EMEND





ECOSYSTEM-BASED MANAGEMENT EMULATING NATURAL DISTURBANCE

EMEND Insights #16

Ecological Messages:

- Residual white spruce trees are vulnerable to windthrow when left at low retention levels, likely because they have shallower roots and a higher wind drag than other species.
- Residual aspen have higher overall mortality than spruce but show a strong, positive growth response following low-retention harvests, likely due to increased light and competitive release.
- Large-diameter trees had lower survival at low retention levels, particularly in white spruce and mixedwood stands.

Management Implications:

- Aspen is slightly more resilient than spruce at moderate levels of dispersed retention (10–20%); with short-term increases in growth, there might be opportunities for second-pass harvests of retained trees.
- White spruce is better suited to higher levels (e.g., 50–75%) of dispersed retention or retention in large patches.
- Large-diameter trees will likely have higher survival if retained in patches (particularly in white spruce stands), improving their value to conservation outcomes.

Designing harvests to increase survival of retention trees

Research led by Dingliang Xing, Scott Nielsen, Ellen Macdonald, John Spence and Fangliang He

A lot of work goes into planning and implementing retention harvests. The gradual die-off of residual trees is an expected outcome that will contribute to the pool of snags and coarse woody debris; rapid and extensive die-off of residual trees, however, is undesirable.

Residual tree mortality can occur following random, uncontrollable events like windstorms. Yet it can be predictably high even in the absence of such events, with retained trees being especially vulnerable shortly after harvest. ***To manage this risk, it is essential to understand which trees, forest stands, and harvest treatments experience the greatest mortality.***

This study used ongoing, long-term data from the EMEND project to determine whether tree characteristics (DBH and crown size) explain patterns in tree growth and mortality following experimental retention harvesting. Site wetness, as measured by Wet Areas Mapping, was tested but did not explain residual tree mortality or growth following retention harvest treatments.

Dispersed, lower-retention harvests (10–20%) were more effective for deciduous-dominated stands, where survival was less affected by harvests and residual aspen growth increased following harvest. In contrast, white spruce and mixedwood stands were more sensitive to harvest with higher mortality rates in low retention blocks, particularly due to windthrow of large retention trees. In these instances, higher dispersed retention or (more realistically) retention patches should result in higher residual tree survival in the first ten years post-harvest.

A contemporary cutblock featuring aspen retention. Photo by J. Witiw (DMI).

The fate of retained trees

Variable retention management has increased in popularity since the 1990s, but many challenges remain when it comes to implementation. Residual trees are intended to play an ecological role, providing wildlife habitat, carbon storage, and potentially promoting future regeneration. As they die, retained trees contribute to the stand's pool of snags and downed logs.

These ecological benefits all assume continued growth and gradual mortality of residual trees. But what is actually happening to residual trees in the years and decades following harvesting? And what effect does retention level have?

In this study, we expanded on work conducted by Kevin Solarik's team in 2012, where they examined patterns of tree mortality at EMEND following retention harvests (see EMEND Insights #1). We expanded on this question by looking at tree growth rates as well as mortality following harvest, and included interactions between retention level and tree characteristics (e.g., DBH) in our analysis. Our results will help managers tailor retention strategies to increase desirable outcomes for residual trees.

Methods

This project used data collected as part of the core database at EMEND. Crews have been collecting data in permanent sample plots since 1998, the year before experimental harvests were applied. We have analysed the fate of trees within these plots using data collected in 1998, 2003, and 2008. We also used Wet Areas Mapping to include site wetness, as quantified using the depth-to-water index, as a potential predictor of residual tree growth and mortality.

Gradual die-off of residual trees provides snags and downed logs in a harvested stand. Photo by J. Witiw (DMI).

About EMEND:

The Ecosystem-based Management Emulating Natural Disturbance (EMEND) Project is a multi-partner, collaborative forest research program. The EMEND project documents the response of ecological processes to experimentally-delivered variable retention and fire treatments. The research site is located in the western boreal forest near Peace River, Alberta, Canada, with monitoring and research scheduled for an entire forest rotation (i.e. 80 years).

Key Findings

Residual trees had rapid growth and high mortality

High residual tree mortality following variable retention harvests has long been a concern for forest managers. Overall, average mortality of residual trees at EMEND was ~4% per year during the first five years for both 10% and 20% retention, decreasing slightly to 3% per year over the second 5-year post-harvest period.

Aspen had higher overall mortality rates than white spruce, including in unharvested stands, but windthrow was an important issue for white spruce in the low retention treatments (10% and 20%). ***In the first five years post-harvest, residual spruce trees in 10% and 20% retention treatments were 7–11 times more likely to die than trees in the controls***, where mortality was very low. At these low retention levels, spruce trees—with their shallow root systems and large crowns—were highly vulnerable to windthrow, which accounted for the majority of residual tree mortality.

We also found, however, that residual trees grew faster at lower retention levels. In the first five years, this response was most pronounced for aspen trees; as a shade-intolerant species, ***aspen grew quickly in response to what amounted to substantial stand thinning***. Residual white spruce also grew faster after lower-retention harvests, but the response was neither as strong nor as immediate as that of aspen.

These findings support the use of patch retention for white spruce, but demonstrate the resilience of aspen to dispersed retention harvests. The increased growth rate of residual aspen trees has important implications for their future ecological value as large wildlife trees or even as a potential future source of fiber.

Residual trembling aspen grew very quickly in the first five years post-harvest. Photo by J. Witiw (DMI).

Larger trees (diameter and crown size) had higher mortality at low retention

At high retention levels (50% and 75%), larger residual trees had higher survival and growth, but ***at lower retention levels these large trees were more susceptible to windthrow.*** For instance, five to ten years after harvest, windthrow of large trees accounted for more than half of residual white spruce mortality.

These results clearly demonstrate that low levels (e.g., 10–20%) of dispersed retention may be less effective for maintaining large wildlife trees and snags in white spruce stands and in stands with very large trees (diameter and crown size). ***Rather, large retention patches or high levels of dispersed retention (i.e., 50%) would be more suitable in these areas.*** These treatments would likely reduce short-term mortality and maximize the intended ecological benefits of residual trees as wildlife habitat, for example for use by cavity nesters.

Site wetness had no observable effect on residual trees in this study

We assessed the effect of site wetness, as quantified by the depth-to-water index (see Box 1), on residual tree mortality and growth, but it was not significant in any of our tests. This may have been due to the low variation of site wetness within the study area—most of the residual trees we studied were on relatively dry sites. Only 23% of the residual trees were found in sites that are considered “wet” (depth-to-water index of <1 m). Future studies that capture a wider range of site wetness may discover effects that were not observed during this study.

Management Implications

This study reveals several factors that increase the probability of residual tree mortality, allowing managers to strategically plan retention harvests to manage this risk.

Our results suggest that ***for white spruce stands and areas with larger-than-average trees, higher levels of dispersed retention or retention in patches would result in greater resilience.*** Patch retention, in particular, would be better-suited for conservation of large-diameter trees for wildlife habitat, not only increasing the probability of residual trees remaining upright (whether alive or as snags), but also improving overall conservation effectiveness for interior forest species (see EMEND Insights #9 and #17).

While this study did not examine mortality within retention patches, previous work has shown that larger patches (>0.5 ha) have lower windthrow rates, particularly when embedded within dispersed retention (see EMEND Insights #12).

Box 1. What is Wet Areas Mapping?

Aerial photo interpretation has typically been used to develop maps showing surface drainage networks, but these maps often lack the level of detail needed to plan forest operations. Following recent advancements in remote sensing, LiDAR data were used in the Wet Areas Mapping tool to create an index of soil depth-to-water (referred to as “site wetness” within this note). A low depth-to-water value, for example, means there is a high probability that water is near or even at the surface of the ground. It is important to note that depth-to-water is not an empirical measure of site wetness, but rather represents the probability of encountering water at a given depth. Researchers can adjust the model to improve its performance at different sites and under different conditions (e.g., drought).

White spruce trees are recommended for retention in large patches. Photo by J. Witiw (DMI).

Further reading

Solarik, K.A., Volney, W.J.A., Lieffers, V.J., Spence, J.R. and Hamann, A. (2012) Factors affecting white spruce and aspen survival after partial harvest. Journal of Applied Ecology 49: 145–154.

Xing, D., Nielsen, S.E., Macdonald, S.E., Spence, J.R. and He, F. Survival and growth of residual trees following variable retention harvest in a boreal mixedwood forest. (submitted to Forest Ecology and Management).

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