

Landscape level impacts of EIS on SBW, other herbivores and associated natural enemies (ACOA RD100 2.2.2)

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Abstract

We report on results from the final year of our research project aimed at addressing three key questions underlying the Early Intervention Strategy: (1) Does treatment cause enough additive mortality (i.e., mortality in addition to what would otherwise occur naturally) to cause populations to decline? (2) Does mass moth migration offset the efficacy of treatments? (3) Do treatments cause unintended effects on non-target caterpillars and natural enemies. In 2017, preliminary results suggest that treatments caused ~20% additive mortality across the range of densities studied. Moreover, intergenerational population growth rates (based on L2 larval collections in 2016 and 2017), indicated that treatments cause mild to significant budworm declines, whereas in untreated sites budworm densities generally increased. Our results also indicated that treating sites relatively early (~L4.5) yielded higher efficacy than treating late (~L6). Validation of molecular approaches to identify parasitoids in frozen larvae remains underway.

Titre

Impacts au niveau du paysage de la SIH sur la TBE, les autres herbivores et les ennemis naturels associés (APECA RD100 2.2.2)

Résumé

Ce rapport présente les résultats de la dernière année de notre projet de recherche visant à répondre à trois grandes questions dans le développement du cadre de travail de la Stratégie d'intervention hâtive : (i) Les traitements causent-ils suffisamment de mortalité additionnelle (c.-à-d., de la mortalité en plus de ce qui se produirait naturellement) pour causer le déclin des populations? (ii) La migration de masse des papillons empêche-t-elle l'efficacité des traitements? (iii) Les traitements amènent-ils des effets non voulus sur les

chenilles non-ciblées et sur les ennemis naturels?. En 2017, les résultats préliminaires suggèrent que les traitements ont causé ~20% de mortalité additionnelle dans la gamme des densités testées. De plus, les taux de croissance intergénérationnelles des populations (basés sur les collections de L2 en 2016 et 2017) indiquent que les traitements ont causé un déclin des tordeuses de faible à significatif, alors que les densités de tordeuses des sites non-traités ont généralement augmentés. Nos résultats indiquent que traiter les sites relativement tôt (~L4.5) amène une plus grande efficacité que de traiter les sites tard (~L6). La validation de la détection et de l'identification des parasitoïdes par biologie moléculaire dans les larves congelées est toujours en cours.

Introduction

Spruce budworm outbreaks have been managed historically through a 'Foliage protection' approach whereby insecticides are used to preserve foliage in severely defoliated forests before substantial mortality or growth loss occur. While foliage protection may offer a short-term reprieve to budworm damage, it is mainly a stopgap measure and does not aim to suppress the overall rise or spread of outbreaks. Recent advances in our understanding of budworm population dynamics (e.g., Régnière et al. 2013) have prompted efforts to develop a complementary approach to managing budworm, the so-called Early Intervention Strategy (EIS). Briefly, the EIS entails controlling relatively low-density populations along the leading edge of outbreaks as a way of containing outbreak spread. In general, the EIS program shares many characteristics with area-wide containment programs often used to contain invasive species, such as the "Slow the Spread" program for gypsy moth being used in the United States. Many practical and theoretical questions underlie the development of a pest containment program. How do we monitor and decide when and where to treat hot spots? What insecticide products should we use and when should they be applied? Does treatment cause enough additive mortality (i.e., mortality in addition to what would otherwise occur naturally) to cause populations to decline? Does mass moth migration offset the efficacy of treatments? In addition, given that natural enemies (parasitoids in particular) are a major source of this natural budworm control, there are also concerns around the potential non-target impacts of treating low density populations. Most of the key parasitoids thought to control budworm are generalists that attack other herbivores when SBW densities are low and these may be adversely affected if a low-density population is treated (Huber et al. 1996; Eveleigh et al. 2007). In particular, an unwanted impact of the treatments on the general community could have an adverse effect on the SBW in years following treatment if parasitoid populations are negatively affected, either directly by insecticide-induced mortality, or indirectly through alternate/alternative hosts mortality.

In this report, we discuss our results from 2017 addressing the above questions. As analyses are still underway, the presented results and conclusions are preliminary. Results for the first three years of this project won't be discussed here and may be found in previous reports (Martel et al. 2015-2017 SERG Reports).

Objectives

- (1) Assess the efficacy of insecticide application over large areas on relatively low-density populations of SBW and determine the ability of moths to invade large areas that have been treated with insecticides.

- (2) Validate the Bar coding ‘chip’ (see Project A2.2) that will provide rapid and precise identification of spruce budworm natural enemies.
- (3) Determine the impact of EIS on parasitoid abundance and impact within the local herbivore community.

Methodology

Objective 1: Treatment efficacy and migration effects

In 2017, we carried out population surveys in 62 total sites spanning northern NB through Cape Breton, NS (Fig. 1). The bulk of sites were clustered inside (21 sites) and outside (28 sites) of the spray block north of Mirimichi, NB, and these will be the focus of this report (very few budworm were found south of Mirimichi). Treatments in 2017 consisted of single applications of either tebufenozide or *Bacillus thuringiensis kurstaki* (Btk) (Fig. 1). Due to a spell of inclement weather in the middle of the treatment period, we also ended up with a *de facto* experiment allowing us to examine the efficacy of relatively ‘early’ (~L4.5) vs. ‘late’ (~L6) treatments. For further details on the timing of application for tebufenozide and Btk application, see Amirault et al. (2018 SERG Report).

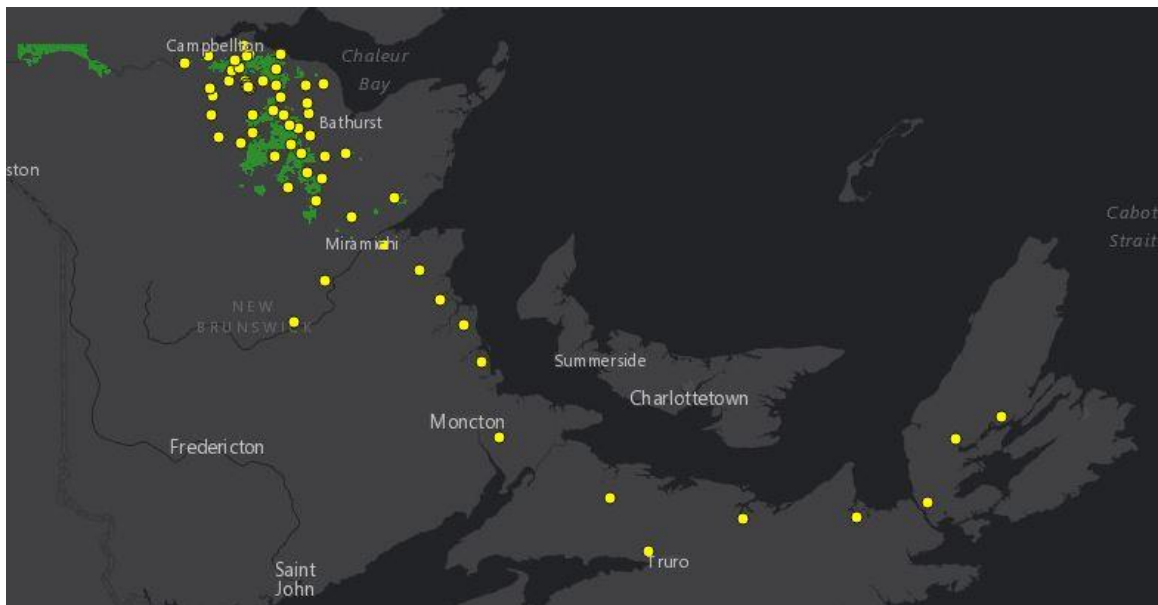


Figure 1. Circles represent study sites used in 2017 to assess spruce budworm population responses inside and outside areas treated with single applications of either Btk or tebufenozide. The shaded areas in northern NB represent the areas treated with the insecticides.

To determine the effects of insecticide treatments on budworm survival, we collected 15-30 branches (45 cm in length) from the mid crown of trees along transects beginning from the edge of the plot and running roughly 100-200 m into each site. We sampled branches at ~L4.5 (prior to treatments) and again at peak L6, early pupation, late pupation, and peak egg lay. Branches were processed in the laboratory in Fredericton and all larval insects (including non-budworm) were identified and assessed for whether they were live or dead. Any collected pupae were placed in petri dishes and reared through to

adult or parasitoid emergence. When collecting branches during the egg stage, we also counted empty pupal cases and identified whether they showed signs of predation, parasitism, or adult emergence. Egg masses were assessed for egg number and categorized as alive, sterile, parasitized, or hatched. All living and dead insects were placed individually in centrifuge tubes and placed in a freezer at -18°C for eventual parasitoid barcoding (see Objective 3). Assessments of seasonal treatment efficacy were based on comparisons of survival from L4.5 to adult ('adult' being derived from the number of 'live' pupae/pupal cases on branches from our final branch collection).

Intergenerational population growth rates, which would reflect both seasonal survival rates and effects of migration/egg lay, were estimated from L2 branch collections carried out in the fall of 2016 and 2017. We used the same protocol described above to collect L2 branches in each site, although the branches were 75 cm long rather than 45 cm.

Objectives 2 & 3: Non-target effects of treatments on natural enemies

All frozen samples collected from branches in the previous section (both budworm and non-budworm) are still awaiting soon processing for parasitoids using the DNA barcoding approach being developed by Smith et al. (2015-2018 SERG Reports).

Results and Discussion

Objective 1: Treatment Efficacy and migration effects

Our *de facto* experiment testing how the timing of treatments influences treatment efficacy suggested that survival was lower when treatments were applied 'early' and less effective when applied 'late' when compared with untreated sites (Fig. 2). It's worth noting that the timing of the late treatment occurred very near to pupation, though there were mainly larvae (mostly L6) found in the collection prior to the 'late' treatment. This trend will require further study with better replication to tease out effects for the different insecticides used.

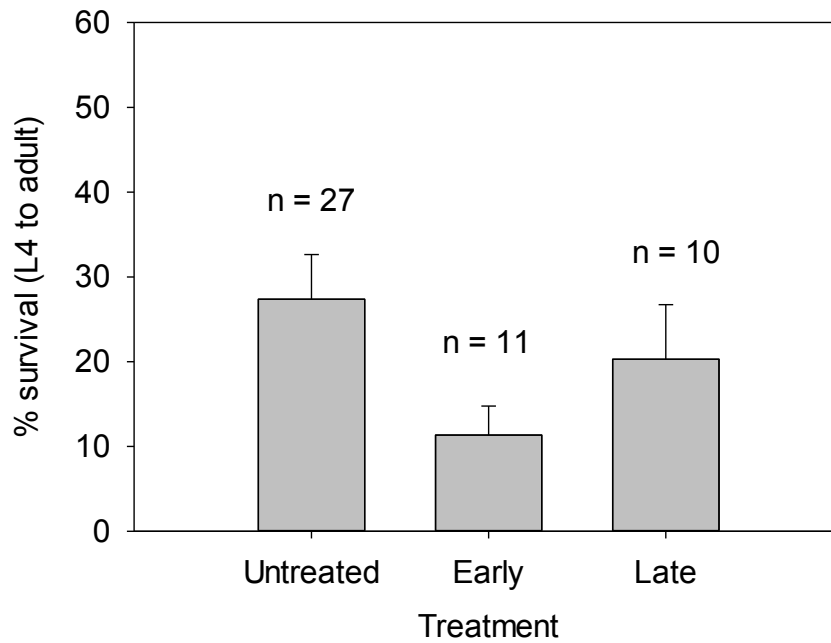


Figure 2. Effects of treatment timing (early vs. late) on spruce budworm survival from L4 to adult compared with untreated sites.

Overall, survival across the range of densities that occurred in the field was ~20% lower in treated vs. untreated areas, suggesting that treatments were providing mortality over and above that occurring naturally (i.e., additive mortality) (Fig. 3a). The magnitude of effects appeared to increase marginally (at least for lower budworm density sites) when we considered only the data collected from the ‘early’ treated sites (Fig. 3b). It is also notable that treatments were effective in sites that had densities exceeding the (tentative) Allee threshold of ~7-8 larvae per branch.

Intergenerational population growth rates, based on comparisons of L2 densities between years, were stable or increased in ~77% of untreated sites (i.e., budworm populations stayed the same or increased from 2016 to 2017) (Fig. 4a), but declined in ~67% of treated sites (i.e., budworm populations declined from 2016 to 2017) (Fig. 4a). However, if we removed all of the ‘late’ treated sites, then all the remaining sites that were treated ‘early’ had negative growth rates (Fig. 4b). Overall, this suggests that the effects of insecticide treatments were not substantially (or at least completely) offset by moth immigration and egg lay and, again, that the strongest effects of treatments may be yielded from treating relatively earlier rather than later in larval development.

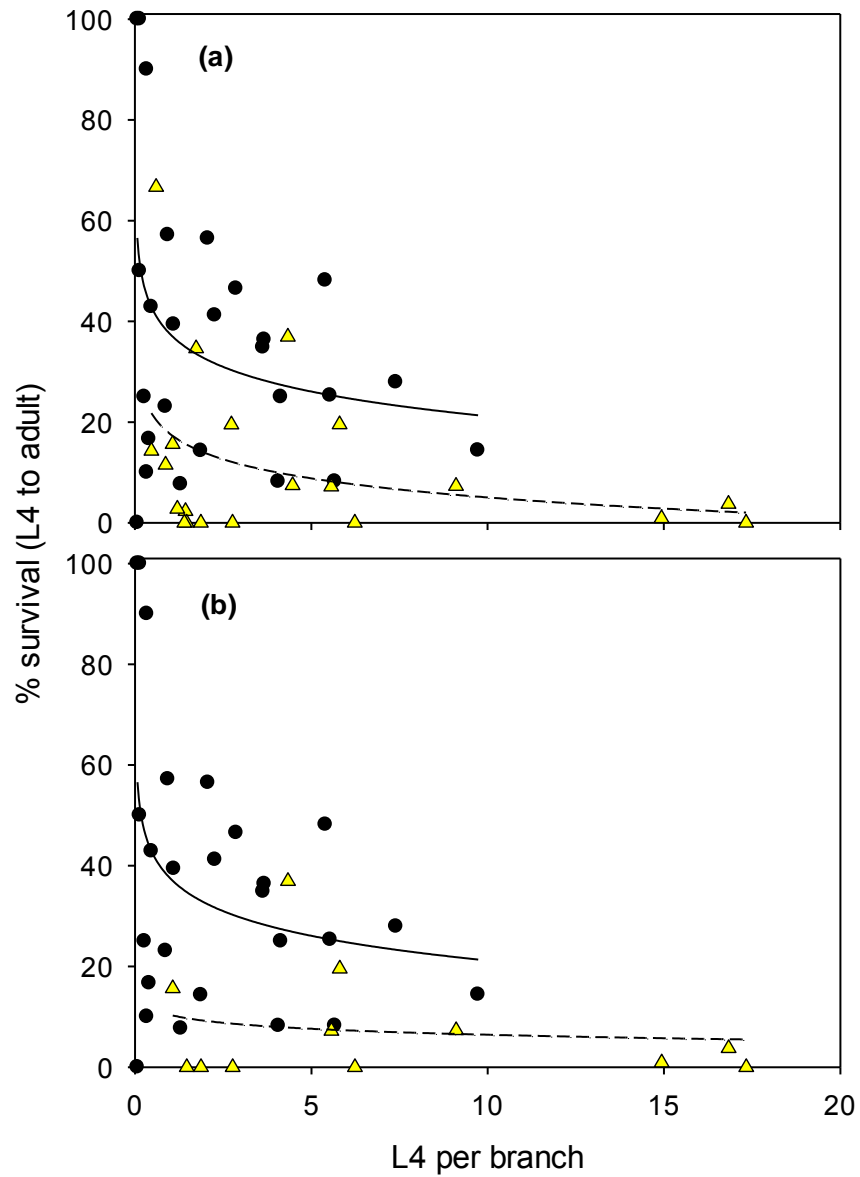


Figure 3. The effect of insecticide treatment in 2017 on spruce budworm survival from L4 to adult and across a range of population densities. Sites treated with tebufenozide vs. Btk are not distinguished. (a) Including both ‘early’ and ‘late’ treated sites, (b) Only including sites treated ‘early’.

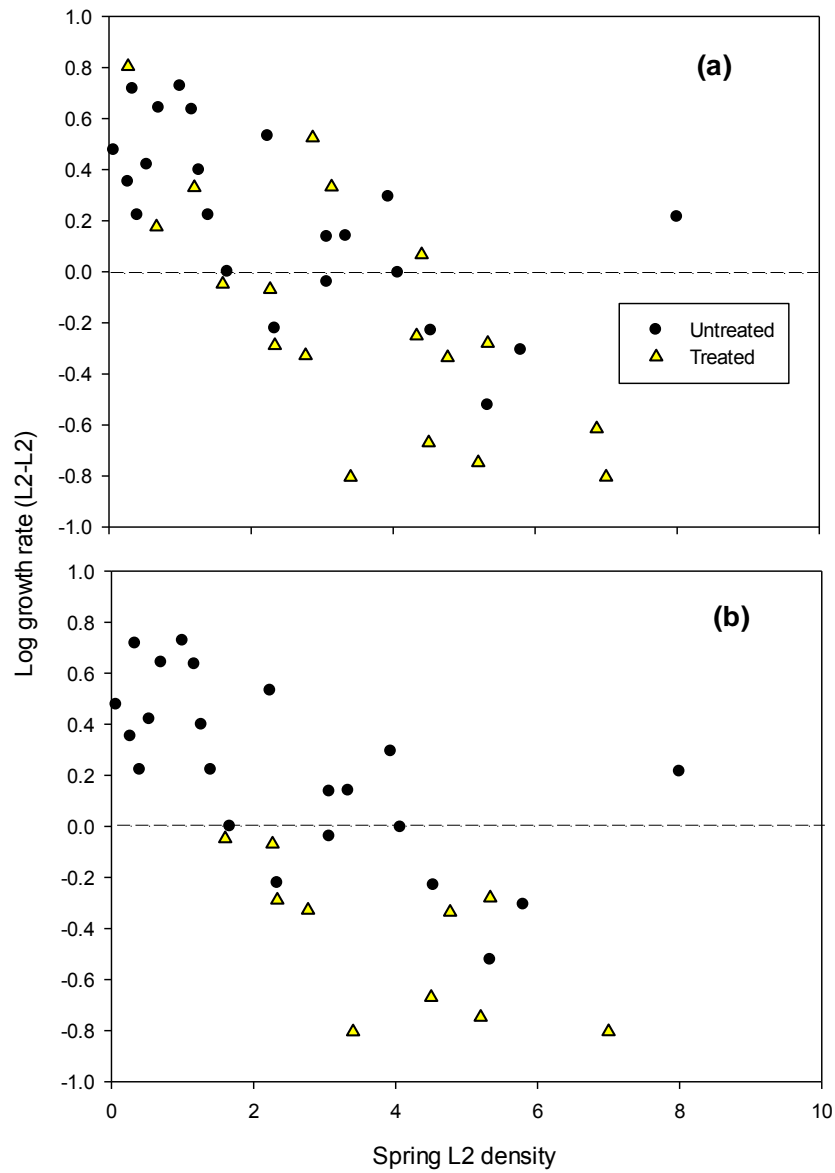


Figure 4. Average budworm densities at different life stages throughout the season from three sites that had been treated in 2015 with a double application of Btk and again in 2016 with a single application of Btk.

Objectives 2 & 3: Non-target effects

Sixteen parasitoid species (5 Diptera and 11 Hymenoptera) among the most important ones have been collected and sequenced. The primers to identify if a budworm larva is parasitized or not, and if it is, if it's by a Diptera (fly) or an Hymenoptera (wasp) have been identified and tested on these 16 species. All of these species react to the identified primers. The next step (starting imminently) will be to test these primers on field-collected SBW larvae (from Lower-St-Lawrence and from North Shore in Quebec) for which we know the parasitism rates for the different species (by rearing the same number of SBW larvae for these sites), as a validation step for the technique. Once this validation step has been completed we will begin processing the multiple years of frozen larvae (budworm and non-target) to assess parasitism.

Tentative Conclusions

Our results to date show some promise for depressing low-density populations in the context of the EIS, though it remains to be seen whether these effects can be sustained or maintained as the outbreak in Quebec continues to encroach on the NB border. In 2017 at least, there were no substantial mass migration events of the kind we saw in 2016, which likely contributed to the effectiveness of treatments this year. Results of our efficacy trials also appear to be consistent with broader L2 trends collected by DERD this year, which suggested only a modest increase in NB budworm densities from the previous year. We suspect that some of this modest growth may have come from sites that were not picked up in L2 treatments and which were therefore untreated. While results to date are encouraging, there remains work to be done to refine both budworm monitoring and treatment efficacy. Moreover, once the barcoding approach is completed and applied to the four years of frozen samples we have, we are likely to accrue additional insights regarding how treatments affect non-target caterpillars and the natural enemy community.

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