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CANADIAN FOREST SERVICE

A conceptual framework for spruce budworm early intervention:

Can outbreaks be stopped?

IMPACT NOTE NO. 65

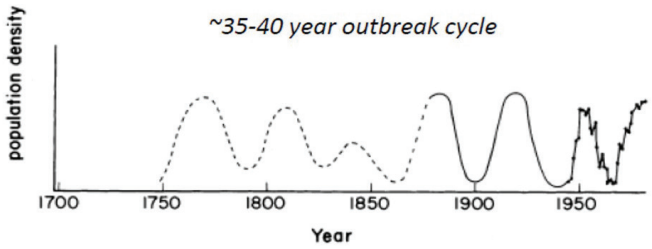
The spruce budworm is a native forest insect that inhabits the spruce-fir forests of northeastern North America. Outbreaks of this insect occur every 30 to 40 years. During this cycle, populations range from being very low (endemic) to very high (epidemic). If left unmanaged, these outbreaks can result in significant growth reduction and mortality of spruce and balsam fir trees.

Previous efforts to protect the forest against spruce budworm were a reaction to an outbreak that was already underway. Insecticide was applied over large areas of forest by aerial spraying after significant defoliation had occurred. This is often referred to as the foliage protection strategy, and its main objective is to keep the trees alive. This reactive approach must be repeated every year until the outbreak ends.

These large-scale foliage protection programs cost governments millions of dollars and generally mitigate only a small fraction of the damage to forests and on the forest industry because the damage has already occurred.

Scientists from Natural Resources Canada's (NRCan) Canadian Forest Service and five Canadian universities are testing a unique approach to managing spruce budworm populations – the early intervention strategy (EIS) for spruce budworm. If successful, the EIS could prevent an outbreak from occurring, with minimal or no defoliation in forests and therefore no impact on the wood supply, the economy, and the ecological services that spruce-fir forests provide.

Changes in spruce budworm density over time. Note that the outbreak peaks occur every 30 to 40 years.



Royama 1984

What causes spruce budworm outbreaks?

The cause of spruce budworm outbreaks has puzzled scientists for decades. Knowing the cause is important for forest managers because it affects how spruce budworm populations are managed during outbreak cycles. The competing theories of outbreak development are oscillatory and double equilibrium.

Oscillatory theory (predator-prey relationship)

The oscillatory theory supposes a predator-prey relationship between the spruce budworm and its natural enemies (i.e. predators, parasites and diseases).

In this theory, natural enemies kill enough spruce budworm to keep populations from growing large enough to cause an outbreak.

However, when the spruce budworm population is small, the population of natural enemies that feed on spruce budworm decreases. When conditions are favourable, this fluctuation can lead to a rapid increase in the spruce budworm population that causes an outbreak over a large area.

If this theory were correct, then a large-scale foliage protection program would be required to minimize the impacts of an outbreak.

The basics of the oscillatory theory are:

- Outbreaks occur over large areas and develop quickly.
- Moth dispersal does not play a strong role in the spread of spruce budworm.
- Regional-scale spruce budworm outbreaks cannot be prevented.
- A traditional foliage protection program is the correct strategy to manage spruce budworm.

Double equilibrium theory (formation of epicentres)

The double equilibrium theory supposes that spruce budworm populations can be at equilibrium at both endemic and epidemic stages.

In this theory, outbreaks originate in areas where spruce budworm populations are low but are growing to a level at which natural enemies and environmental controls cannot keep populations below outbreak thresholds.

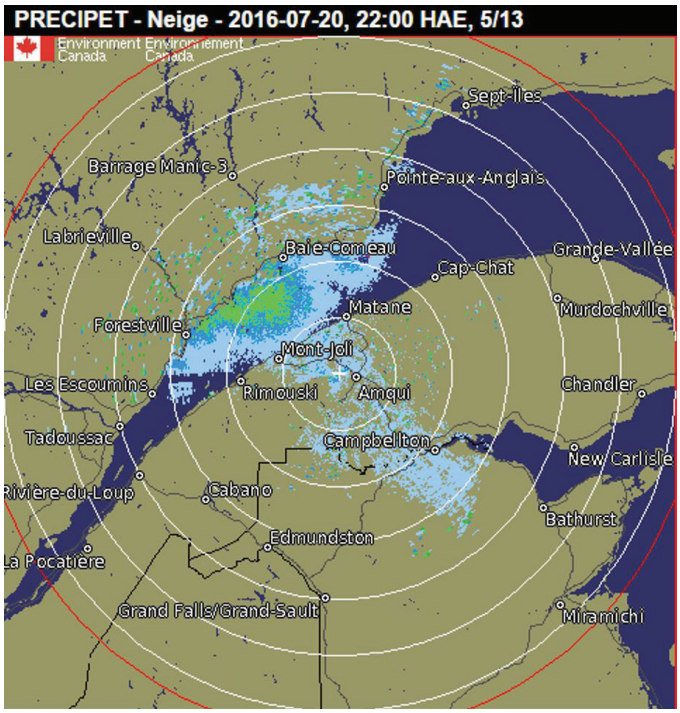
When this happens, spruce budworm populations increase quickly, creating a hotspot from which an outbreak can develop. Spruce budworm moths disperse from those hotspots, adding to existing populations or establishing new hotspots.

If this theory is correct, it may be possible to prevent outbreak spread by proactively suppressing pockets of rising population (i.e. hotspots) along the leading edge of the outbreak. Not only would this prevent populations from establishing and damaging those areas, it would prevent those areas from becoming sources of immigrant moths that would propagate spread.

The basics of the double equilibrium theory are:

- Outbreaks begin in small areas, with rapidly growing populations (hotspots).
- Moth dispersal plays a strong role in outbreak spread.
- Regional-scale budworm outbreaks can be prevented.
- Intervention early in the outbreak cycle is the correct strategy to manage spruce budworm.

A moth dispersal event in July 2016

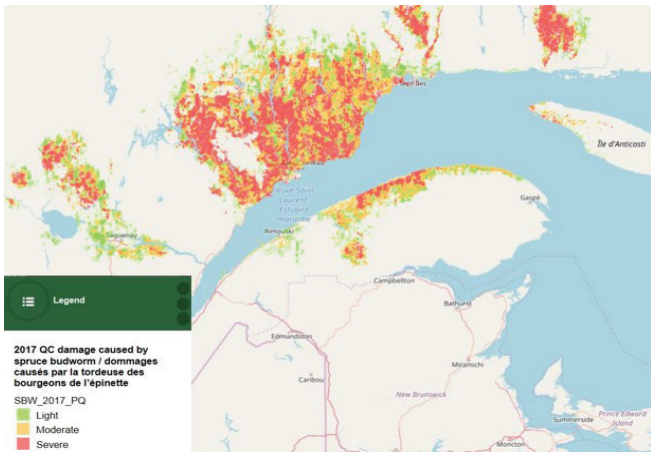


A new outbreak begins

In 2006, a new spruce budworm outbreak started in Quebec. Previous research occurred mostly during the peak and decline of outbreaks. Scientists at NRCan saw an opportunity to study a spruce budworm outbreak early in its cycle.

The research showed that the outbreak might be spreading from areas with high spruce budworm populations and that moth movement was likely contributing to the spread. These observations gave credence to the double equilibrium theory. Scientists theorized that it might be possible to control the spread of a spruce budworm outbreak by treating areas earlier in the cycle – at the leading edge of an outbreak.

Defoliation by spruce budworm in Quebec in 2014



Early intervention strategy

By 2014, the spruce budworm outbreak in Quebec had grown to 4.6 million hectares and was approaching the northern border of New Brunswick. In response to this threat, the Healthy Forest Partnership was formed to study if an early intervention approach could control spruce budworm populations at the leading edge of an outbreak, thereby preventing an outbreak from occurring. The group comprises researchers and representatives from academia, government (provincial and federal), and industry.

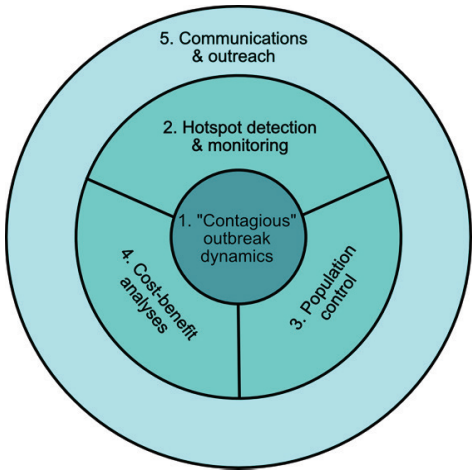
Double equilibrium population dynamics provided the core ecological justification for the early intervention strategy (EIS). EIS management involves applying insecticides on smaller areas or hotspots, that is, areas where populations are still low, but are increasing. The objective is to keep populations low enough to prevent an outbreak from occurring, with minimal or no defoliation to forests.

With smaller geographic areas to treat, the EIS presents forest managers with a lower cost option than a traditional foliage protection program. In addition, the EIS treats the forests before damage occurs, with minimal wood supply and economic losses.

Critical components of a successful EIS treatment are:

- monitoring and prioritizing treatment areas
- population control
- cost-benefit analysis
- communication and outreach

Conceptual framework for the early intervention strategy



Monitoring and prioritizing treatment areas

Intensive monitoring is the backbone of the spruce budworm EIS. Although forest managers and researchers use a variety of methods to assess spruce budworm numbers, sampling overwintering spruce budworm larvae provides the best indication of the number of budworm that will be present the following year. Sampling is the main tool for determining whether a local population needs to be controlled.

The threshold for hotspots is seven overwintering budworm larvae per branch. Once spruce budworm numbers surpass this level, the population is poised to erupt into a full-blown outbreak. Keeping populations below this threshold is the essence of the EIS.

Once hotspots are identified, treatment areas are determined by assessing the risk to the stands in the surrounding areas. Mature balsam fir and spruce stands are more susceptible than mixed wood or pure hardwood stands, and these factors are considered when deciding the area to treat.

Population control

Spruce budworm have a high reproductive capacity, with each female capable of laying an average of 180 eggs. Many natural and environmental factors contribute to mortality and help keep populations low.

Another important factor is mating success. When populations are low, female moths have difficulty finding mates, and reproductive success is affected. As numbers approach the threshold level, mating success improves, and the spruce budworm have a better chance of overcoming the natural controls that help keep populations in check.

The objective of the treatments is not to eradicate spruce budworm but rather to keep numbers below the threshold level and maintain populations at endemic levels. Another objective is to minimize harm to other organisms, including the many natural enemies of the spruce budworm.

Two insecticides (Btk and tebufenozide) are available for use in Atlantic Canada. Btk is a naturally occurring soil bacterium that causes a breakdown in the lining of the insect's gut wall and leads to death. Tebufenozide is a synthetic chemical that mimics a growth hormone found in caterpillars and causes premature moulting, leading to death. Both products are specific to Lepidopteran larvae (caterpillars of butterflies and moths) and are applied by spraying the foliage that the caterpillars eat.

Cost-benefit analysis

The costs and benefits associated with EIS for spruce budworm can be economical, environmental and social.

From a purely economic standpoint, spruce budworm outbreaks cause massive timber supply and economic losses, in part because they cover large areas and cause high tree mortality. Insect outbreaks can also influence local economies through their impact on non-timber forest products and tourism.

Ultimately, the feasibility of an EIS depends on how management costs compare with potential losses from an uncontrolled spruce budworm outbreak. The cost of an uncontrolled spruce budworm outbreak in Atlantic Canada has been estimated to be about $15 billion.

The ecological costs of a spruce budworm outbreak are significant. Dead trees increase the risk of forest fires, increase carbon emissions from the forest, and can affect water quality by increasing the nutrient load and causing stream temperatures to rise. The temperature rise can affect habitat for freshwater fish species such as trout and salmon that prefer cold water. An early intervention approach also has a lower spray footprint, as the treatment areas are substantially smaller than under a traditional foliage protection approach.

Society derives many ecological services from the forest, such as clean drinking water, clean air, recreation, aesthetics and spiritual values. A spruce budworm outbreak and widespread tree mortality put these at risk. In addition, wood supply loss could lead to mill closures and loss of jobs affecting the livelihood of families in resource-dependant communities of Atlantic Canada.

Communication, outreach and engagement

Canadians take a keen interest in their environment. Many remember past outbreaks of spruce budworm and the controversy that accompanied the large-scale insecticide treatment. Regardless of the quality of the science, the ultimate success or failure of an EIS depends on public support. Consequently, the communication and outreach strategy has always been to proactively engage audiences in a transparent manner, using experts as ambassadors.

The EIS includes consulting with government, industry, landowner organizations, Indigenous peoples, provincial and federal parks, and local media. The Healthy Forest Partnership keeps everyone informed about EIS research, treatments and the current spruce budworm outbreak through:

- the partnership website and social media
- presentations to citizens, landowners and communities
- annual general meetings to convene stakeholders
- hundreds of media interviews and meetings

Community scientist program

Public engagement in the EIS is recognized as critical to the success of the EIS. To that end, the Budworm Tracker community scientist program was launched. Each year, community scientists in Atlantic Canada, Quebec, Ontario, and the state of Maine set out budworm traps and contribute valuable information to help scientists plan their EIS. These community scientists contribute valuable research information, are ambassadors of the EIS, and help spread the word to others in their communities.

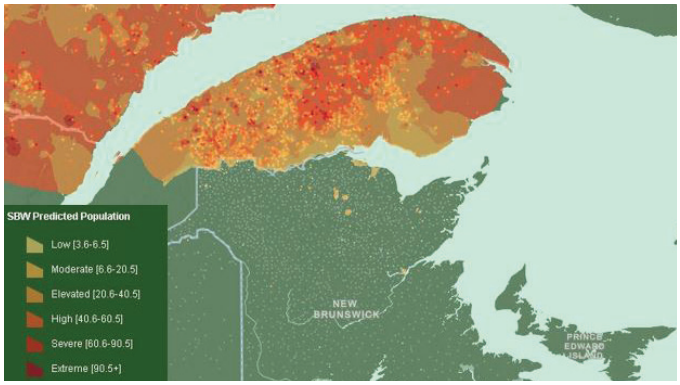
Research and results

The EIS research is yielding valuable information on managing impending spruce budworm outbreaks, and researchers remain cautiously optimistic that the EIS is helping to prevent an outbreak in Atlantic Canada.

New Brunswick has much lower infestation levels than Quebec, and defoliation is minimal because of the EIS, even along the New Brunswick-Quebec border where defoliation is severe on the Quebec side.

Since 2014, no mortality of balsam fir or spruce in New Brunswick that can be attributed to the spruce budworm and only light defoliation levels have been reported in small pockets in northern New Brunswick. However, the risk of an outbreak remains high due to the continuing epidemic in Quebec and from the risk of moth migration into Atlantic Canada. In 2020, Newfoundland and Labrador launched its first EIS treatment, after budworm surveys revealed emerging hotspots or areas that met the threshold for applying the EIS.

Defoliation by spruce budworm in Quebec in 2020



Reference

Johns, R.C.; Bowden, J.J.; Carleton, D.R.; Cooke B.J.; Edwards, S.; Emilson, E.J.S.; James, P.M.A.; Kneeshaw, D.; MacLean, D.A.; Martel, V.; Moise, E.R.D.; Mott, G.D.; Norfolk, C.J.; Owens, E.; Pureswaran, D.S.; Quiring, D.T.; Régnière, J.; Richard, B.; and Stastny, M. 2019. A Conceptual Framework for the Spruce Budworm Early Intervention Strategy: Can Outbreaks be Stopped? Forests 10(10): 910. https://doi.org/10.3390/f10100910

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