Geog 613
Term Project

Influence of Landscape pattern on Regional Distribution of Mountain Pine Beetle: Application of Terrain Analysis in the Rocky Mountain Foothills of Northeastern British Columbia.

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November, 2007

Abstract

The spatial pattern of mountain pine beetle infestations and the influence of topography on infestation establishment is examined from a landscape perspective in northeastern BC, an area of recent range expansion by mountain pine beetle. Helicopter and ground survey data of annual red attack are used as a proxy for infestations while a terrain analysis was completed using a digital elevation model, and Topographic Position Index in an ArcView 3.2 extension. The spatial pattern of mountain pine beetle infestations was examined using Ripley's L. Infestation establishment in relation to landform type was examined using contingency tests. According to Ripley's L aggregation increased from 2004 to 2005 and decreased from 2005 to 2006. The contingency test demonstrated a significant difference between the number of infestations in various landform types and a random distribution. There were a large proportion of infestations in u-shaped valleys and open slopes in all three years. However, serial randomization must be used to validate these results and is part of ongoing research.

Introduction

Under normal conditions mountain pine beetle (*Dendroctonus ponderosae* Hopkins), a bark beetle native to western North America that infests host tree in the *Pinus* genus including *Pinus contorta* and *P. ponderosae*, exists at endemic population levels and can only attack compromised or weak host trees (Lindgren and Borden 1993). Its natural distribution spans from New Mexico , in the south, to central British Columbia (BC), in the north in Canada from Vancouver Island , on the west coast of BC to the BC-Alberta border (Safranyik and Wilson 2006; see Figure 1).

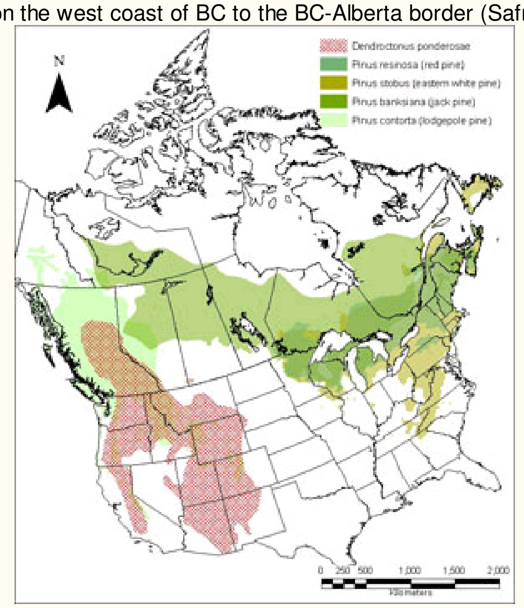

Figure 1 - Generalized historical distribution of: mountain pine beetle; primary host in its northern range, lodgepole pine; and potential hosts, jack, red and eastern white pine (adapted from United States Geological Survey 2006; Natural Resources Canada 2005; Amman *et al.* 1990)

However, mountain pine beetle has formed large coalescing outbreaks in central and southern BC, infesting an estimated 9.2 million hectares of forest, due to a prolonged period of benign climate and a large proportion of susceptible pine on the landscape (Taylor *et al.* 2006; Carroll *et al.* 2004) . Unseasonably cold temperatures, below -40 degrees Celsius, are a large source of mortality for mountain pine beetle populations. In general, temperatures at higher elevations are too cold for mountain pine beetle to successfully establish in a host and reproduce. However, mountain pine beetle has spread beyond its natural distribution into areas such as the Banff and Jasper National Park in Alberta, and more recently into northeastern BC, also known as the Peace River region of BC (hereafter referred to as the Peace), and northern Alberta. Range expansion of mountain pine beetle into the boreal forest of northern Alberta is a large concern for forest managers due to the presence of a highly susceptible host, *P. banksiana*. In addition, the boreal forest stretches from northern Alberta to northern Ontario and may act as a conduit for mountain pine beetle to spread into susceptible host pine in central and eastern Canada . The spread of mountain pine beetle further into the boreal for has the potential to negatively impact the forestry industry across Canada .

At endemic population levels, a majority of emerging mountain pine beetles disperse short distances (within 250 metres) from their original host to find a susceptible host to attack (Safranyik *et al.* 1992) . However, establishment of incipient-epidemic infestations in the Peace has primarily been attributed to mesoscale aeolian transport and deposition resulting from the entrainment of adult mountain pine beetle during dispersal flight (Jackson *et al*. 2005; Moore and Jackson 2004 ;   Byers 2000) . The objective of the following project was to examine how advective transport may have influenced initial distribution of mountain pine beetle (i.e. host mortality) in the southern portion of the Peace Forest District (i.e. the old Dawson Creek Forest District) according to various landscape patterns, such as terrain features. Exploratory data analysis of the spatial pattern of mountain pine beetle infestations in the region was also completed to examine the potential contribution of local (i.e. within the southern portion of the Peace Forest District) and long distance dispersal (i.e. from outside the forest district, specifically from the west) to the continued spread of mountain pine beetle in the region.

Study Area

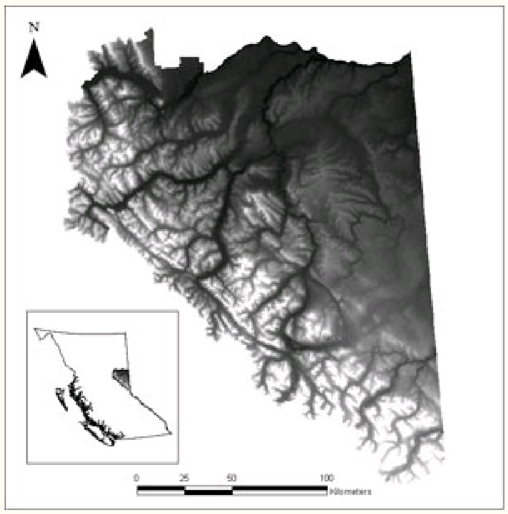

Figure 2 - Research area in northeastern BC including the southern portion of the Peace River Forest District (previously known as the Dawson Creek Forest District).

Data Sources

Three GIS datasets were used in this analysis including:

- Large scale digital elevation model (USGS DEM; 1:250,000 raster; secured from the Canadian Forest Service);
- Helicopter and ground survery data of mountain pine beetle infestations (i.e. annual red attack; point shapefiles; secured from Canfor Inc. and Westerfraser Mills Ltd.);
- And the Dawson Creek Forest District boundary (secured from the Ministry of Forests and Range).

Software Extensions

Two extensions and a script were used in this analysis including:

- Topographic Position Index (for Arcview 3.2a; Jenness 2006);
- Hawth's Analysis Tools (for Arcview 9.x);
- And a visual basic script called GridSpot (ESRIScipts 2007).

Data Manipulation

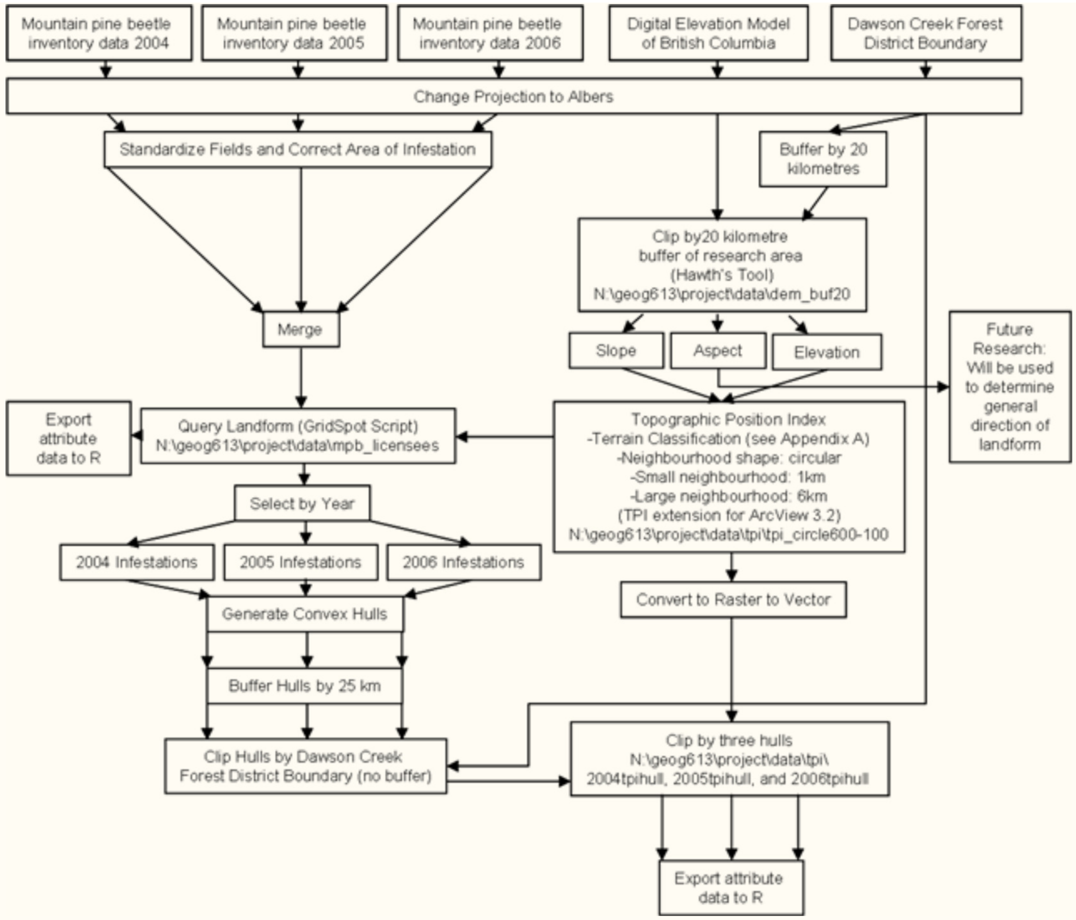

Figure 3 - Data manipulation model.

Methodology and Spatial Analysis

- An initial literature review was completed to identify mesoscale scale terrain features that influence wind patterns including particle dispersal and deposition.
- Ripley's L was calculated for mountain pine beetle inventory data in 2004, 2005, and 2006 to examine patterns of aggregation and inhibition in the data. Ripley's L compares the observed pattern of points with a theoretical random distribution to determine if points are clustering. A critical interval (i.e. a confidence interval) was generated using 1000 Monte Carlo simulations.
- A terrain analysis for the research area was completed using Topographic Position Index in Arcview 3.2a. Due to time constraints, predefined landform classes in the TPI extension were used in the classification (see Appendix A).
- For three years (2004, 2005, and 2006) the pattern of point infestations relative to topographic features was examined using the mountain pine beetle inventory data and topographic position index.
- A contingency test was used to see if there was a significant difference between the number of infestations occurring on or in various landforms and the number of expected infestations, given the prevalence of that landform on the landscape.
  - Observed = Number of infestations on or in various landform classes
  - Expected = Number of infestations based on the prevalence of that landform in the infested landscape (defined as the area encompassing all point infestations for that year and previous previous plus 25 kilometers)
- Statistical analyses were completed in R (R code available in project folder). Due to time constraints serial randomization was not completed; however, this will be addressing in ongoing research.
- Note: Metadata is available for:
  - mpb_licensees.shp
  - 2004tpihull.shp
  - 2005tpihull.shp

Results

- Annual inventory of new mountain pine beetle infestations over three years of initial infestation,2004, 2005, and 2006, resulting in the identification of 10,649, 12,275, and 35, 084 infestations respectively (Figure 4, 5, and 6).
- Ripley's L for the three years identified that there was a significant degree of aggregation with increasing scale, although in 2006 there was a marked decrease in the pattern of aggregation (Figure 7). Only at a very small scale (r ~ 0) did the pattern of infestations approach random.

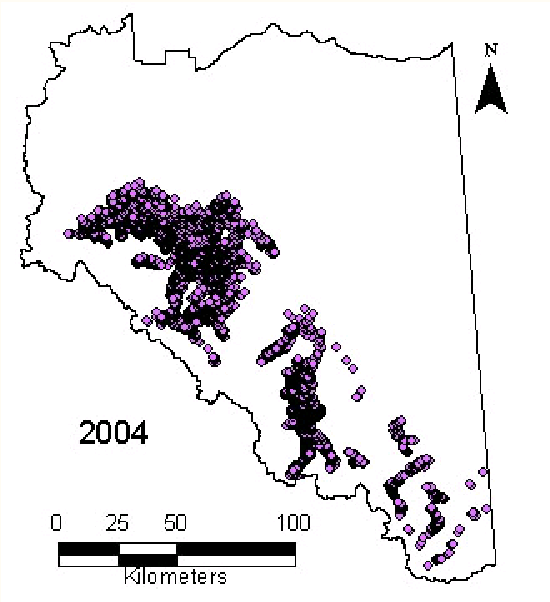

Figure 4 - Distribution of mountain pine beetle infestations in 2004.

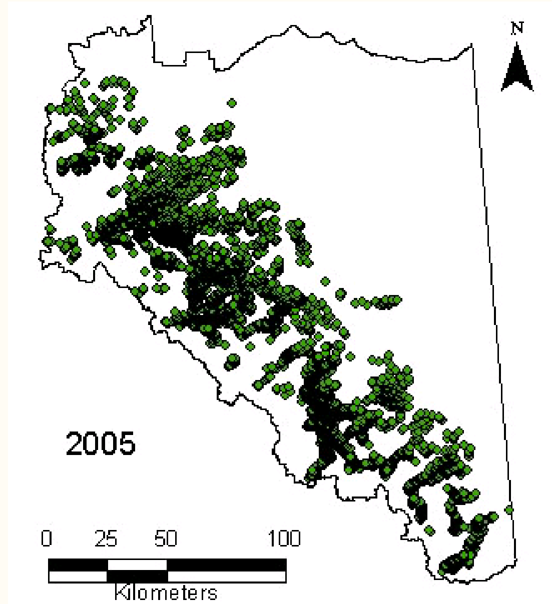

Figure 5 - Distribution of mountain pine beetle infestations in 2005.

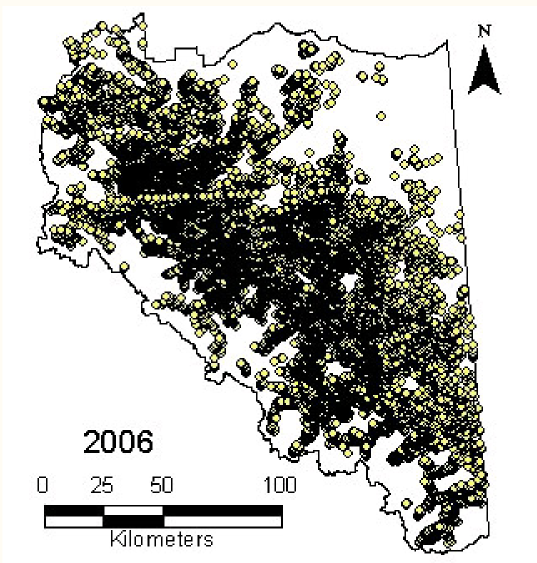

Figure 6 - Distribution of mountain pine beetle infestations in 2006.

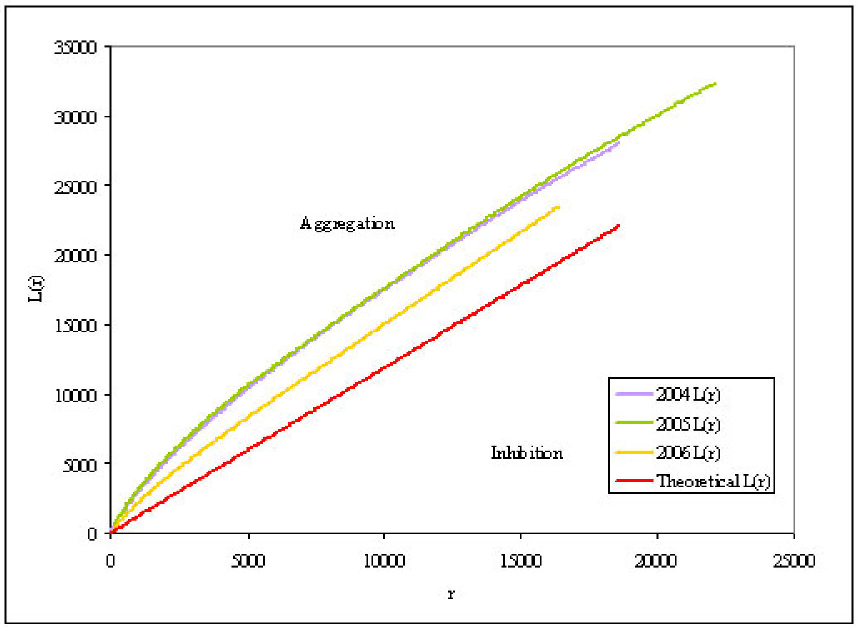

Figure 7 - Observed and theoretical Ripley's L(r) for infestations in 2004, 2005, and 2006.

- According to the Chi Squared test, in all three years the number of observed infestations in various landform classes differed significantly from the expected per landform class according to a random distribution of infestations and the relative proportion of those classes on the landscape (2004: X^2 = 5647.646, df = 9, p-value < 2.2e-16; 2005: X^2 = 7305.234, df = 9, p-value < 2.2e-16; 2006: X^2 = 9429.906, df = 9, p-value < 2.2e-16).
- Overall there was a large proportion of infestations in u-shaped valleys and open slopes in all three years (Figure 8, 9, and 10).

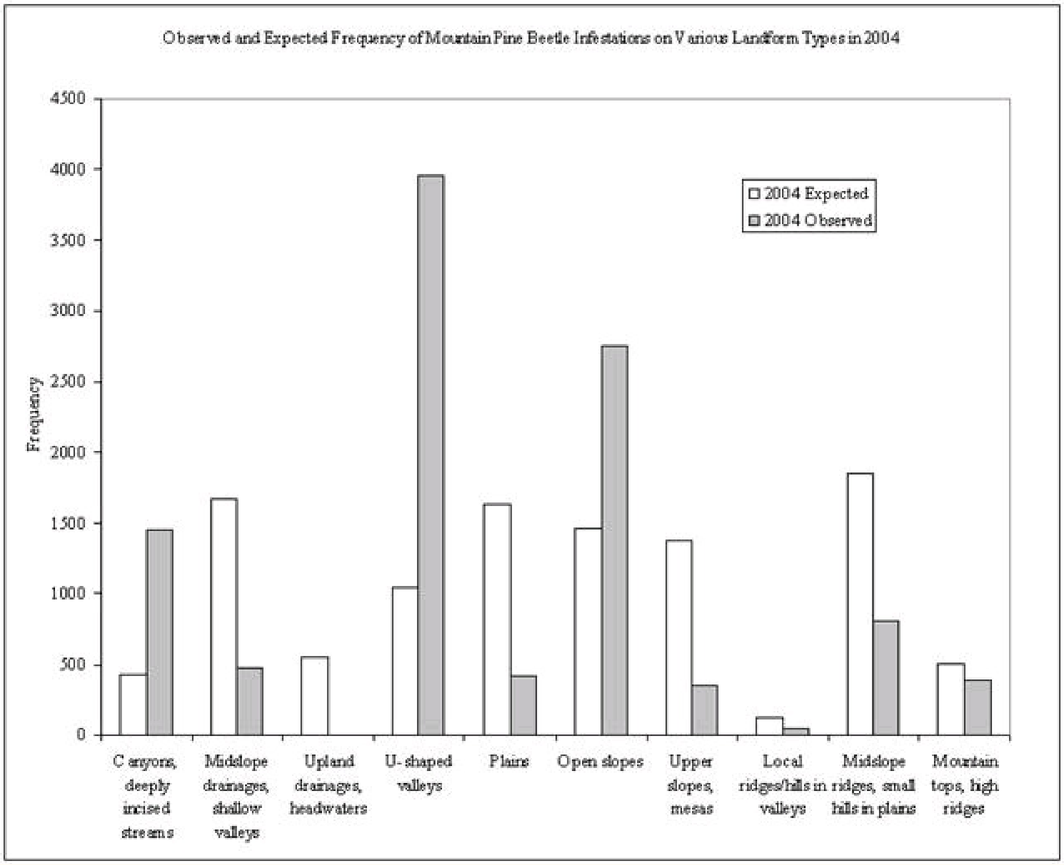

Figure 8 - Observed and expected frequency of mountain pine beetle infestations on various landforms types in 2004.

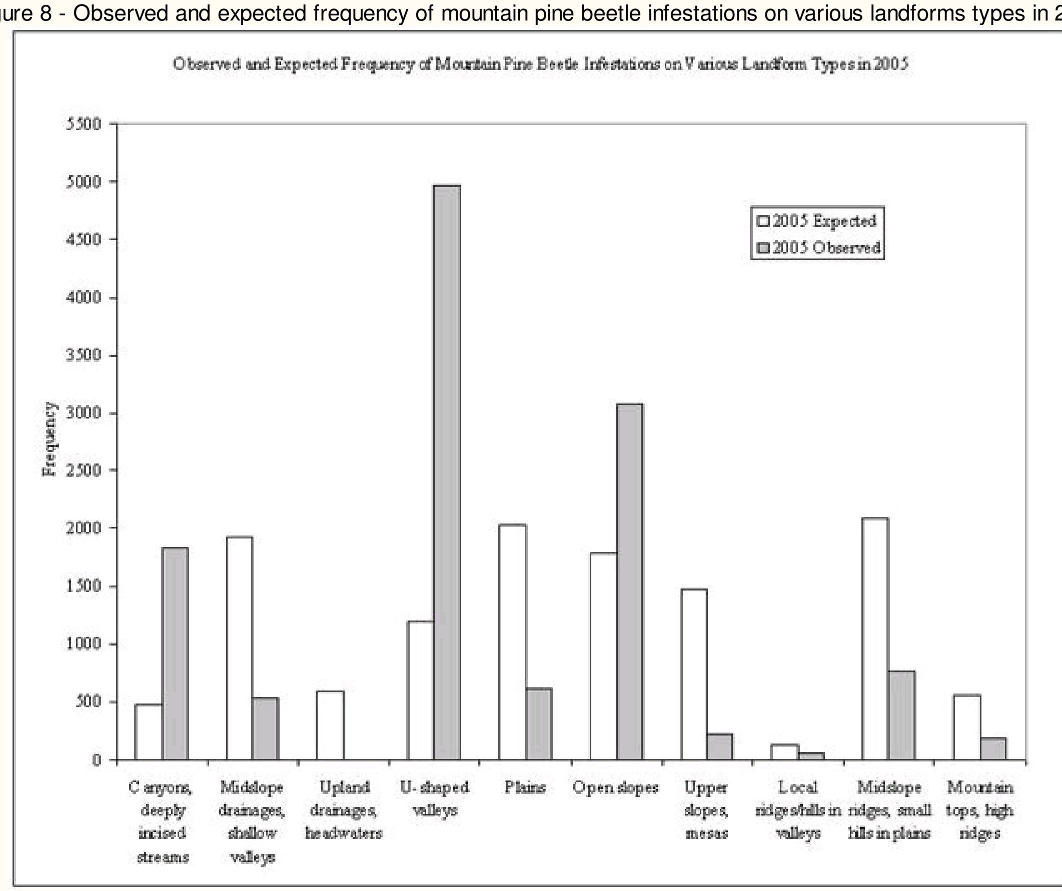

Figure 9 - Observed and expected frequency of mountain pine beetle infestations on various landforms types in 2005.

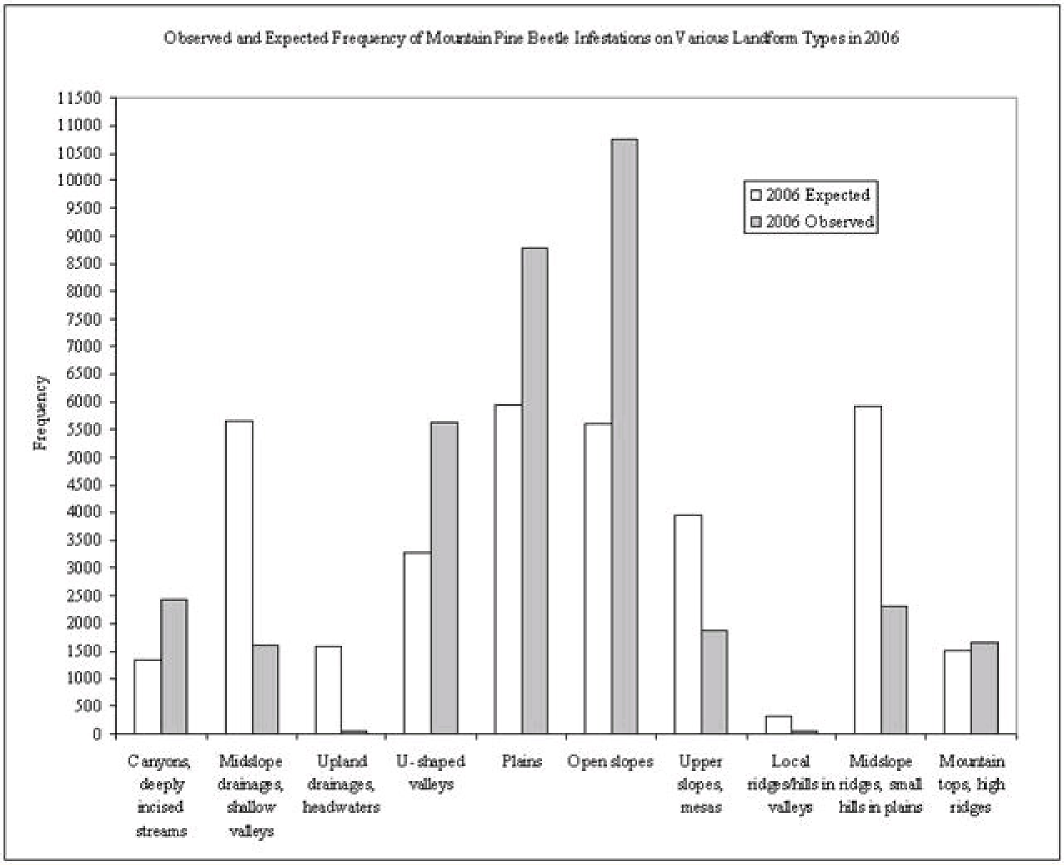

Figure 8 - Observed and expected frequency of mountain pine beetle infestations on various landforms types in 2006.

Conclusions

- Mountain pine beetle infestations in 2004, and 2005 seem to be highly aggregated which is probably due to mass aggregation in susceptible stands and spill over of insect populations into surrounding areas but also potentially due to the initial deposition of insect populations in specific corridors relative to aeolian deposition patterns.
- A few issues arose while examining the distribution of mountain pine beetle infestations relative to landform types including:
  - Certain landform types may not have susceptible hosts or may have a climate to harsh for mountain pine beetle to establish (e.g. Mountain tops, high ridges). The dominance of susceptible stands and climatic conditions for various landform types need to be considered in this analysis before conclusions may be drawn about the influence of landform on occurrence of mountain pine beetle infestations;
  - Currently the chi-squared analysis violates an important assumption namely independence of data. As a result, serial randomization with need to be used to test the strength of the conclusions drawn from this analysis.

Ongoing Research

- Serial randomization in R.
- Clarification of landform types influencing aeolian deposition
- Analyses of the following patterns:
  - Infestations versus susceptible stands;
  - And susceptible stands versus terrain features.

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Appendix A

Landforms
Canyons, deeply incised streams
Midslope drainages, shallow valleys
Upland drainages, headwaters
U-shaped valleys
Plains
Open slopes
Upper slopes, mesas
Local ridges/hills in valleys
Midslope ridges, small hills in plains
Mountain tops, high ridges

TOP