Interpretation of Age-structure Gaps in Hemlock (*Tsuga canadensis*) Populations of Algonquin Provincial Park, Ontario, Canada

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Casual observations have suggested that intermediate size and age gaps may exist in the eastern hemlock (*Tsuga canadensis* (L.)Carr.) populations of Algonquin Provincial Park, Ontario. This was confirmed in vegetation surveys reported here. Several hypotheses, involving mortality risks at different points in the life cycle of hemlock, are proposed to explain the age gap. The hypotheses include seed predation (a period of intense seed predation), seedling establishment (a period of environmental or climatic changes limiting seedling establishment), hare browsing (a period of high snowshoe hare populations and intense browsing), ungulate browsing (a period of heavy ungulate browsing limiting hemlock recruitment), stem exclusion (normal stem dynamics), and canopy suppression (long-lived canopy stretching tolerance limits of hemlock seedlings).

Two hundred and sixteen 0.04 ha plots were randomly placed in stands throughout the west side of Algonquin and classified by five factors: three stand types (hemlock dominated, hemlock patch and scattered hemlock sites); two disturbance types (cut and uncut); three aspect types (north, south and knoll); lakeshore versus non-lakeshore (upland) sites; and deeryard versus nondeeryard sites. Within each plot, all stems $\geq$ 5 cm dbh were recorded by species, age, height and diameter; and stumps by species, diameter and year of cut. Data collected on all hemlock seedlings and small saplings < 5 cm dbh included age at ground level, height and percentage of seedling damaged by browsing, and type of browsing (hare or ungulate).

In the main survey, 5,159 stems $\geq$ 5 cm dbh from 25 species and 19,794 hemlock seedlings < 5 cm dbh were measured.

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A gap was present in the age structure, with a distinct scarcity of hemlock stems between about 40 and 125 years old. The gap was most distinct in deeryard-nonlakeshore plots and least distinct in lakeshore-nondeeryard plots. Past browsing by white-tailed deer (*Odocoileus virginianus* Zimmermann) had limited hemlock recruitment in former deeryard areas while current heavy browsing by moose (*Alces alces* L.) appears to be limiting hemlock recruitment in upland areas and extending the age gap. The latter is suggested by the tagging experiment (17% chance of being browsed if not browsed before, and 34% chance if previously browsed). The browsing hypothesis appears to be the most likely explanation of the hemlock age gap. The age gap also appears to involve older age groups in older stands, suggesting a contributing role of stem exclusion in generating the age gap. There was little support for the canopy suppression hypothesis, as the age gap generally involved ages < 100 years, which is below the limit of shade tolerance for hemlock. There was little evidence in support of the seed predation, hare browsing and seedling establishment hypotheses. Sugar maple (*Acer saccharum* Marsh.) appears to be replacing hemlock, especially in areas with past heavy browsing. A qualitative model is proposed to describe the role of browsing and stem exclusion in the dynamics of hemlock and sugar maple in Algonquin Park.

Implications to management

Managers need to be aware of ungulate population levels in their area and the negative effects they may be having on tree regeneration and recruitment. They also need to be aware of unbalanced age structures in forest stands and how this may affect future wood requirements. If a species such as hemlock has not been recruiting for several decades or more on the landscape level, logging and natural mortality will decrease the abundance of hemlock and change forest composition to dominance by more browse tolerant species, such as sugar maple.