ISSUES – FIGURE SET

Ecological Impacts of High Deer Densities

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White-tailed deer, © Kelly Bolton

Figure Set 1: Deer Browse and Hemlock Regeneration

Purpose: To examine factors that influence regeneration of hemlocks and assess whether deer are altering forest composition.
Teaching Approach: turn-to-your-neighbor
Cognitive Skills: (see Bloom's Taxonomy) — comprehension, interpretation
Student Assessment: minute paper

BACKGROUND

In this study, Rooney and colleagues (2000) examined whether deer browse might be a factor affecting the regeneration of eastern hemlock (*Tsuga canadensis*). A long-lived, shade-tolerant conifer occurring on moist, acidic soils, eastern hemlock once dominated much of the forest in upper Wisconsin and Michigan. Heavily cut over by the 1920s, hemlock-northern hardwood forests were replaced by second-growth hardwoods and have yet to rebound. Today, hemlock remains a common community element in the few remaining primary forests and has partially rebounded in some lowland and riparian areas. Hemlock remains uncommon, however, in previously logged, upland stands and occupies only 0.5% of the upland landscape in the northern Great Lakes region. Restoration of hemlock-dominated landscape elements is being considered by federal land management agencies but significant barriers exist. Even in forest stands where hemlock does compose a substantial portion of the canopy, hemlock seedlings and saplings are conspicuously absent. A variety of hypotheses could explain this mystery. Seedling establishment may be limited by the availability of appropriate microsite conditions, such as moss beds, nurse logs, or bare mineral soil. Or, moisture availability, soil characteristics, or other habitat characteristics may limit hemlock seedlings. Because they grow slowly and provide winter browse, hemlock seedlings are also sensitive to herbivory by white-tailed deer, as demonstrated in several other studies.

To help solve this mystery, Rooney and colleagues studied 100 hemlock stands in northern Wisconsin and western upper Michigan. The sites included land in county, state, and national forests, national lakeshore, Indian reservations, and private ownership. These entities managed their forests for different goals and took different approaches to deer management. The stands selected varied in hemlock density. The researchers sought to understand factors responsible for this variation. In other words, what factors explained why hemlock were regenerating in some sites and not in others? At each study site, researchers counted the number of hemlocks in each of four size classes (seedlings, small saplings, medium saplings, large saplings) and collected data on several factors suspected behind poor hemlock regeneration. These were seed input, leaf litter type, leaf litter depth, light availability, habitat type, and deer browsing intensity. They then conducted statistical analyses to assess which of these factors contributed to variation in hemlock density between sites.

STUDENT INSTRUCTIONS

In preparation for class discussion, examine Figures 1a and 1b. Begin with Figure 1a, which relates the number of medium-sized hemlock samplings found per hectare at 100 study sites with an index of deer browse intensity called the "sugar maple browse index." The sugar maple browse index is the ratio of browsed sugar maple twigs to total sugar maple twigs counted in an area. It provides a measure of deer browsing intensity on a scale from 0 to 1. The higher the sugar maple browse index for an area, the higher we assume the intensity of deer browse to be for other species, including hemlock, that are also palatable to deer. Turn to your neighbor and first describe and then analyze Figure 1a. Take your time and make sure you understand the axes and the variables plotted. What conclusion do you draw regarding the relationship between medium-sized hemlock saplings and deer browse?

Once you understand Figure 1a, take a look at Figure 1b. Figure 1b includes additional variables, including light and ecological subsection (broad, ecologically distinct regions characterized by geomorphology, soils, and potential forest cover types), which affect hemlock trees at different stages of growth. In addition to varying in ecological characteristics, the stands also varied in ownership, which included county, state, and national forests, national lakeshore, Indian reservations, and private lands. The **thickness** (not length) of the arrow represents the strength of the relationship. Take time to examine the figure and understand which factors influence hemlock at different stages of growth.

With your neighbor, "talk out loud" and explain what you see in Figure 1b. Describe the relationships illustrated - what leads to what? Refer to the following questions to help guide your analysis of Figure 1b:

- What factor has the greatest influence on the number of hemlocks that progress from one size class to the next? Remember, the **thicker** the arrow, the stronger the relationship between two variables.

- How does light affect hemlocks - positively or negatively? Why would light availability matter? At what stage(s) of hemlock growth is light availability important?

- How does ecological subsection affect hemlocks - positively or negatively? Why would the ecological subsection matter? Remember that ecological subsections are defined by geology and soil types. At what stage(s) of hemlock growth is ecological subsection important?

- How does deer browse affect hemlocks - positively or negatively? Why would deer browse matter? For which size class is deer browse important?

- Is the pattern that you observed in Figure 1a consistent with those illustrated in Figure 1b?

- How does ownership relate to deer browse? Why would deer browse differ depending on who owns the forest? How does ownership relate to hemlock regeneration?

Once you and your neighbor are confident that you understand the relationships illustrated in Figure 1b, imagine that you are the managers of a protected forest area in northern Wisconsin. This forest has been historically dominated by hemlock, and you would like to restore hemlock in stands where it once existed but now is rare. You are responsible for developing a management plan for hemlock regeneration based on your understanding of the factors that most affect hemlock establishment (initial growth as seedlings) and recruitment (progression into subsequent size classes as saplings).

Consult with your neighbor and discuss the following questions:

- In some stands with few mature hemlocks in the canopy, there are many seedlings and small saplings. What management strategy(ies) would you recommend to increase the likelihood of these saplings reaching the canopy?

- In other stands with few mature hemlocks in the canopy, there are also very few seedlings and small saplings. What management strategy(ies) would you recommend for these stands to restore hemlocks?

- What additional research would you recommend to help you improve your management of hemlock forests?
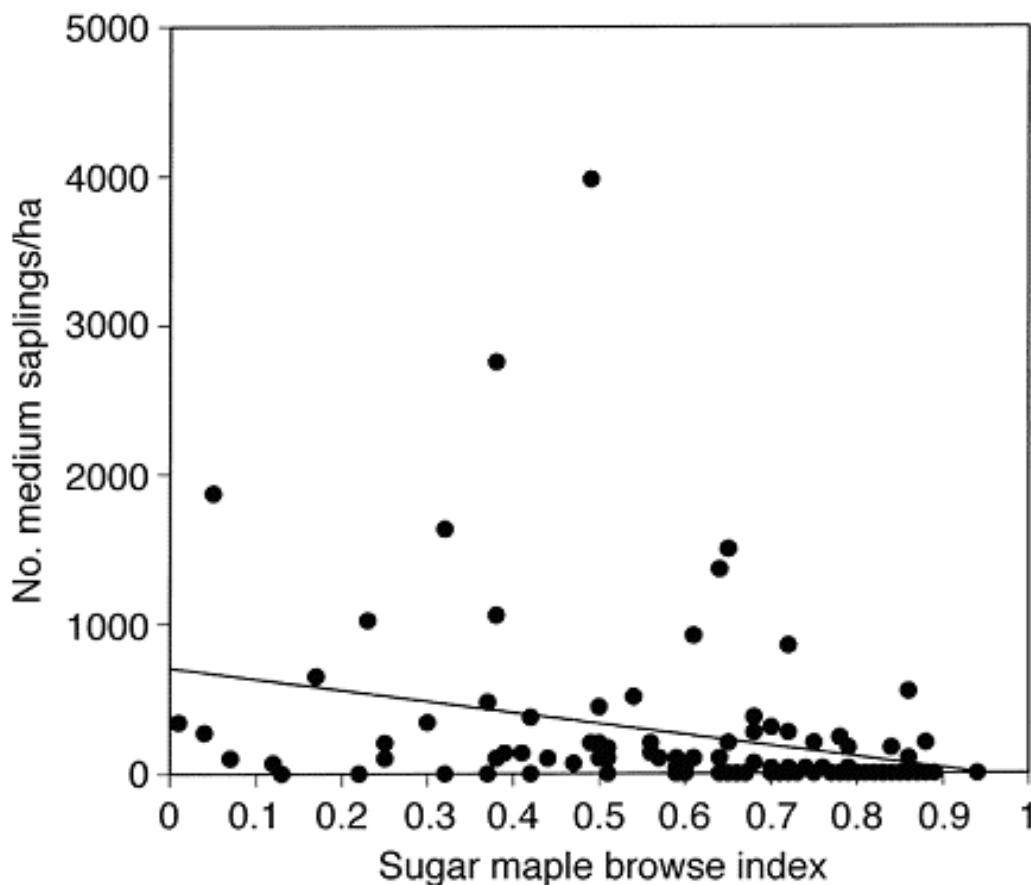
FIGURES

Figure 1a. The number of medium-sized hemlock saplings per hectare as a function of the sugar maple browsing index. The sugar maple browsing index is an indicator of deer browse intensity. The intercept and slope are both significant (ln(saplings) = 2.06—1.58(browse); df = 1, 98; r^2 = 0.083; P = 0.004). (From Rooney, T. P., McCormick, R. J., Solheim, S. L. and D. M. Waller. 2000. Regional variation in recruitment of hemlock seedlings and saplings in the Upper Great Lakes, USA. Ecological Applications 10(4):1119-1132.)
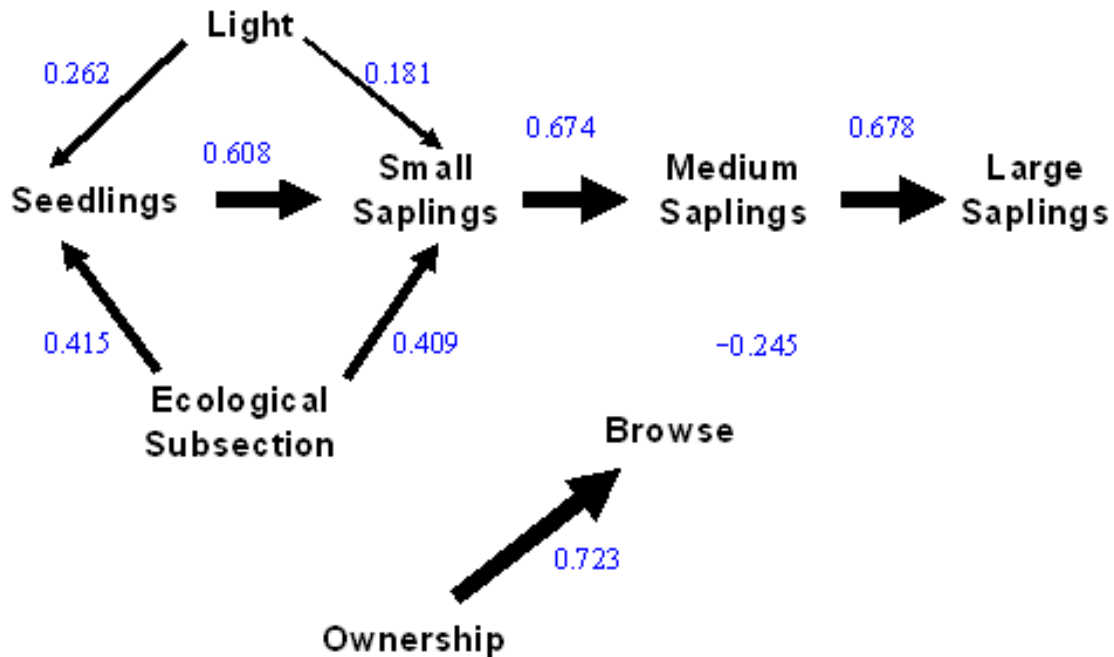
Figure 1b. Inferred causal relationships between variables affecting hemlock regeneration. Thickness of arrows represents strength of relationship. Solid arrows indicate positive relationships. Dashed arrow indicates negative relationship. Numbers adjacent to arrows indicate the standardized partial regression coefficients (path coefficients) between variables. All direct paths shown are significant at $P < 0.05$; direct paths that are not statistically significant have been omitted. "Ecological subsection" refers to a broad, ecologically distinct regions characterized by geomorphology, soils, and potential forest cover types. (Adapted from Rooney, T. P., McCormick, R. J., Solheim, S. L. and D. M. Waller. 2000. Regional variation in recruitment of hemlock seedlings and saplings in the Upper Great Lakes, USA. Ecological Applications 10(4):1119-1132.)

NOTES TO FACULTY

Provide students with the background information, in addition to student instructions and figures, to aid their understanding of figures and associated questions.

Figure 1a is straightforward and illustrates a negative relationship between deer browse and number of medium-sized hemlock saplings on study sites. The sugar maple browse index is conducted by counting the number of browsed and unbrowsed terminal twigs 30-200 cm above the ground. The ratio of browsed to total twigs sampled provides a measure of browsing intensity on a scale from 0 to 1. Thus, the higher the sugar maple browse index for an area, the higher we assume the intensity of deer browse to be for other species, including hemlock, also palatable to deer.

Figure 1b has been simplified from Rooney and colleagues' original representation to ease students' interpretation. The abundance of hemlocks in each size class depends most strongly on the abundance of the immediately preceding size class. In other words, more large saplings were found where more medium saplings grew and more medium saplings occurred where more small saplings and so on. This is known as "demographic inertia." Aside from this demographic momentum, a key point for students to realize is that *different factors were most important to hemlock regeneration at different stages in their growth*. Light availability and ecological subsection (an indicator of different habitat types) affected seedling and saplings, while deer browse influenced the number of medium saplings. As saplings grow, they become more susceptible to browse. This makes sense particularly in the winter when seedlings are covered by snow while taller saplings poking through the snow are vulnerable to deer. Ownership of forest stands strongly influenced the intensity of deer browse. This reflected owners' different approaches to deer management.

Answers to discussion questions for management scenario:

In the first scenario (few hemlocks in canopy but many seedlings and small saplings), management efforts informed by the research of Rooney and colleagues should focus on controlling deer browse through exclosure fences, hunting, or other strategies.

In the second scenario (few hemlocks in canopy and few seedlings and small saplings), management efforts should focus on increasing hemlock establishment by planting hemlock seedlings. In order for this to be successful, control of deer browse could still be necessary to increase recruitment of small saplings into larger size classes.

Additional research could include studies that investigate the effect of other factors not examined by Rooney et al. These include moisture availability and the availability of appropriate microsite conditions like moss beds and nurse logs. Students might also propose research that monitors the effectiveness of their proposed management approaches, investigates methods for reducing deer browse, or examines the effect of deer on other tree species, for example.

Student Assessment: Minute Paper

For a quick assessment of students' comprehension of the figures, select one of the questions that students discussed with their neighbor and ask them to answer it individually in writing on a 3x5 index card or piece of scrap paper. Allow 1-3 minutes for students to respond. For a more in-depth assessment, ask students to respond with a short answer in writing to each of the questions in the student instructions.