Testing new approaches for detecting and locating early increasing populations of the Spruce Budworm for implementing an Early Intervention Strategy

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Abstract

We report that it is rapid and easy to install traps in the upper canopy of balsam fir with the BigShot technique and we confirm that traps placed in the upper canopy were much more efficient than those placed at 2-3 m high. Placing traps in the upper canopy of trees should be considered, particularly if large white spruces are present, at least in a subset of surveyed stands in non-outbreak areas, in an early intervention strategy as well as in moth dispersal studies. We also showed that combining pheromone to a portable light trap did not increased spruce budworm moth catches, contrary to other moths. As it increases sorting time, there is no advantage to combine these attractants for monitoring the spruce budworm. Pheromone trap catches in trace or low population density were similar, which is surprising as trace populations were located in a non-outbreak area, the Laurentian Wildlife Reserve, while the low populations were located in the Lower St-Lawrence region, at the south-western edge of the ongoing outbreak. However, light trap catches were better link with population density of these two regions. Light traps and pheromone traps may provide estimates at different spatial scales and they could thus provide complementary information on spruce budworm populations. The interpretation of these results should be clarified when upcoming L_2 population estimates will be available.

Résumé

Nous rapportons qu'il est facile et rapide d'installer des pièges dans la partie supérieure de la cime de sapins baumier à l'aide de la technique du BigShot, et nous confirmons que les pièges placés dans la cime supérieure étaient plus efficaces que ceux placés à 2-3 m de hauteur. L'installation de pièges dans la cime supérieure des arbres devrait être considéré, particulièrement si de grosses épinettes blanches sont présentes, au moins dans un sous-ensemble d'un réseau de surveillance en région non-épidémique. Cela serait particulièrement utile dans le contexte d'une stratégie d'intervention hâtive ou d'étude de la dispersion des papillons. Contrairement à d'autres espèces, il n'y a aucun avantage à ajouter une phéromone à un piège lumineux pour la tordeuse des bourgeons de l'épinette. Les pièges à phéromone sont des outils de détection utiles dans les populations basses ou à l'état de trace. Or, nous avons constaté avec surprise des niveaux de captures similaires entre les populations basses du Bas St-Laurent et les populations traces de la réserve des Laurentides. Cependant, les captures dans les pièges lumineux reflétaient bien les niveaux de population respectifs des deux régions. L'interprétation de ces résultats devraient être clarifiée lorsque les estimés de populations L_2 seront disponibles.

Introduction

A fundamental component of a successful Early Intervention Strategy (EIS) against the Spruce Budworm (SBW) is the ability to locate rapidly early rising populations or population hotspots, those released from endemic level or establishing after moth immigration. However, this is notoriously difficult to achieve in endemic populations. Pheromone traps are useful monitoring tools known to provide accurate predictions of SBW L_2 density (Rhainds et al. 2016). Pheromone traps are more efficient at capturing SBW moths when placed in tree canopy than when placed at 2 m high (Jobin et al. 1993) and predictions are slightly more accurate when placed in tree canopy (Rhainds et al. 2016). However, for practical reasons, pheromone traps are usually placed at 2 m high where their predictive potential varies more widely from year to year. Relationships between male moths and L_2 density can be weak in certain years ($R^2 < 0.08$) as seen in 2 out of 9 years of the Rhainds et al. (2016) study, even if they are still statistically significant. Pheromone traps capture only males while the next generation depend on females. Captures with these traps may not always be closely link with the extent of female moth dispersal/migration. Moreover, their range of action is unknown and thus the spatial scale at which pheromone trap data should be interpreted remains difficult to appraise.

New approaches using tools providing stand level estimates for detecting developing SBW hotspots may help improving detection of early rising SBW populations. Recent experiments using mark-release recaptures showed that the range of moth attraction of low-powered light traps remains most often within 10 m (Truxa and Fiedler 2012). Light traps can thus provide population estimates at the stand level. Moreover, light traps are also useful for studying moth dispersal and migration. In France, light traps were instrumental for highlighting massive migrations of the green oak tortrix, *Tortrix viridana* (Du Merle and Pinguet 1982). Light traps also capture moths of both sexes and thus provide a sex ratio that is useful to unravel the role of dispersal-migration on SBW population dynamics (Rhainds and Kettela 2014) or help in interpreting male catches in pheromone traps (Delisle et al. 1998). Rhainds and Kettela (2014) showed that light traps placed in the tree canopy provide accurate estimates of SBW egg densities and thus of the upcoming generation. We already showed that SBW moths, particularly females, were much more active in the upper canopy than in the lower canopy (Hébert et al. 2016).

Light trapping used in Maine has also showed that SBW outbreaks were detectable 4 to 7 years before defoliation occurs (Simmons and Elliott 1985). However, light traps used in this project were large, heavy and powered by large batteries that need to be recharge regularly (usually every 2 nights). Such traps are particularly useful for working in a low number of sampling sites with easy access. For example, studies of Du Merle and Pinguet (1982) and Simmons and Elliott (1985) were done respectively with 4 and 10 traps. To widen the utilisation of light traps, we need lighter and more autonomous models that could be used in numerous sites and in remote areas. The Luminoc® trap is a portable light trap (Jobin and Coulombe 1992) that respond to these characteristics and that was shown to be efficient to catch moths of various families, including the SBW. In 1994, when the SBW was at very low levels in Quebec, we collected at least one SBW moth in 9 out of 16 balsam fir stands sampled throughout the province. The highest catches (between 9 and 88 moths/stand) were recorded in the southwestern part of the province, where small and scattered patches of SBW defoliation (total of 2912 ha) were noticed. This indicates that the Luminoc® trap provides reliable estimates of SBW populations, even at endemic level. Moreover, a pheromone can be added to the Luminoc® trap (Delisle et al. 1998) and this often increases male moth captures, while allowing also catching females. The Luminoc® has also been combined with artificial oviposition substrates to sample eggs of the Hemlock Looper (Hébert et al. 2003) and it can be used as pitlight traps to catch forest litter insects (Hébert et al. 2000). Thus, the Luminoc® is a highly polyvalent tool for entomologists but the trap is no longer available commercially and thus, cannot fulfill our needs.

We thus developed a new version of the Luminoc® trap, the Luminoc 2.0, which uses LEDs as attractant rather than a 1.7 W fluorescent light as in the original Luminoc®. LEDs have a much longer life and consume far less energy than fluorescent tubes. Recently, LEDs have shown some potential when used in large light traps, even if they caught significantly less moths than mercury vapor traps (White et al. 2016). However, authors claim that the LED trap may be a viable alternative to the standard mercury vapor trap because of its lower cost. We confirm that this green technology lower the cost of the Luminoc® trap, which was a problem with the original version of the trap. However, a key issue with the SBW is to find ways to hang a trap on small balsam fir branches in the upper tree canopy, where SBW females are much more active (Hébert el al. 2016). One solution might be to lower trap weight as much as possible and this could be achieve by reducing the weight of batteries used to power the trap. Another important challenge is to find a way to rapidly install a device to climb the trap in the upper canopy.

Therefore, in 2017, our objectives were to 1) determine if the combination of a pheromone to a portable light trap could increase male moth catches of the SBW, 2) to test a device for climbing traps in the upper canopy of trees and 3) to compare the predictive potential of SBW L_2 populations for various moth abundances obtained using pheromone, light or light-pheromone traps, placed at 2 or 10 m high.

Materials and methods

Trap descriptions

The Multi-Pher® trap (model 1; Jobin and Coulombe 1988) was used as pheromone trap and two new models of the Luminoc traps were used in 2017. The Luminoc 2.0 trap was built while keeping in mind to lower the cost as much as possible, while maintaining its efficacy. As we targeted the SBW (a microlepidoptera), we used the container, funnel and plate of the Multi-Pher® trap without any modification and without baffles (see photos in Hébert et al. 2016). The upper container houses 8 C-alkaline batteries and an electronic circuit for controlling 4 LEDs. The upper container is a simple plastic recipient of 12-cm diameter and 11-cm high; the overall trap height is 31 cm, and thus the Luminoc 2.0 trap is 7 cm shorter than the original version (Luminoc®). The Luminoc 2.0 trap was described in our 2016 report (Hébert et al. 2016). A lighter version of the trap (Luminoc 3.0) was tested in 2016 and involved using a single LED powered by a 2 AA batteries.

2017 experiments

In 2017, our efforts aimed to 1) determine if combining SBW pheromone to the Luminoc traps could increase moth captures, 2) test a device for climbing traps in the upper canopy of trees and

3) improve forecasting of SBW L_2 populations. Thus, we compared Multi-Pher® pheromone traps (model 1) with two models of portable Luminoc traps (2.0 and 3.0) or a combination of the pheromone attractant with the light traps. The experiment was carried out in 36 mature balsam fir stands, 21 in the Lower St-Lawrence region and 15 in the Laurentian Wildlife Reserve (Figure 1). Stands of the Lower St-Lawrence region were located in areas where SBW populations were high, medium or low, according to the fall 2016 SBW L_2 density maps (Ministère des Forêts, de la Faune et des Parcs 2017). As a result, 6, 8 and 7 stands were located respectively in high, medium and low density areas. Stands located in the Laurentian Wildlife Reserve were considered at the trace level as no L_2 was found in the area (Figure 2). Two tests were carried out in parallel with the louder Luminoc 2.0 trap being hanged on lower balsam fir branches (2-3 m high) and the lighter Luminoc 3.0 trap being placed in the upper tree canopy. We used the SherrillTree BigShot system (Hughes et al. 2014) to hang a rope over a branch and climb a trap in the upper canopy of balsam fir trees. Thus, in each stand, we placed one Multi-Pher pheromone trap, one Luminoc 3.0 and one Luminoc 3.0 + SBW pheromone spaced by 50 m along a transect line and at least at 50 m from any road. On another transect 50 m apart, we placed one Multi-Pher pheromone trap, one Luminoc 2.0 trap and one Luminoc 2.0 + SBW pheromone at 2-3 m above ground, hanged on balsam fir branches. A strip of Vapor Tape II was placed in each trap. Samples were collected weekly between 29 June and 23 August to compare moth catches between various trap types. Anova was used to compare moth captures vs trap type at various SBW density, for each transect (Luminoc 2.0 and Luminoc 3.0) separately.

In early October, five balsam fir branches were collected to determine L_2 density. It has not been possible to process L_2 extraction in fall and thus, branches were placed in cardboard tubes to force L_2 emergence. These results will be available later during winter 2018. Linear regression will be use to assess the strength of the relationships between moth abundance in the various traps and L_2 abundance.

Results and discussion

Our results clearly showed that pheromone traps were far more efficient than portable light traps for catching SBW male moths, both in the upper canopy and at 2-3 m high (Figure 3). Moreover, adding SBW pheromone to the light traps did not increase male moth catches, contrary to other moth species (Jobin and Coulombe 1992). Therefore, there is no advantage to combine the two attractants as the sorting time is increased because the light source attract other moths, that are nearly absent in pheromone traps. Also, very few females were caught in light traps, some being even found in pheromone traps (Tables 1 and 2).

Our results also confirm previous results (Jobin and Bernier-Cardou 1988) that pheromone traps are more efficient when placed in the upper canopy than at 2-3 m high (Figure 4). For early detection, it would thus be advantageous to place traps in the upper tree canopy. The traps were installed rapidly and easily in the upper canopy of trees with the BigShot technique, even on balsam fir, which have small branches. Yet, if white spruce trees could be present in a stand, it would allow climbing traps much higher and it would probably allow using louder traps such as the Luminoc 2.0. Placing traps in the upper canopy, at least for a certain number of sites, would be useful for early detection of increasing populations and for moth dispersal/migration studies.

When used in outbreak areas (medium to high populations), the high efficacy of pheromone traps need counting thousands of moths, which is time-consuming and tedious. As pheromone traps are mainly detection tools, their use should be restricted to non-outbreak areas or at the front edge of an outbreak (low populations) in order to follow population spreading. However, our results of pheromone trap catches in trace or low population density suggest that these stands would have similar spruce budworm density, which is surprising as trace populations were located in a non-outbreak area, the Laurentian Wildlife Reserve, while the low populations were located in the Lower St-Lawrence region, at the south-western edge of the ongoing outbreak (Figure 2). It is interesting to note that light trap catches were better link with population density of the two regions. Light traps and pheromone traps may provide estimates at different spatial scales and they could thus provide complementary information on spruce budworm populations. For instance, even if they were rarely captured, some females were caught in the Luminoc 2.0 in the low populations of the Lower St-Lawrence region, while none was caught in the trace populations of the Laurentian Wildlife Reserve. The interpretation of these results should be clarified when upcoming L_2 population estimates will become available.

Sorting samples collected with the Luminoc 3.0 traps was much faster than for the Luminoc 2.0 traps because fewer non-target moths were caught in the upper canopy than with the Luminoc 2.0 traps at 2-3 m high. Moreover, the Luminoc 3.0 trap caught fewer SBW moths than the Luminoc 2.0. However, we cannot conclude on their respective efficacy as they used 1 vs 4 LEDs and they were placed at different heights. Finally, even if they catch lower numbers of moths, the final appraisal of the usefulness of portable light traps will be possible only when upcoming L_2 population estimates will become available.

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Budget

	2017-18
Technician	15
Field work	15
Supplies	5
Total	**35**
Funding sources	
CFS	12
SERG-I partners	16
iFor	7

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Table 1: SBW moth catches in pheromone baited (P), light baited (L) and pheromone + light baited (P + L) traps in the upper canopy of balsam fir trees.

SBW L_2 density	Males			Females		
	Pheromone	**Luminoc[1]**	**Luminoc[1] + Pheromone**	**Pheromone**	**Luminoc[1]**	**Luminoc[1] + Pheromone**
High	4981.7 ± 640.6	267.0 ± 60.3	4092.7 ± 1035.7	1.7 ± 0.7	4.1 ± 1.0	4.7 ± 1.3
Moderate	1055.8 ± 163.7	92.2 ± 42.0	953.6 ± 228.0	0.3 ± 0.2	0.4 ± 0.3	0.4 ± 0.3
Low	131.0 ± 54.3	3.3 ± 1.7	114.0 ± 21.3	0.1 ± 0.1	0	0.1 ± 0.1
Trace	174.6 ± 36.7	0.4 ± 0.1	162.5 ± 38.3	0	0	0

[1] Luminoc 3.0

Table 2: SBW moth catches in pheromone baited (P), light baited (L) and pheromone + light baited (P + L) traps hanged on branches at 2-3 m high.

SBW L_2 density	Males			Females		
	Pheromone	**Luminoc[1]**	**Luminoc[1] + Pheromone**	**Pheromone**	**Luminoc[1]**	**Luminoc[1] + Pheromone**
High	1561.2 ± 256.6	172.5 ± 68.2	1155.3 ± 199.2	0.8 ± 0.8	5.8 ± 2.1	0.8 ± 0.4
Moderate	330.1 ± 63.5	73.8 ± 15.7	300.0 ± 33.0	0.1 ± 0.1	0.4 ± 0.3	0.9 ± 0.5
Low	24.9 ± 9.8	9.3 ± 2.7	37.7 ± 18.3	0	0.7 ± 0.3	0
Trace	55.2 ± 11.9	0.5 ± 0.2	69.5 ± 24.5	0	0	0

[1] Luminoc 2.0

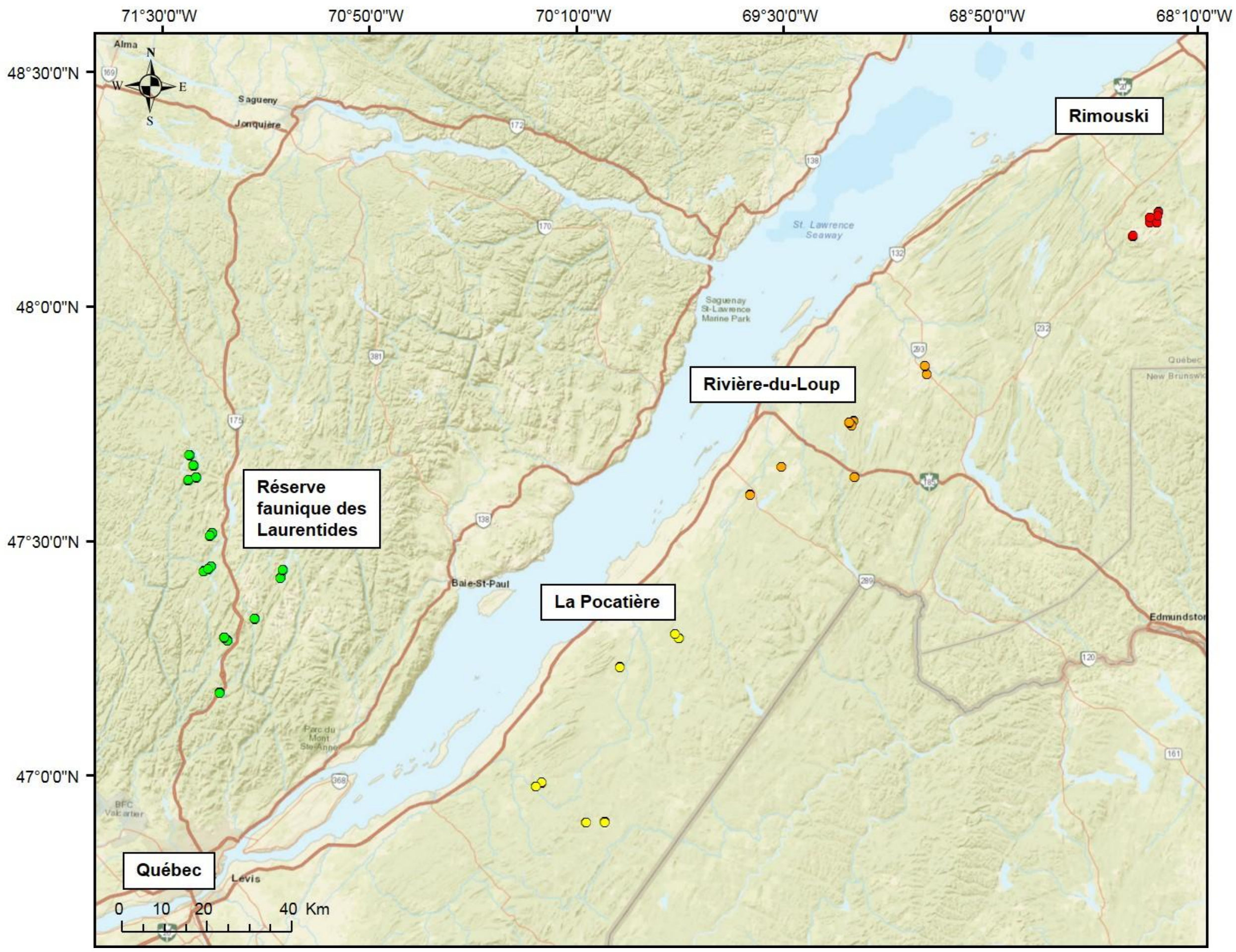

Figure 1: Stand locations in which pheromone, light and light-pheromone traps were installed. The red dots were in an area of high SBW density, the orange dots were in a medium SBW density, while the yellow and green dots were located respectively in areas of low and trace SBW populations.

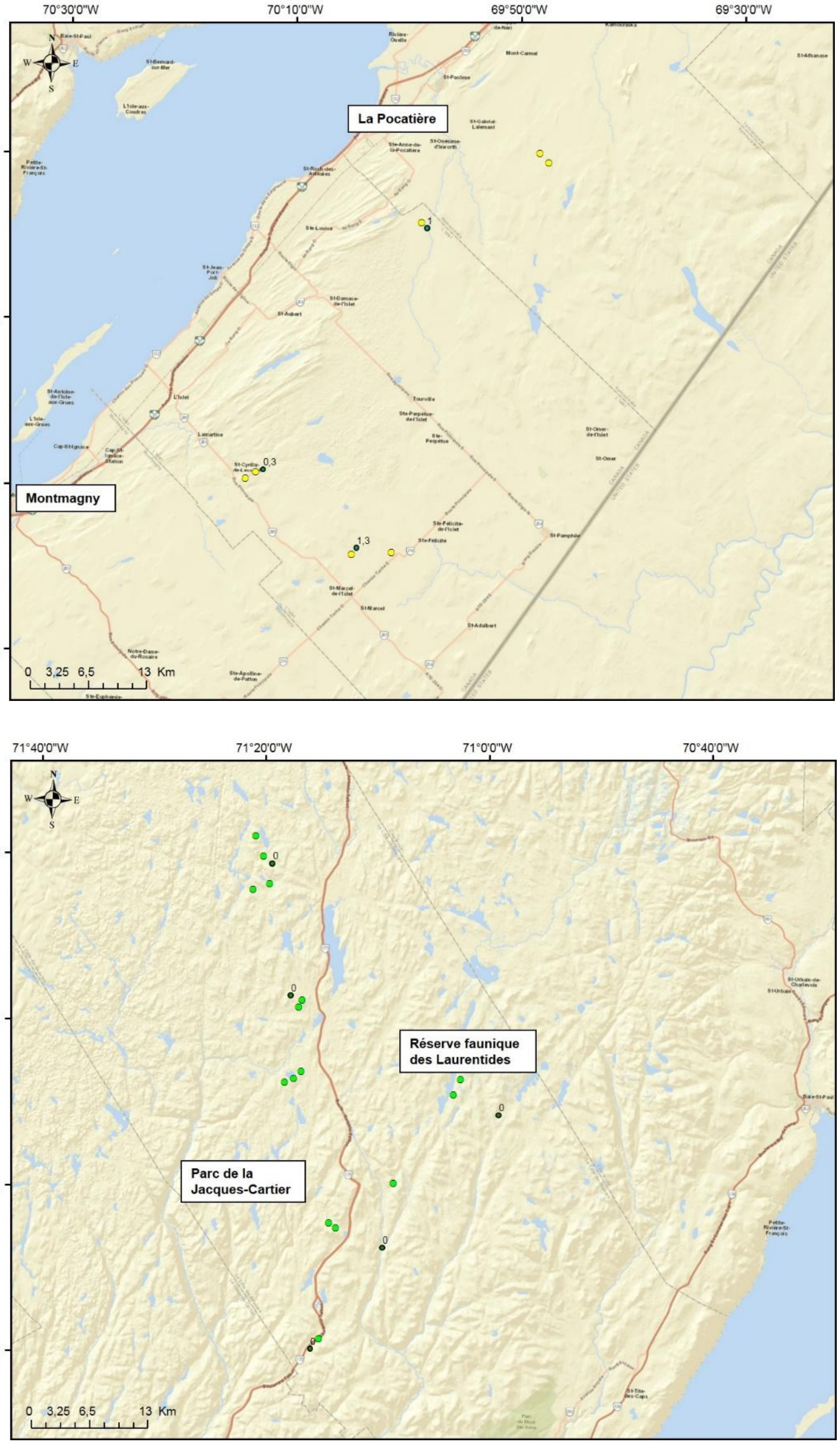

Figure 2: Stand locations and 2016 fall L_2 density showing the Lower St-Lawrence low SBW populations area (upper map) and the Laurentian Wildlife Reserve trace population area (lower map).

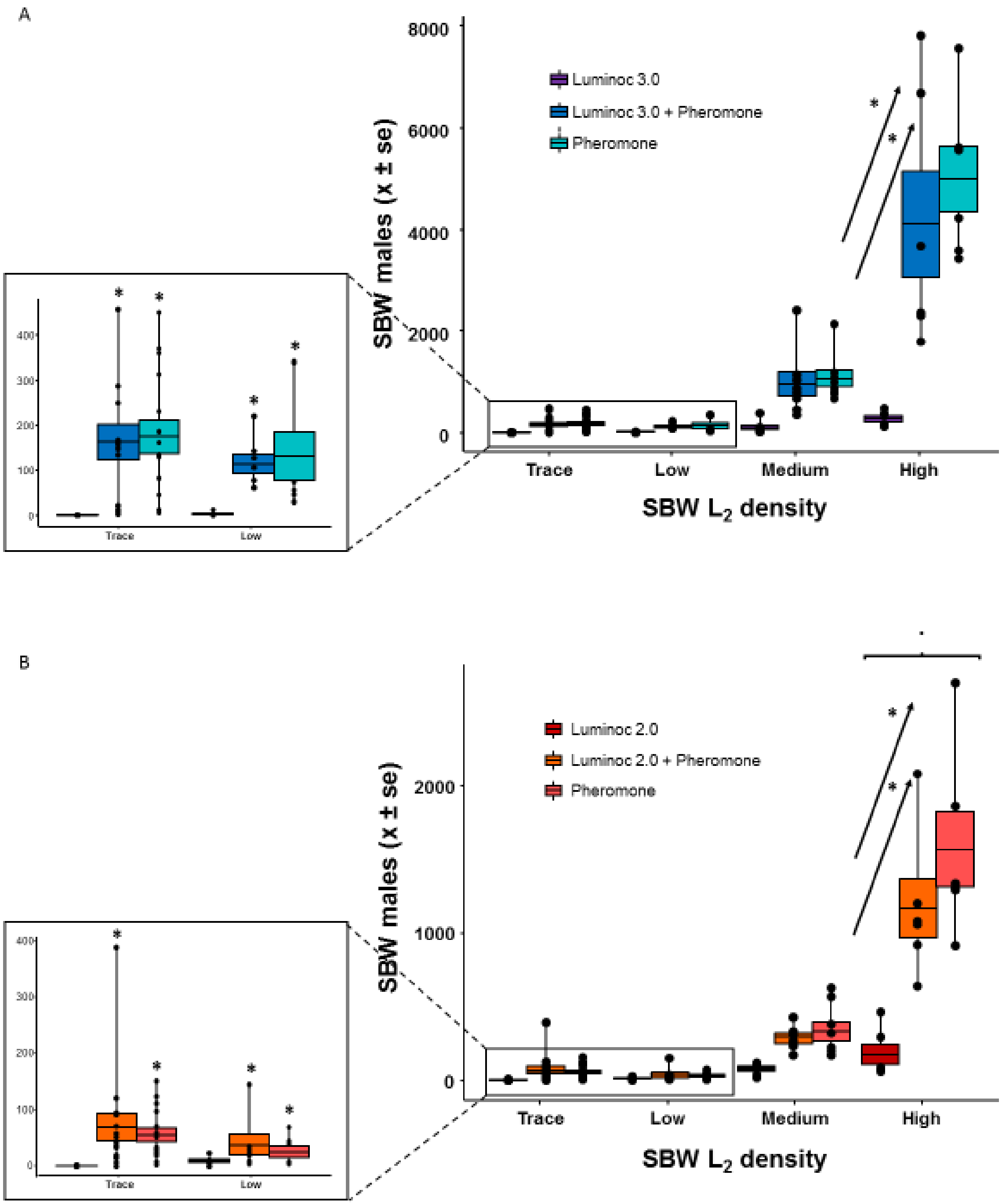

Figure 3: Spruce budworm male moths caught (A) in Luminoc 3.0 traps, pheromone traps and Luminoc 3.0 + pheromone traps placed in the upper canopy according to previous year SBW L_2 density, and (B) in Luminoc 2.0 traps, pheromone traps and Luminoc 2.0 + pheromone traps placed at 2-3 m high according to previous year SBW L_2 density.

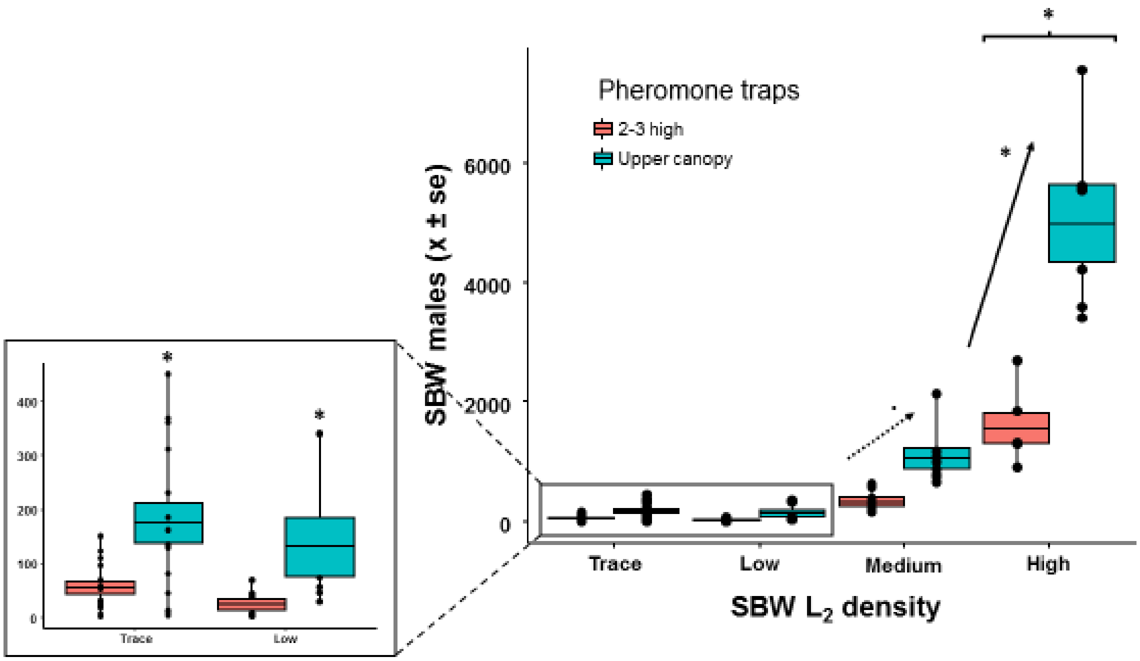

Figure 4: Spruce budworm male moths caught pheromone traps placed in the upper canopy or at 2-3 m high, according to previous year SBW L_2 density.