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Mitigating the effects of insect outbreaks for sustainable forest management

Highlights

- Insect outbreaks are natural and recurring disturbances that have a greater impact on wood-fibre supply than wildfires.
- Proactive rather than reactive management strategies provide the best opportunity to reduce future forest damage.
- An insect outbreak is an opportunity to design and implement strategies such as increasing species and structural diversity that favour long-term system resilience.
- Short-term local action should be balanced with regional coordination to attain long-term goals.

Insect outbreaks in boreal and sub-boreal ecosystems have a larger impact on wood fibre supply than do wildfires. This is partly because large-scale and synchronized regional outbreaks can overwhelm the capacity of forest managers to deal with outbreaks effectively. Managers also face considerable uncertainty and knowledge gaps when managing forests affected by insect outbreaks. However, current scientific knowledge about insect outbreaks is considerable. Thus, despite uncertainties about outbreak frequency and intensity, well planned and properly coordinated short- and long-term forest management choices may reduce losses and improve forest resilience to future outbreaks. In this note we propose some general and preliminary considerations to: (1) identify issues and challenges in insect outbreak mitigation; (2) provide guidance for short and long-term tactics and strategies; and (3) highlight some remaining uncertainties.

The shift from reactive to proactive management

Management response to insect outbreaks is most often reactive rather than proactive. For example, a common response to an intense outbreak is to salvage as much timber as possible before it deteriorates. This can simplify forest conditions and have other undesirable ecological impacts, thereby setting the stage for future intense outbreaks. Yet a growing body of evidence suggests that preventative strategies followed over a long period of time can improve the ability of a forest to withstand insect outbreaks. Such preventative strategies require a shift in management thinking to recognize insect outbreaks as internal ecosystem attributes (and thus integral and inevitable) rather than external disturbance agents to be avoided. No management activity, whether reactive or proactive, can eliminate the risk of future insect outbreaks. However, reactive actions taken now can have negative consequences for future forest conditions, including long-term vulnerability to insect outbreaks. By contrast proactive actions that strive for long-term forest resilience can reduce future damage. Therefore, long-term planning strategies must complement flexible short-term management tactics, balancing short and long-term goals.

Short-term tactics – tools in the toolbox

An insect outbreak is also an opportunity to creatively design and implement a more desirable future forest structure. Long-term goals of biodiversity, future flexibility, and long-term wood supply may be balanced with the short-term need to minimize wood loss. For example, the most heavily damaged and most vulnerable stands (based on stand composition, age, and structure) may be harvested first and the least impacted and least vulnerable stands may be left for last. This tactic requires flexibility in planning but may ensure a more constant wood flow over both the short term and long term. It will help prevent gaps in the forest age class structure and ensure that not all stands mature at the same time (which would render them similarly vulnerable to large-scale outbreaks). Stand conversion by cutting and replanting to alternative species, or selective removal of vulnerable trees to leave non-vulnerable species (as part of normal thinning operations) might also be considered as short-term tactics. Focused sanitation and salvage operations can reduce insect populations or timber losses, while maintaining less vulnerable stands, tree species or sizes that will be important in providing timber and habitat after the outbreak is over.

Long-term strategy

Most insect species that reach outbreak conditions have tree species and age preferences. This results in stands showing different vulnerability to outbreaks (i.e., the likelihood of trees suffering growth loss or mortality due to attack). Apart from a simple reduction of the preferred host, diverse stands and landscapes may offer additional protection through a variety of mechanisms. As research has demonstrated, some insects have more difficulty finding their hosts within mixed species stands, and natural enemies and competitors of such insects are usually more abundant within diverse stands.

Similar mechanisms operating at broader scales can further enhance landscape resistance to insect outbreaks. Unpredicted outbreak events are common because insect outbreaks result from complex processes interacting across scales. Long-term planning can help mitigate these uncertainties by avoiding clearly undesirable landscape conditions (e.g., high vulnerability due to low species and genetic diversity, similarly-aged forests) in favour of more desirable landscape conditions (e.g., high species and genetic diversity, and multiple age classes across a range of scales) that provide greater flexibility and options for both ecosystem recovery and industry response. Therefore, creating a mosaic of age structures and species composition across the landscape can improve the forest's ability to withstand insect outbreaks.

Research Project: Reducing Uncertainty in Forest Sustainability Caused by Insect Outbreaks

This project, funded by the Sustainable Forest Management Network, is led by a team of researchers from universities and science centres in both Canada and the United States.

The project focuses on three of the most important insect pests in Canada: mountain pine beetle, spruce budworm, and forest tent caterpillar. Project objectives are to:

1. Improve estimates of outbreak impacts by combining field, survey and remotely sensed data;
2. Reveal how historical outbreaks have varied over time and space, using tree ring analysis and survey data;
3. Understand how stands respond to disturbance by means of historical and ecological studies;
4. Understand how stand structure and composition influence outbreaks at different phases; and
5. Identify commonalities in the process, patterns and consequences of these three different insects.

For more information, visit:
http://www.er.uqam.ca/nobel/c3016/

Uncertainties limiting proactive management

Despite significant advances in our understanding of outbreak dynamics, many uncertainties about insect outbreaks remain and more are expected to develop as climate change occurs. In particular, knowledge is lacking on long-term consequences of management activities performed at an operational (landscape-regional) scale. Clearly, scientists need to partner with government agencies and the forest industry to perform appropriate long-term and broad-scale experiments and to improve upon the quality of long-term insect surveys. The following is a partial summary of key uncertainties currently limiting proactive management.

Monitoring insect outbreaks and quantifying insect damage

A key limitation to proactive response to insect outbreaks is early detection of rising pest populations. Unexpected consequences of large-scale outbreaks could be predicted and prevented by means of improved insect surveys. Those conducting insect surveys should quantify outbreak severity as precisely as possible, recording the species and size or canopy position of trees under attack, as well as overall defoliation (or mortality) levels and their extent. Remote sensing imagery could help with this early detection, though research is needed to determine reliable, accurate and affordable systems for operational use. Similarly, current methods for broad-scale assessment of insect damage (e.g., aerial surveys) vary widely in their ability to accurately assess damage. Here again remote sensing has the potential to improve damage assessment.

The spillover effect

Evidence from many different insect outbreaks shows that insects attack non-preferred host trees during large-scale outbreaks. We refer to this as the "spillover effect." For example, the mountain pine beetle can attack and kill small pine trees in the forest understory or in plantations during the outbreak's peak, even though such trees would not normally be considered susceptible. This shift to less preferred trees can occur during any severe outbreak regardless of the insect species.

Outbreaks affect non-host trees indirectly

We know that insect outbreaks severely affect host species directly, but they can also impact non-host species indirectly – both negatively and positively. As insects kill an increasing number of trees, the forest canopy opens, which in turn causes changes in microclimatic conditions affecting non-host species. Over time, these changes can negatively affect growth and development of non-host vegetation, even causing some non-host trees to die. In contrast, host tree mortality may also lead to the release of non-host species and to the maintenance of shade-intolerant species, a shift in species dominance, or an alternation between species susceptible to different insects (e.g., a transition from trembling aspen following forest tent caterpillar outbreaks to balsam fir, which is then affected by spruce budworm outbreaks, and so on).

When different types of disturbance interact

Each insect species has its own peculiarities in the characteristics of its outbreaks that can be further complicated by interactions with other pest species and different types of disturbance. Reciprocal interactions between insect outbreaks, wildfire, and harvesting practices are well recognized, but poorly understood. For example, mountain pine beetle and spruce budworm outbreaks can produce large amounts of dry woody fuels. Dead foliage remaining on trees means that fire is more likely to reach the crown and exhibit more extreme behaviour than in a green forest. However the change in fire risk can vary depending on the intensity of the damage, the length of time following the disturbance, and the composition of the remaining forest. On the other hand, suppressing fire can result in large areas of even-aged mature trees that are more prone to insect attack. Similarly, partial harvesting techniques that promote maintenance of advance regeneration can also increase the presence of spruce budworm host species such as balsam fir, whereas short-rotation clearcutting often increases the abundance of aspen, which is a favoured host of the forest tent caterpillar.

Understanding these interactions is very important to managing for pest-resistant forests, and remains a topic of ongoing research.

The role of climate change in insect outbreaks and vice versa

Climatic change will affect forests greatly and thus will change how insect outbreaks unfold. The growth rate, larval development, dispersal and overwintering success of most insects are directly influenced by significant changes in temperature and precipitation. Consequently, an increase in global temperatures can change the geographic distribution and population dynamics of insect pests. Managers should keep in mind that stands currently outside the range of a given insect pest could be within its range in the near future.

In the bigger picture, insects can kill or reduce the growth and regeneration of host trees, thus reducing carbon storage potential (we refer to storing carbon as carbon sequestration and to living forests as carbon sinks). As foliage and dead woody material decomposes, carbon dioxide is released, meaning that insect outbreaks can change regional carbon dynamics, and their role in global warming should be reconsidered. On the other hand, during outbreaks, insects such as mountain pine beetle or spruce budworm do not kill all trees (Figure 1), and survivors still act as carbon sinks and often grow faster after some of their competition dies. Therefore, forest managers should consider managing affected areas to maintain surviving trees rather than using destructive rehabilitation methods (i.e., harvesting and replanting) in order to avoid creating age-structure gaps and susceptible future landscapes, as well as to reduce the future role of a single age-cohort or susceptible species as a positive feedback in global warming.

Figure 1. Example of 'secondary structure,' green trees of non-susceptible species surviving an intensive mountain pine beetle attack. Photo courtesy of Phil Burton, Canadian Forest Service, Natural Resources Canada.

What does it all mean for managers?

Forest managers can reduce potential losses of valuable timber to insect outbreaks by implementing short-term tactics such as improved harvest scheduling, careful salvage logging, and targeted insecticide use. However, by also implementing a long-term strategy of managing for tree species diversity and forest age structure at stand and landscape scales, managers can promote more resistant forests. The aim is to achieve a balance between short and long-term goals, which often means trading some short-term resources for long-term system resilience. Long-term strategic goals should guide short-term management tactics and be re-evaluated during outbreak crises. Insights from each insect species and each region can inform others, but there are important regional and biological differences in the way insect outbreaks behave, so taxa-specific knowledge, local experience and innovation are important. Forest managers must also keep in mind implications of the shifting range of many insects due to climate change and forest practices.

Local forest managers often cannot perform such landscape-scale actions without the collaboration and coordination of higher-level policy makers. Therefore, we highly recommend that both levels of decision-makers pursue the common goal of a more resilient forest landscape. Corporations, agencies, and communities involved in forest management need guidance for both short-term (e.g., harvest re-scheduling) and long-term (e.g., promoting forest resistance) actions. Higher-level decision makers have the power to put tactics and strategies into effect at multiple scales. A combination of short-term and long-term approaches coupled with more detailed and extensive monitoring, involving both ground-based surveys and remotely sensed or aerial mapping, provides the best set of tools to reduce impacts of insect outbreaks.

These approaches will also decrease uncertainty, and improve our knowledge base. However, balance is the key. Higher-level strategic planning that is too rigid can decrease system resilience by changing the nature of the system at increasingly broad scales. Local flexibility must be as important as broad-scale strategic goals. This means that high-level policy makers should recognize local knowledge and innovation, and allow it to flourish under the broader aim of system resilience.

Future insect outbreaks may well be worse than those of the past. Forests worldwide are tending toward simpler composition and structure and our climate is undergoing significant changes. Ongoing scientific research suggests that forest planners, managers and policy makers should include outbreak contingency plans and insect risk reduction strategies in all forest management plans, paying close attention to both short and long-term forest conditions.

Management Implications

- Forest managers and high-level policy makers should balance short-term treatments with long-term goals to mitigate the effects of insect outbreaks.
- Improved harvest scheduling, focused salvaging practices and targeted use of insecticides can reduce short-term losses.
- Maintaining forest diversity (composition and age structure) at different spatial scales can mitigate outbreak effects over the long term.
- Improved survey technologies and long-term research are necessary to reduce the remaining uncertainties about insect outbreaks, such as the spillover effect, non-host legacies, disturbance interactions, and the implications of climate change.

Further reading

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