Anticipating Threats to Northern Hardwood Forest Biodiversity with an Ecological-Economic Model

J.D.A. Millington[1]; M.S. Matonis[1,2]; E.J. Laurent[3]; M.B. Walters[1,2]; F. Lupi[1,4]; K.R. Hall[1,5]; J. Liu[1]

[1]Center for Systems Integration and Sustainability, Michigan State University; [2]Department of Forestry, Michigan State University; [3]American Bird Conservancy; [4]Department of Agricultural, Food and Resource Economics, Michigan State University; [5]The Nature Conservancy

http://csis.msu.edu/eeproject.htm | http://landscapemodelling.net/blog/labels/MichiganUP.html

Direct General Project emails to: jmil@msu.edu (James Millington) and Poster-Specific emails to: matonism@msu.edu (Megan Matonis)

Project Overview

Forest Disturbance

Harvesting and deer browsing are believed to be key disturbance agents altering forest dynamics, and habitat for deer, songbirds and other biota in the northern hardwood forest landscapes of Michigan's Upper Peninsula.

Browsing by white-tailed deer (*Odocoileus virginianus)* in temperate hardwood forests can reduce species diversity and vertical complexity of understory forbs (Rooney and Waller 2003) and tree saplings (Gill and Beardall 2001). In turn these changes can decrease song bird habitat quality and alpha diversity (deCalesta 1994). The pattern and frequency of forest harvesting also affects the composition and structure of the forb and sapling layer (Crow et al. 2002). Few studies have explored interacting impacts of deer and harvesting on forest dynamics at scales larger than the stand.

Project Objectives

We are developing an integrated simulation model to test hypotheses about the spatial interactions among forest dynamics, harvest patterns, deer, and songbird habitat in northern hardwood forests. We will use this model to investigate the mechanistic/quantitative underpinnings of these coupled human-natural processes across multiple scales. The model will serve as a tool to aid management of forested systems for multiple resource objectives.

Study Area

Our study area covers ~4,000 km^2 across parts of five counties in Michigan's Upper Peninsula (Figure 1A). The peninsula is dominated by a patchwork of upland northern hardwood and lowland conifer forest.

Data

Within the study region (Figure 1B), randomly selected landscape units (~10 km^2; Figure 1C) defined areas for the selection of specific plots for vegetation and deer surveys. Within each 30 m radius plot (Figure 1D) we collected vegetation data to characterize vegetation species composition and vertical structure, estimated deer density and conducted point counts of songbirds.

Regeneration of tree species has been quantified in harvest gaps in selectively cut forest stands and measurements have been made to describe the seed source, understory light condition, soil nutrient availability, deer browse pressure and cover of competing vegetation.

We have also quantified timber prices and harvesting costs and conducted surveys for non-market valuation of forest ecosystem services and attributes.

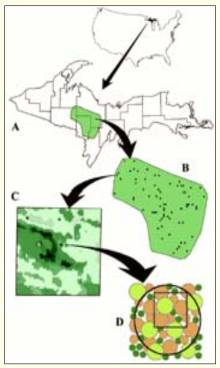
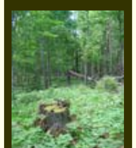


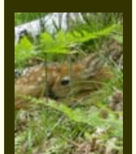
Figure 1. Project study area and levels of ecological data collected

Management Implications and Outreach

Simulation results are intended to provide assistance to private and public managers for anticipating and understanding forest stand- and landscape- level consequences of management alternatives on economic revenue, trade-offs between various ecosystem services and biodiversity.

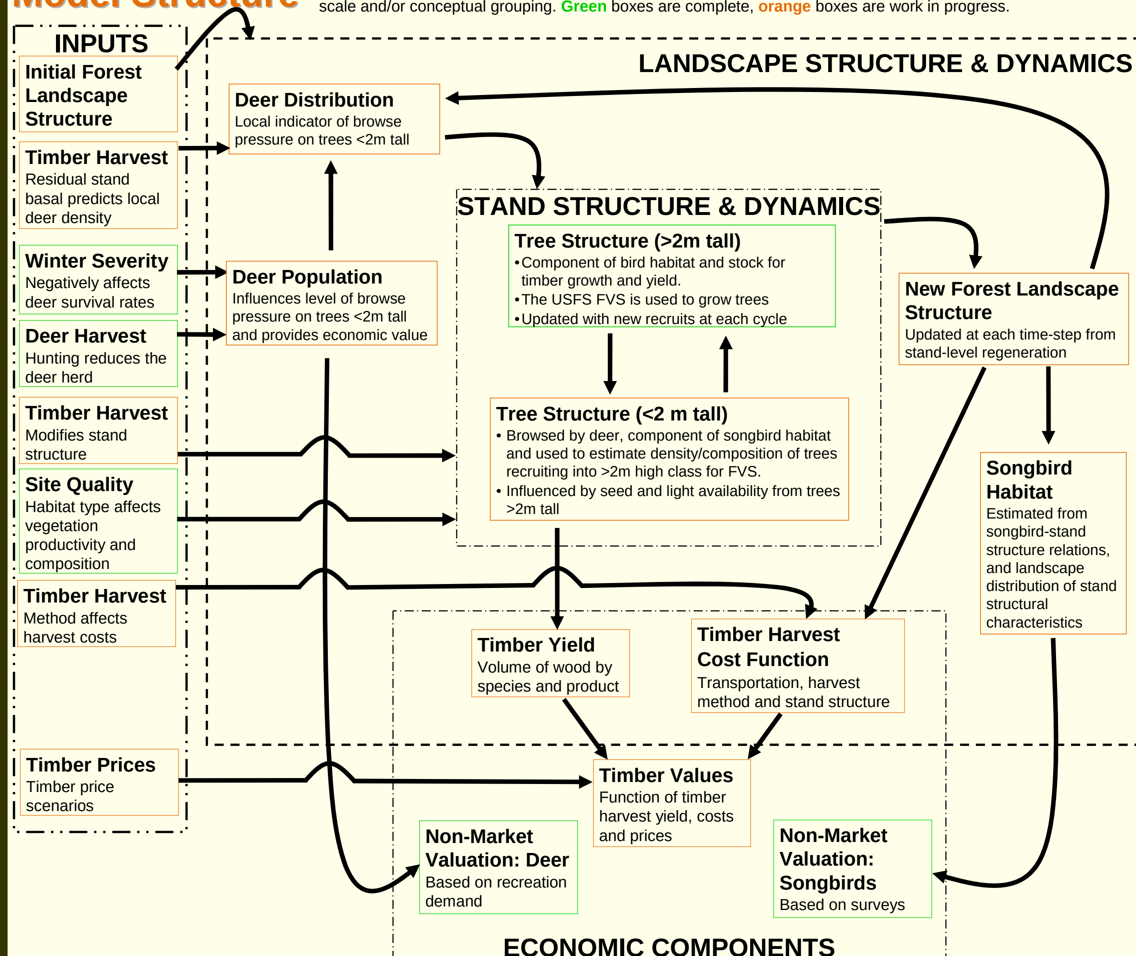
We are continuing to develop relationships with managers of private industrial land in our study area (including Plum Creek Timber Company Inc. and American Forest Management Inc.), conservation organizations (including The Nature Conservancy), and the Michigan Department of Natural Resources.





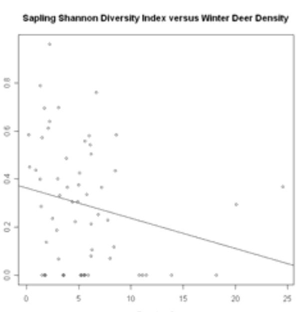
Model Structure

Arrows indicate influences between model components. Dashed boxes indicate components with same scale and/or conceptual grouping. Green boxes are complete, orange boxes are work in progress.



Forest Biodiversity

Tree Sapling Biodiversity



Shannon Diversity Index (H') of saplings 1-2 m tall generally decreases with increasing winter deer density (Figure 2). This relationship was explored using bootstrap analysis and permutation resampling. Non-parametric techniques were utilized instead of OLS regression due to the non-normal nature of the predictor and response variables. The relationship between sapling H' and winter deer density is significantly negative and different from zero based on the 95% confidence interval (-0.032 to -0.001) from bootstrapping (1000 iterations) and is nearly significant (p=0.08) based on results from permutation resampling (10000 iterations).

Winter deer density is just one of several potential factors explaining sapling H'. Others include variation in overstory seed bearing tree diversity, management histories and soil fertility between sites.

Figure 2. Results from bootstrapping (n=59 northern hardwood forest stands harvested from 1993-2007, data collected 2008)

Sapling H' = 0.364 - 0.013 × winter deer density

Songbird Biodiversity

Preliminary analyses of bird species occurrence indicate species specific responses to forest structural variables sensitive to harvesting and deer browse. For example, Black-throated Green Warbler is positively associated only with the standard deviation of canopy openness whereas Ovenbird occurrence is unrelated to canopy openness and instead is negatively related to the bottom of the canopy height for both the overstory and the midstory (Table 1). Furthermore, birds can respond in opposite ways to the same structural variables indicating that deer and harvesting can result in tradeoffs in occurrence between two or more species. For example, Ovenbird is more likely to occur in forests with low canopy bottoms (i.e. forests with branches and foliage closest to the ground) whereas Rose-breasted Grosbeak is more likely to occur in tall forests with bottom branches high in the canopy. Optimizing habitat for a broad range of bird species within northern hardwood forests may hinge upon maintaining high structural heterogeneity among stands which in turn may depend upon spatially heterogeneous harvest patterns and deer browse pressure.

Table 1. Results of logistic regressions predicting bird species occurrence from northern hardwood forest structural characteristics

Species	χ^2	Full model significance	Full model R^2	Structural predictors and direction*
Black-throated Green Warbler	20.38	<0.001	0.36	+SDOpen£
Eastern Wood Pewee	16.90	0.002	0.37	-AcerProp +Top CanOver +AvgOpen +SDOpen£
Ovenbird	8.55	0.014	0.16	-BotCanOver -BotCanMid,
Rose-breasted Grosbeak	8.53	0.014	0.17	+BotCanOver +SDOpen

* Ordered from the most to least significant

£Abbreviations: SDCanOpen, Standard deviation of canopy openness; AcerProp, *Acer saccharum* as a proportion of total saplings; TopCanOver, Height to top of the overstory canopy; AvgOpen, average canopy openness; BotCanOver, height to bottom of overstory canopy; BotCanMid, height to bottom of midstory canopy.

Acknowledgements

This project was supported by the National Research Initiative of the USDA Cooperative State Research, Education and Extension Service, grant number 2006-55101-17369. We are grateful to the Michigan DNR, Plum Creek Timber Company and American Forest Management for data and facilitation of fieldwork. This poster and attendance to the NCSE meeting was supported by the Environmental Science and Policy Program at Michigan State University.

References

-Crow, T.R., D.S. Buckley, E.A. Nauertz and J.C. Zasada. 2002. Effects of management on the composition and structure of northern hardwood forests in Upper Michigan. Forest Science 48 (1): 129-145.

-deCalesta, D.S. 1994. Effects of white-tailed deer on songbirds within managed forests in Pennsylvania. The Journal of Wildlife Management 58 (4): 711-718.

-Gill, R.M.A. and V. Beardall. 2001. The impacts of deer on woodlands: The effects of browsing and seed dispersal on vegetation structure and composition. Forestry 74: 209-218.

-Rooney, T.P. and D.M. Waller. 2003. Direct and indirect effects of white-tailed deer in forest ecosystems. Forest Ecology and Management 181: 165-176.