Short Communication

Type of Intercept Trap Not Important for Capturing Female *Sirex noctilio* and *S. nigricornis* (Hymenoptera: Siricidae) in North America

LAUREL J. HAAVIK,[1,2] ELDER BATISTA,[3] KEVIN J. DODDS,[4] WOOD JOHNSON,[5] JAMES R. MEEKER,[5] TAYLOR A. SCARR,[6] AND JEREMY D. ALLISON[7]

J. Econ. Entomol. 107(3): 1295–1298 (2014); DOI: http://dx.doi.org/10.1603/EC14094

ABSTRACT Current detection tools for *Sirex noctilio* F. (Hymenoptera: Siricidae) in North America are poor. To determine the importance of intercept trap type for capturing females of *S. noctilio* and its native congener, *Sirex nigricornis* F., in eastern North America, we report on seven trap comparison studies from different years and geographic locations. Among studies, total numbers of *S. noctilio* captured were low (mean of ≤1 wasp per trap). Total numbers of *S. nigricornis* caught were generally greater, and ranged from a mean of 1–13 wasps per trap. Nearly all studies found no significant differences among intercept trap types in the number of woodwasps caught. For future studies, we recommend that either panel or 12-unit Lindgren funnel traps be used to catch *S. noctilio* or *S. nigricornis* in eastern North America.

KEY WORDS European woodwasp, invasive species, Lindgren funnel trap, delimitation survey

The European woodwasp, *Sirex noctilio* F., native to Eurasia, is an introduced pest of pines in several countries in the Southern Hemisphere. Its discovery in North America prompted delimitation surveys and research efforts to develop effective monitoring and detection tools (Hoebeke et al. 2005, de Groot et al. 2006). Although *S. noctilio* results in significant economic losses in parts of the Southern Hemisphere, it appears to be a minor pest within its current distribution in North America. If and when *S. noctilio* spreads south or north within North America, it could cause considerable economic damage in pine plantations and natural stands (Yemshanov et al. 2009). Methods used to detect *S. noctilio* in the Southern Hemisphere include aerial or ground surveys, trap trees, and intercept traps (e.g., Carnegie and Bashford 2012).

Trap and lure combinations currently used in North America are poor, and often do not detect *S. noctilio* in areas where its presence is known. Studies have tested and improved lures for woodwasps (Siricidae) (Böröczky et al. 2012, Cooperband et al. 2012, Coyle et al. 2012, Johnson et al. 2013, Barnes et al. 2014), but information on effective trap type is limited to studies of related species (McIntosh et al. 2001, Costello et al. 2008, Barnes et al. 2014). This is probably not because efforts have been lacking, but more likely because of difficulty in comparing low *S. noctilio* catch among different traps. Barnes et al. (2014) found that traps baited with fresh host material were attractive to *Sirex nigricornis* F., which prompted our efforts in 2013 to test different traps baited with host material for capture of *S. noctilio* or *S. nigricornis*.

To provide more information on the importance of trap type for catching *Sirex* spp. in eastern North America, we report results from several trapping efforts in Ontario and the eastern United States. Specifically, we compared efficacy of different intercept traps for capturing *S. noctilio* or the native congener, *S. nigricornis*.

Materials and Methods

In total, we report on seven studies comparing three types of intercept traps (12-unit Lindgren funnel, 12-unit modified-funnel, and panel) from different years and locations in Ontario, and the northeastern and southeastern United States (Table 1). Efforts in 2006 (northeastern United States and southern Ontario) and 2007 (northern Ontario) were part of initial North American *S. noctilio* delimitation surveys, and thus were designed to target high-risk areas of large landscapes and not focused on experimentally testing traps. All traps were hung by a rope between two trees or secured to trap stands so that collecting cups were 2 m from the ground.

Delimitation Survey Methods (Studies 1–3). To delimit the *S. noctilio* population in the United States, a systematic sampling grid of 65 and 93 km^2 was used to

[1] Natural Sciences and Engineering Research Council of Canada, Natural Resources Canada-Canadian Forest Service, Great Lakes Forestry Centre, 1219 Queen Street E, Sault Ste. Marie, ON, P6A 2E5, Canada.

[2] Corresponding author, e-mail: ljhaavik@gmail.com.

[3] Universidade Estadual Paulista (Unesp), Via de Acesso Prof. Paulo Donato Castellane s/n, 14884-900, Jaboticabal/SP, Brazil.

[4] USDA Forest Service, Forest Health Protection, 271 Mast Rd., Durham, NH, 03824.

[5] USDA Forest Service, Forest Health Protection, 2500 Shreveport Highway, Pineville, LA, 71360.

[6] Ontario Ministry of Natural Resources, 64 Church St., Sault Ste. Marie, ON, P6A 3H3, Canada.

[7] Natural Resources Canada - Canadian Forest Service, Great Lakes Forestry Centre, 1219 Queen St., E, Sault Ste. Marie, ON, P6A 2E5, Canada.

Table 1. General information on study design and traps tested

Study	Location	Year	Species caught	Lure	Duration	Collection, rebait frequency	Design	Replicates (no.)
1	Ontario	2006	*S. noctilio* and *S. nigricornis*	70:30 α–β-pinene	June–Oct.	Every 6–8 wk	Paired, 30 m within pairs, >10 km between pairs	P[a] (111); F[b] (111)
2	Northeastern United States	2006	*S. noctilio*	70:30 α–β-pinene	June–Oct.	Monthly	65 or 93 km^2 grid	P[c] (≈650); F[d] (≈650)
3	Ontario	2007	*S. nigricornis*	70:30 α–β-pinene	June–Oct.	Monthly	Paired, 30 m within pairs, >10 km between pairs	P[a] (202); F[b] (202)
4	Louisiana	2011	*S. nigricornis*	*P. taeda* foliage–billets	Oct.–Dec.	Weekly, every 2 wk	Paired, 30 m within pairs, 160 m between pairs[d]	P[e] (10); F[b] (10)
5		2013	*S. nigricornis*	*P. taeda* foliage–billets	Oct.–Dec.	Weekly, every 2 wk	>35 m apart	P[a] (10); F[b] (10); MF[f] (10)
6	Maine	2013	*S. nigricornis*	*P. sylvestris* foliage–billets	Sep.–Oct.	Every 2 wk	RCBD, 15 m apart	P[c] (10); F[d] (10); MF[f] (10)
7	Ontario	2013	*S. noctilio*	*P. sylvestris* foliage–billets	July–Oct.	Every 2 wk	RCBD, 20 m apart	P[a] (10); F[b] (10); MF[f] 7 (10)

P, panel; F, 12-unit Lindgren funnel; MF, 12-unit modified-funnel; RCBD, randomized complete block design.
[a] Purchased from Advanced Pheromone Technologies Inc., Marylurst, OR (now Alpha-Scents Inc., Portland, OR).
[b] Purchased from Pherotech (now Contech) Enterprises Inc., Delta, BC, Canada.
[c] Purchased from IPM Tech., Portland, OR.
[d] Purchased from Synergy Semiochemicals Corp., Burnaby, BC, Canada.
[e] Traps located at one site 19 October–3 November, moved to second site until removed, 30 November.
[f] Purchased from Contech and modified according to Miller et al. (2013).

survey much of New York and parts of Vermont and Pennsylvania in 2006. Data summarized here are only from New York. One trap, either an unmodified funnel or a panel, was placed in each grid cell. Pine stands in each grid cell were prioritized for trap deployment. Approximately 1,300 traps split between the two trap types were deployed along stand edges. In Canada, grid-based sampling was not used. Instead, declining Scots pine, *Pinus sylvestris* L., stands >5 km apart were chosen for trap placement. A pair consisting of one panel and one unmodified-funnel trap, 30 m apart, was placed 30 m from an edge within a stand. Traps were baited with the Sirex lure, a blend of 70:30 α–β-pinene (Ontario lures: Pherotech [now Contech] Enterprises Inc., Delta, BC, Canada; U.S. lures: Synergy Semiochemicals Corp., Burnaby, BC, Canada).

Experimental Trap Tests (Studies 4–7). Panel and funnel traps were compared for effectiveness at capturing *S. nigricornis* in Louisiana in 2011. Traps were first placed in a recently thinned loblolly pine, *Pinus taeda* L., plantation on 19 October and moved to a newly thinned site containing fresher slash (i.e., green pine tops) on 3 November (Catahoula Ranger District) in anticipation of peak flight (Johnson et al. 2013). All traps were placed within the forest interior, at least 20 m from an edge. Lures were large mesh bags (≈25 by 85 cm) baited with fresh *P. taeda* foliage (5–10 boughs) and 4–12 log billets (created by quartering logs; ≈13 cm in diameter by ≈40 cm long). Foliage and billet pieces were changed every 2 wk.

In addition to panel and multiple-funnel traps, modified funnel traps (see Miller et al. 2013 for a description) were added to experiments in Ontario, Maine, and Louisiana in 2013. In southern Ontario (Simcoe County), traps were placed at two sites, both unthinned *P. sylvestris* forests. Experiments in Louisiana were established around a wood processing mill, with traps distributed in linear arrays throughout the *P. taeda* stands (Catahoula Ranger District). In Maine, traps were established in a recently thinned (3–5 yr) white pine, *Pinus strobus* L., -dominated forest (Massabesic Experimental Forest). All traps were placed within the forest interior, at least 20 m from an edge, except in Louisiana where 21 of 30 traps were on forest edges. Bags of fresh foliage and billets (described above) from regional or exotic pine species were used as lures at each trap (Table 1).

Woodwasp Collection. Collection protocols were similar for all surveys and experiments. Propylene glycol was used as the collection and preservation liquid. Traps were collected weekly, every 2weeks, or monthly throughout the trapping period. Female wasps were identified to species according to Schiff et al. (2006); no males were captured. Species collected in New York were confirmed by E.R. Hoebeke (Department of Entomology, Cornell University, Ithaca, NY), and those collected in Ontario were confirmed by H. Goulet (Canadian Food Inspection Agency).

Data Analysis. We analyzed data in the R statistical environment, version 2.15.0 (R Development Core Team 2012, Vienna, Austria). Different tests were conducted according to study design (Tables 1 and 2). For

Table 2. Results of trap type comparisons

Study	Location	Year	Species	No. traps[a]	Panel	Funnel	Modified funnel	Test	Test statistic[b]; df; *P* value
1	Ontario	2006	*S. noctilio*	36	1.0 ± 0.1	0.9 ± 0.2		GLM	0.13; 70; 0.722
		2006	*S. nigricornis*	60	2.6 ± 0.5	1.3 ± 0.2		GLM	25.14; 118; <0.001*
2	Northeastern United States	2006	*S. noctilio*		21[c]	22[c]			
3	Ontario	2007	*S. nigricornis*	107	2.4 ± 0.4	2.3 ± 0.3		GLM	0.34; 212; 0.560
4	Louisiana	2011	*S. nigricornis*	10	11.8 ± 0.9	12.6 ± 2.9		ANOVA[d]	1.11; 28; 0.302
5		2013	*S. nigricornis*	10	7.8 ± 2.3	9.7 ± 2.9	5.4 ± 1.6	ANOVA	0.34; 2,27; 0.714
6	Maine	2013	*S. nigricornis*	10	1.6 ± 0.8	1.9 ± 0.7	2.7 ± 0.7	ANOVA	1.46; 2,18; 0.259
7	Ontario	2013	*S. noctilio*	10	0.5 ± 0.3	0.3 ± 0.2	0.5 ± 0.2		

Includes mean (±SE) number of *Sirex* spp. caught per intercept trap in panel and 12-unit Lindgren funnel traps, tested separately by location, year, and lure.*denotes statistical significance. Ontario 2013 and northeastern United States 2006 data not analyzed because of low trap catch and confounding effect of site (northeastern United States). ANOVA = analysis of variance for randomized complete block design (effect of block was not significant for any), effect of site also included in model for Louisiana in 2011; GLM = generalized linear model (link = log; family = Poisson).

[a] Number of trapping sites positive for respective *Sirex* spp. for delimitation surveys (studies 1–3), no. of replicates of each trap type for experimental tests (studies 4–7).

[b] *F*-test for ANOVA; chi-quare test for GLM.

[c] Total number traps positive for *S. noctilio*.

[d] Effect of site was significant.

experimental tests, we used analyses of variance (ANOVA) to test the effect of trap type (and site for Louisiana in 2011). We log-transformed trap captures (after adding 0.5 to original values) so that response data met assumptions of normality and homogeneity of variance. For delimitation surveys in Ontario, trap captures approximated a Poisson distribution, so we used generalized linear models (GLM) with log as the link function (family = Poisson). For all tests, statistical significance was set at $P < 0.05$. Because of the confounding factors of site (New York) or low trap captures (Ontario), trap type was not compared statistically for *S. noctilio* captures in the New York delimitation survey or the 2013 Ontario experimental test.

Results

Among the seven different trapping efforts, in only one instance was there a significant difference in number of *Sirex* spp. captured among panel, modified, or unmodified multiple-funnel traps; all others resulted in no difference between the three trap types (Table 2). Trap catch for the exotic *S. noctilio* was very low overall (range: 0–4 wasps per trap).

Delimitation Surveys (Studies 1–3). In the northeastern United States, the number of traps positive for *S. noctilio* was nearly the same for panel (21) and funnel (22). In total, 51 females were captured among ≈1,300 traps. In southern Ontario (2006), 71 *S. noctilio* females were captured among 222 traps. Four *S. noctilio* were captured in northern Ontario (2007; 404 traps), all in funnel traps. Total captures of *S. nigricornis* in Ontario were higher: 234 and 497 in 2006 and 2007, respectively. The number of *S. nigricornis* captured per trap was variable, and ranged from 0 to 18 and 0 and 27 in 2006 and 2007, respectively.

Experimental Trap Tests (Studies 4–7). There were no significant differences in the number of *S. nigricornis* captured by intercept trap type in Louisiana or Maine (Table 2). In 2011, 244 females were captured among 20 traps (range: 0–23 wasps per trap), and significantly more wasps were captured at the second compared with the first site (mean ± SE: 3.0 ± 0.6 vs. 9.2 ± 1.3 wasps per trap at the first vs. second site, respectively). In 2013, 229 *S. nigricornis* were captured among 30 traps (range: 0–29 wasps per trap). In Maine, 62 *S. nigricornis* were captured among 30 traps. In Ontario, 13 *S. noctilio* were captured among 30 traps.

Discussion

Results from several efforts in different locations and years suggest that there is no difference in efficacy between panel and 12-unit funnel traps for *S. noctilio* or *S. nigricornis* in eastern North America. Although not explicitly designed for experimental testing, results from delimitation surveys provided several large data sets of woodwasp trap captures over a large geographic area, which were useful for confirming our experimental results. Other studies reported similar findings. In Louisiana, Barnes et al. (2014) also found no differences between panel and multiple-funnel traps in the number of *S. nigricornis* caught. McIntosh et al. (2001) found no difference among several trap types, including multiple-funnel traps, for capturing Siricidae in western Canada. Costello et al. (2008) found no difference between panel and multiple-funnel traps for capturing *Sirex juvencus* (L.) in South Dakota. Either panel or multiple-funnel traps can be confidently used to survey for *S. noctilio* or *S. nigricornis*. Modified-funnel traps could also be used, but were not tested as rigorously as the other two traps (in three vs. seven studies).

Low *S. noctilio* populations, such as those at many sites in southern Ontario and the northeastern United States where traps were placed in 2006 and 2013 (≤2.4 $m^2\ ha^{-1}$ of pine basal area attacked; Dodds et al. 2010), complicate the problem of poor detection tools. Bioassays conducted in controlled environments to test putative attractants or trap types are one way to circumvent this problem. Another is to conduct field tests of trap and lure combinations with a closely related, but more common species, as we and others (Coyle et al. 2012, Johnson et al. 2013, Barnes et al. 2014) have done with *S. nigricornis.* High numbers of *S. nigricornis* caught in the southeastern United States (Table 2; Johnson et al. 2013, Barnes et al. 2014) suggest that these locations are ideal for such studies. However, it is unknown whether *S. nigricornis* populations are generally greater in this region than further north, or locations chosen for trap placement were more attractive to wasps (i.e., near a lumber mill in Louisiana vs. an unthinned *P. sylvestris* plantation in Ontario).

Poor efficacy of intercept traps in capturing *S. noctilio* may also be due, in part, to ineffective lures. Although not examined in our study, lure type has been investigated, and shown to be important for *S. nigricornis.* Intercept traps baited with the commercially available Sirex lure caught more *S. nigricornis* than unbaited traps, and those baited with pine foliage and log billets caught even more (Barnes et al. 2014). Johnson et al. (2013) found that intercept traps baited with semiochemicals (e.g., Sirex lure + ipsenol + ipsdienol) generally caught more *S. nigricornis* than trap trees. Semiochemicals are important for attracting *S. noctilio* as well (Böröczky et al. 2009, 2012; Cooperband et al. 2012), but an effective combination and quantity of attractants has yet to be found. Future investigations should focus on developing and testing an effective attractant for *S. noctilio.*

Acknowledgments

Authors thank Reg Nott, Nick Boyonoski, Sarah Crispell, Katelyn Kotska, Chanel Fall, Cydney Mihell, Ed Czerwinski, Sarah Drabble, Elizabeth Reichert, Steve Marks, and Claudia Martel for field assistance in Ontario and Al Foley for access to the Ontario Tree Seed Facility. The 2006 Sirex survey occurring in New York was a multiagency effort that included personnel from the New York Department of Agriculture & Markets, NY State Department of Environmental Conservation, U.S. Department of Agriculture–Animal and Plant Health Inspection Service (USDA-APHIS), and U.S. Forest Service. Marc F. DiGirolomo and Justin Williams assisted with setup and collections in Maine. Alex Mangini, Valli Peacher, Billy Bruce, and Chris Steiner (R8-FHP) provided field assistance in Louisiana. This collaborative work was funded in part by Natural Resources Canada, Ontario Ministry of Natural Resources, Canadian Food Inspection Agency, and the U.S. Department of Agriculture–Forest Service–Forest Health Protection.

References Cited

Barnes, B. F., J. R. Meeker, W. Johnson, C. Asaro, D. R. Miller, and K.J.K. Gandhi. 2014. Trapping techniques for siricids and their parasitoids (Hymenoptera: Siricidae and Ibaliidae) in the southeastern United States. Ann. Entomol. Soc. Am. 107: 119–127. (doi:http://dx.doi.org/10.1603/AN13036).

Böröczky, K., D. J. Crook, T. H. Jones, J. C. Kenny, K. E. Zylstra, V. C. Mastro, and J. H. Tumlinson. 2009. Monoalkenes as contact sex pheromone components of the woodwasp *Sirex noctilio.* J. Chem. Ecol. 35: 1202–1211. (doi:http://dx.doi.org/10.1007/s10886-009-9693-6).

Böröczky, K., K. E. Zylstra, N. B. McCartney, V. C. Mastro, and J. H. Tumlinson. 2012. Volatile profile differences and the associated *Sirex noctilio* activity in two host tree species in the Northeastern United States. J. Chem. Ecol. 38: 213–221. (doi:http://dx.doi.org/10.1007/s10886-012-0077-y).

Carnegie, A. J., and R. Bashford. 2012. *Sirex* woodwasp in Australia: current management strategies, research and emerging issues, pp. 175–202. *In* B. Slippers, P. de Groot, and M. J. Wingfield (eds.), The *Sirex* Woodwasp and its Fungal Symbiont: Research and Management of a Worldwide Invasive Pest. Springer, NY.

Cooperband M. F., K. Böröczky, A. Hartness, T. H. Jones, K. E. Zylstra, J. H. Tumlinson, and G. J. Masters. 2012. Male-produced pheromone in the European woodwasp, *Sirex noctilio.* J. Chem. Ecol. 38: 52–62. (doi:http://dx.doi.org/10.1007/s10886-012-0060-7).

Costello, S. L., J. F. Negron, and W. R. Jacobi. 2008. Traps and attractants for wood-boring insects in ponderosa pine stands in the Black Hills, South Dakota. J. Econ. Entomol. 101: 409–420.

Coyle, D. R., J. A. Pfammatter, A. M. Journey, T. L. Pahs, V. J. Cervenka, and R. L. Koch. 2012. Community composition and phenology of native Siricidae (Hymenoptera) attracted to semiochemicals in Minnesota. Environ. Entomol. 41: 91–97. (doi:http://dx.doi.org/10.1603/EN11192).

de Groot, P., K. Nystrom, and T. Scarr. 2006. Discovery of *Sirex noctilio* (Hymenoptera: Siricidae) in Ontario, Canada. Great Lakes Entomol. 39: 49–53.

Dodds, K. J., P. de Groot, and D. Orwig. 2010. The impact of *Sirex noctilio* in *Pinus resinosa* and *Pinus sylvestris* stands in New York and Ontario. Can. J. For. Res. 40: 212–223. (doi:http://dx.doi.org/10.1139/X09-181).

Hoebeke, E. R., D. A. Haugen, and R. A. Haack. 2005. *Sirex noctilio:* discovery of a palearctic siricid woodwasp in New York. Newsl. Mich. Entomol. Soc. 50: 24–25.

Johnson, C. W., J. R. Meeker, W. G. Ross, S. D. Petty, B. Bruce, and C. Steiner. 2013. Detection and seasonal abundance of *Sirex nigricornis* and *Eriotremex formosanus* (Hymenoptera: Siricidae) using various lures and trap trees in central Louisiana, U.S. J. Entomol. Sci. 48: 173–183.

McIntosh, R. L., P. J. Katinic, J. D. Allison, J. H. Borden, D. L. Downey. 2001. Comparative efficacy of five types of trap for woodborers in the Cerambycidae, Buprestidae and Siricidae. Agric. For. Entomol. 3: 113–120.

Miller, D. R., C. M. Crowe, B. F. Barnes, K.J.K. Gandhi, and D. A. Duerr. 2013. Attaching lures to multiple-funnel traps targeting saproxylic beetles (Coleoptera) in pine stands: inside or outside funnels? J. Econ. Entomol. 106: 206–214. (doi:http://dx.doi.org/10.1603/EC12254).

R Development Core Team. 2012. R: A language and environment for statistical computing, R Foundation for Statistical Computing, Vienna, Austria.

Schiff, N. M., S. A. Valley, J. R. LaBonte, and D. R. Smith. 2006. Guide to the siricid woodwasps of North America. U.S. Department of Agriculture Forest Service, Morgantown FHTET-2006-15. p. 110.

Yemshanov, D., F. H. Koch, D. W. McKenney, M. C. Downing, and F. Sapio. 2009. Mapping invasive species risks with stochastic models: a cross-border United States-Canada application for *Sirex noctilio* Fabricius. Risk Anal. 29: 868–884. (doi:http://dx.doi.org/10.1111/j.1539-6924.2009.01203.x).

Received 12 March 2014; accepted 31 March 2014.