Climate change implications for spruce budworm (*Choristoneura fumiferana*) outbreaks in Atlantic Canada

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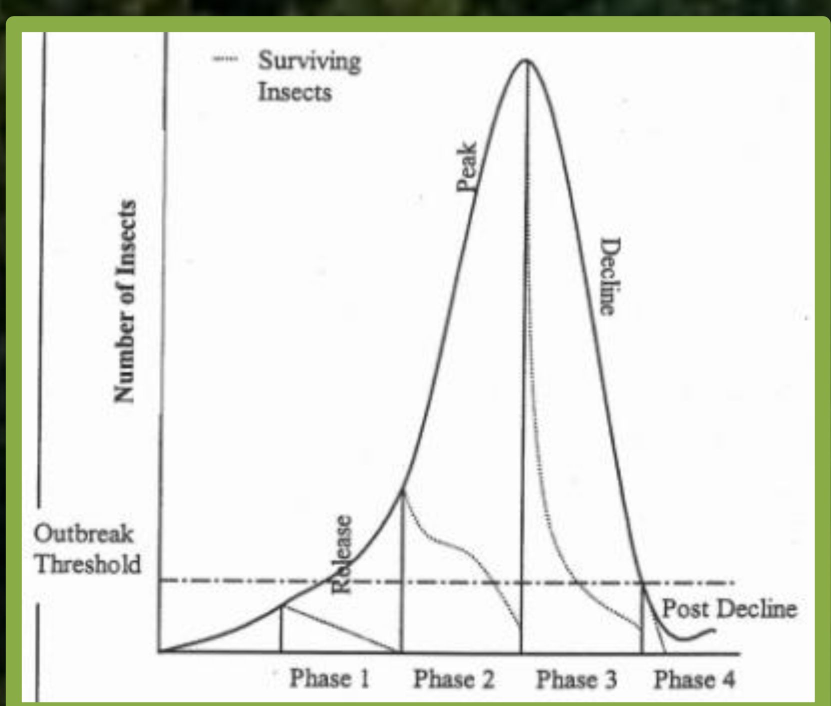
INTRODUCTION

Changing climatic conditions are anticipated to have lasting effects on forest pests and their hosts. Insect species have a great capacity for adaptive response and evolutionary change, owing to a high degree of genetic variability in populations, short generation time, high reproductive output, and peripatetic nature (Price et al., 2013).

Increases in severity of pest outbreaks result in widespread tree mortality, reductions in forest productivity and carbon storage, and a consequential feedback loop between outbreaks and climate change (Haynes et al., 2014).

Predators that regulate pest populations may be forced to relocate due to climate changes. Pest boom and bust cycles impact the entire trophic chain (Harvey et al., 2020).



Four phases of pest outbreaks with corresponding outbreak threshold separating endemic and epidemic levels. Figure from Brookes et al., 1978.

Spruce Budworm (SBW)

The SBW is a moth native to Canada; difficulty in regulation has deemed it a pest. SBW is capable of complete defoliation of a spruce-fir host and host mortality within 5 years (Government of Canada, 2020b).

SBW outbreaks normally occur every 30 – 40 years (Government of Canada, 2020c).

Future outbreaks are predicted to last 6 years longer than present infestations, with 15% greater defoliation (Gray, 2008).

RECOMMENDATIONS

Use of early intervention strategy through a proactive approach is effective in reducing budworm population. Early intervention strategies emphasize controlling an outbreak before it has begun (Johns et al., 2019).

Before treatment methods are applied, provisions must be taken for effective use (hotspot monitoring, cost-benefit analysis, population control, public collaboration).

One of two aerially applied insecticides are considered, *Bacillus thuringiensis var. kurstaki* (Btk) and tebufenozide (Johns et al., 2019).

Pre-emptive spraying of Btk has shown successful on the Great Northern Peninsula, with over 32,000 ha of forest being treated (VOCM, 2021).

PHENOLOGICAL RESPONSE

Climate trends are inducing phenological changes in many symbiotic species and is predicted to alter the interactions between trophic levels. These biological responses to changing conditions alter the synchrony of larval emergence with budburst of host species (Pureswaran et al., 2018).

Phenological trends cause defoliation periods to begin prematurely in the season but as forests' growing seasons continually expand into earlier springs and delayed winters (Gunderson et al., 2012), the impacts of SBW also increases. Pests will be able to persist in previously unhospitable habitats, even during vulnerable life stages (Pureswaran et al., 2015).

MORPHOLOGICAL CHANGE

Changes in body structure occur in response to climatic and precipitation variability (Gardner et al., 2011). Response rates vary by taxonomic groups, thus likely to cause disparity in ecosystem services via a knock-on effect of diminishing resources.

Univoltine species, like the SBW, make use of a longer growing season by getting larger (Fenberg et al., 2016).

RANGE SHIFTS

Insect pest ranges are being altered through temperature-induced changes and trophic relations between spruce-fir hosts, pests, and pest predators.

As northward temperatures increase and SBW's geographic range follows, host populations of black spruce will be targeted as balsam fir becomes less prominent. This is significant as black spruce encompass a larger ecological area in Canada and are an important wood fiber source.

This migratory shift comes with unknown long-term repercussions (Pureswaran et al., 2015).

ECONOMIC REPERCUSSIONS

Epidemic defoliation periods entail substantial economic implications. Under a moderate outbreak scenario, losses of \$3.3 billion are expected per province affected over the course of an outbreak, while a severe outbreak could result in \$4.7 billion in timber supply losses (Chang et al., 2012).

Every \$1 allocated to early prevention avoids \$3 in regulatory costs once an outbreak has established (Government of Canada, 2020d).

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