Two-Lined Chestnut Borer Risk Assessment in North Central Minnesota

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A localized recent outbreak of two-lined chestnut borer (*Agrilus bilineatus* Weber) in North Central Minnesota has caused significant damage to oaks. This infestation came on the heels of two years (2001-02) of widespread defoliation by forest tent caterpillar (*Malacosoma disstria* Hubner). The forest tent caterpillar (FTC) defoliation was recorded on 16 Forest Health Monitoring plots in 2001 and on nine in 2002, and was mapped by aerial survey statewide in both years. A special double-intensity aerial survey of the extent and severity of two-lined chestnut borer (TLCB) infestation in 2002 recorded 11,078 acres of trace-to-heavy dieback and mortality in Aitkin, Itasca, Cass and Beltrami counties (inset far right). This poster describes an attempt to identify causal and contributing factors and map risk of future infestation by modeling in a geographic information system (GIS) environment.

Figure 1. Adult Two-Lined Chestnut Borer

USDA Forest Service - www.insectimages.org

Figure 2. TLCB Larvae and Damage

USDA Forest Service - www.insectimages.org

An assortment of existing and custom GIS layers representing possible causal or contributing factors was assembled. Selection was based on a review of the literature, professional experience, and availability of raw data. We cross-tabulated the 2002 TLCB occurrence maps with the following mapped or derived products:

- forest tent caterpillar defoliation for 2000, 2001, and 2002
- droughty soil types
- precipitation deficit
- cover type
- slope
- aspect

This empirical method indicated that precipitation deficit (Figure 3), previous-year defoliation (Figure 4), slope and aspect were correlated with TLCB infestation to a greater or lesser degree. Somewhat surprisingly, droughty soils did not seem to be a significant contributor.

Figure 3. Cumulative precipitation departure from normal 1/1/02 – 6/2/03 with TLCB damage for 2002.

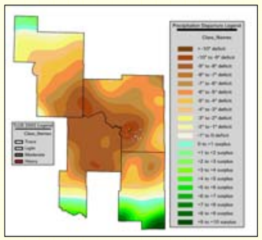
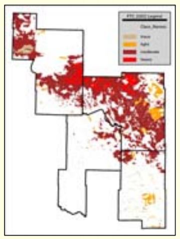
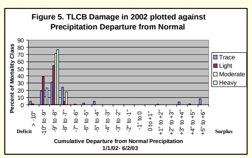
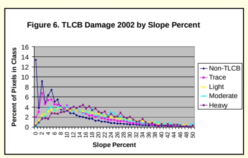


Figure 4. Forest tent caterpillar defoliation in 2002.



Figures 5 and 6 show examples of this initial examination. In Figure 5, levels of 2002 TLCB damage are plotted against cumulative departure from normal precipitation from January 2002 to June 2003. A preponderance of the damage occurred in areas that were experiencing major precipitation deficits. Trace damage in areas where precipitation was abundant may indicate that other stressing factors were at work, that precipitation arrived after the infestation was established or that residual damage is present from years before the deficit. In Figure 6, cross-tabulation of slope with 2002 TLCB shows damage generally increasing with slope, until data trails off for steeper slopes not common in the four counties under study.





A multi-criteria risk model was built to create a risk map of potential 2003 infestation. The model's first assumption is that TLCB will infest areas of suitable habitat. Land cover data from the USGS' Gap Analysis Program (GAP) was used to identify suitable habitat. This data set was derived from Landsat TM imagery from the early 1990s. It remains one of the best available statewide datasets of land cover in MN and should still be valid on the assumption that TLCB damage is predominantly in older trees that would have been present in the early 90s.

Cross-tabulation results of the 2002 TLCB infestation and GAP cover types showed that TLCB was significant in the northern hardwood types and aspen/birch. The "northern hardwood" label includes the GAP classes Bur/White Oak, Red Oak, and Maple/Basswood. The occurrence of TLCB in aspen/birch seems problematic. Another cross-tabulation with proximity to northern hardwood types showed that 75-90% of the area of infestation was within 120 meters of northern hardwood types. The 120 meter buffer is some compensation for rough mapping of TLCB in 2002, inaccurate GAP classifications, and/or inclusions of significant oak components in other than northern hardwood types.

Risk agents were divided into three groups: environmental, previous defoliation by FTC, and previous damage by TLCB. The environmental risk agent included three criteria: precipitation deficit, slope and aspect. The insect agents each have a single criterion derived from the previous year's map. These risk agent criteria must be ranked and weighted to arrive at an appropriate model.

The analyst, with the aid of resident forest health specialists familiar with TLCB, estimated relative importance of contributing agents on a nine-point rating scale (Eastman et al. 1995) from "extremely unimportant" to "extremely important". The scale values for continuous environmental data were then entered into a pair-wise comparison matrix (Table 1). The table entries reflect how the row criteria are weighted to each of the column criteria. For example, slope was deemed moderately less important than precipitation deficit as a contributing agent and given a score of 1/3 in the pair-wise matrix. The top half of the matrix contains reciprocal values, and the diagonals are "1" as each agent is "equal" to itself.

Table 1. Pair-wise comparison matrix (Eastman et al. 1995) for Two-lined chestnut borer environmental criteria.

	Precipitation Deficit	Slope	Aspect
Precipitation Deficit	1	3	5
Slope	1/3	1	3
Aspect	1/5	1/3	1

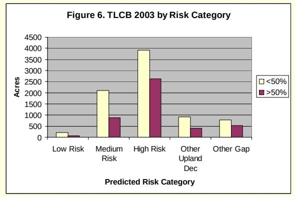
Weights for these agents are calculated with a method that approximates principal eigenvector analysis. Each column is summed to get the column marginal total. The individual ranking is then divided by the marginal total of its column. The average of each row is then calculated as the weight for that criterion. Each weight for the environmental criteria must then be multiplied by the risk agent weight to come up with an overall comparative weight. The calculated criteria weights are shown in Table 2.

Table 2. Risk agent and criteria weights for GIS modeling.

Risk Agents	Weight	Criteria	Weight
Environmental	0.600	Precipitation Deficit	0.391
		Slope	0.130
		Aspect	0.079
FTC defoliation the previous year	0.330	FTC defoliation the previous year	0.330
TLCB damage the previous year	0.070	TLCB damage the previous year	0.070

The GIS layers were rescaled to a range of 0-20 with non-zero values implying some contribution to risk. The rescaled values were multiplied by the criteria weights and summed to arrive at a relative risk value. The model was restricted to "upland forest" areas within 120 meters of pixels classified as northern hardwood. The risk values from this procedure ranged from 1-19 and were aggregated to Low (1-7), Medium (8-11), and High (12-19) risk categories for easier visualization and to even out a multi-modal distribution of the risk data. These risk classes are shown at right over the 4 county area.

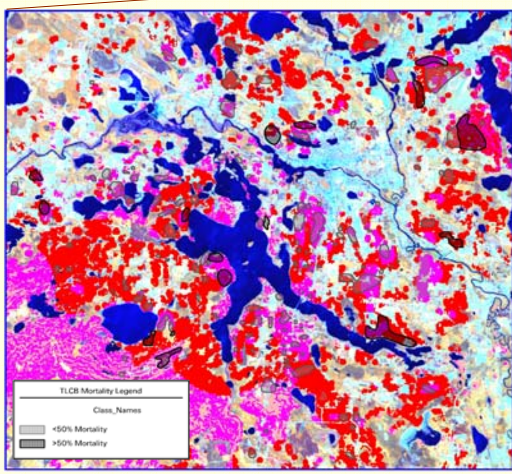
Mapped TLCB mortality for 2003 was cross-tabulated with the predicted risk categories that showed the patterns seen in Figure 6. The majority of TLCB mortality fell within the predicted high risk category with a reduced distribution in the medium and low risk categories. More 2003 TLCB mortality occurred outside the buffered northern hardwood class than in the low risk category. This could be due to afore-mentioned mapping inaccuracies of TLCB in 2003, inaccurate GAP classifications, or inclusions of significant oak components in other than northern hardwood types. Figure 7 below shows the actual mapped polygons of TLCB mortality in 2003 overlaid on the areas of predicted risk.



These views of the data indicate that the model did a reasonable job of predicting areas of relative risk for the two-lined chestnut borer to cause mortality. It does not follow that the borer caused mortality in all or most of the areas labeled as high risk. Only 1.8% of the area identified as high risk with this model actually showed mortality in 2003. Tweaking the model to a narrower focus may reduce the acres of potential high risk, but at the expense of more errors of omission; e.g. mortality in areas of lower predicted risk.

This rudimentary attempt at predicting relative risk of infestation by TLCB shows promise. Adjustments to the model and more or better data inputs may allow more precise predictions. Examples on a map data wish-list include stand age (or a surrogate such as tree height), more accurate species maps, and historical (~15 year) records of TLCB occurrence and recent silvicultural treatments. Accurate predictions of future occurrence would allow managers to take steps to reduce damage to this valuable resource. These management options would include reducing stressful activities in commercial forest stands, watering yard trees and others.

Figure 7. Actual 2003 TLCB mortality overlaid on predicted risk classes.



Scale: 1 inch = 1.25 Miles

Reference:

Eastman, J.R., W. Jin, P.A.K. Kyem, and J. Toledano. 1995. Raster procedures for multi-criteria/multi-objective decisions. *Photogrammetric Engineering and Remote Sensing* 61(5):539-547.

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