Final Report: Jack Kimmel Research Grant

Impacts of an invasive beetle on spruce budworm outbreaks

Steve Heard (with Rob Johns and Mallory MacDonnell)

Project summary: An outbreak of spruce budworm (*Choristoneura fumiferana*), the major defoliating pest of fir and spruce in central and eastern Canada, is currently spreading. In Nova Scotia, prediction of budworm's impact is complicated by the arrival of an invasive spruce-feeding beetle, the brown spruce longhorn beetle (*Tetropium fuscum*, or "BSLB"), not present during previous budworm outbreaks. BSLB infestation may make trees either more or less susceptible to budworm damage, either because BSLB attack reduces foliage quality, or because BSLB attack triggers induced defences of trees against herbivory. Effects of BSLB have the potential to alter both outbreak dynamics and the fate of individual, high-value trees and stands (including those in urban settings). We proposed to determine the influence of BSLB attack on budworm feeding and larval performance on red spruce (*Picea rubens*), the primary North American host of BSLB and a secondary host for spruce budworm. We measured density-defoliation relationships for budworm on trees in four experimental treatments: unmanipulated, stressed (chainsaw-girdled), BSLB (experimentally infested) and stressed+BSLB (chainsaw-girdled plus experimentally infested). Trees in each treatment were exposed to a range of budworm densities, held in sleeve cages on small (~45 cm) branches that were later assessed for defoliation. We also measured budworm growth and survival in all treatments. This work constitutes the MSc. thesis research of Ms. Mallory MacDonnell.

Work completed: We executed BSLB/budworm experiments as proposed in the summers of 2014 and 2015. All experimental branches were scored for defoliation before and after the experiment, and all surviving budworm adults were collected for measurement. All proposed field work is complete and all data are in hand and analyzed. Ms. MacDonnell is currently completing her thesis for intended defense in the summer or early fall of 2016, following which we will publish her work in the peer-reviewed literature.

We summarize here the two most important results (more detailed analyses available by request): the impact of BSLB on defoliation, and an unexpected nonlinearity in defoliation by budworm regardless of BSLB attack.

(1) The impact of BSLB on defoliation.

Density-defoliation relationships from experiments like ours are assessed by regression of (usually logit-transformed) defoliation on budworm density. All our experiments reveal (unsurprisingly) dependence of defoliation on budworm abundance. However, we detect additional significant effects of girdling stress, with the same budworm densities inflicting more defoliation on girdled trees than on controls (Figure 1). However, there was no significant effect of BSLB infestation, for one or two years, on defoliation. This suggests that early stages of attack by BSLB will not increase damage by spruce budworm. Girdling is analogous to longer-term BSLB infestation (which damages phloem), and thus the significant girdling effect suggests

that trees with advanced BSLB damage will experienced increased budworm defoliation. However, such trees are likely to be moribund anyway, and increased defoliation might hasten but will not cause their demise.

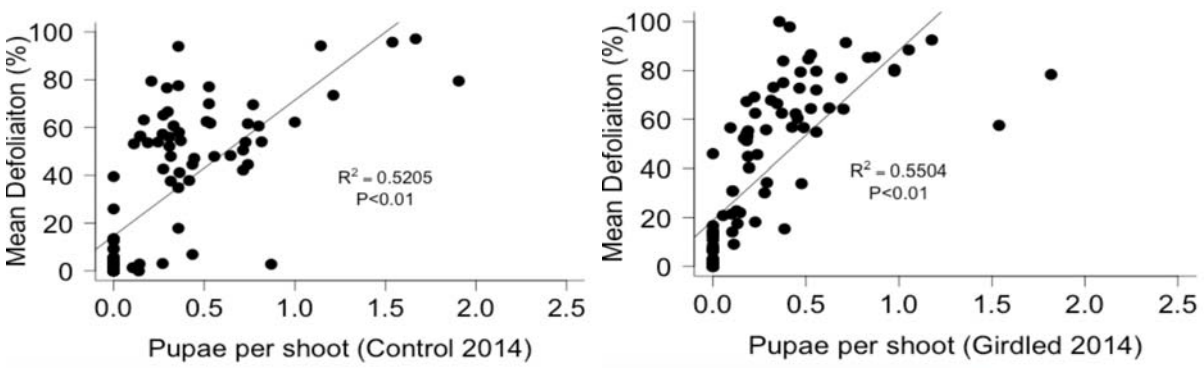

Figure 1. Effects of girdling stress on defoliation by spruce budworm. Representative data.

(2) Nonlinearity in defoliation by budworm.

While defoliation rates generally increased with budworm densities, we were surprised to find that very high budworm densities actually led to *less* defoliation than moderate densities (Figure 2; this result was independent of BSLB treatment, and so represents a serendipitous discovery about budworm/tree interactions). Decomposing defoliation into losses of current-year and older foliage revealed the likely explanation. Budworm prefer to feed on current-year foliage, but even at fairly low densities they exhaust this resource (100% defoliation, Figure 2A). Larvae are then forced to attempt "backfeeding" on older needles. At low to moderate densities, larvae exhaust current-year foliage, but not before growing large enough to attack older needles successfully. Losses of older foliage are then high (Figure 2B/C/D, below about 5 larvae/shoot). At high densities, however, budworm exhaust current-year foliage while they are still too small to handle older, tougher, less digestible needles. Many budworm die (data not shown) and defoliation is only moderate (Figure 2B/C/D, above about 5 larvae/shoot).

This nonlinearity has important implications for budworm ecology and outbreak management. First, this represents very strong density-dependence that could potentially control outbreaks at peak population, maintaining densities short of those that immediately kill trees. This can be an explanation for the relatively long persistence of outbreak levels (often 5 to 10 years) without population collapse. Second, this suggests that when populations are at outbreak levels, attempts to control budworm with chemical or biological agents could backfire. If control measures were to reduce budworm densities from high to moderate levels, damage to trees could actually increase, leading to more rapid tree mortality. Spray programs are thus likely to be more effective during the increase phase of an outbreak, and of little use at peak populations unless control is expected to be extremely effective.

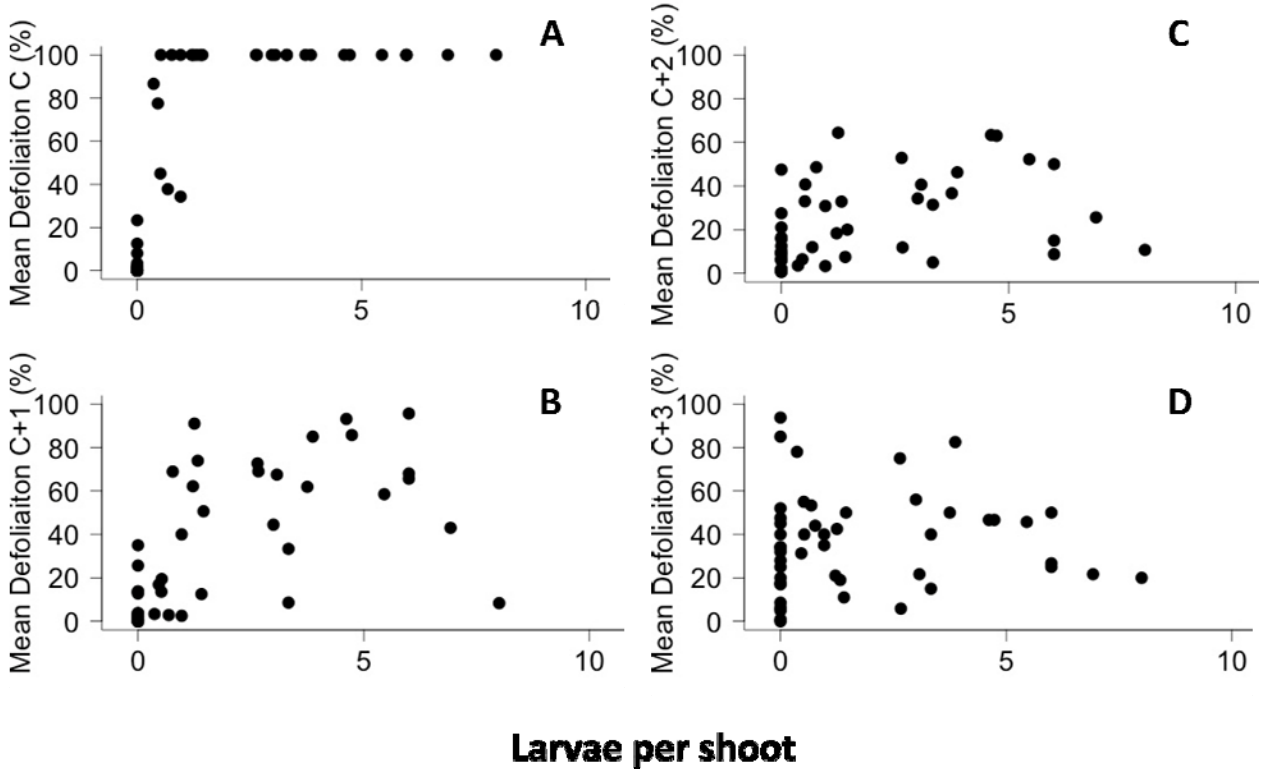

Figure 2. Defoliation relationships for current-year (A), one-year-old (B), two-year-old (C), and three-year-old (D) foliage in control trees, 2015.

Presentations and publications: Ms. MacDonnell presented results of the funded work at three conferences: November 2015 at the Entomological Society of Canada; June 2016 at the Acadian Entomological Society; and July 2016 at the Canadian Society for Ecology and Evolution ("When outbreaks collide: Interactions between an invasive beetle and a native defoliator on red spruce"; M MacDonnell, SB Heard, & R Johns). Following her defence, manuscripts will be submitted for publication, with likely journal targets being *Entomologia Experimentalis et Applicata* or *Forest Ecology and Management.*

Spending: Jack Kimmel Research Grant Funds were spent as proposed: on graduate stipend support for Mallory MacDonnell, and on travel costs for Ms. MacDonnell to present research results to the Canadian Entomological Society (Nov 2015, Montreal).