Popular Summary

Challenges in defining the disturbance regimes of northern British Columbia

Phil Burton[1], **Steve Taylor**[2], **and Gurp Thandi**[3]

Abstract

The British Columbia Natural Disturbance Database is analyzed for patterns of wildfires and insect outbreaks in northern British Columbia during the period from 1961 to 2000. In terms of annual area affected by these disturbances, forests are generally more likely to experience insect outbreaks than wildfires, but with distinctive differences among ecological zones. Multivariate analysis of 21 northern ecoregions reveals clustering along a gradient of maritime to continental influences, resulting in decreasing importance (from west to northeast) of western balsam bark beetle and increasing importance of eastern spruce budworm and fire. Existing data provide an incomplete picture of the disturbance ecology in most parts of the province, and the characterization of a suite of infrequent events is constrained by the size of sampling windows in space and time. Progress is being made in characterizing the individual and joint probabilities of disturbance by various agents at a variety of scales, which should improve the ability of policy makers and managers to manage risk.

KEYWORDS: *boreal cordillera, boreal forest, disturbance history, disturbance regime, ecological land classification, ecoregions, forest fires, insect outbreaks, risk analysis, wildfire.*

Contact Information

1 Manager of Northern Projects, Pacific Forestry Centre, Canadian Forest Service, Natural Resources Canada, University of Northern British Columbia, 3333 University Way, Prince George, BC V2N 4Z9. Email: pburton@pfc.cfs.nrcan.gc.ca

2 Forestry Officer, Natural Resources Canada, Canadian Forest Service, Pacific Forestry Centre, 506 West Burnside Road, Victoria, BC V8Z 1M5. Email: staylor@pfc.cfs.nrcan.gc.ca

3 Geographic Information Systems Technician, Natural Resources Canada, Canadian Forest Service, Pacific Forestry Centre, 506 West Burnside Road, Victoria, BC V8Z 1M5. Email: gthandi@pfc.cfs.nrcan.gc.ca

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Introduction

Throughout the history of forest management, efforts have been made to protect timberlands from the destructive forces of uncontrolled fires, insects, and other agents of tree mortality. It is recognized that the susceptibility of forests to damage from these various biotic and abiotic agents is largely under the control of climate, terrain, and current forest composition. Year-to-year variation in weather and the population levels of insects and fungi make the annual incidence of tree mortality difficult to predict. Yet over the long term, distinctive patterns of forest disturbance are evident in their legacy of forest age-class structure, patch size distributions, and species composition (Frelich 2002).

Considerable effort is placed on the control of some forest disturbances such as wildfire, while scant attention is paid to other less dramatic causes of tree death. Forestry practices can sometimes prevent or lessen the impact of some disturbances (e.g., by managing species composition and age through harvesting and silviculture, by designing roads and cutblock edges to minimize the risk of landslides and windthrow). Natural disturbances are also recognized as important generators of diversity in forest landscapes, creating open habitats at a variety of scales and initiating or releasing new growth that had previously been suppressed by mature trees (Van der Kamp 1991; Parminter 1998). The importance of natural disturbances to commercial fibre production and to biodiversity conservation, coupled with our limited ability to prevent them, compels forest managers to operate within the constraints of regional disturbance regimes. Indeed, the emulation of natural disturbances is considered an appropriate approach for protecting biodiversity at the habitat or coarse-filter level (Bergeron *et al.* 2002; Lindenmayer and Franklin 2002).

The purpose of the research described here is to explore broad disturbance patterns found in the forests of northern British Columbia, using existing data of mapped wildfires and insect outbreaks. We look at regional differences and examine some of the associated environmental factors and consequences of those regional differences. This analysis focuses on that portion of the Boreal Cordillera Ecozone found in British Columbia, and contrasts its attributes with those of neighbouring ecozones. We explore the disturbance spectra of northern ecoregions, and discuss alternative means of portraying, predicting, and mapping forest disturbance regimes.

The British Columbia Natural Disturbance Database

The Canadian Forest Service and the B.C. Ministry of Forests and Range have been collectively documenting the locations of forest fires and insect outbreaks since early in the 20th century. Delineated as mapped "events" each year on paper, linen, mylar, and eventually digital maps, these records constitute a immense, multidimensional database on the recent history of major disturbance agents in British Columbia's forests. This information has been recently compiled in a single digital database at the Pacific Forestry Centre (Taylor 2005). Coverage is understandably incomplete for some insect species and for remote areas, especially in past decades. So for the purposes of this exploratory analysis, we limited our examination to fire and the 15 most important forest insect pests, for the 40-year period from 1961 to 2000.

The British Columbia Natural Disturbance Database consists of separate "layers" of data in an ArcInfo geographic information system (GIS), each one mapping the area of forest affected by each disturbance agent in each year. These layers were intersected with various levels of ecological land classification and associated summaries of environmental attributes (Marshall *et al.* 1999), following the Canada-wide framework of ecoregion classification (Environment Canada 2005). The database file generated from the intersection of annual disturbance events and ecological classifications was then imported into the SAS statistical analysis system to determine mean annual disturbance rates for each agent. Values were converted from hectares per year to percent per year using the documented area of vegetated land cover for each region under consideration. Mean disturbance intervals (in years) were calculated as the inverse of mean disturbance rates in percent per year. These values were compared for different ecozones and ecoregions, and the combination of 16 disturbance agents was summarized using principal components analysis (PCA). The prevalence of individual agents and PCA scores was then correlated with environmental attributes at the ecoregion level.

Patterns and Correlations

Over the 40-year period under consideration, the area of forest annually affected by insect outbreaks typically has been greater than that affected by forest fires across most ecoregions of northern British Columbia. Nevertheless, distinctive differences exist in the prevalence of fire and outbreaks of various insect species in different parts of the broad region north of approximately 52° latitude. Fire (from both lightning and human ignitions) was most prevalent in the Boreal Plains Ecozone, where it burned 0.196% per year. In contrast, forest fires burned an average of only 0.015% of the northern portions of the coastal Pacific Maritime Ecozone every year, while the Montane Cordillera (0.059% per year) and the Boreal Cordillera (0.157% per year) ecozones were intermediate. The area of forest annually affected by insect outbreaks was similar to that of fire in the Boreal Cordillera (0.165% per year), but the cumulative effects of defoliators and bark beetles were much greater (in area annually affected) than that of fire in the Taiga Plains (1.664% per year) and Boreal Plains (0.289% per year) ecozones. The Montane Cordillera supports a wide diversity of insects capable of killing forest trees, at an average rate of 1.100% per year.

If the incidence of fire remains relatively uniform over time, and if all stand ages are uniformly susceptible to burning, then more than one third of a forest will consist of stands older than the calculated fire return interval (Van Wagner 1978). It is interesting to compare the mean return interval of insect outbreaks with that of wildfire in different ecological zones, as longer fire return intervals imply a greater likelihood that insects will attack stands before they burn. In the Taiga Plains Ecozone, the eastern spruce budworm (*Choristoneura fumiferana*) attacks large areas of white spruce (*Picea glauca*) and can be a more important agent of tree mortality than is fire. Similarly, the forest tent caterpillar (*Malacosoma disstria*) can repeatedly attack trembling aspen (*Populus tremuloides*), especially in the Boreal Plains Ecozone. No single insect species is more important than fire in the Boreal Cordillera, though collectively they are just as likely to affect forest stands as are fires. In the Montane Cordillera, on the other hand, stands are more likely to be attacked by 2-year cycle budworm (*Choristoneura biennis*), western balsam bark beetle (*Dryocetes confusus*), forest tent caterpillar, mountain pine beetle (*Dendroctonus ponderosae*), spruce beetle (*Dendroctonus rufipennis*) or western spruce budworm (*Choristoneura occidentalis*) than by fire.

Further differences in the combination of insect pests and the incidence of fire can be seen among individual ecoregions within ecozones. When British Columbia's boreal and northern sub-boreal regions are analyzed by PCA, the first axis is dominated by increasing amounts of eastern spruce budworm and fire, and decreasing amounts of western balsam bark beetle; the second axis is associated with increasing amounts of western balsam bark beetle and (to a lesser degree) eastern spruce budworm (Figure 1).

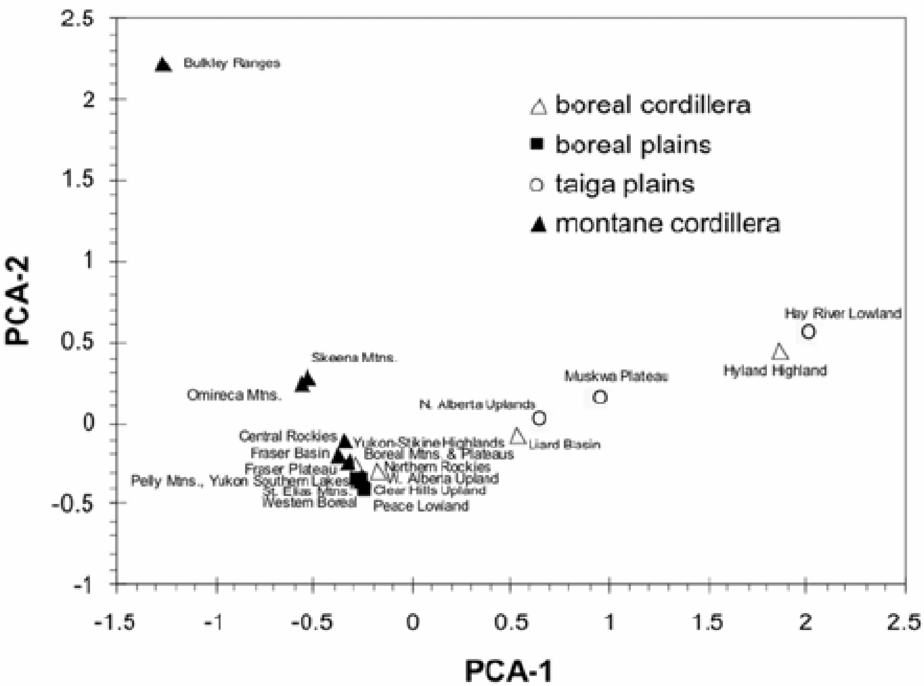

FIGURE 1. Principal components analysis of a 40-year history of wildfire and insect outbreaks in the ecoregions of four interior ecozones in northern British Columbia.

The first PCA axis is significantly correlated with lower mean winter temperatures, lower elevations, and higher growing degree-days above a 15°C threshold, indicative of a general gradient of increasing continentality; we found no significant environmental correlates with the second PCA axis. Plotting the first and second PCA scores of 21 northern ecoregions results in clusters that cross ecozone affinities. For example, the Bulkley Ranges Ecoregion in the west stands out as characterized by western bark beetle outbreaks and a general absence of fire, forest tent caterpillar or spruce budworms. The Liard Basin and Hyland Highland ecoregions, though part of the Boreal Cordillera Ecozone, behave much more like part of the Boreal Plains Ecozone, with frequent wildfires and outbreaks of eastern spruce budworm. Although most (13 of 21) northern ecoregions can be mapped as experiencing a similar spectrum of disturbances, others are clearly more extreme in their coastal or continental affinities (Figure 1).

Challenges and Implications

We recognize that this is an incomplete picture of the disturbance ecology of northern British Columbia. We have been trying to classify the disturbance spectra of ecodistricts and smaller geographic areas independent of ecological land classification, but such areas are often too small to have experienced the full range of natural disturbances (over the 40-year period under consideration) expected from the regional ecology. This is a limitation of working with mapped data of historic events, in that the calculation of disturbance rates is sensitive to the size of the window used. Another problem is that information on many natural disturbance agents is missing, notably the extent of damage from windstorms, landslides, avalanches, and floods. Although insect outbreaks have been mapped according to several levels of severity, we have no such stratification of fire severity. It is well known that different intensities of disturbance determine not only the species and sizes of trees that may die or survive, but also influence the trajectory of post-disturbance successional recovery (Frelich 2002). Older fire maps are especially uneven in the degree to which they portray islands and fingers of unburned forest within the polygons describing large fires.

Few disturbance rates have been stable over the last several decades, with fire and insect outbreaks decreasing in some ecoregions and increasing in others. Wildfires have a strong human-caused component, even in remote northern areas. Insect outbreaks, particularly bark beetles, are strongly driven by forest age dynamics and so may be somewhat controllable to the extent that management can manipulate forest age structure. Timber harvesting is relatively minor in much of the north, and one might argue that most forests in northern British Columbia are essentially unmanaged in that the amount of timber lost to natural mortality exceeds the amount harvested (Clutter *et al.* 1983). Thus, managers have to work within and react to the natural disturbance regime when forests are in a transition from a natural to managed state. The recent province-wide eruption of mountain pine beetle is particularly unprecedented (see *http://mpb.cfs.nrcan.gc.ca/biology/introduction_e.html*), suggesting that an historic approach to the analysis and emulation of natural disturbance regimes can take us only so far in our efforts to understand and sustainably manage our forests.

At some point, process models of disturbance agents and their combination will provide more useful information than historical analysis. For example, Taylor *et al.* (2005) have recently developed logistic regression models for predicting the incidence of wildfires (started by lightning, people, or both) in 1-km^2 cells across the province. Drawing on prevailing fire weather index norms, terrain attributes, lightning density, road density, and descriptions of forest type and land cover, a similar approach could predict the incidence of various insect outbreaks or the PCA scores indicative of a particular combination of insects and fire. This takes us closer to a unified "risk analysis" of the factors threatening forest trees, stands, and landscapes. The mapping of risk and hazard classes is already the approach taken by geomorphologists in assessments of terrain stability, avalanche dangers, and flood return probabilities. We hope to incorporate these agents in descriptions and models (both statistical and simulation) of landscape disturbance regimes. Although some options may exist for disturbance risk reduction through forest management, we suspect that a more promising avenue to explore will be the repackaging of forest management units to reduce overall risk.

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