



Notes on the life-history of the balsam shootboring sawfly in the Maritimes region

R. Drew Carleton, Rob C. Johns, Andrew Morrison and Benoit Morin

ABSTRACT

Balsam shootboring sawfly (BSS), *Pleroneura brunneicornis* Rowher (Hymenoptera: Xyelidae), is a poorly understood insect pest of balsam fir (*Abies balsamea* [L.] Mill. (Pinaceae)) in northeastern North America. Recent increases in BSS populations have raised concerns among commercial Christmas tree growers, prompting research on its emergence phenology, larval development, and parasitism. Ground emergence traps in New Brunswick (NB) and Nova Scotia (NS) indicated adults emerged from the soil immediately after snow had melted from beneath balsam fir tree crowns in mid to late April. Adults were collected from emergence traps for 2 weeks and remained active in or on trees until the end of May. Both mating and oviposition were observed and photographed up until the end of May in NB. Weekly shoot dissections from stands in NB indicated the presence of four larval instars. All larvae had exited shoots by the end of June, presumably to spin cocoons in the duff layer where overwintering occurs. Parasitoids caused mortality throughout the larval developmental period and appear to be a significant mortality factor for BSS, with 52% of fourth-instar larvae in NB showing signs of parasitism.

RÉSUMÉ

Le perce pousse du sapin (PPS), *Pleroneura brunneicornis* Rowher (Hymenoptera: Xyelidae), est un insecte ravageur peu compris du sapin baumier (*Abies balsamea* [L.] Mill. (Pinaceae)) dans le nord-est de l'Amérique du Nord. Les récentes augmentations des populations du PPS ont soulevé des inquiétudes parmi les producteurs commerciaux de sapins de Noël incitant ainsi des efforts de recherche portant sur la phénologie d'émergence, le développement larvaire, et le parasitisme. Des pièges d'émergence au Nouveau-Brunswick (N.-B.) et en Nouvelle-Écosse (N.-É.) ont indiqué que les adultes émergent du sol immédiatement après la fonte de la neige sous les sapins baumiers du milieu à la fin d'avril. Des adultes ont été capturés dans les pièges d'émergence pendant 2 semaines et sont restés actifs dans ou sur les arbres jusqu'à la fin du mois de mai. L'accouplement et la ponte ont été observés et photographiés également jusqu'à la fin du mois de mai au N.-B. Des dissections hebdomadaires de pousses des peuplements du N.-B. ont indiqué la présence de quatre stades larvaires. Toutes les larves étaient sorties des pousses à la fin de juin, sans doute pour tisser un cocon dans la couche d'humus où se produit l'hivernage. Les parasitoïdes ont causé de la mortalité pendant la période de développement larvaire et ils semblent être un facteur de mortalité important pour le PPS, avec 52% des larves du quatrième stade larvaire au N.-B. montrant des signes de parasitisme.

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INTRODUCTION

Balsam shootboring sawfly (BSS), *Pleroneura brunneicornis* Rowher (Hymenoptera: Xyelidae), is a nuisance pest of young balsam fir, *Abies balsamea* [L.] Mill. (Pinaceae), in North America. Occasional outbreaks of BSS have been reported in both the United States and Canada (Webb and Forbes 1951; Anonymous 2000). A recent increase in BSS damage on balsam fir Christmas trees in New Brunswick (NB) and Nova Scotia (NS) concerned Christmas tree growers and prompted our study of the basic biology and life history of this insect as a foundation for the development of management strategies.

Information about *Pleroneura* spp. is sparse, although a basic description of BSS is provided by Webb and Forbes (1951). In this study, adult BSS were observed in late May and survived only about 3 d when kept in cages. Mating was observed but not described, and oviposition was not observed but speculated to have occurred shortly after bud scales had dropped. Eggs were laid singly and needle browning was observed at the site of oviposition. Head-capsule measurements of larvae collected periodically through the developmental period suggested five larval instars. Once feeding was completed, larvae exited the shoot and dropped to the soil to overwinter (Webb and Forbes 1951). Although the study of Webb and Forbes (1951) provided basic information on BSS, much of the work was preliminary with limited or unspecified replication and thus lacked the detail needed to draw any firm conclusions on the life history traits of BSS.

To provide more detailed quantitative information on the general biology and life history traits of BSS, we carried out a 1-yr field study at several sites in NB and NS to determine the emergence period and general behaviors (i.e., flight period, mating, and oviposition) of adult BSS and to quantify the number of larval instars. Moreover, larvae were examined for indications of parasitism and, where possible, the main parasitoids attacking BSS were identified.

MATERIALS AND METHODS

Study Areas

In New Brunswick, we selected three young balsam fir stands (previously cultivated for Christmas tree production) showing evidence of BSS damage from the previous year. These stands were located in McGivney (46°20'25"N, 66°33'47"W), Keswick Ridge (45°59'27"N, 66°53'12"W), and Upper Gaspereau (46°15'57"N, 65°51'00"W). Stands had not been operational as Christmas tree stands for the previous 3–5 yr, so the effects of previous cultivation practices—e.g., pesticide and fungicide application,

shearing (shaping the tree), and mowing of vegetation around the trees—were minimal. Stands did, however, retain the general physical structures of operational stands (i.e., 2–3 m spacing and height ranging from <1 m–>4 m). In the New Germany area of Nova Scotia (44°33'42"N, 64°45'08"W), three operational Christmas tree stands were selected based on evidence of prior infestation. These stands had been cultivated using typical Christmas tree management practices for that region: sheared seasonally, grasses mowed throughout the growing season, and trees treated with insecticides if necessary. All stand data were pooled by province for analyses of trends.

Emergence pattern

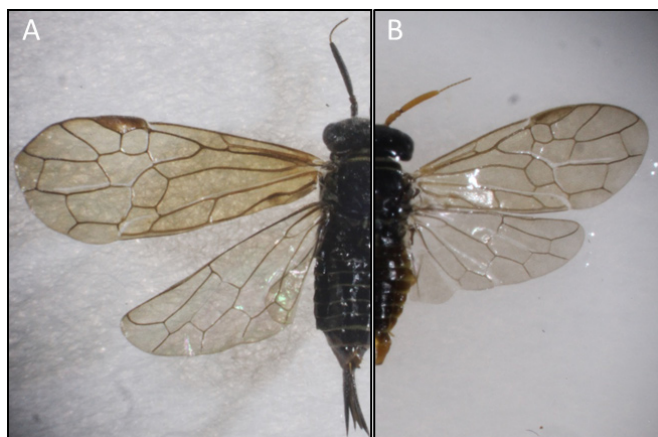
In all stands in NB and NS, ground emergence traps (N = 15) were placed under the drip-line of trees of marketable size (2–3 m) that showed signs of BSS damage from the previous year. Emergence traps were modified from the design described in Akar and Osgood (1987). Briefly, traps were constructed with spruce plywood measuring 60 cm L x 45 cm W x 40 cm H. The top of the trap was cut out and replaced with white polyester fabric sheer (Fabricville™, Montreal, Que.) and 1.25 cm mesh hardware cloth to prevent damage by branches and wildlife (Figure 1). Preliminary results indicated that this material provided sufficient transparency to allow the interior environment (both soil and air) of the emergence traps to mimic ambient conditions. An opaque polypropylene funnel (Fisher Scientific International Inc., Whitby, Ont.) with an interior diameter of 5.0 mm was glued to the interior rim of a jar lid glued over a hole on either end of the emergence trap, and 500 ml glass preserves jars (Bernardin Ltd., Richmond Hill, Ont.) were inserted over the funnels into the jar lids. This set-up allowed adult BSS to enter the jar for easy collection. Before collections, a piece of carpet with a heavy rubber backing was placed over the top of the trap to block all sources of light except for that coming from the collection jars. The carpet was left in place for ~30 min before collections were carried out to allow the positively phototactic adults to move into the jars. In another 15 trees per stand, we tied passive (i.e., non-baited) yellow delta sticky traps (ISCA Technologies Inc., Riverside, CA) from branches 1.5 m from the ground on trees spaced 10 m apart. All traps were placed as soon as stands became accessible after snow melt (17–19 April 2013) and were removed on 30 June 2013, several weeks after adults were no longer observed in flight. Emergence traps and delta traps were checked daily in NB, every second day in NS. In all cases, traps were checked at ~12:00 h. Adults were collected from

jars using an aspirator and identified as females (Figure 2A) or males (Figure 2B) under a dissection microscope.

Figure 1. Ground emergence trap under drip line of a balsam fir tree. (Photo: D. Carleton)



Figure 2. Female (A) and male (B) Balsam shootboring sawfly, *Pleroneura brunneicornis* collected from McGivney, New Brunswick, 2013. (Photos: D. Carleton)



Observations of adult behavior

We observed adult sawfly behavior daily during the course of monitoring emergence traps (17 April–20 May), as well as on 22, 25, and 28 May. There was no set protocol but we took detailed notes and photographs of specific behaviors such as mating and oviposition.

Instar development

We collected about 100 shoots each week from each of the three stands in NB starting from 14 May–7 July 2013;

shoots for this part of the study were not sampled from the NS stands. Shoots were sampled based on signs of needles damaged by oviposition (Figure 3A, B, C) or larval feeding (Figure 4B, D). No more than 10 shoots were sampled from any individual tree, and new trees were selected on each sample date so that no tree was ever sampled twice. Damaged shoots were dissected by carefully peeling off needles to expose the larval feeding chamber (Figure 4A, C); larvae were then removed, and head-capsule widths were measured to the nearest 0.02 mm using a dissection microscope and an ocular micrometer. Larvae that appeared to contain parasitoids (i.e., appearance of a subcutaneous black object) (Figure 5) were noted so that their head-capsule widths could be compared with those of apparently non-parasitized larvae to determine if parasitism may effect head-capsule size. We stopped collecting shoots once dissections indicated that all larvae had either completed development (i.e., all shoots were empty) or were dead.

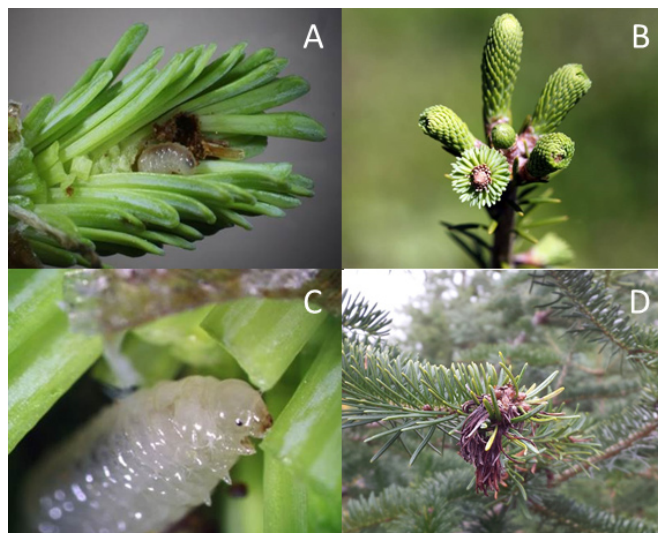
Figure 3. Early symptoms of *Pleroneura brunneicornis* oviposition; A) damaged needles, B) newly laid egg and, C) egg surrounded by browning needles. (Photos: B. Morin)



Rearing for Parasitoids

On 9 July 2012, we collected ~1000 damaged shoots from

Figure 4. Early-instar *Pleroneura brunneicornis* larvae (A), corresponding feeding damage (B), late-instar larva (C), and late season shoot damage (D). (Photos: D. Carleton and B. Morin)



the stand in Upper Gaspereau. It was evident from field observations that the vast majority of BSS larvae had exited shoots before this date, and thus, it was assumed that any insects found in these shoots were either of poor vigor or of compromised health (e.g., parasitoid attack, or pathogens). All insect materials were extracted from their shoot and placed on moistened filter paper in sterile plastic 55 mm diameter Petri dishes and allowed to develop under laboratory conditions (i.e., ~22°C, ~60% RH). All insects reared from this process were submitted to the Canadian National Collection (CNC) for formal identification.

RESULTS AND DISCUSSION

Emergence pattern

BSS were first recorded in emergence traps on 21 and 25 April 2013, respectively, in NS and NB. Emergence occurred within days after snow had melted, adults were collected within 1–3 d after emergence traps were set, and emergence lasted for about 2 wks (Figure 6A, B). Adults may have emerged before these dates, but it seems unlikely because the top layers of the ground were frozen during the installation of emergence traps. Peak male emergence occurred approximately 1 d after that of females (Figure 6A, B). Oviposition and mating were observed on 28 May 2013 in NB, 2 wks after the latest date that adults were collected from emergence traps. This suggested that adults survived longer than the 4 d reported by Webb and Forbes (1951). We suspect these discrepancies are largely

Figure 5. *Pleroneura brunneicornis* larvae with endoparasitoid larvae (dark spot), from shoot collected in McGivney, New Brunswick in 2013. (Photos: B. Morin)



because Webb and Forbes (1951) made their observations relatively late in the adults' lifespan (25–28 May); however, without weather data from their study, we cannot be sure.

Delta traps were relatively ineffective at monitoring adult flight (Figure 7), collecting only one adult within the first 5 d of emergence and trapping 4.5 times fewer total adults than emergence traps in NB. In NS, where populations were relatively low, delta traps failed to capture any adults. BSS had patchy distribution within our stands, as indicated by the large variation in the number of adults captured by emergence traps (1.9 ± 0.68 SE adults/trap). Our data suggest that unbaited delta traps are ineffective for monitoring BSS and that other monitoring methods, such as pheromone lures and pheromone-baited traps, should be developed.

Description of Adult Behaviors

BSS flight, mating, and oviposition were frequently observed as early as the first day of adult emergence on 17 May. All three activities were readily observed throughout photophase (observations were not conducted during scotophase), with mating and oviposition occurring on the crown of the tree. Mating was frequently observed on 1-year-old shoots adjacent to the buds used for oviposition. During mating, males and females aligned themselves end-to-end, females grasped a needle with their fore legs, and males appeared to hang onto females, suspended in air, relying on their parameres for positioning (Figure 8A). Omhart and Dahlsten (1977) described a similar behavior for *Pleroneura* spp. on white fir, *Abies concolor*

Figure 6. Pattern of adult *Pleroneura brunneicornis* emergence in ground emergence traps combined from three sites (N = 45) in (A) New Brunswick and (B) Nova Scotia in 2013. Female *Pleroneura brunneicornis* (black) peaked in emergence 6 d before males (white).

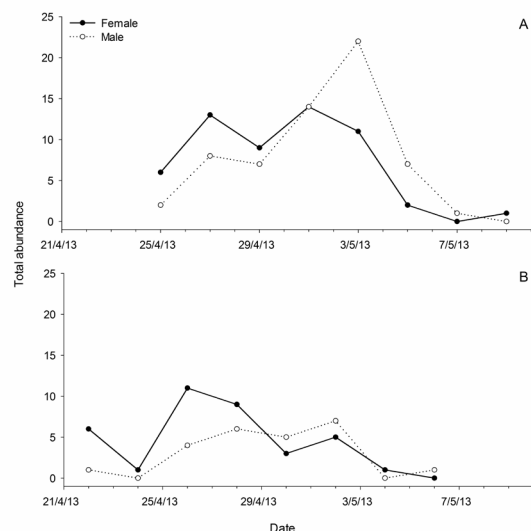
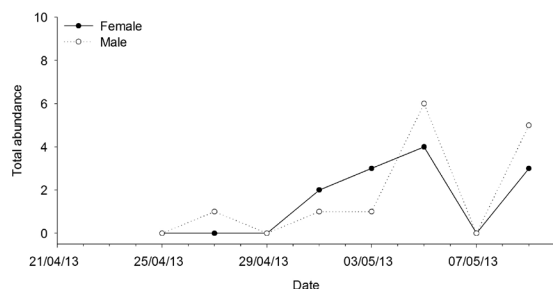
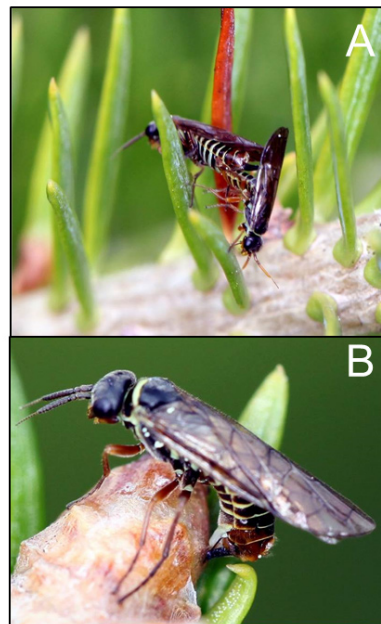


Figure 7. Pattern of adult *Pleroneura brunneicornis* emergence reported in delta traps combined from three sites (N = 45) in New Brunswick, 2013.



(Gord. and Glend.) (Pinaceae). Oviposition was observed exclusively on tight buds whose bud scales remained intact (Figure 8B); this preference was evident even at the end of the active flight period (i.e., 28 May 2013), by which time the vast majority of available new shoots had burst. Omhart and Dahlsten (1977) suggested that the successful establishment of *Pleroneura* spp. larvae in white fir required that oviposition occur on buds where needles had not yet begun to expand, thereby reducing the risk of desiccation, this may also be true for BSS. Webb and Forbes (1951) suggested that eggs were laid soon after bud scales had

Figure 8. *Pleroneura brunneicornis* mating on balsam fir tree (A) and oviposition (B) in McGivney, New Brunswick, 2013. (Photos: B. Morin)

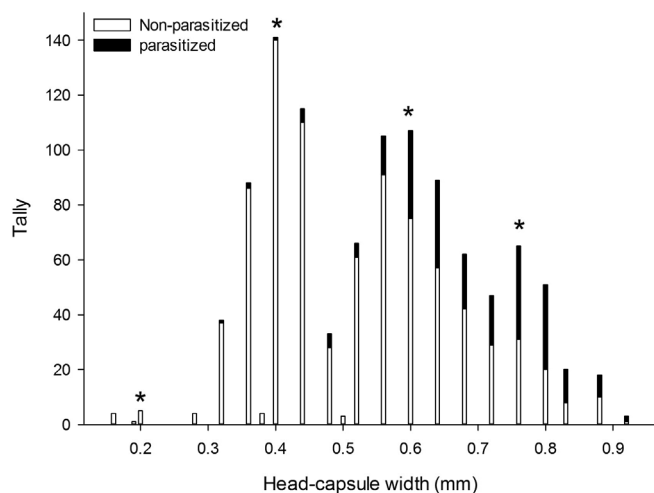


dropped but were unable to observe the behavior. If females did in fact oviposit in buds that had burst, it may have been because better quality oviposition sites were not available within the sleeve cage as most of those buds, would have shed their scales by the end of May. Females of numerous insect species will “dump” eggs on poorer quality sites when choices are limited (Engelmann 1970). A second possible explanation is that symptoms of oviposition are not apparent until after scales are shed and Webb and Forbes (1951) assumed eggs were not laid until that time.

Instar identification

Dissections of larvae (N = 1070) collected during weekly shoot samples identified four peaks in the width of larval head capsules corresponding to 0.20 mm, 0.40 mm, 0.60 mm, and 0.75 mm (Figure 9, see asterisk). In general, these peaks agree with those predicted by Dyar’s rule (Dyar 1890), which predicts geometric increases in head-capsule width with each larval molt. There was considerable overlap in head-capsule measurements on any given collection date, likely due to the lengthy oviposition period. Signs of oviposition [a single, shortened needle or group of needles (Figure 3A) or several browned needles surrounding the egg (Figure 3C)] were not apparent until after bud scales had dropped, which typically did not occur

Figure 9. Frequency distribution of head capsule width of *Pleroneura brunneicornis* excluding parasitized larvae (white bars) and including parasitized larvae (black bars) in New Brunswick. **NOTE:** Asterisk indicate larval instars based on Dyar's rule.

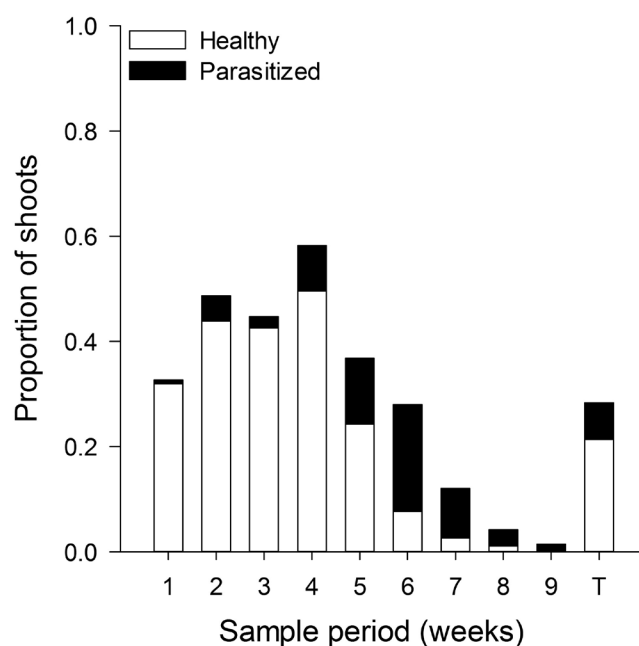


until several days after. The delay in our ability to detect oviposition meant that many of the larvae collected during weekly samples had been established for several days, therefore the numbers of first-instar larvae are weak and underrepresented (Figure 9). Our results did not indicate the presence of fifth-instar larvae as reported by Webb and Forbes (1951). One possible explanation for this discrepancy is that variations in environmental condition(s), such as temperature, humidity, or food quality, etc., caused larvae to undergo an additional instar (see Esperk et al. 2007). Alternatively, it may be that females develop through an additional instar, but were not represented in our larval populations due to low mating success. This alternative, however, seems unlikely given our frequent observations of mating and the fact that adult sex ratios from ground emergence traps indicated that mates were plentiful.

Parasitism

Endoparasitism by unknown spp. was reported in NB during all weekly collection dates and in all larval instars, affecting 14–28% of all larvae in any given sample (Figure 10). By mid-season, as many as 28% of sampled shoots in one stand in NB were parasitized (data not shown), and by the time BSS had reached the fourth instar, parasitoids were present in 52% of all larvae in NB (Figure 9). Thus, parasitism could be a significant mortality factor of BSS. Although parasitoids were detected in all larval instars, their presence did not appear

Figure 10. Proportion of shoots with *Pleroneura brunneicornis* larvae excluding parasitoids (white bars) and including parasitized larvae (black bars) based on weekly collections of damaged shoots from three stands in New Brunswick, 2013.



to alter head-capsule measurements (Figure 9, black bars). The presence of parasitoids in first-instar larvae (0.32 mm) indicates that oviposition by some parasitoid species occurred very soon after BSS eggs were laid.

Laboratory rearing of specimens collected in July 2012 yielded 25 parasitoid adults, with the majority ($N = 17$) identified as *Pteromalus* spp. (Hymenoptera: Chalcidoidea: Pteromalidae). The remaining wasps were identified to family only: Ichneumonidae ($N = 7$) and Braconidae ($N = 1$). Voucher specimens of *Pteromalus* spp. were retained at the CNC as well as at AFC, Fredericton, NB.

Despite its apparent status as a persistent nuisance pest for Christmas tree growers in the Maritimes region for many decades, there has been a general lack of basic biological information on BSS. Our paper confirms some old observations and also expands our understanding of the basic life-history traits and behaviors of BSS that appear to be more or less consistent with studies of other *Pleroneura* species (e.g., Ohmart and Dahlsten 1977).

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