N O T E

Siricid Parasitoids (Hymenoptera: Ichneumonidae) From Eastern White Pine and Associated Pine Species in Southern Appalachia[1]

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The potential impact of the recent invasion by the exotic woodwasp *Sirex noctilio* F. (Hymenoptera: Siricidae) into eastern North America (Hoebeke et al. 2005, Newsl. Mich. Entomol. Soc. 50: 24–25) will depend on factors such as (a) host suitability and abundance, (b) competition with native siricids, and (c) mortality by native parasitoids (Corley et al. 2019, J. Pest Sci. 92: 131–142; Coyle and Gandhi 2012, Environ. Entomol. 41: 731–739). Although impacts have been minimal to date (Dodds et al. 2010, Can. J. For. Res. 40: 212–223), attacks by *S. noctilio* in other countries (Australia, New Zealand, South Africa, and South America) have resulted in significant levels of pine mortality (Ciesla 2003, J. For. 101: 18–23). Siricid parasitoids are native to North America, preying on eggs or larvae of native siricid species (Schiff et al. 2012, Can. J. Arthr. Ident. No. 21). Due to the recent detection of *S. noctilio* in New York (Hoebeke et al. 2005), surveys have been conducted to verify the occurrence and abundance of siricid parasitoids in Canada and the United States, particularly those that prey on the related pine-inhabiting species *Sirex nigricornis* F. In 2007, Long et al. (2009, Can. Entomol. 141: 153–157) found emergence of the siricid larval parasitoids *Rhyssa lineolata* (Kirby) and *Megarhyssa nortoni* (Cresson) (Hymenoptera: Ichneumonidae) from Scots pine (*Pinus sylvestris* L.) infested with *S. noctilio* and/or *S. nigricornis* in New York. Also in New York, Standley et al. (2012, Proc. Entomol. Soc. Wash. 114: 238–249) reported *Rhyssa crevieri* (Provacher) emerging from siricid-infested Scots pine and red pine (*Pinus resinosa* Aitken) in 2010. In 2012–2013, Meeker et al. (2014, J. Entomol. Sci. 49: 206–210) collected male and female *Rhyssa howdenorum* (Townes) ($n = 43$) and 1 female *R. lineolata* emerging from loblolly pine (*Pinus taeda* L.) logs in Louisiana

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along with numerous *S. nigricornis* and *Ibalia leucospoides ensiger* Norton (Hymenoptera: Ibaliidae), a common egg and early instar larval parasitoid of *S. nigricornis*.

Our goal was to document the occurrence of siricid parasitoids in eastern white pine (*Pinus strobus* L.) as there is a lack of knowledge of siricid parasitoids associated with this common and dominant tree species in Southern Appalachia. In his 1970s surveys, Kirk (1974, J. Entomol. Sci. 9: 139–141) found *R. howdenorum*, *R. lineolata*, and *Rhyssa persuasoria* L. emerging from pitch pine (*Pinus rigida* Miller) in northern Georgia and western North Carolina. He also found *R. howdenorum* associated with siricid-infested loblolly pine, shortleaf pine (*Pinus echinata* Miller), Virginia pine (*Pinus virginiana* Miller), and longleaf pine (*Pinus palustris* Miller) at other locations in the southeastern United States. However, neither he nor anyone else has reported any siricid parasitoids associated with eastern white pine.

Our protocol was to place stacks of siricid-infested pine logs in rearing cages to collect any insects emerging from those logs. To acquire infested logs, pairs of live pine trees (diameter = 15–25 cm at breast height) were felled, limbed, and bucked into short logs, each measuring approximately 1 m in length. For each pair of trees, logs were placed at the felling site into a single stack with three to six parallel logs per row and each row oriented 90° from the ones below and above (Haavik et al. 2013, Entomol. Exp. Appl. 149: 177–184). Trees were felled and logs stacked during the period of mid-August to mid-October as the flight period of female *S. nigricornis* in western North Carolina starts in early September and ends by mid-November (Miller 2020, J. Entomol. Sci. 55: 291–294). Stacks of pine logs were left in the woods for 10–11 mo to allow logs to be attacked by *S. nigricornis* in late fall/early winter and larval *S. nigricornis* to be attacked by parasitoids in late spring/early summer of the following year. Stacks were then removed from the woods and relocated to the Whitehall Experiment Forest, University of Georgia, Athens, GA (N 33.895°, W 83.360°) with each stack placed in one of 12 outdoor rearing cages (1.8 m × 1.8 m × 1.8 m, 20 × 20 mesh) (BioQuip Products, Rancho Dominguez, CA) set on one of two concrete pads (7.9 m × 8.8 m) under open-sided metal carports (2.1 m × 6.1 m × 7.9 m), six cages per carport. The carports provided protection from direct sunlight and rain.

In 2015, 12 log stacks of white pine were created in Southern Appalachia during 31 August–20 October. Four stacks were located at two sites in Rabun Co. in north Georgia (GA1: N 34.409°, W 83.233°; GA2: N 34.936°, W 83,231°) with stacks at each site. Eight stacks were in western North Carolina with four stacks in Jackson Co. (NC1: N 35.409°, W 82.888°) and four stacks in Henderson Co. (NC2: N 35.210°, W 82,597°). All log stacks were relocated to Athens, GA, during 26 July–12 August 2016.

A total of 66 *S. nigricornis* emerged from three white pine log stacks over the period 6 September–18 October from two locations (GA1 and NC2) in 2016; none emerged from the other stacks. Two males emerged from one NC2 stack whereas five females and three males emerged from one GA1 stack. The second GA1 stack was heavily infested and produced three females and 53 males. Only three larval siricid parasitoids emerged from log stacks in the following spring: one female *M. nortoni* from the heavily infested GA1 stack (emergent date [ED] = 11 April 2017) and two female *R. howdenorum* from a NC2 stack (ED = 23 March 2017). Also

emerging from GA1 stacks were two female and four male *Pseudorhyssa nigricornis* (Ratzeburg) (ED = 12–19 April 2017), a cleptoparasite of *Sirex* spp. via siricid parasitoids such as *R. howdenorum* (Standley et al. 2012). No other parasitoids associated with siricids were collected from the other log stacks in 2017.

In the fall of 2017, we attempted to verify results of Kirk (1974) with pine species associated with white pine in Southern Appalachia. Twelve log stacks of various pine species were created in western North Carolina during 11 October–7 November and in north Georgia on 14 November. Six stacks were in Madison Co., NC (NC3: N 35.891°, W 82.810°), with two stacks each of white pine, Virginia pine, and Table Mountain pine (*Pinus pungens* Lambert), whereas four stacks were in Cherokee Co., NC, with two stacks of white pine at one site (NC4: N 35.0843°, W 84.122°) and two stacks of Virginia pine at the second site (NC5: N 35.086°, W 84.141°). We created one stack of Virginia pine and one stack of shortleaf pine in Rabun Co., GA (GA3: N 34.756°, W 83.274°). All log stacks were relocated to Athens, GA, during 7–24 August 2018.

A total of 49 *S. nigricornis* emerged from pine over 2 October–12 December 2018 (none from the four stacks of white pine) with 33 associated with Virginia pine: three females and 11 males from an NC3 stack, two females from an NC5 stack, and three females and 14 males from a GA3 stack. Nine females and five males emerged from the GA3 shortleaf pine stack, whereas two females emerged from one of the NC3 Table Mountain pine stacks. Only three larval sirex parasitoids emerged from log stacks in the following spring: one female *R. lineolata* from the Virginia pine NC3 stack (ED = 6 April 2019), one female *R. howdenorum* from the Virginia pine NC5 stack (ED = 13 April 2019), and one female *R. howdenorum* from the shortleaf pine GA3 stack (ED = 15 April 2019). Three female *P. nigricornis* emerged from one Virginia pine NC5 stack (ED = 12–13 April 2019). No other parasitoids associated with siricids emerged from the other log stacks in 2019.

Several species of Cerambycidae (Coleoptera) also emerged from log stacks with *Rhagium inquisitor* L. being the most common and emerging from all log stacks in both emergence years. In 2017, a total of 153 *R. inquisitor* emerged from the 12 white pine stacks; six from NC1, 50 from NC2, 53 from GA1, and 44 from GA2 (ED = 22 February–23 March). In 2019, a total of 490 *R. inquisitor* emerged from log stacks (ED = 9 February–21 March) with 20 from the white pine NC3 stacks and 144 from the white pine NC4 stack. Virginia pine stacks produced 70 beetles from NC3, 112 from NC5, and 18 from GA3, whereas the shortleaf pine GA3 stack produced 51 beetles; the two NC3 stacks of Table Mountain pine produced 75 beetles. Other cerambycid species emerging from white pine log stacks in 2017 and 2019 included *Asemum striatum* (L.) ($n = 1$), *Astylopsis arcuata* (LeConte) ($n = 3$), *Astylopsis sexguttata* (Say) ($n = 3$), *Leptostylus transversus* (Gyllenhal) ($n = 4$), *Monochamus notatus* (Drury) ($n = 13$), *Monochamus scutellatus* (Say) ($n = 24$), *Monochamus titillator* (L.) ($n = 3$), and *Typocerus zebra* (Olivier) ($n = 1$).

A common parasitoid of cerambycids, *Atanycolus* spp. (Hymenoptera: Braconidae) (Wang et al. 2009, ZooKeys 27: 31–41) also emerged from white pine log stacks in both trials. In 2016, three females and one male emerged from NC2 stacks (ED = 16 August), whereas eight females and 10 males emerged from GA1 stacks (ED = 16 August–19 September). In 2018, two females and one male *Atanycolus* spp. emerged from the GA3 shortleaf pine stack (ED = 30–31 August), whereas 10 *Atanycolus* spp. emerged from NC3 stacks: one female from Table Mountain pine

stack (ED = 11 September), two females and one male from Virginia pine stack (ED = 8–14 August) and three females and three males from white pine stack (ED = 6–29 August). Three parasitoids emerged from a white pine NC4 stack: two males in the fall (ED = 19 August 2018) and one female in the spring (ED = 13 April 2019). In Europe, hosts for *Atanycolus denigrator* (L.) and *Atanycolus initiator* (L.) include *R. inquisitor* and *Monochamus* spp. (Wang et al. 2009).

In conclusion, we documented the occurrence of the following siricid parasitoids in the southern Appalachian Mountains: *Megarhyssa nortoni* in eastern white pine; *Rhyssa howdenorum* in eastern white pine, Virginia pine, and shortleaf pine; and *Rhyssa lineolata* in Virginia pine. Furthermore, we documented the cleptoparisitoid species *Pseudorhyssa nigricornis* in eastern white pine and Virginia pine. The low number of siricid parasitoids is likely a consequence of low numbers of *S. nigricornis* as suggested by the low number of infested log stacks and a highly male-biased sex ratio in emerged adults of this haplo-diploid species. However, the presence of the cleptoparasite *P. nigricornis* likely indicates significant numbers of siricid parasitoids over a broader landscape level. The abundance of the cerambycid *R. inquisitor* emerging from stacks might suggest competition for woodwasps infesting pine logs. These observations provide useful baseline information regarding host associations of native pine siricids, their parasitoids, and potential resource competitors in the southern Appalachian Mountains, should the invasive *S. noctilio* eventually become established in this region.

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