Deer and Sedge: Bottlenecks to Seedling Regeneration in Northern Hardwood Forests and Potential Restoration Techniques Aimed at Reversing the Effects

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Abstract: *High white-tailed deer densities lead to tree recruitment failure, decreased vertical structure complexity, and shifts in composition to species such as sedge (e.g. Carex pensylvanica) in Great Lakes northern hardwood ecosystems. We tested various treatments to identify mechanisms by which deer and competing vegetation interact with tree seedlings to reduce survival, seedling height, and stem biomass using a field study in mesic northern hardwood stands in the Upper Peninsula of Michigan, USA. We used three sedge removal treatments (varying in severity) plus a control in deer exclosures and paired open areas in an attempt to increase seedling regeneration into and through the zone of deer herbivory (0.25m – 1.5m) while maintaining herb layer richness. After four years, sedge biomass was still significantly lower in the three treatments relative to the controls, while herb biomass, which rebounded within two years, was at or above control levels. Planted sugar maple seedling survival, total height, and stem biomass were significantly greater in deer exclosures (68% survival, 23.6 cm height, 1.05 g stem biomass) compared to open areas (25% survival, 13.1 cm height, 0.5 g stem biomass). Of the surviving planted sugar maple seedlings, 82% were damaged in areas open to deer. Within deer exclosures we found an interaction between sedge and light; higher light levels increased the negative effects of sedge on seedling height and biomass. Recruitment into higher height classes was completely suppressed in areas open to deer irrespective of treatment. In contrast, deer exclusion areas had seedlings in higher height classes with greater numbers in sedge removal areas. Our data revealed that sedge did impact seedling height and biomass especially in high light environments, but that the main bottleneck to seedling survival and recruitment into higher height classes was the effect of deer.*

In another experiment we tested operationally feasible treatments (summer vs. fall glyphosate applications) and their effects on sedge and non-target vegetation. We found that: 1) sedge was controlled almost as thoroughly in fall treatment areas as in summer treatment areas, 2) there was very little effect on non-target species with fall application, while large negative effects were evident with summer spraying, and 3) more sugar maple seedlings germinated and had higher survival in fall treatment areas than in summer or control areas. It is important to note that we did find increasing deer damage to surviving seedlings in treated areas, especially those in summer application areas. Thus long term growth and survival may still be compromised in high deer density areas.

Land use and deer management practices in Michigan have caused unprecedented high deer densities. Intense deer browsing has strong negative impacts on forest herbs, tree recruitment, and forest vertical structure. There are some species, however, that are avoided as browse. One of these, Pennsylvania sedge (*Carex pennsylvanica*), has increased dramatically. Even if deer are completely removed it is believed that established sedge maintains dominance by out-competing reestablishing tree seedlings and herbs. Thus, tree seedling regeneration and forest herbs can be negatively impacted by deer directly via browse, and indirectly via competition from high sedge densities. However, the relative effects of deer vs. sedge on tree regeneration and herbs are unknown. It is possible that if sedge effects are strong, reducing sedge densities with management interventions such as herbicides could increase tree, shrub, and herb establishment even in the presence of deer browse pressure. In a series of experiments we examined the effects of deer and sedge removal on vegetation, and evaluated the effectiveness of practical sedge removal treatments on tree regeneration.

Effects of Sedge and Deer Removal: Trees

Our preliminary analyses indicate that at high deer densities (>31 deer/mi^2 outside our deer exclosures) maple seedlings greater than 25 cm tall were very rare (Figure 1a), leaving virtually no potential for future sapling-sized trees. At high deer densities with sedge *removed*, seedling densities were higher than without sedge removed, but still there was no recruitment to larger size classes (Figure 1a). In contrast, four years after deer removal (using exclosures), sugar maples grew into larger size classes both with and without sedge removal, but recruitment into taller height classes was much greater with sedge removed (Figure 1b). Thus, both deer and high sedge densities negatively impact height growth and survival of tree seedlings. Removing sedge alone may not be adequate to get sufficient tree recruitment in areas with very high deer density. Removing *all* vegetation with a broad spectrum herbicide applied in summer killed nearly all advance regeneration, resulting in low densities of young seedlings. No recruit sized individuals existed 4 years after spraying (Fig 1a).

Effects of Sedge and Deer Removal: Herbaceous Vegetation

In addition to killing advance tree regeneration, using broad-spectrum herbicides in summer to control sedge also kills non-target species, such as forest herbs. Surprisingly, in exclosures four years after complete vegetation removal with non-selective herbicide we found a 20% increase in the number of herb species present (i.e., species richness). However, this increase was largely due to an increase in "weedy" species such as mullein, mustard, and Linaria spp., rather than native forest herbs. Removing sedge alone should be an improvement over broad-spectrum herbicide in maintaining forest herbs, but we found that sedge removal and high deer densities decreased herb species richness. The remaining vegetation may be more nutritional and/or more visible to deer. This result must be interpreted carefully since the small size of each treatment area (10x10m) may have contributed to herbaceous species declines by creating a small "oasis" of high quality browse that contrasted sharply with the sedge-dominated landscape surrounding it. If sedge were removed over a much larger area, herbs and tree regeneration may be able to overcome browse pressure by saturating deer with high quality food.

Timing Broad-Spectrum Herbicide Application to Control Sedge and Minimize Unwanted Impacts

Over larger (1/2 acre) study plots than used in our first experiment and without exclosures (deer ~ 30/mi^2), we compared the effects of summer (July 15th) vs. fall (Nov 1st) spraying of a broad-spectrum herbicide on sedge and other vegetation. We found that both summer and fall applications decreased sedge biomass two years after application (figure 1c), but the early fall application had little impact on non-target species. In fact, fall application increased the plant species richness compared to areas not sprayed (in contrast to our results from 10 x 10 m plots, above), whereas summer application reduced species richness (Fig.1d). Fall and summer treatment areas had 14 and 9 species, respectively, which were absent in non-sprayed areas. Of these, 43% and 78% respectively were weedy species. Thus, fall spraying resulted in increased species richness and decreased invasion of weeds compared to summer spraying.

Management Recommendations

Our results suggest that summer application of broad-spectrum herbicide has too many negative impacts on potential tree recruits and herbaceous vegetation to be useful for controlling sedge in most situations. Also, selective sedge removal may not increase tree seedling recruitment and plant diversity in small treatment areas with very high deer densities. However, in areas with lower deer densities, and/or possibly if applied over large areas, selective sedge removal may enhance the growth rates and survival of tree seedlings and maintain/increase non-target plant diversity. In summary, for northern hardwood stands that have been or will soon be partially (e.g. selection) harvested within two years:

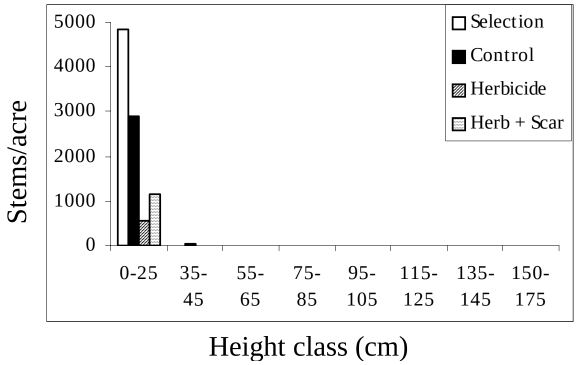
1) Apply broad-spectrum herbicide just after leaf off in autumn. At this time sedge and some grasses are the predominant photosynthetically active (and thus herbicide sensitive) plants. In special cases, summer treatment may be desirable if the understory has high densities of undesirable advanced regeneration such as ironwood.

2) Apply herbicide to relatively large areas (i.e., several acres). This may be especially effective in areas where deer densities are moderated by factors such as distance to winter thermal cover and increased snow depth (for further details see LeBouton et al.). The increased browse quantity and quality resulting from spraying are more likely to saturate and thus overcome local deer browse pressure if these effects occur over a larger area.

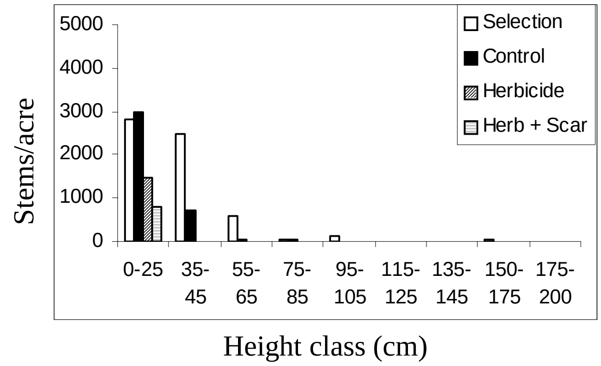
3) Consider reducing basal area to lower levels (50-60ft^2/acre) than those typically used for partial cutting to open the canopy for aerial spraying and to promote rapid growth of seedlings into and through the zone of deer foraging.

4) Factors other than deer and sedge may be limiting tree seedling recruitment. These factors include a) seed limitations that could result from insufficient densities of large seed producing trees, and b) stand structure. For example, self-thinning closed canopy forests transmit little light to the forest floor resulting in low seedling densities.

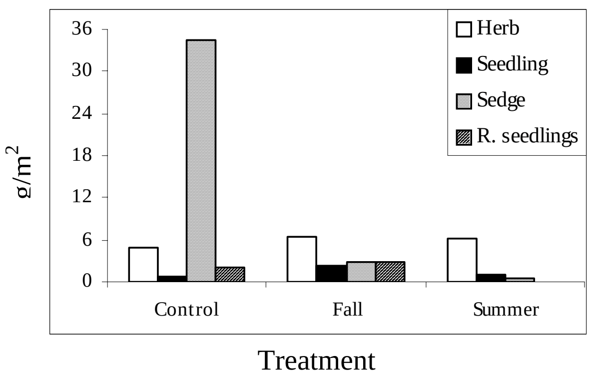
Sugar maple seedling stems/acre – Open to deer



Sugar maple seedling stems/acre – Excluding deer



Harvest biomass (summer 2004)



Species / Area curves (summer 2004)