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# Dynamics of stand structure and understory plant diversity in northwestern Ontario

## Highlights

- Mixedwood and old forest stands are important landscape elements which contribute heavily to structural diversity.
- Forest succession from broadleaf to coniferous is a main driver of plant diversity on the landscape and should be considered in management actions.
- Fires create a pulse of snags which are later recruited as downed woody debris, creating a series of critical habitats for biodiversity.
- Deadwood recruitment is largely absent under traditional clearcutting, but can be supplemented through management techniques.

## Stand structure and understory plant diversity

**Forest stand structure** and understory vegetation play critical roles within forested ecosystems. Forest stand structure includes the attributes of live trees, standing deadwood (snags), and downed woody debris (DWD). Historically, stand-replacing wildfire was largely responsible for shaping the structure and composition of stands on the North American boreal landscape. More recently, however, commercial forest harvesting has become an increasingly common stand-replacing disturbance.

Clearcutting is the most common harvesting technique in the boreal forest. While clearcutting can mimic the landscape pattern of natural boreal forest, many stand attributes differ after clearcutting compared to wildfire. This research note summarizes our studies that compare stand structural and understory vegetation dynamics following both wildfire and clearcutting. We surveyed 72 stands of varying overstory compositions that initiated between 7 to 201 years after either clearcutting or wildfire in the Spruce River Forest of northwestern Ontario, Canada. These comparisons provide a greater understanding of the important structural and compositional features left after wildfire that are not emulated by clearcutting, so forest practitioners can make more informed management decisions.

## Stand structure

### *Influences of stand age and composition on overstory structure*

In mixedwood and broadleaf stands, stand volume decreased from 72-90 years to 201 years after wildfire, following the typical trajectory expected within the boreal forest. Meanwhile, stand volume

decreased from 72-90 years to 124-139 years after wildfire in conifer stands before increasing in 201 year-old stands. Although the observed decrease in stand volume beyond maturity in some stands may have undesirable economic consequences, its value for biodiversity increases. For example, we found that stands aged 124-139 years-old had the highest diversity of live tree diameter and height among age classes, suggesting the highest heterogeneity of overstory forest structure at this stage of stand development (Figure 1).

**Figure 1.** High overstory structural heterogeneity in a 139 year-old post-fire conifer dominated stand. Photo courtesy of Stephen Hart.

Mixedwood stands also tended to have equal, or greater, heterogeneity of overstory structure than conifer or broadleaf overstory types in all age classes. Since increased bird diversity has been positively linked with high overstory structural heterogeneity, maintaining mixedwood stands and older stands on the managed landscape may be important for their conservation. These results also emphasize the importance of maintaining some stands beyond traditional rotation ages of 80 years to encourage the development of these diverse structural compositions.

## *Influences of disturbance type and stand age on deadwood recruitment*

### Disturbance type

The greatest difference between stands regenerating after wildfire versus clearcutting was found in snag and DWD volumes. In fire-origin stands, we noted a high snag volume in young stands (7 years-old), which was attributed to the death of the pre-fire cohort that inputs a large pulse of snag volume into the young stand. Most of these snags were then recruited as DWD onto the forest floor in 25 year-old stands, therefore maintaining their contribution to the ecological value of the system (Figure 2). In contrast, because of the extensive removal of the overstory during clearcutting, 7 year-old clearcut stands had much lower snag and DWD volumes (Figure 3). In addition, coarse woody debris (CWD), which includes snags and DWD, within these clearcutting-origin stands was mostly non-merchantable tree species and smaller in size; a sharp contrast to the high variability in species and sizes which were recruited following wildfire.

**Figure 2.** High snag volume in a 7 year-old post-fire stand dominated by jack pine (left) and low snag volume in a 25 year-old post-fire stand dominated by jack pine (right). Photo courtesy of Stephen Hart.

Interestingly, snag volume began to converge between fire and clearcutting origins in the 25-31 year-old age class, as most fire-generated snags had fallen down, and stands were not yet old enough to have generated many new snags through self-thinning. DWD volumes, however, were much higher in fire than clearcutting-origin stands as a result of the continual recruitment of fire-generated snags to DWD over time (Figure 3). These results show that snag and DWD volume are highly related, and that in fire-origin stands, there is a continual recruitment of DWD through the fall of snags to the forest floor. Because clearcutting-origin stands lack such a recruitment cycle, retention strategies appear to be necessary in order to more closely emulate the patterns observed in fire-origin stands.

The strong differences between clearcut and fire-origin stands have important consequences for biodiversity. For example, populations of cavity-nesting birds, mammals, and invertebrates are sensitive to reductions in snag and DWD volumes and size-variability within these young clearcuts. Greater retention after clearcutting of snags, or green tree retention to create future snags, is of paramount importance to ensure that biodiversity is not reduced on the managed boreal landscape.

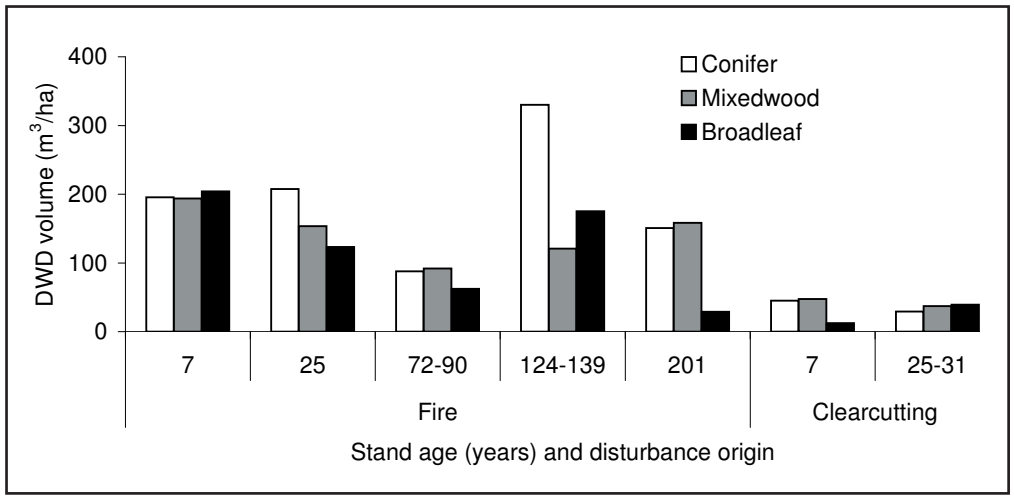


**Figure 3.** Dynamics of downed woody debris (DWD) volume in fire- and clearcutting-origin stands of different overstory types.

### Stand age

Snag volume increased in 72-90 year-old stands once longevity-related mortality of the pioneering cohort had begun, and was maintained at moderate levels in old stands by gap dynamic processes. DWD volume in all overstory types was high until 72-90 years after wildfire, when most of the inputs generated by the stand-replacing disturbance had decayed, causing a decrease in DWD volume (Figure 3). Similar to snag volume, the death of the pioneering cohort, which inputs substantial volumes of CWD initially as snags and later as DWD, caused DWD volume to increase in older stands. We predict that CWD dynamics may be similar in older clearcutting and fire-origin stands, however, commercial harvesting of the study area has not occurred over a long enough period to compare long-term dynamics.

## Understory plant diversity

The successional gradient found within the boreal forest proved to be of great importance for understory plant diversity, emphasizing the value of maintaining a range of overstory types and stand ages for sustaining plant biodiversity. For example, understory vegetation communities were found to be compositionally (the types and abundance of species) distinct for all overstory types and age classes. In addition, vascular plant assemblages (higher order plants such as asters, blueberries, and maples) were more diverse within broadleaf and younger stands, while nonvascular plant assemblages (lower order plants such as mosses and lichens) were more diverse in conifer and older stands (Figure 4). Mixedwood stands were found to support understory communities that were intermediate between conifer and broadleaf overstory types. Conifer, mixedwood, and broadleaf overstory types of varying ages have unique understory plant communities. Therefore, maintaining a range of overstory types of all ages is critical towards sustaining plant biodiversity by allowing understory plant communities to undergo a complete range of successional changes.

Compared with post-fire stands of similar age, post-clearcutting stands had similar total understory cover and richness. Vascular plant cover and richness, however, were higher on post-clearcutting than post-fire stands, and nonvascular plant cover and richness lower. It is clear that post-clearcutting stands do not create the conditions suitable for the establishment of nonvascular species of plants, which generally require less competitive growing conditions. Understory vegetation communities in fire-origin and clearcutting-origin stands showed no convergence within the first 25 years after stand-replacing disturbance, even though some variables were not significantly different between disturbance origins. Compositional differences between the two disturbance origins appear to be driven by higher

pre-established rhizomatous species like sedges and higher number and abundance of herbaceous species such as large leaved aster on post-clearcutting compared to fire-origin stands. In contrast, fire-origin stands had a greater abundance and number of 'fire-adapted' and colonizing plant species. Consequently, fire is an important process in the boreal forest for maintaining certain 'fire-adapted' plant species on the landscape that might otherwise be eliminated.

**Figure 4.** Different understory vegetation communities under a 25 year-old fire-origin jack pine overstory (left) and trembling aspen overstory (right). Photo courtesy of Stephen Hart.

## Management considerations

The results of our studies suggest that clearcutting, in its current form, does not emulate most of the structural and compositional attributes found in post-fire stands, at least early in stand development. While the nature of clearcutting precludes perfect emulation of wildfire, alternative harvesting practices, like the ones we discuss below, may be appropriate for reducing the negative effects of forest management on many ecosystem attributes.

- Partial harvesting: Since young post-clearcutting stands are missing a substantial input of large-sized snags, and the corresponding recruitment of DWD, when compared to post-fire stands, partial harvest methods (e.g., patch cuts, green tree retention, and harvesting with understory protection) should help bridge this gap. Increased residual structure should increase habitat availability for many species of cavity-nesting birds, as well as mammals and large raptors.
- Cut-to-length harvesting and redistribution of roadside debris: The significant reductions in DWD after clearcutting compared to wildfire is an obvious reflection of tree removal. However, by redistributing roadside debris back onto the site after clearcutting, or employing cut-to-length harvesting at the stump, some of the negative effects that DWD reduction has on some components of biodiversity and nutrient cycling can be mitigated. That being said, many species depend specifically on larger-sized DWD, and as a result, provision of large-sized DWD should remain a priority for managers.
- Longer rotations: Harvest rotations of 80 years or less are common in the North American boreal forest. However, unless some managed stands are allowed to reach older stages of stand development, certain components of biodiversity that rely on the unique structural and compositional characteristics of old forest (e.g., high CWD volume, dominance by later successional tree species, diverse overstory size and age structures) may be lost, thereby reducing biodiversity.
- Burning after harvest: Although prohibitive in many cases because of safety and cost, burning after harvest is the silvicultural treatment most likely to result in overstory and understory vegetation communities similar to those developing after wildfire. This is because fire creates conditions after clearcutting which are suitable for the establishment of a number of post-fire adapted species. This practice also has the added benefit of increasing nutrient availability, stimulating nitrogen fixation, and eliminating 'undesirable' species from post-clearcutting stands.

## Future work

Fire is not the only natural disturbance common to the boreal forest. Insect outbreaks and wind throw are also common disturbances. To better understand the differences between natural and anthropogenic disturbances on forest dynamics, further research is needed on how the effects of clearcutting and wildfire may differ from those of insect outbreaks and wind throw on stand structural and understory vegetation dynamics. In addition, the dynamics of other important ecosystem processes, such as carbon and nutrient cycling, must be further investigated to ensure that the ecological attributes of managed forests are within the range of natural variability.

### Management Implications

- Management options which facilitate CWD recruitment in post-clearcutting stands will help to more closely emulate the conditions after wildfire.
- Stand age is a main driver of diversity on the boreal landscape, and as such, maintaining longer rotations, to some degree, is recommended.
- Burning after harvest may be a necessary management tool in order to encourage the establishment of vegetation communities similar to those following wildfire.

## Further reading


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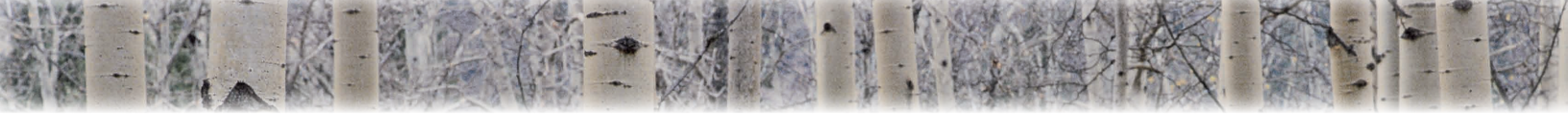

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