

**SFM Network**
Research Note Series
No. 63

Bryophyte conservation in the managed boreal mixedwood mosaic

Highlights

- Bryophytes (mosses, liverworts, and hornworts) contribute to biodiversity and functioning of boreal mixedwood forests but are susceptible to forest harvesting.
- Forest canopy closure and composition were strong predictors of bryophyte species composition five to six years after partial harvest, in part through their influence on forest moisture levels.
- Greater levels of canopy retention conserved more bryophytes, although liverworts and species that grow on decayed wood and tree bark were sensitive to any amount of canopy removal.
- Variation in canopy composition provides a range of substrate types and growing conditions to support a greater diversity of species.
- Bryophyte propagules (e.g., spores and plant fragments used for reproduction) found in forest soils may facilitate the recolonization of some species under appropriate growing conditions.

The Ecosystem 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, and is scheduled to last for an entire forest rotation (i.e., 80 years). Individual research projects evaluate which forest harvest and regenerative practices best maintain biotic communities, spatial patterns of forest structure, and functional ecosystem integrity, compared to mixedwood landscapes created by natural disturbances. Furthermore, economic and social analyses evaluate the long term viability and acceptability of these practices. This research note, part of a series about the EMEND project, summarizes research on bryophytes in mixedwood forests.

Mosses and liverworts: critical components of boreal forests

Influence on forest ecosystems

Mosses and liverworts, along with hornworts, are collectively known as bryophytes. They are often referred to as “miniature forests” owing to their small size and wide variety of growth forms. Bryophytes are readily apparent in boreal forests and, despite their small size, can have a considerable influence on plant species diversity and ecosystem processes. Many mosses and liverworts inhabit substrates that are not readily colonized by other plants, such as the bark of trees and decayed wood on the forest floor. These substrates are capable of supporting large numbers of bryophyte species and are important drivers of bryophyte diversity in forest ecosystems.



Decayed aspen log supporting a variety of bryophyte species in intact forest.
Photo courtesy of R. Caners.

The substantial influence of bryophytes on ecosystem processes is in part related to the high biomass they can attain on the ground beneath closed forest canopies, where they have been shown to regulate forest soil moisture and temperature, nitrogen fixation and nutrient sequestration, and tree regeneration, as well as provide habitat for invertebrates and fungi. However, the specific substrate requirements and unique physiology of bryophytes make them susceptible to changes in local habitat and growing conditions following disturbance. Many species colonize only wood of a certain type (broadleaf or conifer) and decomposition stage. Furthermore, unlike larger vascular plants, mosses and liverworts are unable to control their internal water balance, making many species dependent on moisture from their immediate surroundings for continued growth and survival.

Although boreal bryophytes are part of a forest biome that is adapted to recurrent natural disturbance, notable differences exist between the effects of fire

as an historical agent of disturbance, and the effects of industrial forest harvesting. Recently, there is growing interest in documenting the effects of forest management practices on landscape scale patterns of forest stand structure and composition, and how these changes can affect forest biodiversity.

Impacts of harvesting on mosses and liverworts

Past research has shown that clear-cutting results in the rapid loss of certain bryophyte species, and declines in others, with effects that can persist for decades. Species that are sensitive to increased exposure and moisture loss are most affected by canopy removal. Recently, forest management policy has shifted towards harvesting practices that promote biodiversity conservation on the managed land base. This is being implemented, in part, through the retention of greater levels of residual forest structure after harvest. This practice has been recommended as a means to facilitate the conservation of biological diversity (Canadian Council of Forest Ministers [CCFM] Criterion 1) by promoting species survival in the harvested matrix. It is also designed to enhance ecosystem resilience (Canadian Standards Association Sustainable Forest Management Element 2.1 of CCFM Criterion 2) by improving chances of local dispersal and colonization of species after harvesting. The effectiveness of different amounts of canopy retention for the conservation of mosses and liverworts was previously unknown, and was the driving motivation behind our research.

This research note synthesizes some of our most pertinent findings on the effectiveness of residual forest structure for the protection of boreal mixedwood bryophytes in the short term, following experimental variable retention harvesting. We also provide suggestions for the best ways to manage for bryophytes in harvested mixedwood forests.

Assessing bryophyte responses to canopy retention and composition

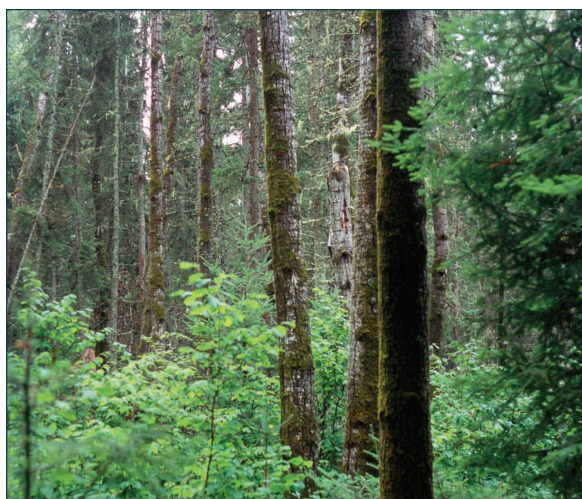
The EMEND experiment in northern Alberta provided a template with which to study the effects of partial harvesting on biodiversity conservation. We examined the responses of bryophytes in 24 10-ha forest stands, five to six years after 10%, 50%, and 75% dispersed green-tree retention harvesting (unharvested stands as controls), in mixed broadleaf-conifer (primarily aspen and white spruce) and conifer-dominated (primarily white spruce) forests. Bryophytes were sampled using six large (> 0.1 ha) circular plots per stand in order to capture a wide range of habitat types and associated species.

Dispersed retention: beneficial for some bryophytes, not for others

Bryophyte responses to harvesting

Greater levels of canopy retention after harvesting were generally found to be increasingly beneficial for bryophytes. In particular, increased retention was associated with higher numbers of species and increased similarity in species composition (types and abundances of species) when compared to intact forest. These trends were consistent between mixed and conifer-dominated forest types. However, some bryophyte groups experienced greater benefits from retention than others. Liverworts, which comprised nearly one third of all sampled species, shifted in composition following any degree of harvesting, and declined in richness and diversity at the lowest levels (10% and 50%) of retention as compared to intact forest (Figure 1). In contrast, moss richness and diversity did not differ among retention levels, but composition at the lowest retention levels differed from intact forest. The weaker response of mosses to residual forest structure as compared to liverworts was partly attributable to species turnover among retention levels. Namely, some moss species decreased in abundance or were absent at greater harvesting intensities, whereas other species preferred more disturbed habitat and increased in abundance or were found only at greater harvesting intensities. There was less turnover of liverwort species along the range of harvesting levels.

Bryophytes that preferentially colonize decayed wood (epixylic species) and the bark of trees (epiphytic species) declined in richness with any level of harvesting. Many species belonging to these groups were significant indicators



High abundance of bryophytes on aspen trees in intact forest. Photo courtesy of R. Caners.

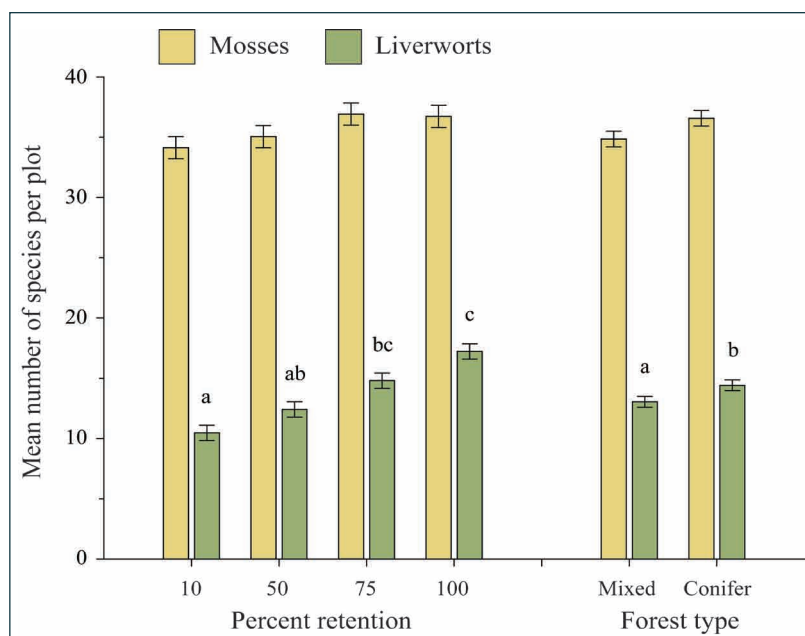


Figure 1. Mean (± 1 standard error) richness of mosses and liverworts per plot for each retention level and forest type. Bars with different letters were significantly different (tests were performed separately for mosses and liverworts). No interaction was detected between retention levels and forest types.

of intact (control) forest. A detailed study of epiphytic bryophytes on aspen trees revealed that greater harvesting intensities resulted in increased epiphyte mortality, more areas of uncolonized bark on trees, and the loss of epiphyte community structure. Under some circumstances, bryophytes can provide protection from stressful growing conditions for their closest neighbours; increased epiphyte mortality with harvesting may reduce the benefits provided by multispecies communities on trees. Richness of species that preferentially colonize other substrate types (e.g., animal excrement and bones, forest floor, exposed soil) were apparently not as strongly affected by the amount of retention after harvesting, whereas generalist species increased in richness with increasing harvesting intensity.

Moisture loss as a driver of change

Our research implicates moisture loss as an important driver of bryophyte change after harvesting. We used the recent shoot growth of common forest floor moss *Hylocomium splendens* ("stair-step moss") as a surrogate measure of forest moisture at each site. The species is a sensitive biological indicator, responding closely in terms of growth to local moisture conditions. The strong shift in liverwort composition and reduced numbers of epixylic and epiphytic species with any level of harvesting were accompanied by significant reductions in forest moisture as detected by the growth of stair-step moss. Although the lowest levels of retention were able to support species with high tolerance to harvesting, some of the most sensitive species will require areas of intact forest where forest moisture levels are greatest.

Forest canopy composition affects bryophyte diversity

The relative abundance of broadleaf and conifer trees among the sampled forest stands was also found to be an important determinant of bryophyte richness and composition, and this was unrelated to the degree of harvesting. Conifer-dominated forest supported a greater number of liverwort species than mixed forest, partly because intact conifer forest had higher moisture levels. The two forest types differed in terms of moss and liverwort composition, and each contained unique indicator species. Some indicator species, for example, preferentially colonize conifer wood, whereas others colonize broadleaf wood. Maintaining variation in forest canopy composition in managed mixedwood forests will be critical for ensuring that natural variation in bryophyte communities is preserved.



Conifer-dominated forest with low (10%) retention after experimental harvest.
Photo courtesy of R. Caners.



The liverworts *Calypogeia suecica* (narrow shoots with propagules) and *Riccardia latifrons* (larger thalli) grow only on decayed wood and are strong indicators of intact forest. Photo courtesy of R. Caners.

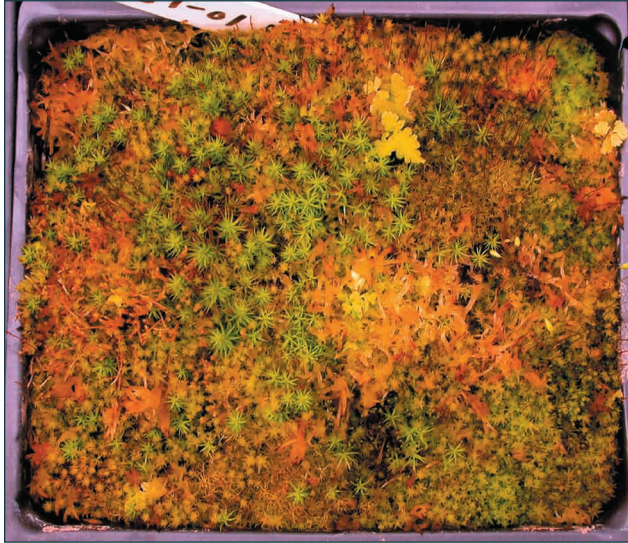
Buried propagule banks may promote species establishment after harvesting

The loss of several sensitive species from harvested sites requires an understanding of potential mechanisms for species recovery. We approached this problem through an examination of bryophyte propagule banks that occur naturally in the upper mineral soil horizons of mixedwood forests, and contain viable spores and other vegetative propagules capable of regeneration. We conducted a growth cabinet study in order to regulate the ambient growing conditions (e.g., air temperature, and light intensity, quality, and duration) and found a relatively large number of species germinated from the soil samples. Although the majority of germinated species grow preferentially on exposed soil under natural

conditions, other species that prefer decayed wood, tree bark, forest floor, animal excrement, and aquatic habitats also germinated. Some of these species were ones that had been found to be sensitive to forest harvesting in our study of aboveground bryophyte communities. Germinated species composition did not differ among harvesting intensities or forest types, implying that buried propagule banks may serve as a persistent source of species for recolonization under the appropriate growing conditions.

That being said, few liverwort species germinated from the mixedwood propagule banks. This may have resulted from several factors, including poor viability in buried propagule banks, unsuitable growth cabinet conditions during germination, or the strong preference of most liverworts in our study area for decayed wood as opposed to mineral soil substrates. The high sensitivity of liverworts

to canopy removal and their poor representation in propagule banks suggest that existing populations in mixedwood forests require protection. The majority of liverworts in mixedwood forests have low abundance and require decayed wood as habitat. Therefore, protecting these species and habitats from direct and indirect effects of harvesting will be important for the conservation of this group of species.



Bryophytes growing from forest soils in a growth cabinet experiment. Photo courtesy of R. Caners.

Further reading

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Management Implications

- The amount and composition of forest canopy retained after harvesting should be considered when managing for bryophyte conservation. While several species were able to persist at low retention, liverworts and species that prefer decayed wood and tree bark habitats declined following any canopy removal. Many of these species will require areas of intact forest for their continued preservation.
- Maintaining variation in forest canopy composition at the stand level will preserve the range of substrate types and growing conditions required by different bryophyte species.
- Research is needed on the mechanisms and rates of species recovery to assess the long-term effects of harvesting on bryophytes.
- Bryophyte propagule banks in the soil may serve as a persistent source of some species for post-disturbance recolonization but only under the appropriate growing conditions and not for most species that were sensitive to harvesting.

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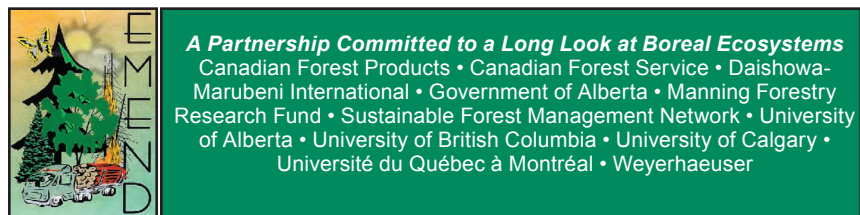
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