QuickNotes

Science summaries from fRI Research

Dynamic species distribution modelling to predict mountain pine beetle boreal invasion

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Even though the aggressive direct control strategy implemented in 2006 by the Government of Alberta has minimized mountain pine beetle (MPB) impacts (Carroll et al. 2017), epidemic populations continue to spread eastward, and boreal jack pine forests remain at high risk of invasion (Cooke and Carroll 2017). Effective tools to predict the potential for spread into the transcontinental boreal forest are critical. This research aims to develop models to predict current and future MPB dispersal capacity on an annual basis and therefore directly addresses Research Theme 2 (MPB Dispersal) of the fRI Mountain Pine Beetle Ecology Program. The proposed approach is distinct from existing models (e.g., MPBSpread) since it is not reliant on detailed forest inventory data that are lacking for much of the western boreal forest. Results also have implications for detection and control efforts (Theme 3), ecological and social impacts (Theme 4), and wildfire behaviour after MPB (Theme 5) as we will generate information on factors affecting MPB establishment under the influence of climate change. We will determine whether the niche for epidemic MPB has been conserved during its range expansion and if niche mismatches have arisen due to local adaptations or evolution. We will also calculate MPB niche stability and whether the niche is expanding/evolving over time and determine if the entire area defined by the niche has been invaded. Our results will facilitate more targeted and coordinated MPB surveillance and management programs throughout the western boreal forest.

The rationale for this research is based on the reality that the Canadian boreal forest faces unprecedented threats from invasive forest pests that can cause irreversible damage to the environment (Gauthier et al. 2015). The number

Federal-Provincial MPB Research Partnership

Mountain Pine Beetle remains a severe threat to Alberta's pine forests despite the province making positive progress in controlling its spread within the province and reducing the risk to the rest of Canada.

Natural Resources Canada and Alberta Agriculture and Forestry have provided funding to a suite of projects with the goals of limiting the spread of Mountain Pine Beetle and mitigating damages where it has already invaded.

Natural Resources Canada Ressources naturelles Canada

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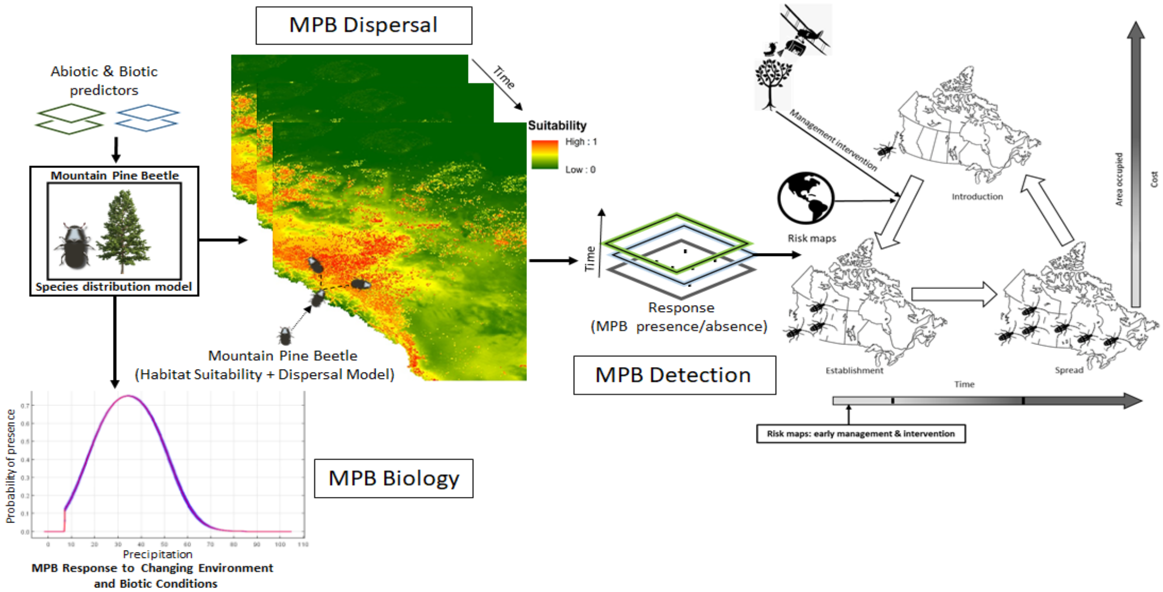
Alberta Agriculture and Forestry



Proposed modelling framework to create a dynamic species distribution model (DSDM) to predict the risk of establishment of MPB in the boreal forest

of new introductions and interceptions of forest invasive species is escalating at an alarming rate (Humble and Allen 2006). Moreover, native forest insects (e.g., some aggressive bark beetle species) are expanding their ranges and are becoming invasive pests, causing substantial damage to Canadian forests (Raffa et al. 2008). Alien- and native-invasive species threaten Canada's capacity to provide long-term economic, ecological and social benefits that range from fibre supply, jobs, carbon storage, nutrient cycling, water and air purification, soil preservation and maintenance of wildlife habitat (NRCan 2013).

Anthropogenic activities further drive global and regional spread of invasive species (Seebens 2019). There is a positive correlation between a country's economic activity, as measured by GDP, and the number of invasive pests. The number of new introductions and interceptions of FIS is escalating at an alarming rate and the movement of goods and people appears to be responsible for most of the documented invasions (Seebens 2019). Canada, as one of the world's wealthiest nations, exports and imports over $500B worth of goods (2014 estimates); thus, putting Canada's forests at increasing risk into the future.

The key to reducing the risk of negative impacts from alien- and native-invasive species lies in vigilant biosurveillance to increase preparedness and facilitate early interventions through robust interception and surveillance frameworks (Lafond et al. 2020). Unfortunately, biosurveillance programs are costly and require regional prioritization. Canada's National Forest Pest Strategy (NRCan 2013), supported by the forest industry, provinces, territories, regulatory agencies and federal departments, identifies preparedness, early detection and rapid interventions as key to managing invasive species with minimal or no disruption to global trade. Developing efficient detection systems for biosurveillance of invasive species has become an urgent task. Early response tactics involve surveying and monitoring areas at risk of invasion to find infestations in their earliest stages of establishment, while they are most amenable to management (Srivastava et al. 2020). To identify areas at risk of invasion, species distribution models (SDMs) show promise. SDMs are based on the classical assumption that species will be able to establish populations in areas outside of their native range that closely match the environmental conditions of their native distributions (Wiens 2011; Srivastava et al. 2020). However, classical SDMs have been criticised for their inability to include dispersal and other factors relating to biotic interactions. An increasingly popular approach to these concerns is coupled SDM models or dynamic species distribution models (DSDMs). DSDMs incorporate dispersal and landscape features into projections of species distributions and in few cases population growth (Mieszkowska et al. 2013). Thus, by matching environmental conditions while accounting for species specific biological interactions, researchers can discern meaningful information about invasive species potential range in new habitats and forest managers can proactively monitor those areas to detect the spread of invasive species and implement relevant management tactics.

A critical limitation of existing models of spread by epidemic MPB is that they are reliant on habitat suitability surfaces derived from forest inventory data. This reliance limits model applicability to jurisdictions with detailed data such as BC (VRI) and Alberta (AVI) and precludes broader assessments of MPB spread potential into the boreal forest where relevant forest inventory data are lacking (i.e., SK, MB). Our research will construct a MPB DSDM using detailed data from Alberta to develop an idealized framework for estimating risk of epidemic MPB infestation in areas where less or no data are available. More specifically, we will integrate emergent habitat suitability models derived from vegetation resource inventory data (e.g., predicted r-values), remote sensing (RS) data, climate data and dispersal models (i.e., MigClim and MPBSpread) to generate current and future predictions of MPB occurrences (Fig.1). We hypothesize that integration of dispersal and process-based predictors that capture biotic and abiotic interactions, will improve the predictive power of SDMs

We will create annual MPB distribution maps beginning in 2009 and projecting into the future to assess the potential for further range expansion and identify directional trends over time and space. We will develop base SDMs and DSDMs for Alberta and then apply them to the remainder of the western boreal forest to predict epidemic MPB habitat suitability and spread. Our approach will also allow us to identify key information relating to MPB biology in terms of the beetle's response to changing environmental conditions. In addition, we will investigate the similarity of the MPB niche in different provinces to further define the potential for future range expansion. Mismatches in MPB niches may arise from local selection and adaptation as the beetles encounter new forest types (e.g., jack pine), but its relevance to spread is currently unknown. Our goal is to identify these differences while providing insights that will be useful in understanding range expansion and invasion potential of MPB. This information will facilitate targeted decision-making toward effective management of MPB in the future – an approach developed by V. Srivastava and currently used by the Canadian Food and Inspection Agency and US Forest Service for pest risk analysis .

Our research will allow predictions of current and future epidemic MPB spread under climate change in Alberta and throughout the boreal forest, thereby contributing to all of the key outcomes identified by Anon (2020): limit the spread of MPB (i) into the eastern boreal forest, and (ii) along the eastern slopes of Alberta; (iii) mitigate damage to Alberta's pine resources in locations where MPB is already established; and (iv) generate knowledge and innovative management techniques to support MPB management. More specifically, our research will contribute to early detection and effective management of existing MPB in Alberta, and infestations that may occur to the east in future through detailed risk distribution maps that will facilitate targeted pest management activities. Furthermore, our research has the potential to be directly integrated into land-use planning processes (e.g., spatial harvest sequences) by projecting MPB occurrence and population dynamics metrics, and identifying high probability (and therefore risk) pathways for invasion.

Objectives

1. To develop an idealized SDM framework to generate time-series MPB distribution maps by integrating annual RS and biotic predictors with an existing habitat suitability model,
2. To develop a dynamic SDM (DSDM) to simulate dispersal of MPB from areas of high risk,

3. To validate the MPB SDM and DSDM using detailed presence/absence data derived from the invasion of Alberta pine forests that began in 2006, and data from ongoing monitoring of the invasion front in Saskatchewan,
4. To apply the MPB SDM and DSDM to predict current areas of high probability of MPB occurrence in the western boreal forest and future risk of continued eastward expansion (i.e., into Saskatchewan and Manitoba) under climate change,
5. To compare MPB niches in British Columbia, Alberta and Saskatchewan to understand MPB niche similarity, stability and expansion.

Expected outcomes

The research team will remain in direct contact with the forest health offices in Alberta and Saskatchewan and the forest industry as our research progresses and if conditions permit we will participate in Annual Research Forums. Research manuscripts will also be an important outcome of this research; for example,

1. Srivastava V., Carroll AL., Seely B., Welham C and McIntosh R. Time-series maxent modelling for native invasive species- Incorporating time and population fitness into the traditional species distribution modelling framework. Target journal- Ecography.
2. Srivastava V., Carroll AL., Seely B., Welham C and McIntosh R. Predicting Mountain Pine Beetle Potential Range Expansion and Invasion Potential in Canadian Boreal Forests, Now and In the Future. Target journal-Forest Ecology and Management.

Implications for Land Management

The outcomes of our research have multiple implications for operational decisions, risk assessment and policy development such as:

- Risk distribution maps to facilitate targeted management activities in areas with established MPB infestations.
- Risk distribution and invasion pathway maps that will facilitate planning and proactive management activities to minimize the spread and impact of expanding MPB infestations.

Expected date of completion of the project

March 31, 2023

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