# The effect of landscape pattern on mountain pine beetle spread.

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**Abstract**

Landscape patterns of forested ecosystems influence the operation of ecological processes. The extent to which landscape patterns influence the spread of forest insects across a landscape is thought to vary for different insect species. This study investigates the effect of landscape patterns on the spread of the mountain pine beetle (Dendroctonus ponderosae). Using two years of mountain pine beetle survey data from British Columbia, Canada, we calculated the average rate of spread by associating nearest neighbour infestations from consecutive years. We define landscapes of 1 km and approximately 30 km resolution for computing landscape metrics measuring forest patchiness and forest edge. Spread clusters were identified using local indicators of spatial association (LISA) and significance was determined by randomization. Preliminary results indicate an epicentral spread pattern at 30 km resolution and more variable spread patterns at 1 km resolution. Furthermore, spread of mountain pine beetles may be facilitated by edge habitats at the 1 km landscape size.

## Background and Relevance

Forest ecosystems experience frequent changes to spatial patterns and therefore often exhibit substantial spatial heterogeneity (Riiters et al. 2002). Harvesting removes habitat and increases fragmentation (Mladenoff et al. 1993). Natural disturbances such as insect infestation, windthrow, fire, and landslides impact the configuration of forest landcover. Within this dynamic environment, species respond to landscape patterns and pattern changes. Landscape pattern indices (LPIs) offer a useful way of capturing the spatial pattern of a forested landscape in order to assess the impact of pattern on a particular species or process (Gustufson 1998).

The impact of landscape patterns on populations in forest ecosystems has primarily focused on the habitat requirements and responses of species in order to understand spatial ecological relationships and ultimately plan for species conservation (e.g., Hargis et al. 1999). While the role of insects as disturbance agents, changing forest patterns, is the subject of extensive research, the impact of landscape pattern on insect population processes is not. The general effects of forest fragmentation on forest ecosystems include changes in solar radiation, wind exposure, and hydrologic cycles (Saunders et al. 1991).

Our objectives in this research are two fold. Firstly, we aim to establish empirically the rate of spread for mountain pine beetles during outbreak populations. Estimates of average dispersal distance from field-based mark recapture experiments (i.e., 30 m in Safranyik et al. 1989) suggest that beetles typically disperse locally within stand, with environmentally-driven stochastic long distance dispersal events. We aim to establish the average rate of spread over a two year period in order to identify the approximate spatial scale at which beetle spread is occurring. The rate of spread will then be used to help identify the size of landscapes at which to assess pattern effects on spread, our second objective. In order to use LPIs to address the impact of pattern on spread, they must be calculated relative to the process under investigation (Wiens 1989), and assessed at multiple scales to determine the stability of such effects (Wu 2004). Understanding if and how landscape pattern influences spread of mountain pine beetles will yield information regarding both dispersal ecology and strategies designed to mitigate and manage rapidly spreading beetle populations (see Carroll et al. 2006).

## Methods and Data

Locations of mountain pine beetle presence in the years 2000 and 2001 were differenced to create a new dataset indicating the locations of newly colonized habitat in 2001. The shortest distances between newly infested locations in 2001 and locations of beetle presence in 2000 were then d0etermined. The distribution of shortest distances were used to assess the nature of mountain pine beetle spread over one year, and infer the spatial scale at which spread was occurring

We selected LPIs that characterize two aspects of spatial pattern that describe the nature of forest fragmentation: the amount of forest edge and the 'patchiness' of the forest landscape. For each spatial scale, our goal was to characterize the spread of mountain pine beetles between 2000 and 2001. To isolate spatial variability in spread, we computed a bivariate local indicator of spatial association (LISA) on landscapes which summarize the number of pixels with infestation in 2000 and new infestations in 2001. The bivariate LISA is based on the local Moran's I statistic, which is a local version of the Moran's I spatial autocorrelation index (Anselin 1995).

The bivariate local Moran's I values can be categorized into one of four classes based on the Moran scatterplot. The high-high category indicates a landscape had a large number of infested cells in 2000 and a high level of spread to neighboring cells in 2001, low-low indicates relatively few cells infested in 2000 and little spread to neighboring cells in 2001, low-high indicates a small number of infested cells in 2000 and spread to a large number of cells in 2001 and high-low indicates a large number of infested cells in 2000 and little spread to neighbouring cells in 2001. For ease of interpretation, we refer to these as classes of spread clusters: intense, incipient, diffuse, and focal.

Landscapes were partitioned based on four categories of spread clusters: intense, incipient, diffuse and focal. LPIs were computed for each landscape and their distributions were compared by plotting the mean for each of the spatial association categories. Examining changes in the mean of each LPIs across categories and between spatial scales relative to changes in proportion (PF), allowed us to draw some general conclusions about the nature of pattern effects on spread.

## Results

The overall pattern of spread in British Columbia varied from epicentral at the 30km scale, to much more variable at the 1km scale. For 30km landscapes, landscape pattern indices appear to be driven primarily by forest proportion. For 1km landscapes, spatial patterns indicating rapid spread were associated with higher edge density and total forest edge, and higher indices representative of forest patchiness. This suggests that forest fragmentation may enhance the spread of mountain pine beetles at a local scale.

## Conclusions

The relationship between forest fragmentation and mountain pine beetle spread has important consequences for forest management. In western Canada, the ongoing outbreak is expanding the mountain pine beetle's geographic range as climate change redefines the historic boundaries delineated by latitude and elevation (see Carroll et al. 2006). Further, there is interest in managing for spread into the boreal forest where jack pine (Pinus banksiana) is considered a susceptible host species for mountain pine beetle. Our results suggest that increasing forest fragmentation at small scales through patch harvesting may actually facilitate the spread of mountain pine beetles across the landscape. At larger scales, the effects of fragmentation appear to be no greater than what occurs due to loss of habitat. Identifying a scale at which landscapes are not crossable by mountain pine beetles remains an elusive, if not impossible task.

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