A Decision-Support System for Forest Management under Forest Tent Caterpillar Defoliation

Theme #3
Principal Investigator(s):
Ruth D. Yanai, SUNY-ESF, rdyanai@syr.edu
107 Marshall Hall, SUNY-ESF, 1 Forestry Dr., Syracuse, NY 13210
Dylan Parry, Doug Allen, SUNY-ESF; Laura Lautz, Syracuse University;
Jerry Carlson, New York State DEC; Sandy Wilmot, Vermont DFPR

Collaborators and affiliations:
Charlie Burnham, Massachusetts DCR; Dave Struble, Maine Forest Service;
Kyle Lombard, New Hampshire DFL

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Sugar maple stands defoliated during the latest forest tent caterpillar outbreak (2002-2007) had higher crown dieback and mortality if they were located in concave terrain positions, had drier growing seasons during the outbreak, and occurred on soils low in Ca, Mg, and K. These results could be used by forest managers to identify sugar maple stands most susceptible to decline following future defoliation events.

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Sugar maple (*Acer saccharum* Marsh) is a keystone species of the northern hardwood forest type. An important stressor of sugar maple is forest tent caterpillar (*Malacosoma disstria* Hübner, FTC), an indigenous defoliator. The recent outbreak of FTC (2002-2007) was the largest to occur in the region in the last 50 years and affected millions of acres of forest in the northeastern U.S. and Canada.

This project had two parts. In Part I of this project, we were interested in understanding why some sugar maple stands recover, while others decline, following insect defoliation. This research assessed the condition of sugar maple trees in 47 new or previously monitored North American Maple Project (NAMP) stands in Massachusetts (2006, 2007), Vermont and New York (2007, 2008), following the collapse of the recent FTC outbreak and tested environmental factors contributing to mortality and crown dieback following defoliation. Sugar maple is known to be susceptible to decline especially on sites with low soil Ca and Mg, and we found this to be the case. Low soil K, concave site terrain shape, short-term drought, low temperatures, and defoliation were also important to sugar maple condition. User-friendly hazard rating tables were made to show which sugar maple stands were more vulnerable to decline. Land managers in the Northeast can utilize this research to assess sugar maple stands defoliated by FTC, and we suggest that fertilizer application may benefit stands with low base cations that are more susceptible to decline.

Part II of this project investigated the susceptibility of fragmented and continuous northern hardwood forest stands to defoliation based on the duration of the recent FTC outbreak. This study found that FTC outbreak duration lasted longer in continuous northern hardwood forests, which was opposite of findings in aspen dominated forests in Canada. Results suggest that the relationship between insect outbreak duration and forest fragmentation may not be universal, even within the range of a single defoliator species.
Background and Justification

Forest tent caterpillar (FTC) is the most important defoliator of northern hardwood forests, and its preferred host is sugar maple. Defoliation is an important factor in sugar maple decline; two or three consecutive years of defoliation can cause significant crown dieback and whole-tree mortality. Previous researchers have found that sugar maple in poor condition following defoliation were predisposed to decline by low soil base cation concentrations. The recent outbreak of FTC in the northeastern U.S. and Canada occurred from 2002 to 2007, and allowed us to evaluate the susceptibility of sugar maple stands to defoliation and their vulnerability to decline. The first objective of this project was to assess the vulnerability of sugar maple to decline following defoliation by FTC and determine if stands more susceptible to decline were predisposed by environmental variables such as temperature, precipitation, site topography, landform, terrain shape, soil rockiness, and soil chemistry.

Previous work in aspen forests in Canada found FTC outbreaks to last longer in fragmented forests. The second objective of this project was to investigate the susceptibility of fragmented and continuous northern hardwood forest stands to defoliation based on the duration of the recent FTC outbreak.
Background: Defoliation

- Reduces starch content of roots making trees susceptible to drought and frosts.
- Reduces sap flow and sugar content in trees.
- Reduces tree growth, increases crown dieback, and can lead to tree mortality.
Background: Forest Decline

Important predisposing and inciting factors that we studied were...

Part I: Study Sites

- 47 North American Maple Project (NAMP) stands
  - 37 original NAMP
  - 10 established in NY in 2007 where FTC defoliation occurred
- Stand basal area
  - ≥ 50% sugar maple
- Five 1/10 acre subplots
  - Average of 54 sugar maples with DBH of ≥ 10 cm per stand
  - No management in the last 15 years

Locations of 47 northern hardwood forest stands assessed following the FTC outbreak (2002-2007). Circles represent stands (N=31) where soils were collected and analyzed for base cation concentrations. Squares represent sites where soils were not collected. Shading of symbols represent the number of years defoliated during the outbreak.
Part I: Methods

Environmental Variables

- **Stand**
  - Crown closure (full, moderate, open)
  - Crown structure (single story, two story, multi-story)
  - BA (m²/ha)
- **Site**
  - Terrain
  - Landform
  - Microrelief
  - Slope
  - Soil rockiness
  - Exchangeable soil cations
- **Climate**
  - Temperature
  - Palmer’s Z-index
- **Defoliation**
  - Defoliated/Non-defoliated
  - Total years
  - Defoliation severity index
    (sum of % yearly defoliation X intensity – heavy, moderate, light, none)
Soils Collection & Analysis

- 31 stands
- 5 pits per stand
  Sampled from:
  A horizon (when present)
  Upper B horizon

- Soils were air-dried, ground and sieved (2 mm)
- Composited by horizon for a stand average
- Cations extracted from 5 g soil with 100 ml 1 M NH₄Cl
- Analyzed using Inductively-Coupled Plasma Spectrometry (ICP)
Dieback and mortality were both greater in defoliated (n=27) than nondefoliated (n=24) stands (P=0.07). Dotted lines of the box plot indicate the mean value. Lines represent the 25th percentile and 75th percentile. Whiskers represent 99% of the sample distribution and outliers are represented by x.

Relationships between outbreak mean Z-index and sugar maple dieback and mortality. Stands were healthier in wetter sites.

Relationships between site microrelief and sugar maple dieback and mortality. Stands were healthier on convex microrelief.

**Results: Part I**
User-friendly Hazard Rating Table

- Sugar maple vulnerability to mortality – high (orange), medium (yellow), low (beige) – if defoliated in 2006 during the peak year of outbreak.

- Stands had higher mortality if they were defoliated, had lower temperatures and precipitation during the outbreak, and had concave terrain shapes (microrelief).

- Similar table also made for dieback.
Soil Chemistry

• Sites with lower concentrations of soil base cations had higher sugar maple mortality.

• Observed soil thresholds below which sugar maple had >4% mortality within one year:
  Ca = 1.7 cmol$_c$ kg$^{-1}$
  Mg = 0.15 cmol$_c$ kg$^{-1}$
  K = 0.07 cmol$_c$ kg$^{-1}$

• All base cation concentrations were higher than previously established thresholds on the Allegheny Plateau, below which sugar maple could not withstand drought and defoliation stress.

The effects of exchangeable soil cation concentrations in the A horizon (n=29) and upper B horizon (n=31) on sugar maple mortality in Massachusetts, Vermont, and New York. Each circle represents a plot. Shading of circles indicates number of years each plot was defoliated during the FTC outbreak (2002-2007). The dotted line represents the proposed thresholds.
Study regions (St. Lawrence County, NY; Windsor & Rutland Counties, VT; Sullivan County, NH; Berkshire County, MA) showing forest cover and aerially observed defoliation damage. Defoliation by year from 2002 to 2006 is depicted by transparent layers to allow multiple defoliation events to be seen.
Part II: Methods

- Study regions selected because northern hardwoods were the dominant forest cover type, they experienced significant defoliation during the recent outbreak, and defoliation was aerially mapped and subsequently ground-truthed to determine the defoliating insect species was FTC.
- Defoliation layers were aerially sketch-mapped by state agencies.
- Forest cover data layers extracted from the 2001 National Land Cover Database.
- Each point contained plots with radii:
  - 100m, 500m, 1000m
- Plots were not used if they contained large areas of agriculture, water, or urban development.
- Outbreak duration assessed at plot center.
- Analysis done using ArcGIS9 & GeoDa.

The VT-WR study region showing the sample locations. Sampling points were used only if they fell on or within 50m of forest cover.
• FTC outbreak duration lasted longer in continuous forests than in fragmented forests.

• Opposite of results found in aspen dominated boreal forests of Canada.

Outbreak duration (0, 1, ≥2 yr) as a function of average forest cover and average forest edge for each of the four regions. The sizes of the symbols indicate the three plot sizes used in the study. Error bars represent the standard error of the mean.
Implications and applications in the Northern Forest region

• The study was conducted over a broad geographic range, which most studies have lacked.

• In the short-term, findings can help guide management decisions for pest management and silviculture.

• Sugar maple may be at risk of decline on soils with higher base cation concentrations than were defined by earlier studies.

• Application of dolomitic limestone to sugar maple stands might help prevent decline following defoliation.
Future directions

- Add data from before recent FTC outbreak, as well as from earlier FTC outbreaks (VT has the best long-term records).
- Assess mortality in these stands 5 years from now to see the long-term effects of the defoliation.
- Research the presence of *Armillaria* root-rot fungus (below) in these stands – it is a key contributing factor in forest and sugar maple decline.
List of products

Peer-reviewed Publications

Other Publications
Wood, D.M. 2008. Evaluating the susceptibility of sugar maple stands to defoliation by forest tent caterpillar (Malacosoma disstria Hübner) and the vulnerability to decline. M.S. Thesis, SUNY-ESF, Syracuse, NY.
List of products (continued)

Conference Presentations
List of products (continued)

Conference Presentations


