraphus*, *I. grandicollis*, *I. pini*, *O. caelatus*, *T. piniperda*, and *X. saxeseni*. These differences likely were due to variation in lure release rates, host preferences, and/or species-specific pheromone attraction.

Hylurgus ligniperda (Fabricius) is a pest of pine (*Pinus*) and is native to Eurasia and northern Africa (Browne and Laurie 1968, Schwenke 1974, Wood and Bright 1992). In addition to the US, *H. ligniperda* has also been accidentally introduced into Australia, Japan, New Zealand, South Africa, Brazil, Chile, and Uruguay (Browne and Laurie 1968, Neumann 1987, Wood and Bright 1992, Haack 2001). *Hylurgus ligniperda* is considered a secondary pest in most instances, attacking the lower bole and roots of recently dead or severely weakened pine trees (Fabre and Carle 1975, Tribe 1991a, b, 1992, Reay and Walsh 2001). However, there have been some reports of this bark beetle attacking and killing healthy trees and seedlings (Neumann 1987, Ciesla 1988, Neumann and Marks 1990).

Although a few *H. ligniperda* adults were collected in survey traps near Rochester, Monroe County, NY, as early as 1994, the first established breeding

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populations in North America were not found until November 2000 near the town of Webster, Monroe County, NY (Haack 2001, Hoebeke 2001). Surveys were initiated in spring 2001 to determine the distribution of *H. ligniperda* populations and, subsequently, the bark beetle was found in two adjacent New York counties: Ontario and Wayne. As of December 2004, *H. ligniperda* populations were only known from these same three New York counties, as well as a new infestation in Los Angeles County, California, that was discovered in 2003 (Penrose et al. 2005).

When surveys were being planned, questions arose regarding the most effective lure and trap for capturing this bark beetle. A survey of the literature found trap logs were the most common method of attracting *H. ligniperda* adults (Tribe 1991a, b, 1992). At the time of our study in 2001, no literature was available comparing commercially available traps and attractants for this bark beetle. However, more recent studies have found combinations of ethanol and α-pinene or β-pinene were attractive to *H. ligniperda* in Chile (Mausel 2002) and New Zealand (Reay and Walsh 2002).

Our objective was to determine the effectiveness of several commercially available scolytid lures and traps in surveying for *H. ligniperda* adults. This information could be used by forest health specialists and regulatory personnel to select the most effective lure and trap for surveying and monitoring for *H. ligniperda* adults.

METHODS AND MATERIALS

The study took place during April – May 2001 in a managed Christmas tree plantation near the town of Webster, Monroe County, NY (ca. 43° 11’ N Lat., 77° 24’ W Long.), the same site where *H. ligniperda* was first found established in North America (Hoebeke 2001). The plantation consisted of a mixture of Austrian pine (*Pinus nigra* Arnold), white pine (*P. strobus* L.), Scots pine (*P. sylvestris* L.), blue spruce (*Picea pungens* Engelm.), Fraser fir [*Abies fraseri* (Pursh) Poir.], white fir [*A. concolor* (Gord. and Glend.) Hildebr.], and Douglas-fir [*Pseudotsuga menziesii* (Mirb.) Franco]. Christmas trees ranged in size from newly planted seedlings to trees more than 4 m tall. We compared the following three trap designs for their effectiveness in capturing *H. ligniperda* adults: 1) 12-unit Lindgren funnel trap (Phero Tech, Inc., Delta, BC, Canada), 2) Intercept panel trap (IPM Technologies, Portland, OR), and 3) Theysohn slot-trap (El-Tech Technologies, Larchmont, NY). All three traps have proven to be effective in capturing bark beetle adults (Lindgren 1983; Perny 1994, 1995; Czokajlo et al. 2001). We baited traps with α-pinene low release and ethanol lures. Chemical purities, release rates, and release devices for lures are given in Table 1. Lures were attached near the bottom one-third of each trap. This was done assuming that volatiles released from the lures would rise and spread the length of each trap. Traps were deployed in a completely randomized block design between rows of Christmas trees, with ten replicates for each trap design. Traps were spaced a minimum of 20 m apart.

We also tested five different lure combinations and release rates for attractiveness to *H. ligniperda* adults. Lures consisted of the following components: 1) α-pinene high release and ethanol, 2) α-pinene low release and ethanol, 3) β-pinene and ethanol, 4) α-pinene low release, and 5) the “exotic bark beetle lure” that contains ipsdienol, *cis*-verbenol, and 2-methyl-3-buten-2-ol (Table 1). All lures were purchased from Phero Tech, Inc. The compounds ethanol, α-pinene, and β-pinene are common pine volatiles, and are attractive to numerous scolytid species (Borden 1982, Wood 1982). The exotic bark beetle lure was selected because it is a standard lure used in many exotic bark beetle detection programs in North America. Lures were attached near the bottom one-third of each Lindgren funnel trap, and traps were deployed a minimum 20 m apart in a completely randomized block design. Each lure combination was replicated five times.

Table 1. Release devices and release rates for various lure components obtained from Phero Tech, Inc., (Delta, BC, Canada) and tested for attractiveness to *Hylurgus ligniperda* and other Scolytidae.

Lure	Enatiomeric ratio (%)	Release device	Release rate (mg/day)[1]
α-Pinene high release	93 (–)/7 (+)	5 polyethylene bottles	750
α-Pinene low release	93 (–)/7 (+)	2 polyethylene bottles	300
β-Pinene high release	mostly (–)[2]	polyethylene sleeve	2000
Ethanol	no chiral center[3]	polyethylene sleeve	280
Exotic bark beetle			
Ipsdienol	50 (–)/50 (+)	bubble cap	0.15
cis-Verbenol	80 (–)/20 (+)	bubble cap	0.35
2-Methyl-3-buten-2-ol	no chiral center	bubble cap	10

[1]Release rates measured at 20 °C.
[2]Mostly (–) but exact purity not currently available.
[3]95% pure

Traps were placed in the field 6 April 2001 and insects were removed from traps on 8 and 31 May 2001. We placed a 2 cm by 2 cm piece of dichlorvos No-Pest Strip (Spectrum Group, St. Louis, MO) in the collection cup of each trap to quickly kill any insects captured. Insects from each trap were placed in labeled bags and frozen in the laboratory until processed further. Another study occurring in the same Christmas tree plantation, first captured *H. ligniperda* adults between 18-24 April 2001 (E. Richard Hoebeke, Cornell University, Ithaca, NY, personal communication). Therefore, we are confident that our traps were in the field before initial spring flight. In the laboratory, all Scolytidae were sorted from the trap catches and identified. Voucher specimens were sent to E. Richard Hoebeke for species confirmation.

Data were analyzed using Proc GLM (Proc GLM, SAS 1989). Before analysis, log (x + 1) transformations were used to normalize data. Means that were significantly different at the $P < 0.05$ level were separated using Tukey's Honestly Significantly Difference test (SAS 1989). Disturbed traps, i.e., traps that were blown over by wind, were deleted from the data set.

RESULTS

Trap comparison. *Hylurgus ligniperda* was the most commonly collected scolytid in our trap comparison study, with more than 1700 adults collected during 6 April-31 May (N = 18 traps × 2 collections; disturbed traps were deleted from the data set). All three trap designs captured *H. ligniperda* adults, however, the mean number captured varied significantly among trap types (df = 2, 33; F = 7.3; $P = 0.0067$). Lindgren funnel traps collected the highest mean number of *H. ligniperda* adults (Mean ± SE = 80.0 ± 12.1 adults/trap/collection period), while Intercept panel traps and Theysohn slot-traps captured significantly fewer *H. ligniperda* (Table 2).

Several other scolytid species were also collected in the different trap types, and three of the five most common species varied significantly among trap types (Table 2). Funnel traps collected higher mean numbers of *Tomicus piniperda* (L.) and *Hylastes opacus* Erichson compared to Theysohn and Intercept traps. Significantly more *Orthotomicus caelatus* (Eichhoff) were collected in Theysohn traps, whereas *Ips grandicollis* (Eichhoff) and *Xyleborinus saxeseni* (Ratzeburg) collections did not vary significantly among trap types (Table 2).

Table 2. Total and mean number (± SE) adults of the six most common scolytid species collected per trap per sample period in each of three different commercial trap designs baited with α-pinene (release rate = 300 mg/day) and ethanol (release rate = 280 mg/day) from 6 April through 31 May 2001 in Monroe Co., New York.

Species	Total no. adults collected[1]	Mean no. adults (± SE) per trap per sample period		
		Funnel	Intercept	Theysohn
Hylastes opacus	82	4.2 ± 1.4 a[2]	0.9 ± 0.3 b	1.8 ± 0.7 b
Hylurgus ligniperda	1762	80.0 ± 12.1 a	36.8 ± 5.7 b	30.1 ± 6.6 b
Ips grandicollis	155	3.4 ± 0.6 a	4.3 ± 1.3 a	5.3 ± 0.8 a
Orthotomicus caelatus	194	3.8 ± 1.1 b	2.8 ± 0.9 b	9.6 ± 3.2 a
Tomicus piniperda	187	11.2 ± 2.7 a	0.9 ± 0.3 b	3.5 ± 1.3 b
Xyleborinus saxeseni	145	4.4 ± 1.6 a	2.7 ± 1.4 a	5.0 ± 2.0 a

[1]Total number of adults captured for all three trap types.
[2]Means (within rows) followed by the same letter were not significantly different at the $P = 0.05$ level (Tukey's Honestly Significantly Difference test).

Lure comparison. As in the trap comparison study, *H. ligniperda* was the most commonly collected beetle in the lure comparison study, with 1456 adults collected during 6 April – 31 May (N = 20 traps × 2 collections; disturbed traps were deleted from the data set). The mean number of *H. ligniperda* adults collected varied significantly among the different lure combinations ($F = 31.9$; df = 4, 35; $P < 0.0001$; Table 3). Traps baited with high-release α-pinene and ethanol captured significantly higher *H. ligniperda* adults compared to low-release α-pinene and the exotic bark beetle lure. *Hylurgus ligniperda* capture rates using low-release α-pinene and ethanol, and high-release β-pinene and ethanol were intermediate. The exotic bark beetle lure had the lowest *H. ligniperda* capture rate of all the lures tested (Table 3).

Capture rates of the eight most common other Scolytidae collected varied significantly among the different lures tested (Table 3). For example, *Dendroctonus valens* (LeConte) and *H. opacus* were most attracted to the high-release β-pinene and ethanol, while *O. caelatus* was most attracted to lures that included ethanol or the exotic bark beetle lure. Both *Ips calligraphus* (Germar) and *I. pini* (Say) were most attracted to the exotic bark beetle lure.

DISCUSSION

Trap comparison. The effectiveness of the traps tested varied for *H. ligniperda*, as well as for three other scolytids that were commonly collected (Table 2). Numerous studies have found different trap types to vary in effectiveness among various scolytids as well as other forest Coleoptera (Canaday 1987, Peng and Williams 1991, Mizell and Tedders 1999, Flechtmann et al. 2000, Czokajlo et al. 2001, Mihalciuc et al. 2001). Differences in capture rates may be attributed to the visual attractiveness of different trap designs. Several studies have found a dark cylindrical silhouette to be an important visual cue for certain scolytid species (Shepherd 1966, Kerck 1972, Vité and Bakke 1979, Borden et al. 1982, Lindgren et al. 1983, Chénier and Philogène 1989a). Strom et al. (1999, 2001) found trap catches of *Dendroctonus frontalis* Zimmermann and *Dendroctonus brevicomis* LeConte to be significantly higher in black funnel traps compared to white funnel traps. Furthermore, visual orientation is believed to be more important when beetles use host kairomones rather than specific pheromones to locate hosts (Chénier and Philogène 1989a). It is possible that *H. ligniperda* and certain other scolytid species find the silhouette of

Table 3. Mean number (± SE) of the nine most common scolytid species collected per trap per sample period in funnel traps baited with each of following lure combinations: 1) α-pinene high release (α-P high; 750 mg/day) and ethanol (EtOH; 280 mg/day), 2) α-pinene low release (α-P low; 300 mg/day) and ethanol, 3) β-pinene (β-P high; 2000 mg/day) and ethanol, 4) α-pinene low release, and 5) Exotic bark beetle lure [(EBB; ipsdienol (0.15 mg/day), *cis*-verbenol (0.35 mg/day), and 2-methyl-3-buten-2-ol (10 mg/day)] from 6 April through 31 May 2001 in Monroe Co., New York.

	Total no. adults collected[1]	Mean number adults (± SE) per trap per sample period by lure				
		α-P high + EtOH	**α-P low + EtOH**	**β-P high + EtOH**	**α- P low**	**EBB**
Dendroctonus valens	46	0.5 ± 0.3 b[2]	0.4 ± 0.2 b	4.8 ± 1.6 a	0 b	0.1 ± 0.1 b
Hylastes opacus	292	4.6 ± 1.5 bc	3.1 ± 1.2 bc	23.4 ± 9.5 a	4.0 ± 1.1 b	1.4 ± 0.6 c
Hylurgus ligniperda	1456	71.0 ± 22.2 a	42.3 ± 13.1 ab	36.6 ± 6.6 ab	28.0 ± 7.8 b	4.1 ± 1.9 c
Ips calligraphus	35	0 b	0 b	0.1 ± 0.1 b	0 b	4.3 ± 1.6 a
Ips grandicollis	99	4.4 ± 1.2 a	3.8 ± 1.4 a	0.6 ± 0.4 b	3.5 ± 0.5 a	0.1 ± 0.1 b
Ips pini	31	0 b	0.1 ± 0.1 b	0 b	0 b	3.8 ± 1.1 a
Orthotomicus caelatus	203	4.5 ± 1.0 ab	3.1 ± 0.8 b	9.8 ± 1.7 a	0.4 ± 0.2 c	7.6 ± 3.4 ab
Tomicus piniperda	563	19.8 ± 6.6 a	16.3 ± 4.9 a	18.9 ± 5.4 a	15.5 ± 5.9 a	0 b
Xyleborinus saxeseni	45	1.0 ± 0.4 ab	1.3 ± 0.6 ab	3.1 ± 1.3 a	0.1 ± 0.1 b	0.1 ± 0.1 b

[1]Total number of adults captured for all five lure combinations.
[2]Means (within rows) followed by the same letter were not significantly different at the $P = 0.05$ level (Tukey's Honestly Significantly Difference test).

funnel traps the most attractive of the three designs tested (Table 2). If this is true, we could assume trap shape is not as critical in host selection for species such as *I. grandicollis* and *X. saxeseni* (Table 2).

Variation in flight and landing behavior among different scolytid species also may influence the efficacy of different trap designs. For example, Fatzinger (1985) found the "stovepipe trap" to be most effective in capturing *Dendroctonus terebrans* (Olivier) and other pine-infesting Coleoptera, where insects first bounce off of the vertical portion of the trap and collect in a catch basin that surrounded the upright stovepipe. The designs of the funnel and Intercept trap would be more conducive for capturing insects that impact the trap surface at a relatively fast speed and then bounce off. By contrast, the small entrance slots of the Theysohn trap likely make it more effective in capturing beetles that fly and land at a slower speed.

Beetles also will land and walk on trap surfaces (Mizell and Tedders 1999). Theysohn traps could be very effective in capturing beetles that behave in this manner, e.g., when they walk through the small entrance slots to the inside of the traps where the lures were located. Beetles entering and falling to the bottom of Theysohn traps would likely succumb quickly to the dichlorvos vapors before they could escape. Beetles that land on the trap surface, but for some reason attempt to fly away, would be most effectively captured by Lindgren funnel traps (Lindgren 1983). For example, we observed *T. piniperda* landing on the surface of individual funnels and then walking downward on the outer surface toward the narrow end of the funnel. Once they reached the bottom edge of the funnel, beetles attempted to fly away and often impacted the inner-surface of the next lower funnel. Upon impact, beetles then fell through the lower funnels to the collection container at the bottom. Conversely, beetles able to land on the side of Intercept panel traps and Theysohn slot-traps would encounter fewer obstacles to prevent them from escaping if they attempt to fly away. In addition, it is possible that the open design of the Intercept trap allowed insects to escape from the collection container before they were killed by the dichlorvos, a phenomenon that could be prevented by use of a liquid killing agent (de Groot and DeBarr 1998).

Lure comparison. Lures containing α-pinene or β-pinene were the most attractive lures for *H. ligniperda*, with high-release α-pinene and ethanol having the highest absolute mean capture rate. Reay and Walsh (2002) found both α-pinene and β-pinene attractive to *H. ligniperda*, with ethanol increasing the attractiveness of both of these monoterpenes. Comparing the mean capture rate of low-release α-pinene and ethanol to low-release α-pinene alone in our study, addition of ethanol increased attraction of *H. ligniperda* to α-pinene in absolute terms, however, the difference was not statistically significant (Table 3). Similarly, the mean capture rate of high-release α-pinene and ethanol was higher in absolute terms than low-release α-pinene and ethanol, but the difference was not statistically significant (Table 3). Only when both the α-pinene release rate was increased and ethanol was added did we see a significant difference, i.e., high-release α-pinene and ethanol compared to low-release α-pinene alone (Table 3). We do not know if β-pinene would have shown the same trend that we found with α-pinene because our study did not include a lower release rate of β-pinene and ethanol or β-pinene alone.

Ethanol has been found to increase the attraction of other scolytids and related Coleoptera to various monoterpenes (Fatzinger 1985, Tilles et al. 1986, Phillips et al. 1988, Chénier and Philogène 1989b, Joseph et al. 2001). In our study, *O. caelatus* was more attracted to lures that included ethanol, as compared to α-pinene alone (Table 3).

Capture rates for other scolytid species differed significantly among the lures tested, likely due to responses of those species to specific host compounds and pheromone components in the exotic bark beetle lure. For example, *D. valens* was significantly more attracted to traps baited with β-pinene than other lures tested. β-pinene is known to be a strong attractant of *D. valens* (Hobson et al. 1993, White and Hobson 1993, Joseph et al. 2001; Table 3). *Hylastes opacus* was also most attracted to traps baited with β-pinene (Table 3). Lindelow et al. (1993) found *H. opacus* attracted to a terpene blend that consisted of β-pinene, α-pinene and 3-carene, combined with ethanol.

Ips calligraphus and *I. pini* were most attracted to the exotic bark beetle lure (Table 3), which contains ipsdienol, a major pheromone component of these two species (Wood 1982). *Orthotomicus caelatus* also showed strong attraction to the exotic bark beetle lure, as well as to the α-pinene or β-pinene lures when combined with ethanol (Table 3). Furniss and Livingston (1979) found *O. caelatus* attracted to logs that contained male *I. pini* adults and baited with ipsenol.

In conclusion, all traps tested captured *H. ligniperda* and all five lures tested were attractive to *H. ligniperda*. However, the Lindgren funnel trap was the most effective trap in capturing *H. ligniperda*, and lures containing α-pinene or β-pinene and ethanol were most attractive. Any of the three traps we tested, baited with either α-pinene or β-pinene and ethanol with release rates comparable to the minimums tested in this study, should be effective in capturing *H. ligniperda* for survey purposes. Our results suggest that increasing release rates of α-pinene in the presence of ethanol will increase attraction of *H. ligniperda*. To further elucidate these responses, future tests should include a variety of α-pinene and β-pinene release rates tested alone and combined with ethanol.

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