FIELD TRIP GUIDE

Forest ecology and management of deadwood in the eastern boreal mixedwood forest

Bienvenue

Nous vous souhaitons la bienvenue dans la Forêt d'enseignement et de recherche du Lac Duparquet (FERLD)! Cette excursion de mi-semaine a pour but de permettre aux participants de découvrir la forêt boréale mixte de l'Est du Canada, de comprendre certains aspects de la dynamique de cet écosystème et en apprendre davantage sur des recherches portant sur le bois mort ainsi que la façon dont celui-ci est géré à la FERLD. Pour ce faire, nous nous déplacerons à environ une heure au nord-ouest de Rouyn-Noranda où nous visiterons la forêt naturelle et aménagée ainsi que la station de recherche où nous nous arrêterons pour diner. Si tout se déroule comme prévu, nous serons de retour à Rouyn-Noranda vers 17h30, à temps pour le banquet!

Nous désirons souligner la collaboration de nombreux organismes qui ont aidé à couvrir les frais de cette excursion, en particulier le Centre local de développement d'Abitibi-Ouest (CLDAO). Vous avez d'ailleurs trouvé, dans votre sac de congressiste, un DVD produit par le CLDAO qui met en valeur la beauté et les attraits de l'Ouest de l'Abitibi et qui, nous l'espérons, vous incitera à revenir nous visiter!

NOTE: Étant donné que le programme d'excursions est assez chargé et que la taille des groupes est assez grande, nous vous prions de vous déplacer à un bon rythme pour accéder aux sites ainsi que lors des embarquements/débarquements de l'autobus afin que nous puissions respecter l'horaire.

Welcome

Welcome to the Lake Duparquet Research and Teaching Forest (LDRTF)! The objectives of the mid-week excursion are to allow symposium participants to get out and into the eastern boreal mixedwood forest, learn about the dynamics of this ecosystem and about some of the deadwood research and management activities that are underway in the LDRTF. We will drive about an hour northwest of Rouyn-Noranda where we will visit both natural and managed forests as well as the Lake Duparquet Forest research station where we will have lunch. If all goes according to schedule, we will be back in Rouyn by 5:30, in time for the banquet!

We are grateful to a number of agencies that have helped cover costs of this excursion, particularly the *Centre local de développement d'Abitibi-Ouest (CLDAO)*. As you probably noticed, we included in your program kit a DVD produced by the CLDAO that highlights the beauty and attractions of western Abitibi and which will hopefully entice you to make a return trip!

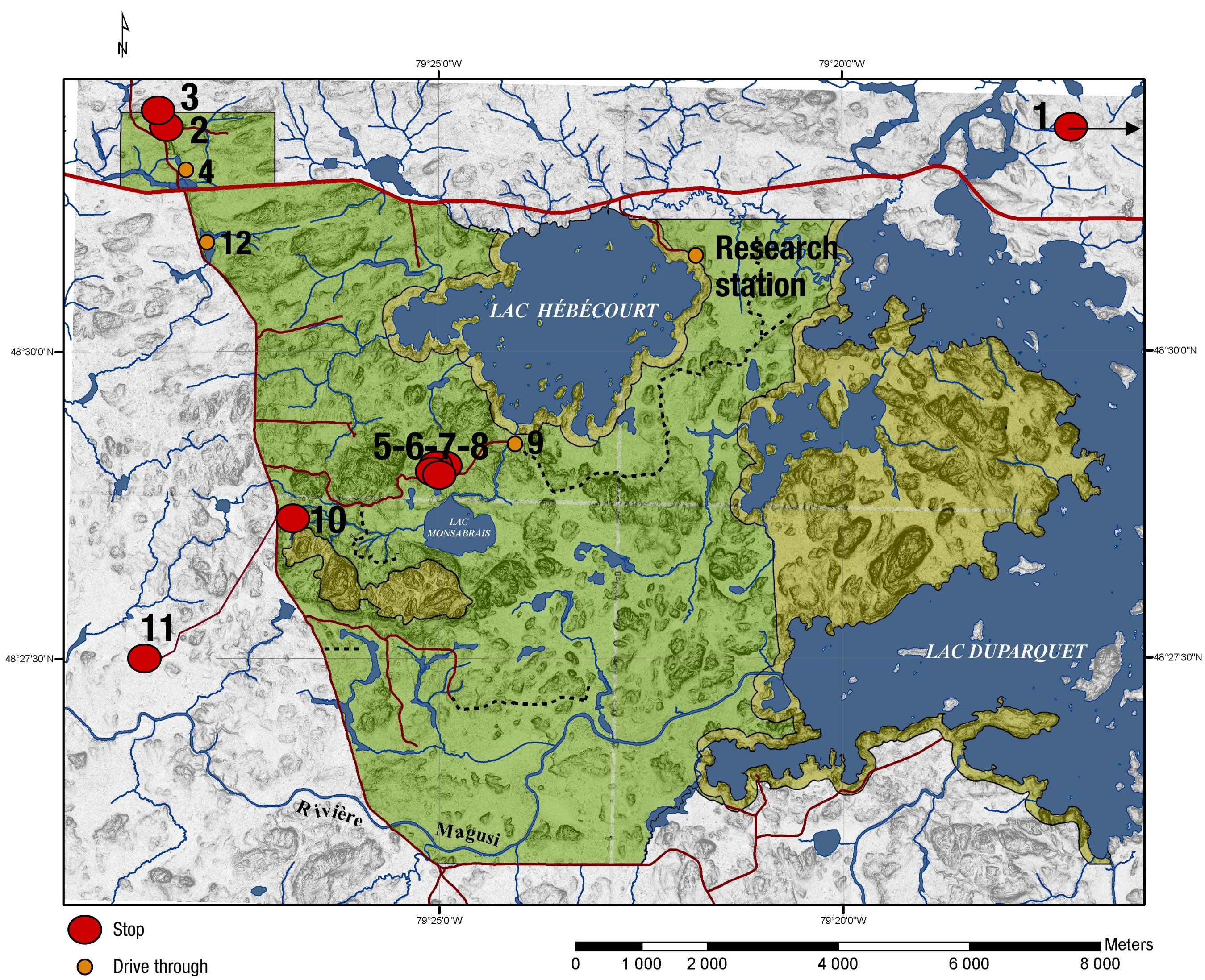
NOTE: Because the excursion program is tight and the groups are fairly large, please stick with the group and move at a good pace between the bus and the sites so that we can stay on schedule.

Brian Harvey, Director
Lake Duparquet Research and Teaching Forest

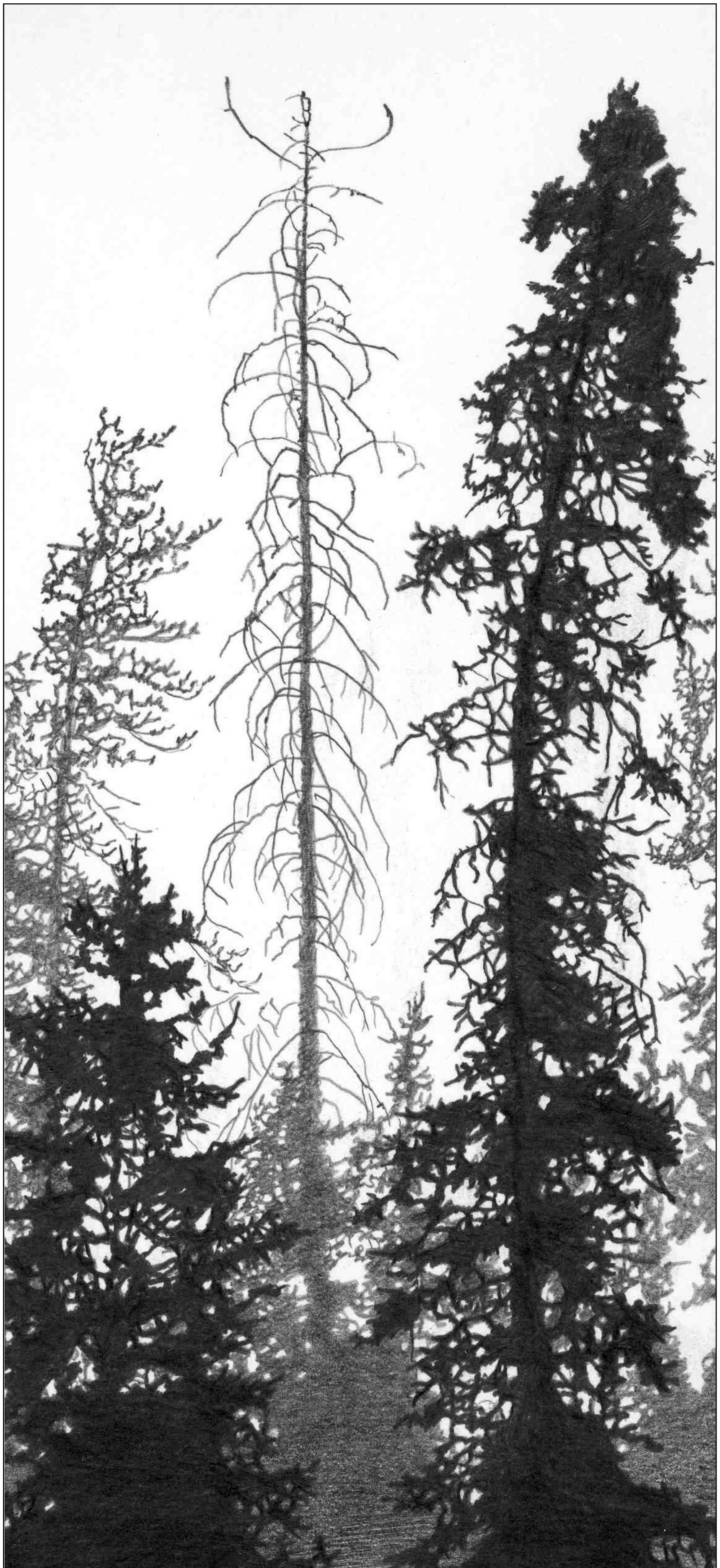
Forêt d'enseignement et de recherche du lac Duparquet

Mid-week Field Trip Map and Itinerary

Stops



	Bus 1	Bus 2	Bus 3	Bus 4
Guide	Daniel Lesieur	Pierre Godbout	Dave Gervais	Julien Moulinier
7h30	Departure	Departure	Departure	Departure
8h15	Stop 1 - Jack Pine Stand			Stop 1 - Jack Pine Stand
8h30		Stop 2 - Old White Cedar Stand	*Stop at the research station*	
8h45				
9h00		Stop 3 - Irregular Shelterwood	Stop 11 - Linear Habitat and Cavities	
9h15				Stop 10 - Biomass Harvesting
9h30	Stops 5-6-7-8 Natural dynamics and forest ecosystem management and silviculture in the mixedwood	4 - Lake Francis (Drive through)		
9h45				
10h00*		Stops 5-6-7-8 Natural dynamics and forest ecosystem management and silviculture in the mixedwood		
10h15			Stop 10 - Biomass Harvesting	Stop 11 - Linear Habitat and Cavities
10h30				
10h45				
11h00				
11h15	9 - Variable Retention (Drive through)		Stop 2 - Old White Cedar Stand	
11h30	12 - Beaver Dam (Drive through)			12 - Beaver Dam (Drive through)
11h45		9 - Variable Retention (Drive through)	Stop 3 - Irregular Shelterwood	
12h00	Lunch at the research station			Lunch at the research station
12h15			4 - Lake Francis (Drive through)	
12h30		Lunch at the research station	Lunch at the research station	
12h45				
13h00				Stop 2 - Old White Cedar Stand
13h15	Stop 11 - Linear Habitat and Cavities			
13h30		Stop 10 - Biomass Harvesting	Stops 5-6-7-8 Natural dynamics and forest ecosystem management and silviculture in the mixedwood	Stop 3 - Irregular Shelterwood
13h45				
14h00				4 - Lake Francis (Drive through)
14h15				
14h30*	Stop 10 - Biomass Harvesting	Stop 11 - Linear Habitat and Cavities		Stops 5-6-7-8 Natural dynamics and forest ecosystem management and silviculture in the mixedwood
14h45				
15h00				
15h15			9 - Variable Retention (Drive through)	
15h30	Stop 2 - Old White Cedar Stand			
15h45		12 - Beaver Dam (Drive through)	12 - Beaver Dam (Drive through)	
16h00	Stop 3 - Irregular Shelterwood		*Stop at the research station*	
16h15		Stop 1 - Jack Pine Stand		9 - Variable Retention (Drive through)
16h30	4 - Lake Francis (Drive through)		Stop 1 - Jack Pine Stand	
16h45				
17h00				
17h15		Arrival in Rouyn		Arrival in Rouyn
17h30	Arrival in Rouyn		Arrival in Rouyn	
18h30	Cocktail			
19h00	Banquet			



Pin gris by Michel Villeneuve, 2009

Human occupation of Abitibi (in a nutshell)

Archaeological finds indicate that aboriginal people, ancestors of the Algonquin Nation, have lived in this region for over 6,000 years. This region forms the heart of the ancestral lands of the Anichinabek, the name employed by the Algonquins meaning simply "the people". The major waterways of the Ottawa River (to the south) and the Moose River (to the north) were important routes for commerce and vital to the fur trade between Europeans and aboriginal people that began in the middle of the 17th century.

Completion of the Abitibi section of the National Transcontinental Railway in 1912 (Fig.1) ended the isolation of the northern part of the Abitibi region, in the James Bay watershed, and opened it up for settlement. Two regional colonisation plans in the early 1930s created 34 parishes and orchestrated the settlement of over 5,000 families who arrived on train from southern Quebec to clear the forest and scratch out a modest existence on the land. Sawmills were built along the railway at the confluence of major waterways.

In the early 1920s, rich copper and gold reserves were discovered in Rouyn Township, beginning one of the most important exploration and mining rushes in 20th century North America. In the following decades about 50 mines were developed along the Cadillac Fault between Val d'Or and Rouyn-Noranda (Fig.2).

Today, the economy of the Abitibi region is dominated by mining and forestry, along with agriculture and the service sector, and as such, has ridden the high and lows of the global economy like most other resource-based regions. The regional population is currently about 146,000 (density 2.5/km^2) and has seen a slight increase in recent years.

Photo credit: Archives nationales du Québec

Figure 1. National transcontinental 1909-1913.

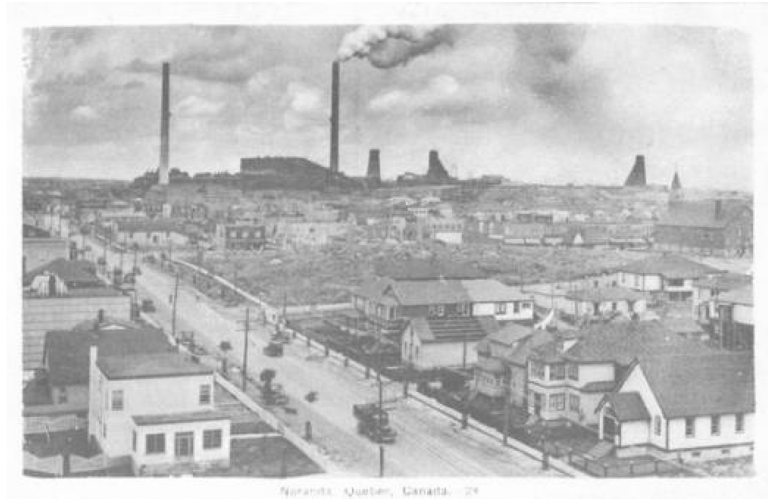


Figure 2. Noranda Mine in the 40's or 50's (*postcard*).

Québec Forest Regime

Vegetation zones

Forests cover close to 761,000 km^2 –*almost half* – of the land area of Quebec. The extensive Boreal Zone, includes the boreal taiga (roughly above 52°N) and the tundra furthest north, and the continuous boreal forest, divided into the Balsam fir- White birch bioclimatic domain (≈ 48°-49°N) and the immense Black spruce- Feather-moss bioclimatic domain (≈ 49°-52°N). The Northern Temperate Zone of Southern Quebec is a hardwood-dominated forest containing sugar maple bioclimatic domains and a transitional Balsam fir – Yellow birch mixed-wood domain, generally situated south of the boreal zone (See fig.3, Map of Vegetation Zones and Bioclimatic Domains).

Forest ownership

About 92% of the land area in the province is public and of this, over half is covered by commercial forest. The current northern limit of the commercial forest is situated between the 51° and 52° N. Of the total productive and accessible forest area, roughly 81% is public. Most private forests (19% of productive forest land) are situated in southern Quebec and along the St. Lawrence River valley, with other concentrations in the Abitibi-Témiscamingue region and around Lac St-Jean. The annual allowable cut (2009) from public forests was about 32 million m^3 and 12 million m^3 from private forests. However, largely because of the fallout in U.S. housing construction, only about half of the allowable annual cut (AAC) was harvested in public forests and a quarter in private forests.

Forest industry

Forestry is an important industrial and economic sector in Quebec, particularly in the "resource regions", as they are called. About 320 saw mills, 30 pulp & paper mills and 20 plywood and various panel mills are scattered throughout the province and forest exports were worth $3 billion in 2007. The forest industry creates about 68,000 direct and indirect jobs (2009). The province accounts for 20% of Canadian softwood lumber production and over 60% of hardwood lumber production. The U.S. accounted for 50% of softwood lumber destinations in 2004 but this figure has dropped to just over 30% in 2008 as a result of an on-going softwood trade dispute between the two countries and the downturn in the U.S. economy. Newsprint production has dropped by almost half since 1990 but Quebec still produces about 8% of total world production. (Source: 2009 Statistiques. Conseil de l'industrie forestière du Québec)

Forest policy

Like most other jurisdictions, forest management policy (a provincial jurisdiction in Canada) has evolved considerably in the last two decades. In fact, a new forest law, passed in 2010 and effective in 2013, will make some sweeping changes to policy so we are currently in an important transition phase.

Most public forest in Quebec is partitioned into Forest Management Units (FMU) managed by companies that have a license to operate wood transformation mills. An office of Chief Forester was created in 2005 with the mandate of determining annual allowable cut and reporting on the state of the forest and sustainable forest management in Quebec. Up until 2013, forest companies are responsible for management planning (including public consultation), harvesting and silvicultural activities on their FMUs as specified in their 25-year Forest management and wood procurement contracts (renewable every 5 years). The provincial Ministry of Natural Resources and Wildlife is currently responsible for evaluation of plans and reports, monitoring of harvesting and silviculture, forest inventory, nursery production and research.

Forest ecosystem management and integrated resource management are central to the new forest policy. The following are among the biggest changes that will come into effect in 2013: Forest companies that operate mills will lose their forest management and planning responsibilities as these activities will henceforth be assumed by the Ministry. As well, the companies' 25-year management and wood procurement contracts will be replaced by 5-year wood supply guarantees at levels of about 75% of current volume attributions. Wood marketing boards are currently being set up and will be responsible for placing the remaining 25% of volume available from public forest in a free market environment. The objectives are to provide new wood processing opportunities, determine market value of the resource (as a reference for stumpage fees) and maximizing revenues. Other elements of the new forest policy include a certain level of regionalization of management of forest resources, more formalized public consultation and functional zoning of public forest to include zones for intensive forest management.

Regional climate, physiography, vegetation and disturbance regime

According to Rowe's (1972) classification of forest regions of Canada, we are located centrally in the Missinaibi-Cabonga forest region, an upland area that includes eastern and switches central Quebec and west almost to the northeast shores of Lake Superior in Ontario. Upland indeed! Abitibi is an Algonquin name meaning "where the waters separate". Rouyn is located in the Ottawa River watershed that flows into the St. Lawrence River and out to the Atlantic Ocean while the Lake Duparquet Forest is situated in the James Bay watershed whose waters mix with those of Hudson Bay and the Arctic Ocean. So we will be crossing between two major watersheds today – twice!

The Quebec classification of ecological regions (Saucier

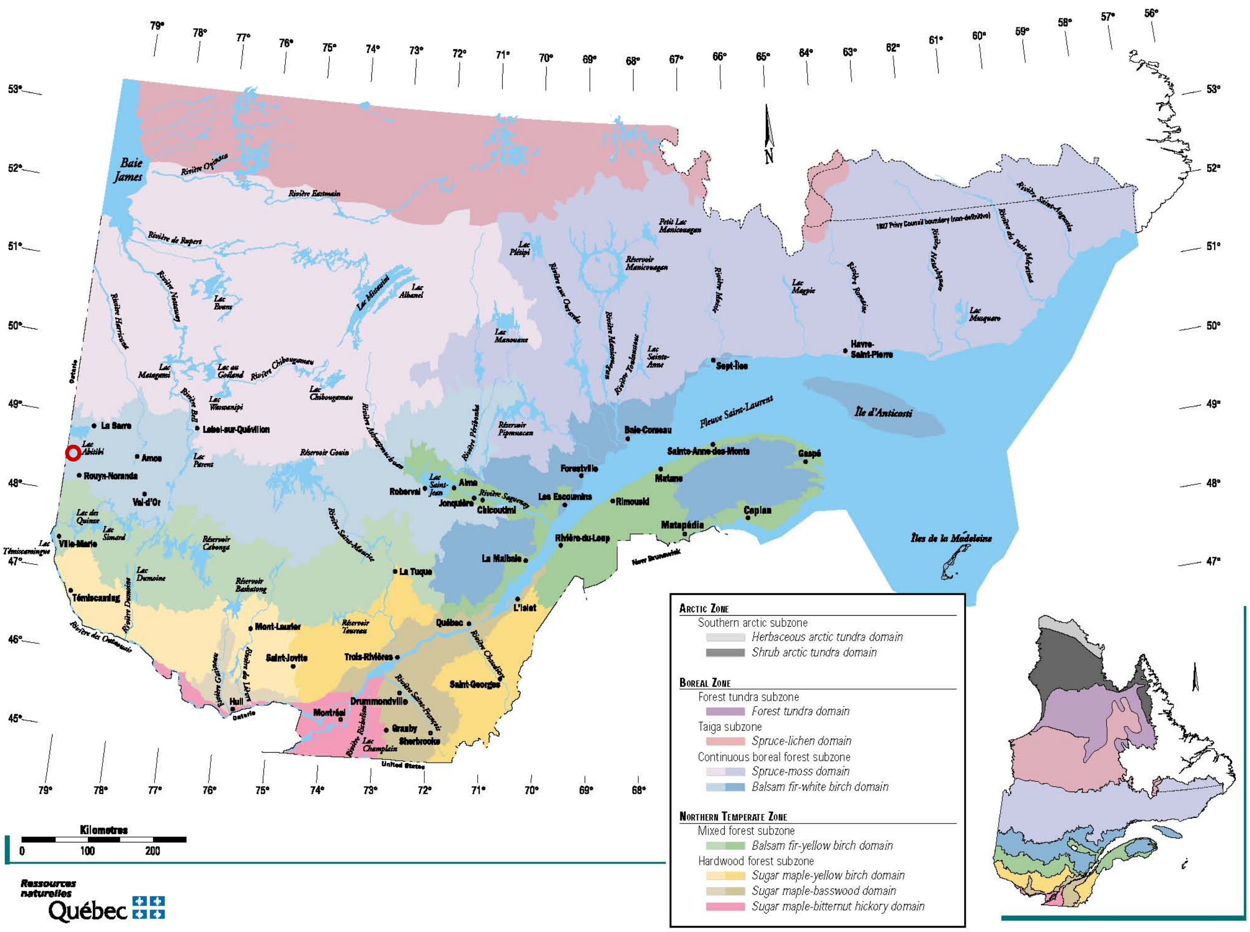


Figure 3. Vegetation zones and bioclimatic domains in Québec.

et al. 1998) situates us in the Abitibi Lowlands Ecological Region and, more generally, in the Balsam fir –White birch (*Abies balsamea - Betula papyrifera*) bioclimatic domain. This domain forms a subzone of the continuous boreal forest between the Northern Temperate Forest to the south and the Black spruce – Feathermoss boreal forest to the north. Mean annual temperature varies between 0 and 1.0°C, mean annual precipitation is about 860 mm (25 % as snow) and mean frost-free period per year is 64 days (Fig.3).

We are also situated centrally in a large physiographic region known as the Great Claybelt characterized by the presence of extensive clay deposits that originated from the proglacial Lake Barlow-Ojibway (Veillette 1994). Born from melt waters during the glacial retreat about 10,000 yrs BP, this lake lasted about 2,100 years and during this time millions of tonnes of fine glacial sediment (clay, silt and sand) were sorted and deposited; the coarser particles in the agitated shallow waters and the finer sediments in the calmer, deeper waters of the lake. The region includes low rocky hills covered with reworked tills, as well as humid, organic soils and a variety of moisture class conditions (Bergeron et al. 1983).

Balsam fir (*Abies balsamea*) is the dominant species in mature forests and is associated with white spruce (*Picea glauca*), black spruce (*Picea mariana*) and white birch (*Betula papyrifera*). Following fire, jack pine (*Pinus banksiana*), trembling aspen (*Populus tremuloides*) and white birch form extensive monospecific or mixed stands (Bergeron and Bouchard 1984). These early successional stand types are generally gradually replaced by stands containing more shade-tolerant species, balsam fir, white spruce, black spruce and eastern white cedar (*Thuya occidentalis*).

Historically, forest fires have been the most important disturbance agent in the region. Relationships between changes in fire interval and forest cover during the Holocene Period are discussed briefly at the Lake Francis drive-by stop. More recent fire disturbance (last 300 yrs) in the mixedwood and black spruce forest regions of western Quebec have been well documented, notably by Bergeron *et al.* (2004) (see fire history map). Fire frequency has greatly decreased since the end of the Little Ice Age (about 1850 – see Table 1) in both forest regions; however, many large fires occurred between 1910 and 1923 during the period of intensive colonization and when the climate was favourable and between 1930 and 1945, particularly in the more populated mixedwood region (Bergeron *et al.* 2004). Fires have been smaller and probably of lower severity in the mixedwood region due to the greater presence of intolerant hardwood forests and water bodies that can act as fire breaks. While fires have been, on average, larger and more severe in the black spruce forest region, fire cycles and mean number of years since fire are remarkably similar between the northern black spruce and more southerly mixedwood forests.

Table 1. Fire cycle estimates (mean and confidence intervals) per region and period (From Bergeron *et al* 2004).

Fire cycle period	Mixedwood forest	Black spruce forest	Total
Before 1850	83 (65-105)	101 (79-129)	93 (75-113)
1850-1920	111 (88-140)	135 (108-171)	124 (102-150)
Since 1920	326 (250-426)	398 (302-527)	360 (281-458)

Other natural disturbances, including insect outbreaks and severe wind events also occur in the region. Morin *et al.* (1993) documented three Spruce budworm (*Choristoneura fumiferana*) outbreaks in the 20th century (1919-1929, 1930-1950 & 1970-1987) and the Ministry of Natural Resources and Wildlife's most recent inventories have detected an important increase in the budworm population, particularly in the Témiscamingue region, south of Rouyn-Noranda. Outbreaks of an important defoliator of broadleaved species, the Forest tent caterpillar (*Malacosoma disstria*) outbreaks, have also occurred at relatively regular intervals in the region (1943-1944, 1952-1956, 1964-1979 & 1999-2002). The most recent outbreaks of tent caterpillar and spruce budworm have ultimately generated considerable standing and fallen deadwood that will be evident at several stops on this visit.

References

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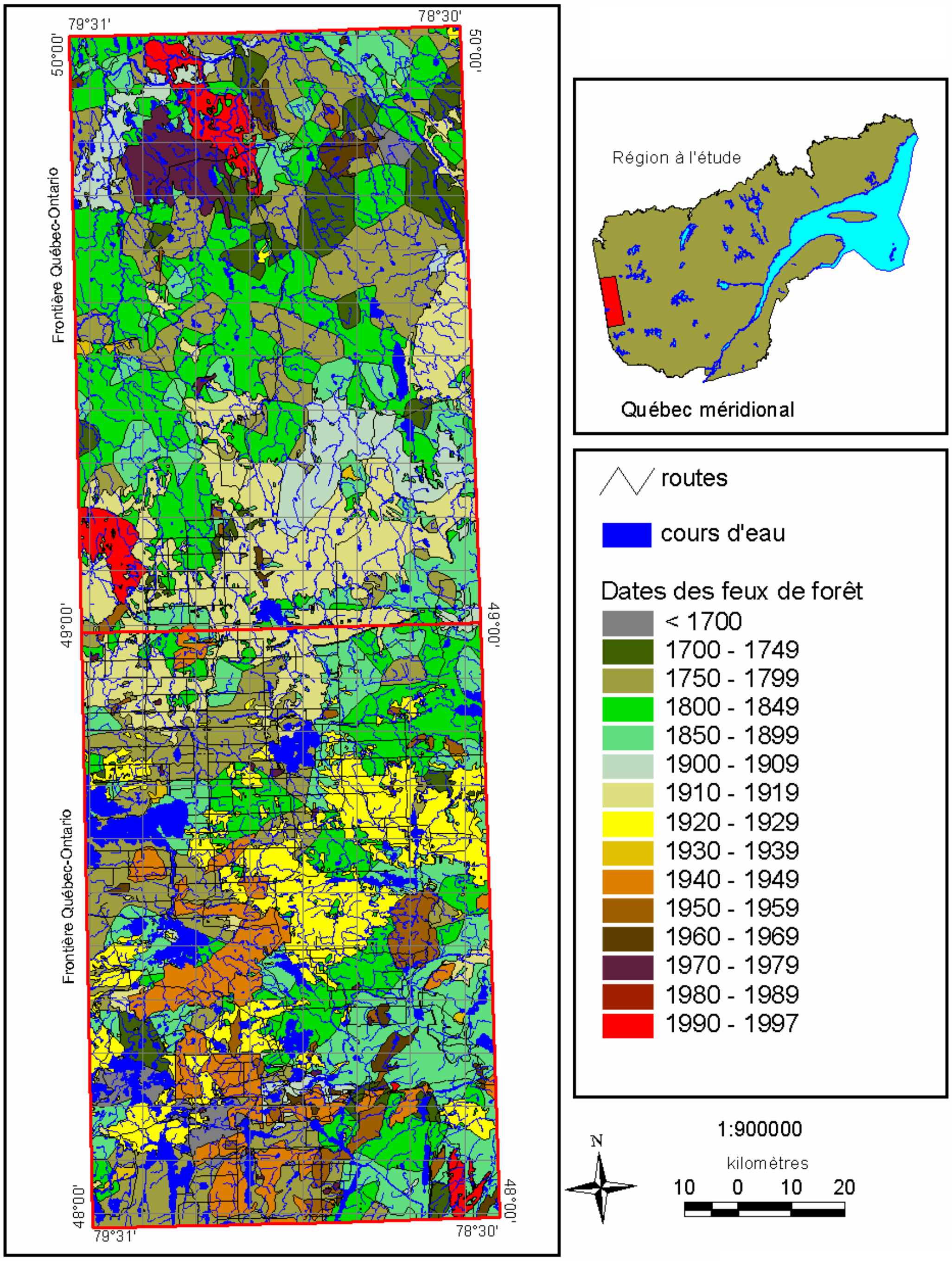


Figure 4. Fire history map of western Abitibi.

Notes

The Lake Duparquet Research and Teaching Forest

The Lake Duparquet Forest (80 km^2) is managed by the Université du Québec en Abitibi-Témiscamingue and the Université du Québec à Montréal and representatives of two forest companies, Tembec and Norbord Industries, as well as the Quebec Ministry of Natural Resources and Wildlife. Forest research began in the area in the late 1970’s when Yves Bergeron undertook field work here for his Ph.D. under the direction of the late André Bouchard at the Université de Montréal. Research activities increased rapidly in the mid ‘80s and 90’s, and lead to the official creation of the Lake Duparquet Forest in 1995 and to construction of the research station in 2005. A second housing facility was added in 2010.

Much of the focus of research has been on understanding the natural dynamics of the eastern boreal mixedwood and developing and testing a forest ecosystem management approach based on this knowledge. Intensive silvicultural practices are also being tested.

When the Lake Duparquet Forest was officially created, the territory was divided into two functional zones, a conservation zone and a management zone. The conservation zone covers roughly 25% of the area and contains a mosaic of forests that originated from a dozen fires that occurred between 1717 and 1944. The 230 year chronosequence covered by this forest mosaic has been extremely useful for understanding the temporal dynamics of the boreal mixedwood. This area has been set aside for ecological monitoring and assessment and serves as a reference area for evaluating the effects of management practices in the remaining 75% of the forest. About 65% of the forest is dedicated to silviculture adapted to natural stands in the management zone. Because this zone covers most of the forest, certain measures are taken to maintain key habitat attributes (coarse filter) within the managed forest matrix.

Finally, an intensive forest management zone (within the management zone) covers the roughly remaining 10% of the territory and is aimed at increasing wood production to compensate for decreases associated with the two other zones. In this zone, plantations established during the 1980s to 1990s have been intensively tended. This includes at least one manual (brushsaw) cleaning and fill planting to attain near full-stocking and, over a large area, pruning and a manual sanitary treatment of stems infected by white pine weevil (*Pissodes strobe* Peck). On a small part of the intensive management zone, we are also evaluating the potential of highly intensive silvicul-


Claude-Michel Bouchard

Figure 5. Conservation zone (25%).


Annie Desrochers

Figure 7. Intensive management zone (2%ligniculture) (10%).


Claude-Michel Bouchard

Figure 6. Management zone (65%).

ture, or ligniculture, using poplar and larch hybrids and genetically improved white and Norway spruce (*Picea abies* [L.] Karst.) and intensive plantation tending to maximise fibre production. This three-tiered vocation approach to zoning – conservation (25%) ecosystem management (65%) and intensive/ligniculture management (10%) – while not necessarily representing the proportions generally associated with Seymour and Hunter's (1992) original triad approach, does represent the essence of the concept.

For more information about the forest, visit
http://ferld.uqat.ca/

Figure 8. Research station of Lake Duparquet Research and Teaching Forest.

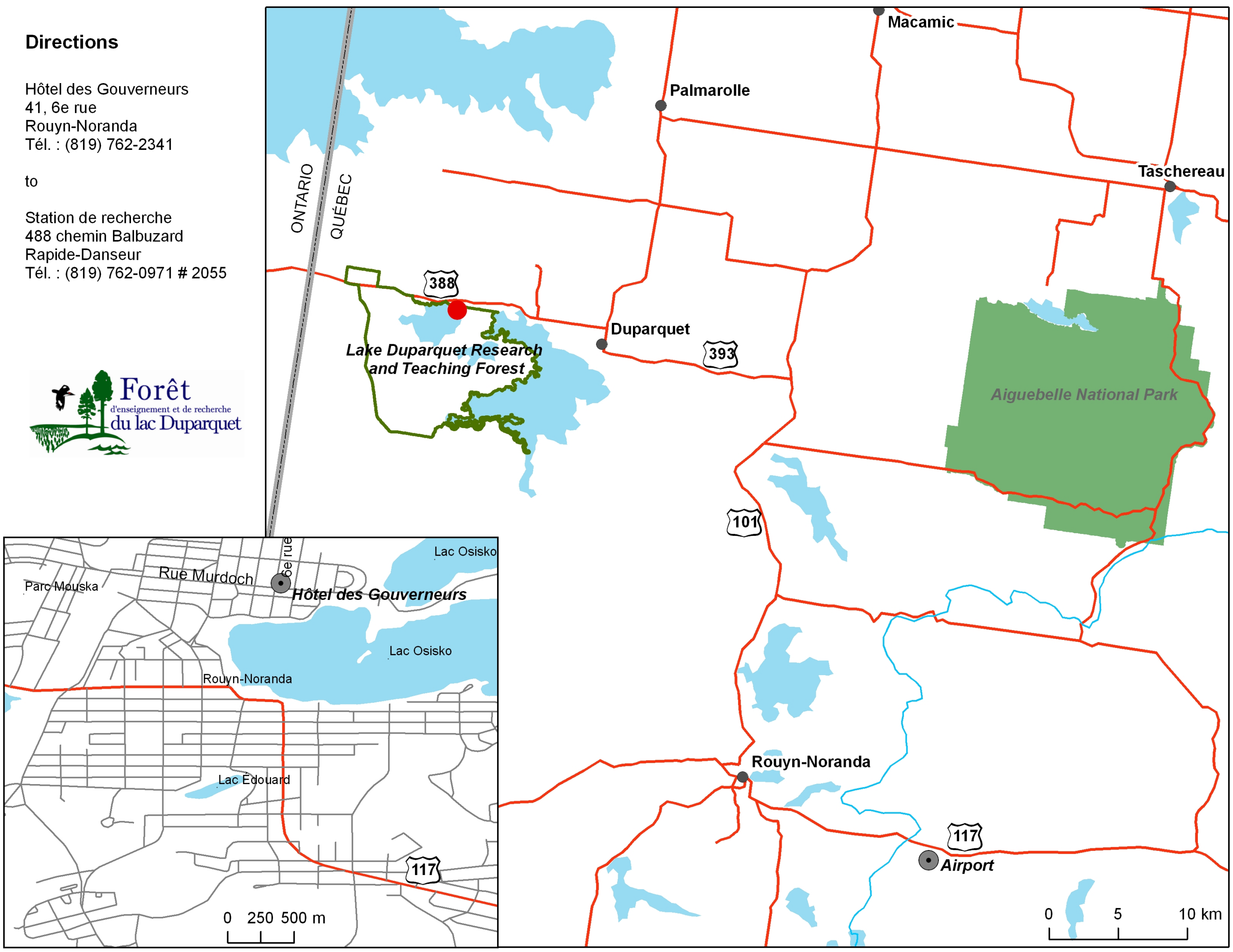


Figure 9. Location of Lake Duparquet Research and Teaching Forest.

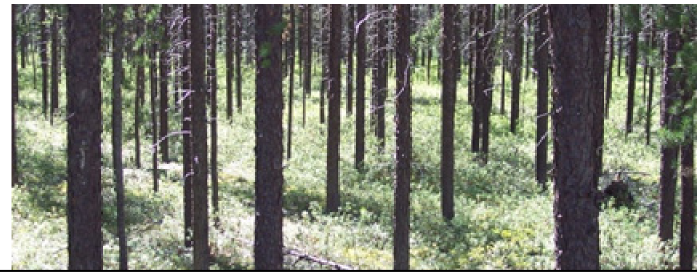
STOP DESCRIPTIONS

Borealie by Michel Villeneuve, 2010

Stop 1

Pure Jack pine stand

Suzanne Brais, Université du Québec en Abitibi-Témiscamingue



M-Eve Sigouin

Glaciofluvial landforms are prominent features of the Abitibi landscape

Eskers are large bodies of glaciofluvial sands and gravel formed in the period of glacial maximum. The coarse-textured sediments are smoothed, sorted and stratified - reflecting the fluvial and changing environment of their formation (Fig.12). Because of their number and dimension, eskers are an important feature of the Abitibi landscape. The clay plain formed by sedimentation at the bottom of glacial Lake Barlow-Ojibway lies between the eskers and the transition zone between the eskers and the plain is often covered with reworked coarse-textured material overlaying the bottom of the lake. Glaciofluvial complexes represent about 10% of the land area of the region and can constitute major aquifers with high quality water. Because of their quality for road construction, they are easily accessible and are often situated close to populated areas. They can support productive forest ecosystems that generate timber and non timber resources important to the local economy and recreational activities.

Fire regime and vegetation dynamics on coarse textured sites (modified from Smirnova et al. 2009)

In the region, glaciofluvial complexes are commonly occupied by jack pine (*Pinus banksiana*) or mixed jack pine – black spruce (*Picea mariana*) stands of fire-origin. Jack pine stands are generally characterized by an even-aged structure resulting from stand replacing fires and jack pine stands can attain high densities (>30,000 stems ha^{-1}) in the first years following fire. Canopy openness and jack pine density significantly decreases with time since stand replacing fire, while black spruce density and CWD volume significantly increase. However, non-lethal fires that leave behind surviving trees have also been reported for jack pine stands. Compared to stand replacing fire, non lethal fire increase mean jack pine basal area, decreased average stand density and CWD volume, delayed the replacement of jack pine by black spruce in the canopy and significantly increase bryophyte mass.

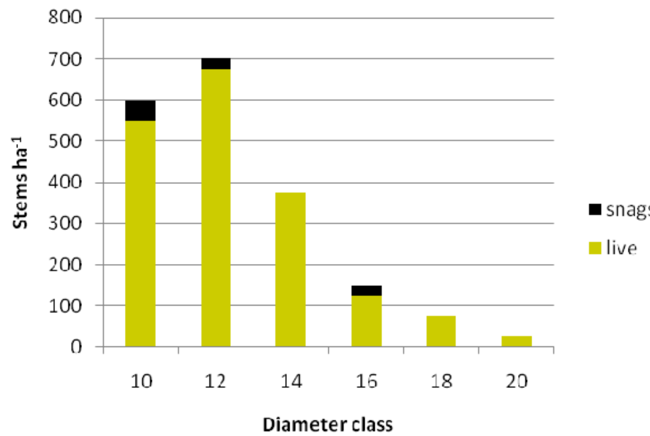


Figure 10. Live and dead stems (all Jack pine) per hectare.

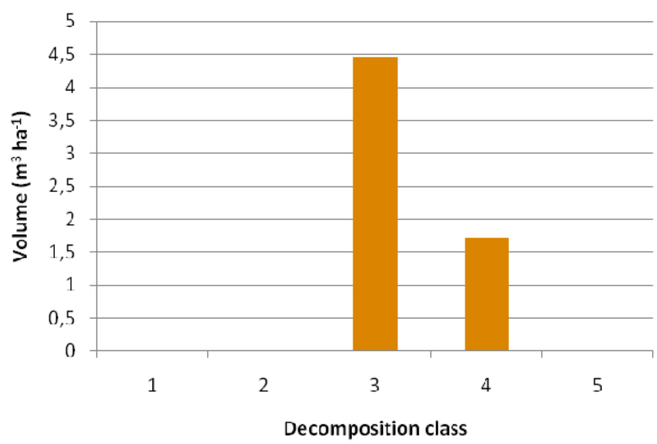


Figure 11. CWD volume per decomposition class per hectare.

It is our working hypothesis that a continuous input of slow-decomposing organic matter is of particular relevance for coarse-textured soils where stabilisation of organic C by clay is minimal, most of the soil cation exchange capacity depends primarily on its organic fraction and where soil organic matter contributes significantly to soil water retention.

Site productivity and soil organic matter

In a second study (Brais et al. 2005), twelve jack pine stands on sandy, mesic sites of glaciolacustrine origin were surveyed. Snags, logs and buried wood were inventoried, soils were sampled and stem analyses were conducted. Downed log mass accumulation followed a

Figure 12. In the Abitibi, soils on coarse - glaciolacustrine or fluvioglacial surface deposits are classified as Humo-ferric Podzols or Dystric Brunisols (Soil Classification Working Group, 1998).

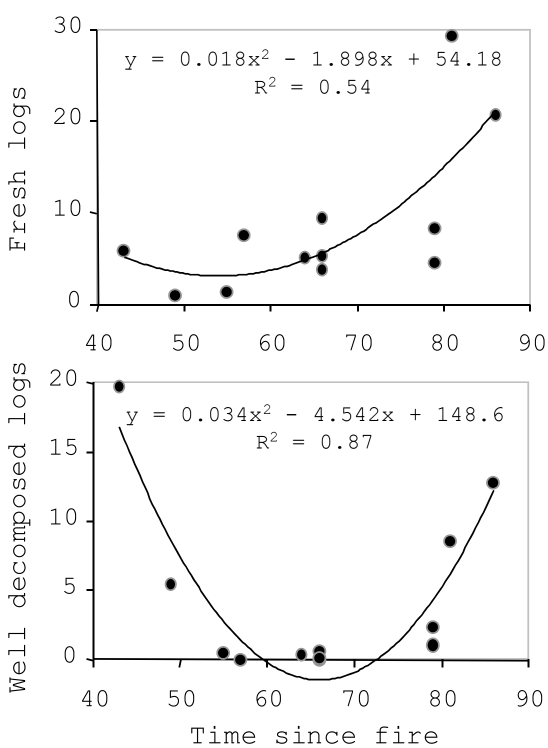


Figure 13. Volume (m^3 ha^{-1}) of fresh and well decomposed downed logs, in twelve natural boreal jack pine stands in relation to time since the last fire (Brais et al. 2005).

"U shaped" successional pattern with time since fire. Volume of buried wood within the forest floor varied between 1 and 57 m^3 ha^{-1} (4 to 92 % of total site CWD volume) and showed no relationship with time. The most productive sites (tree height at age 25) were characterized by higher forest floor dry weight, effective CEC and water holding capacity in the mineral soil. Buried wood water holding capacity was negligible compared with that of the 0-20 cm mineral soil layer.

The Duparquet jack pine site

The stand we are visiting today dates from a fire in 1955. Being very close to the town of Duparquet, it is possible that some of the burned wood was harvested for residential heating. Part of the stand was submitted to precommercial thinning in the 70's and was commercially thinned in 1996-97. Trees were hand-felled and logs transported using light tractors and trailers. The volume of downed wood is low but within the variation observed in natural stands of comparable age (Fig. 13). However, future recruitment of downed wood following tree senescence will be limited due to thinning.

References

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Notes

Stop 2

Old white cedar stand

Huaitong Xu and Nicole Fenton

Université du Québec en Abitibi-Témiscamingue

M-Eve Sigouin

Eastern white cedar

The primary range of Eastern white cedar (*Thuja occidentalis* Linnaeus) extends from the Gulf of St. Laurence in the East to south-eastern Manitoba in the West, and from James Bay in the North to Tennessee and North Carolina in the South. Cedar tends to occur in the upper riparian zone around Lake Duparquet (Denneler et al 2008) and is found in pure and mixed stands and on a wide range of organic and mineral soils (Bergeron & Bouchard 1983; Denneler et al 1999). Rare in early successional stages, it is found more frequently in intermediate stages in association with balsam fir, white and black spruce, trembling aspen and white birch, and generally dominates old-aged stands with common associates like balsam fir and white birch (Bergeron 2000). Some old cedar stands in the research forest, dated to a fire in 1760, have never been affected by human disturbance. Several stumps, still visible in this stand where we are today, are vestiges of a partial cut that occurred in the early 1950s.

Genetic structure of eastern white cedar

The natural distribution of cedar populations in western Quebec near the edge of its range provides an opportunity to study several possible factors controlling its genetic structure. Xu's Ph.D. study investigates three of these factors: 1) climate along a latitudinal gradient, 2) forest dynamics, particularly the importance of sexual and asexual reproduction, along a post-fire successional gradient and 3) cedar population fragmentation.

Hypotheses: 1) Genetic diversity will decrease in populations from the continuous to the discontinuous part of the species' range along the latitudinal gradient. 2) The relative contribution of sexual to vegetative recruitment to cedar propagation will tend to decrease along a successionnal gradient (More sexual recruitment in younger stands (1916) and more vegetative recruitment in older stands (1760)). 3) Fragmentation may have a negative genetic impact on cedar populations in mainland fragments. 4) Cedar populations fragmented in a lacustrine landscape may be resistant to genetic diversity losses due to high gene flow.

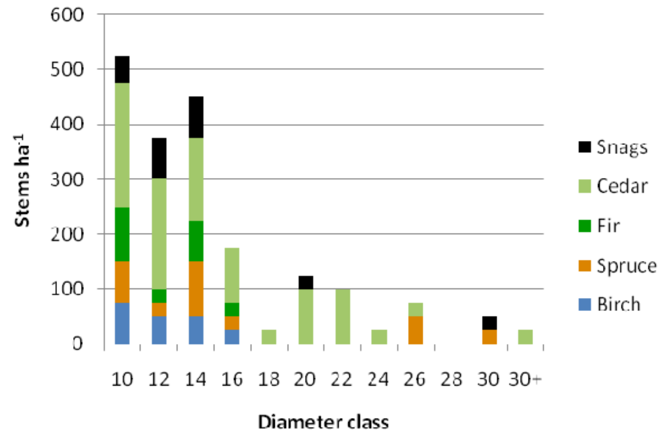

Figure 14. Live and dead stems (all species) per hectare.

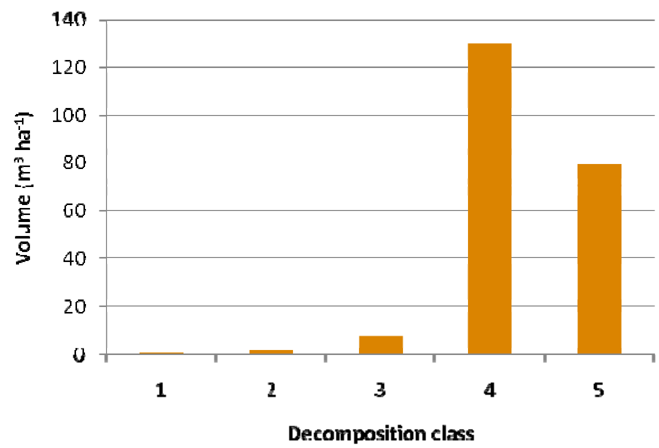

Figure 15. CWD volume per decomposition class per hectare.

Preliminary results

1. Four populations from the marginal distribution range, and four from the discontinuous distribution range have significant and positive Fis values, indicating a heterozygosity deficit. One population from the discontinuous distribution range has a significant and negative Fis value, indicating heterozygosity excess.

2. Correlations between observed heterozygosity (Ho), inbreeding coefficient (Fis) and latitude of population origin are highly significant, indicating high latitudinal effects on genetic diversity of cedar populations.

3. Mantel tests showed a positive and very significant correlation between genetic and geographical distances for all 24 studied populations indicating isolation by distance (IBD). A positive and highly significant correlation for the group of populations from the marginal distribution range at the distribution limit largely accounted for IBD on all 24 populations.

4. Bayesian analysis using the program STRUCTURE detected 3 clusters that demonstrated the presence of population structure. Neighbour Joining Tree analyses clustered samples into four main groups, generally reflecting the geographic origins of population. AMOVA analysis indicated an absence of genetic structure among individuals within populations from the continuous distribution region.

M-Eve Sigouin

Figure 16. Eastern white cedar.

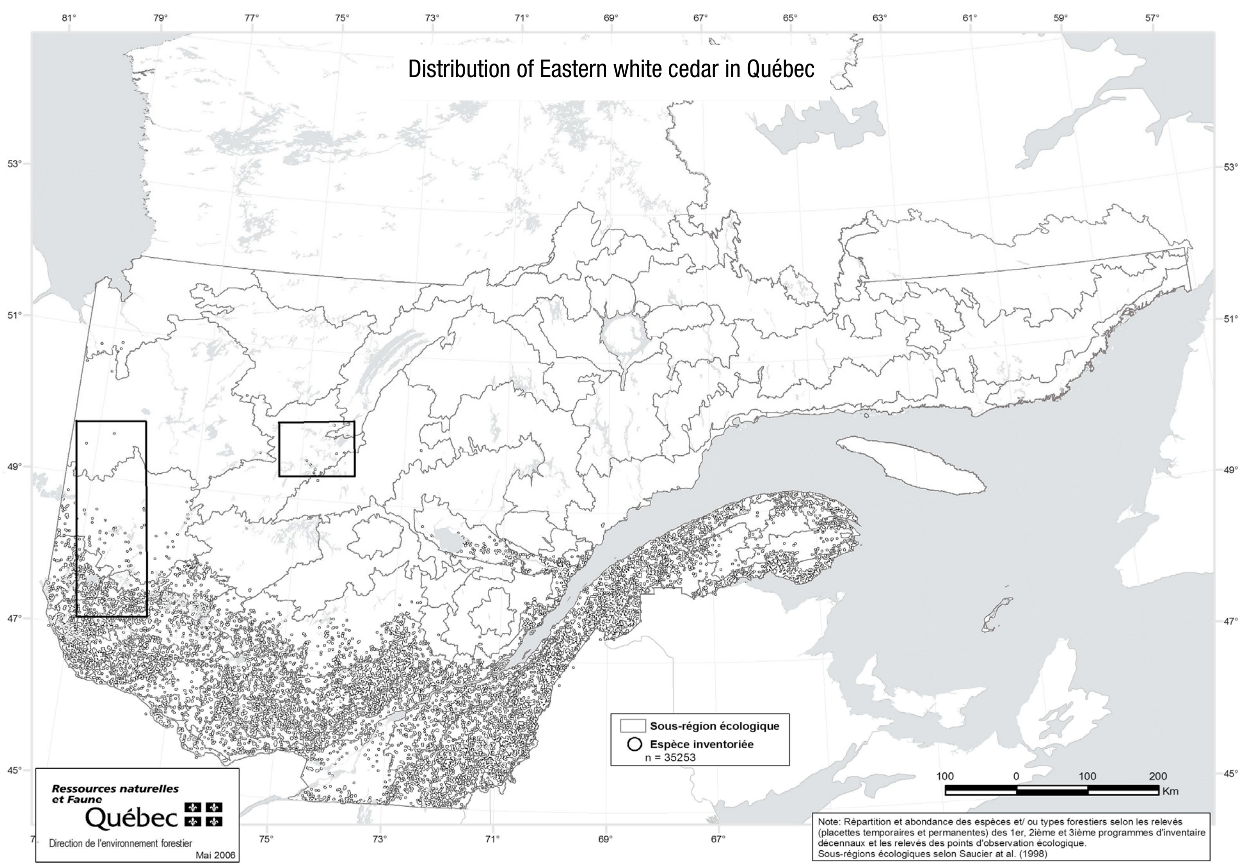

Figure 17. Study areas and distribution of Eastern white cedar in Quebec.

Bryophytes and deadwood: partners for biodiversity

As demonstrated in this cedar stand, deadwood is a highly suitable substrate for bryophytes. In fact, the volume and variety of decomposition stages of deadwood within a stand is a good indicator of bryophyte richness. Deadwood is a suitable substrate for bryophytes for a number of reasons:

Humidity

As non-vascular plants, most bryophytes are dependent on a continually humid environment, especially during the particularly vulnerable establishment phase. Deadwood provides a continually humid environment that acts as a reservoir of humidity during dry phases.

Protection from competition

Leaves: Heavy deciduous leaf litter smothers bryophytes growing on the forest floor, as they are unable to pierce the leaf layer. Bryophytes growing on deadwood are generally protected from smothering as the rounded deadwood sheds fallen leafs to the sides.

Other bryophytes: In coniferous stands there is generally a continuous carpet of bryophytes on the forest floor composed of feather mosses (*Pleurozium schreberi*, *Hylocomium splendens*, and *Ptilium crista-castrensis*). These relatively large, fast growing bryophytes exclude other smaller bryophytes from establishing on the forest floor. In these stands deadwood substantially increases the species richness in the bryophyte layer by providing a substrate that is free from feather moss competition.

Deadwood in black spruce-feathermoss forests: *Sphagnum* spp. incubators

In the black spruce-feathermoss forests to the north of the FERLD bryophytes dominate the forest floor, and influence the ecosystem dynamics. A major characteristic of these forests is that they become paludified over time, i.e. a thick layer of organic material accumulates over the mineral soil. One of the most significant drivers of this process is the replacement of the feather moss carpet by *Sphagnum* spp. Deadwood plays a significant role in this process, as the feather moss carpet is a very hostile environment for *Sphagnum* spp. spore germination; in one study over 70% of *Sphagnum capillifolium* colonies were established on deadwood (Fenton et al. 2007). Once established, and as light availability increases with canopy breakup, these *Sphagnum* spp. colonies expand over the surrounding feather mosses, and eventually dominate the forest floor (Fenton and Bergeron 2006). As a consequence, the forest floor becomes colder, wetter and less nutrient rich, all conditions which significantly affect tree growth and seedling establishment (Simard et al. 2007).

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Fenton, N.J., Bergeron, Y. 2008. Does time of habitat make old-growth forests species rich? Bryophyte richness in boreal *Picea mariana* forests. Biol. Cons. 141:1389-1399.

Figure 18. a) Mosses on woody debris, b) *Ptilium crista-castrensis* and c) *Sphagnum capillifolium.*

Notes

Stop 3

Irregular continuous cover shelterwood

Presented by Claude-Michel Bouchard[1 2] and Nicole Fenton[2]

[1]Lake Duparquet Research and teaching forest, [2]Université du Québec en Abitibi-Témiscamingue

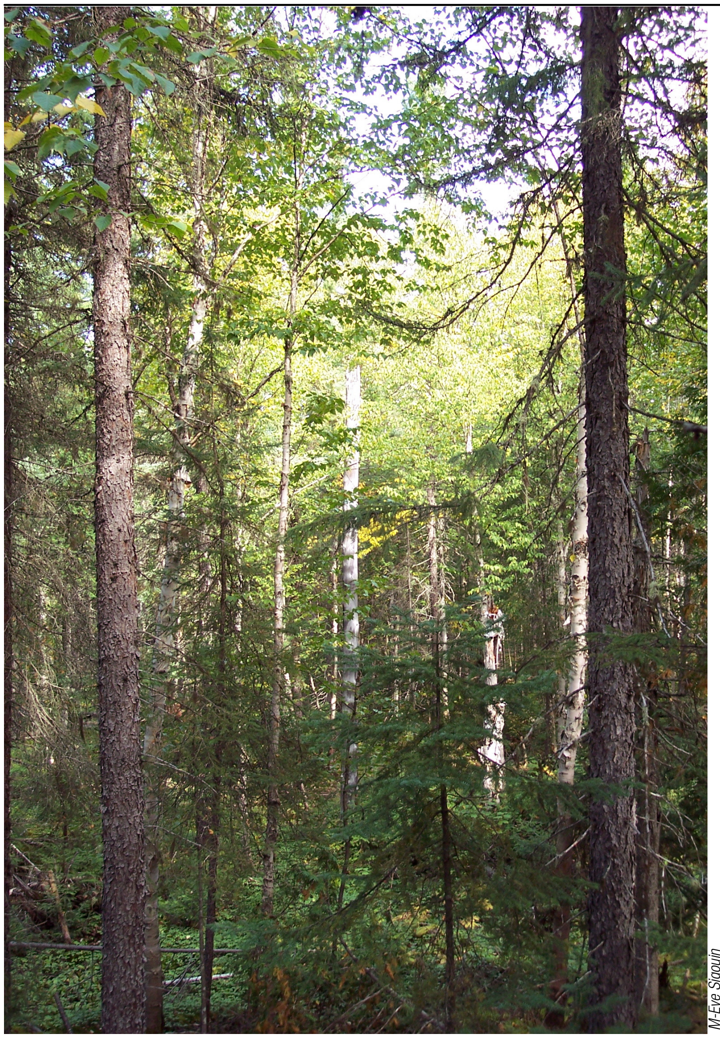

Figure 19. Irregular continuous cover shelterwood.

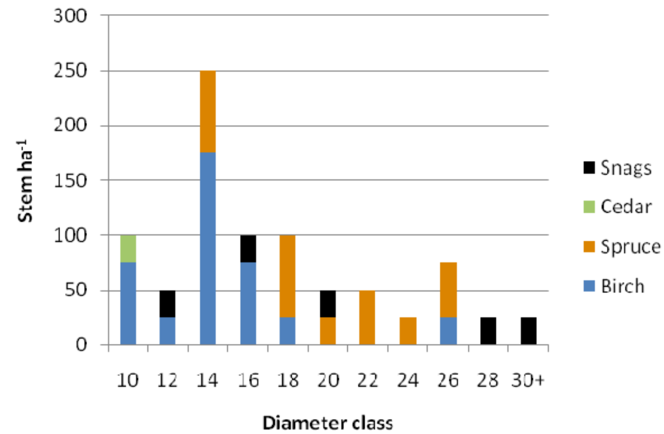

Figure 20. Live and dead stems (all species) per hectare.

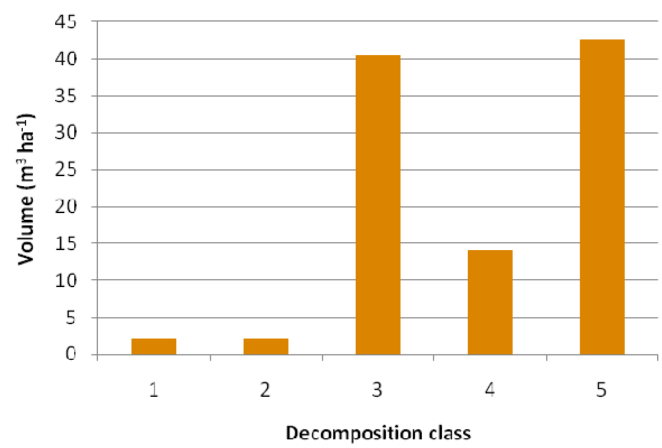

Figure 21. CWD volume per decomposition class per hectare.

Background

One of the objectives of « cohort-based management » is to maintain stand type diversity over the managed landscape and, more critically, to ensure that part of the forest maintains structural and compositional attributes of over-mature and old forests (Bergeron & Harvey 1997, Bergeron et al 1999, Harvey et al 2002). In this part of the eastern boreal mixedwood, these forests are generally occupied by shade-tolerant and late successional tree species such as balsam fir, black and white spruce, cedar, and, less frequently, white birch, and are characterized by greater structural complexity than young, even-aged stands. Abundant standing and fallen dead wood, a broad size-class distribution of stems, horizontal and vertical structural diversity are generally important characteristics of these older forests.

In order to maintain forest age structure and composition that approximate conditions of a landscape influenced essentially by natural disturbance dynamics, roughly 40 to 50% of the managed zone of the Lake Duparquet Forest is intended to be maintained in what we refer to as “2nd and 3rd cohort” stand structures by applying some variant of partial cutting or continuous cover shelterwood.

Treatment objectives

⇒ Maintain continuous cover in irregular to uneven diameter structure;

⇒ Maintain and allow recruitment of snags and fallen deadwood;

⇒ Favour improved quality of residual stems;

⇒ Reduce pioneer species and fir component of stands.

Two stand types were treated in this sector: an uneven-aged black spruce stand on an organic-glaciolacustrine sand contact zone and a mixed spruce-fir-cedar-birch stand on thin till and sand interface that is part of the visit. Both stands originated from a fire in 1760 and had some diameter-limit cutting in the early 1950s. Most of the large snags and fallen deadwood on this site are jack pine that originated from the original 1760 fire.

Harvesting was done in summer 2003. Negative marking (trees to be harvested) was done by the logging foreman prior to harvesting. Although the original target of 30% basal area removal was overshot by 10%, the uneven diameter structure of the stand was essentially maintained. Main skid trails occupied less than 10 % of the area. Trees were manually harvested, delimbed and hauled between trails using small "CM 2000" skidders. Harvesting priority was as follows: stems with deformities or apparent low vigour; white birch, balsam fir, black spruce, white spruce, cedar.

Claude-Michel Bouchard

Figure 22. CM 2000 skidder.

Claude-Michel Bouchard

Figure 23. Cable skidder.

Table 2. Summary characteristics of 2003 harvest treatment.

	Before	After	Difference
Mean diameter (cm)	14	14	0
Basal area (m^2/ha)	26	16	10
Total merchantable volume (m^3)	142	95	47
Stems/ha	1,369	770	599

Since harvesting, the site has seeded in naturally, particularly black spruce in skid trails, but balsam fir, cedar and birch are also regenerating.

FERLD

Figure 24. Snag of Jack pine that established after 1760 fire.

Drive through (4)

Lake Francis

Figure 25. Lake Francis

Fire, climate and vegetation : A 7,000 year history

Like boreal forests around the globe, forests here have evolved under natural disturbance regimes since the retreat of the last ice age about 10,000 years ago. Dendroecological studies have traced the fire history of the Lake Duparquet Forest by dating and mapping the limits of all major fires that have burned in the forest since the 1700s. Palynological and anthracological studies conducted on the sediments of Lake Francis, a tiny kettle lake, permitted reconstruction of fire events and intervals for a longer period, up to more than 7000 BP. This double approach allowed us to study first the climate-fire relationship and then, fire-vegetation relationship.

Fire frequency reconstruction

Fire frequency reconstruction at Lake Francis (Fig. 27) indicates that fires were not very frequent between 6800-2200 BP. Mean fire interval was about 260 ± 208 years before a dramatic decrease to 85 ± 55 years at about 2200 BP. Because this change corresponds and permits confirmation of the change recorded by temporal low-resolution analysis in Quebec, it provides evidence of the robustness of the fire reconstruction at Lake Francis. This permits comparison of local fire-frequency reconstruction with the pollen curves from the main tree species present over the last 7000 years (Fig. 28). Reconstruction of the fire-vegetation and fire-climate relationships thus provides a basis for discussing the ecological consequences of climate changes.

Between 9500-7500 BP, and after 2200 BP, fire frequency was relatively high resulting from a higher drought frequency. However, the latter period change was not synchronous with changes in vegetation (Fig. 16). Indeed, during the period of low-fire frequency between 6800-2200 BP, the vegetation surrounding Lake Francis was dominated by white pine and the Eastern white cedar, while all other boreal tree species were already present. When fire interval decreased, birch pollen accumulation rate increased, and a few centuries later (*ca*. 1500-1000 BP), the current boreal forest dominated by balsam fir occupied the region. There appears to be a lag of a few centuries in vegetation changes in relation to changes in fire frequency.

Figure 26. Sediment core

Despite the broad range in fire cycles during the Holocene, a paper by Cyr *et al.* (2009) suggests that cumulative effects of forest harvesting over the past 40 years has pushed forest age structure outside of the historical range of variability, notably by reducing the proportion of old forest and generally rejuvenating the forest matrix.

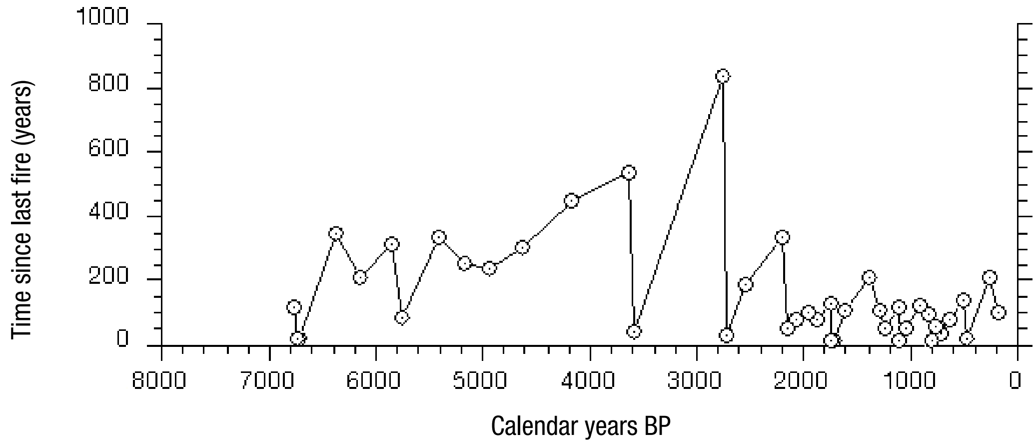

Figure 27. Frequency of fire events chronology at Lake Francis.

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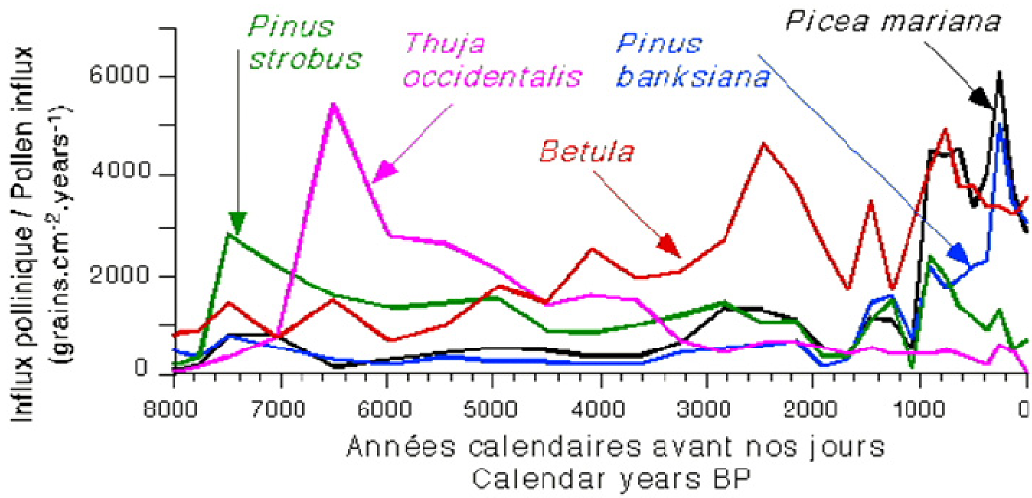

Figure 28. Pollen curves of major tree-taxa describing long-term plant dynamics over the last 7000 years.

Notes

Stops 5-6-7-8

Natural dynamics, forest ecosystem management and silviculture in boreal mixedwoods

Suzanne Brais[1], Brian Harvey[12], Jenna Jacobs[3] and Manuella Strukelj[1]

[1]Université du Québec en Abitibi-Témiscamingue, [2]Lake Duparquet Research and teaching forest, [3]Université du Québec à Montréal

Stop 5 - Brian Harvey

The management approach proposed for the eastern boreal mixedwood forest and applied in the Lake Duparquet Forest is based on a conceptual model developed from ecological studies undertaken in the area (Bergeron and Harvey 1997, Bergeron et al. 1997). The model incorporates natural disturbance dynamics to set regional-level objectives for forest composition and integrate stand-level dynamics into silviculture. Forest composition targets for three broad successional stages, or "cohorts" (Fig. 29), are based on the regional fire cycle: about 50% of the forest should be in the "1st cohort" and about 25% of the area in each of the "2nd and 3rd cohorts" (Harvey et al. 2002). Simply explained, at the stand-level, clearcutting with retention is used to generate 1st cohort stands composed of characteristic post-fire species; variants of partial cutting are used as succession analogues and selection cutting or continuous cover shelterwoods are aimed at reproducing gap dynamics and maintaining attributes of old forests (Fig. 30).

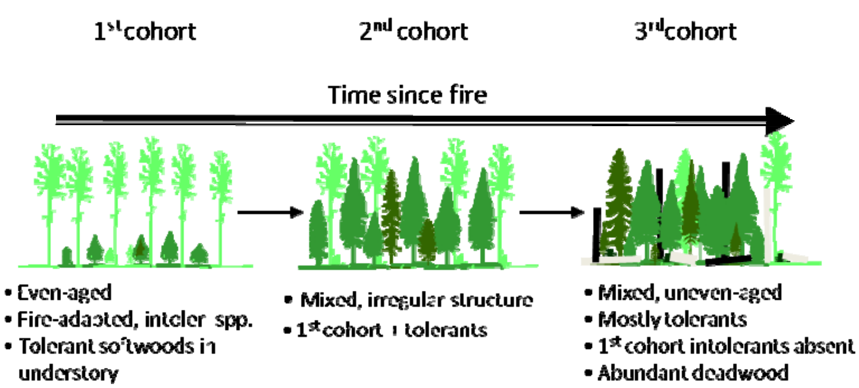

Figure 29. Characteristic composition and structure of three cohorts, or broad successional stages.

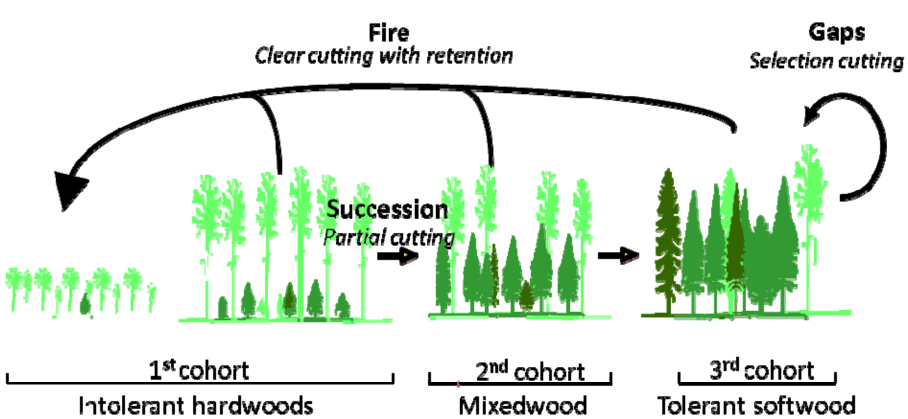

Figure 30. Silvicultural analogues to natural stand dynamics.

Working hypothesis: By diversifying silvicultural approaches and by targeting, in particular, certain attributes of old forests, it is possible 1) to maintain an age structure and forest composition close to that of the mosaic created by the natural disturbance regime and 2) to maintain indigenous biodiversity and the ecological functions of forest ecosystems. Like any model, the passage from theory to practice requires an experimental framework that allows hypothesis testing in the field. To this end, the **SAFE** project (***S****ylviculture et* ***A****ménagement* ***F****orestier* ***É****cosystémique* or Silviculture and Forest Ecosystem Management) includes a series of silviculture experiments conducted in stands of different ages, compositions and structures that aims at testing the hypothesis mentioned above and the operational aspects of adaptive silviculture practices (Brais et al. 2004). This part of the visit includes several stops in the phase 1 of the SAFE project, established in 1999 in 75 year old aspen-dominated stands that originated from a fire in 1923. Four treatments have been replicated three times: uncut controls, clearcuts and two intensities of partial cuts (light low thin and heavy crown thin) (Fig. 31). As well, a variety of forest residue treatments, including controlled burning, were conducted in the clearcut treatments of SAFE 1.

Figure 31. In-stand and profile views of control and partial cutting treatments.

Table 3. The SAFE Experiment: General description of the three phases.

Phase	Cohort	Stands	Fire year	Treatments	Established
1	1	Aspen	1923	Clearcuts, 1/3 & 2/3 dispersed partial cuts, controls Residues	1998-1999
2	3	Mixed, post-spruce budworm	1760	Clearcuts, controls, Residues	1999-2000
3	2	Mixed	1910	Clearcuts, 40% gap & dispersed partial cuts, controls	2000-2001

While we will be visiting only Phase 1 of the SAFE project (SAFE 1) on this excursion, several of the research projects presented today include results from sampling in Phases 2 and 3 as well (Table 3).

Stop 6- Brian Harvey

Changes in stand structure and CWD following partial cutting

A central question to SAFE 1 is what type and intensity of partial cutting facilitates the transition of stands from an even-aged, intolerant hardwood dominated composition to a more complex structured, mixed species stand? Other questions associated with these experiments include: Does partial cutting in even-aged stands accelerate the development of attributes associated with older stands? What is the response of residual trees, advance regeneration and the understory following partial cuts of different intensities? Does group selection or gap cutting generate more structural complexity than diffuse commercial thinning treatments? What are the effects of different intensities and configurations of treatments on dead wood dynamics and on associated living organisms and ecological processes?

Live stem and snag diameter distributions (Fig. 32) as well as fresh and well decomposed downed woody debris values (Fig. 33) are presented for controls and the two partial cutting treatments for 1999 and 2010. As changes between 1999 and 2010 in live stem and snag densities in controls clearly indicate, these stands are starting to break up. Over the 10 year period, snag basal area has almost tripled in controls and fresh downed wood has doubled. As expected, partial cutting has the effect of short-circuiting snag production by recuperating "imminent mortality". Live stem diameter distribution has flattened out in partial cuts during this period, particularly in the 2/3 high thinned treatment where many small diameter (& low vigour) residual aspen stems have died in the first 10 years.

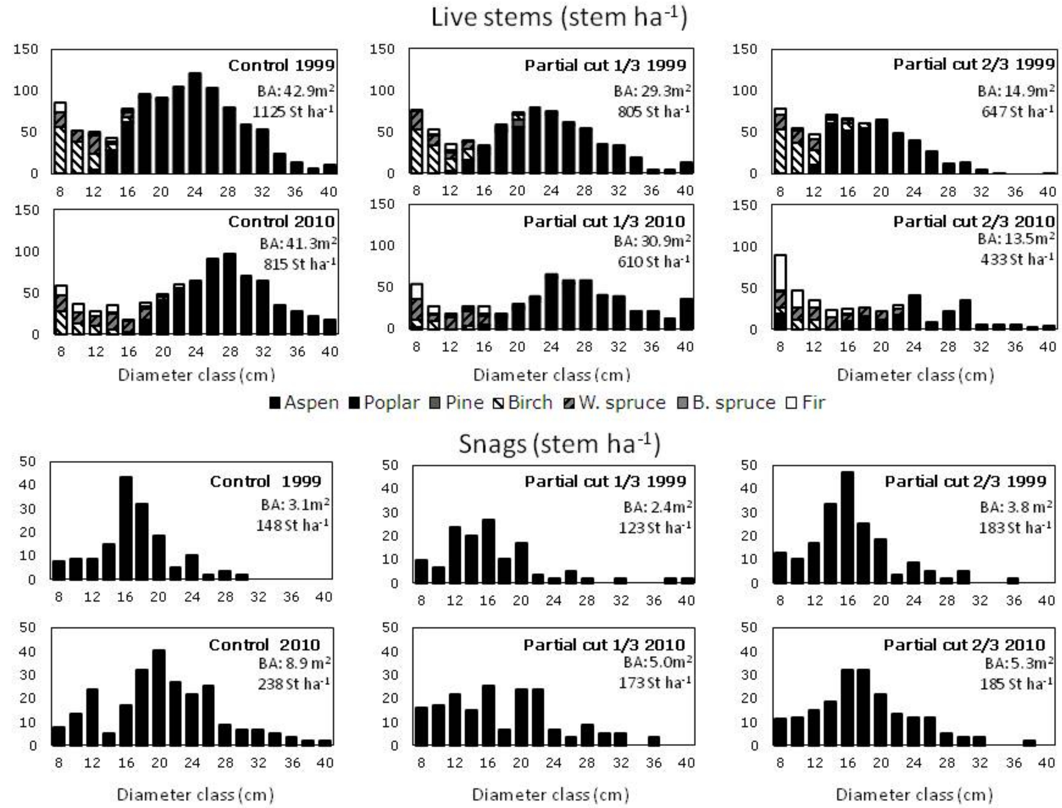

Figure 32. Diameter distributions of live and dead stems in control stands and partial cuts in 1999 (immediately following treatments) and in 2010.

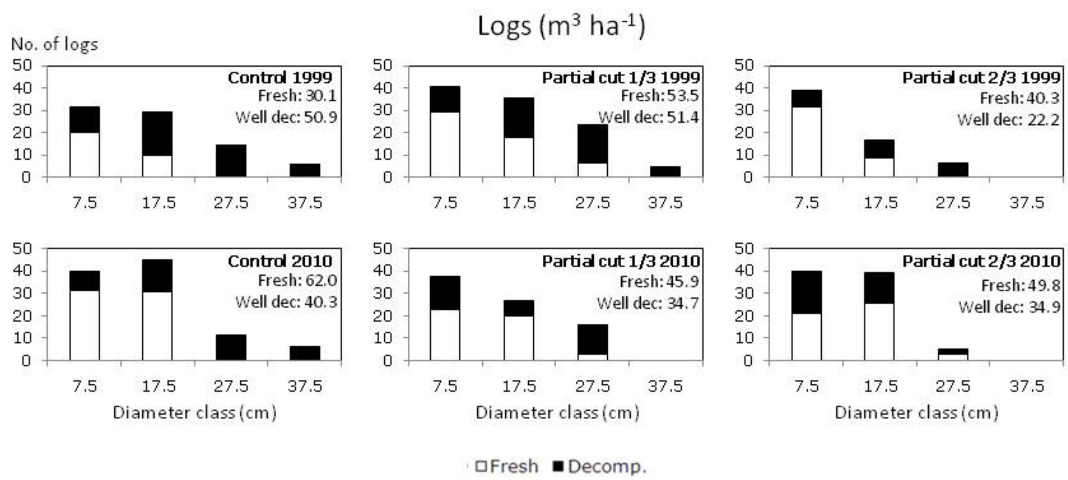

Figure 33. Coarse woody debris in control stands and partial cuts in 1999 (immediately following treatments) and in 2010.

Notes

Stop 7

1760 post-budworm stand

Stop 7a

Spruce budworm-related mortality

In the space of several metres we have moved from an even-aged, intolerant hardwood stand that originated from a fire in 1923 to a much older, more structurally complex stand dominated by late-successional species. This stand resembles control stands of SAFE 2. Although this forest has not burned since 1760, it has been affected by other disturbances, including non-mechanized timber harvesting and, more importantly, several spruce budworm outbreaks. Spruce budworm larvae feed on the young needles of balsam fir and spruce, although balsam fir is by far the most vulnerable species. As forests develop following fire, the proportion of balsam fir in the canopy generally increases and, consequently, so does the vulnerability of stands to mortality as a result of budworm defoliation (Fig. 34).Three outbreaks, occurring at intervals of 25 to 30 years (with exceptions) have occurred in this area during the 20th century (Morin *et al.* 1993). Recent research, however, shows that mortality rates are not constant from one outbreak to another, with mortality being more important in every second outbreak.

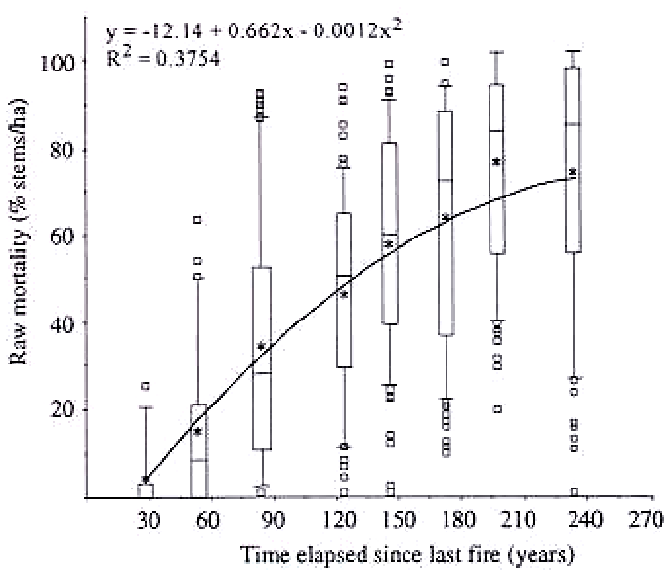

Figure 34. Raw mortality of balsam fir in relation to the time elapsed since the last fire from which the stands originated. Box plots portray the median (midbar in the box) and the 10th, 25th, 75th and 90th percentiles. Asterisks show the mean values.

From Bergeron *et al.* 1995

The vast majority of mature fir trees in the area were killed during the most recent epidemic, which lasted from 1970 to 1987 (Bergeron *et al.* 1995). It is still possible to see some standing dead trees from this outbreak. Surprisingly, the rate of mortality of non-host species increases in the decade following the end of the outbreak, probably due to the opening of the canopy and changing of environmental conditions for residual trees (Bouchard *et al.* 2005).

Gaps created by spruce budworm outbreaks may cover large areas, depending on the abundance of balsam fir in the stand. Fir seedlings are only rarely affected by the budworm and are generally the most abundant species in the regeneration layer. As a result, they will usually replace the dead overstory fir and form the next stand. However, the presence of extremely large gaps, as found in older coniferous stands, may result in a decrease in fir density, to the advantage of other species such as aspen, cedar and woody shrubs (Kneeshaw & Bergeron 1998).

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Kneeshaw, D. & Bergeron, Y. 1999. Spatial and temporal patterns of seedling recruitment within spruce budworm caused canopy gaps. Ecoscience. 6(2):214-222.

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Stop 7b

Fungi diversity, carbon forms and tree regeneration along a chronosequence of decaying logs

From tree senescence to its incorporation into the forest floor, coarse woody debris (CWD) is central to many complex ecological processes and functions. Moreover, the relationships between certain forest practices, decreases in deadwood quantity and quality and the loss of forest diversity are well recognized. Ecosystem management or natural disturbance-based approaches to forest management have been proposed for extensively managed forests as a means of alleviating the effects of management and harvesting on forest biodiversity, functions and resilience. However, our understanding of CWD contributions to ecosystem functions is still fragmentary for eastern Canadian boreal forests.

The following information results from three different studies based on a common chronosequence of decaying logs of five different tree species. Up to 165 logs (depending on studies) were sampled along a decomposition gradient in nine unmanaged stands representing three successional stages of the boreal mixedwood forest of the region. Log species were identified from wood structural and anatomical features and included trembling aspen, white birch, jack pine, balsam fir, and spruce spp.

Stop 7b i)- presented by Manuella Strukelj

Species composition of saproxylic fungal communities on decaying logs in the boreal forest

Hedi Kebli[1], Pascal Drouin[1], Suzanne Brais[1] and Gavin Kernaghan[2]

[1]Université du Québec en Abitibi-Témiscamingue
[2]Mount St-Vincent University

Kebli et al. (2010) used a molecular fingerprinting technique (Denaturing/Temperature Gradient Gel Electrophoresis (DGGE/TGGE)) to assess fungal community Shannon-Weaver diversity index, richness and composition of 102 logs. Amplicons that generated prominent DGGE bands were selected for cloning and sequencing. A total of 33 operational taxonomic units (OTU) were found. The mean number of OTUs per log was 6.3. The maximum number of OTUs (16) was from a fresh spruce log in the oldest stand (1760 fire) and the second highest (15 OTUs) was from a trembling aspen log of the medium decay class in the mixed aspen stands (1910 fire). Spruce logs supported the highest fungal Shannon-Weaver diversity index and OTU number. We found no effects of log decay class on diversity. Stand composition, volume of coarse woody debris and log chemical composition were all involved in structuring fungal communities. Maintaining the diversity of wood decomposing communities, therefore, should require the presence of dead wood of a variety of log species.

Hedi Kebli

Figure 35. Mushroom on a fallen log.

Hedi Kebli

Figure 36. Mushrooms on a fallen log.

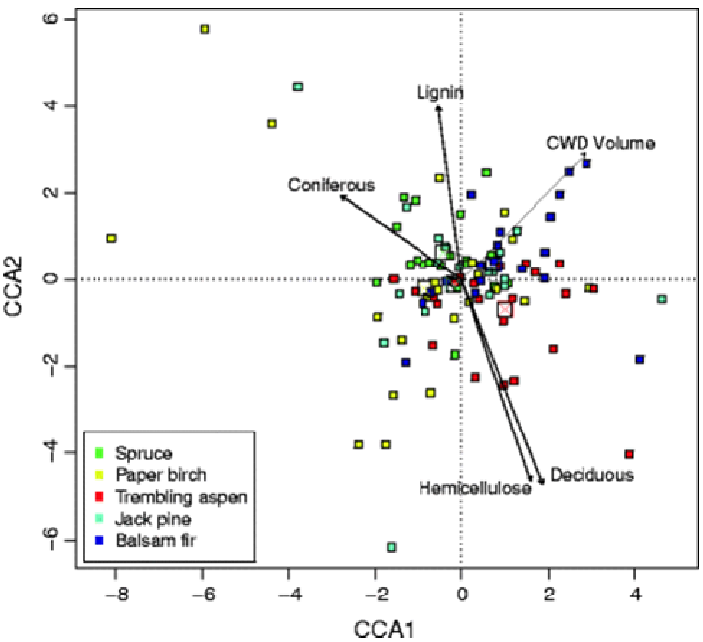

Figure 37. Canonical correspondence analysis of the saproxylic fungal communities (based on the DGGE profiling) of 102 logs of different wood species. *Multiplication symbol inside the box* centroids of each log species. Only site scores are plotted. Axis 1 and 2 are displayed .

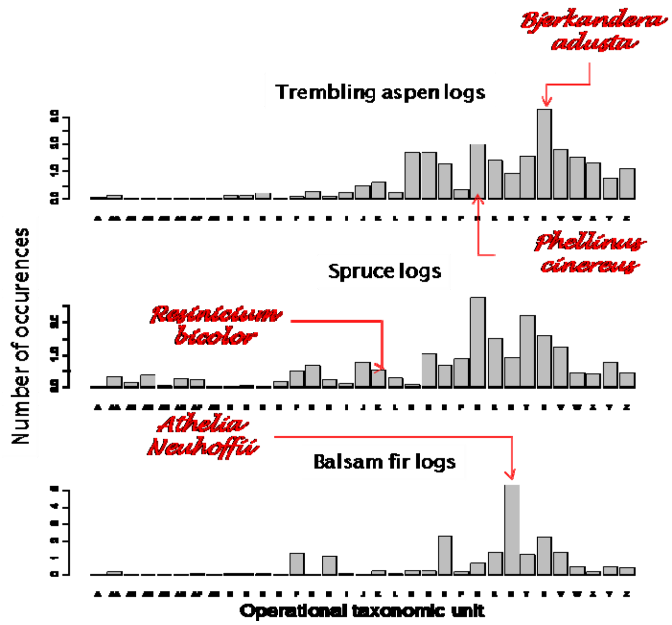

Figure 38. Number of occurrences of 33 OTUs distinguished by DGGE profiling in relation to wood log species.

Table 4. Sequence analysis of bands excised from DGGE gels from decaying logs of white birch (*Betula papyrifera*), trembling aspen (*Populus tremuloides*), Jack pine (*Pinus banksiana*), balsam fir (*Abies balsamea*.) and spruce (*Picea glauca* or *Picea mariana*).

OTU	Most closely related fungal sequence	Similarity (%)	Environment where related sequence have been isolated	Occurrence [a]
E	*Leptodontidium elatius* isolate A39WD232	97	Stump of *Picea abies* (Latvia)	7.8%
F	Uncultured *Mortierella*	99	Forest soil (Canada)	11.8%
G	*Calocera cornea*	99	Culture collection	7.8%
K	*Resinicium bicolor* strain JLL13731[b]	99	Isolated on aspen (Canada, Ontario)	17.7%
O	*Ascocoryne cylichnium* isolate N31	99	Stump of *Picea abies* (Latvia)	25.5%
Q	*Phellinus cinereus* [c]	99	Strain isolated from fruiting body	36.3%
R	*Ascocoryne* sp. isolate E2	97	Decayed wood of *Picea abies* (Latvia)	40.2%
S	*Athelia neuhoffii*	95	Culture collection	39.2%
T	*Phlebia centrifuga*	99	*Pinus ponderosa* (Arizona)	41.2%
U	*Bjerkandera adusta*	98	Decayed wood of *Picea abies* (Latvia)	51.0%
X	Uncultured fungus clone Singleton_24-2804_2353	86	Phyllosphere of *Quercus macrocarpa*	26.5%
Z	Uncultured fungus	99	Sporocarp of ectomycorrhiza isolated from a mature beech maple forest	18.6%
AB	Uncultured fungus clone Singleton_(159-1104_0519)	83	Ectomycorrhizosphere of *Quercus* spp.	6.9%

Stop 7b ii)

Chemical transformation of decaying logs of five boreal species

Manuella Strukelj-Humphery[1], Suzanne Brais[1] and Sylvie Quideau[2]

[1]Université du Québec en Abitibi-Témiscamingue
[2]University of Alberta

Figure 39. Decaying log

Coarse woody debris constitutes an important reserve of carbon in boreal forests. Wood is mainly composed of celluloses and lignins. Lignin exhibits a high resistance to microbial degradation and is considered as important precursor of humic substances. While nitrogen enhances decomposition in the early stage of decay, it also reacts with lignin to form recalcitrant complexes in later stages. Recalcitrant aromatic compounds of wood, such as tannins, can sequester proteins forming complexes resistant to decomposition. However, Alkyl compounds, including cutin, suberin and lipids, are the most recalcitrant to decomposition.

The chemical properties of wood differ between species and will determine the pathways of C loss or C accumulation in soil. The objective of this study was to characterize the chemical composition of decaying logs of five boreal species along the chronosequence focusing on stable forms of carbon. Wood samples were analysed by solid-state ^{13}C CPMAS NMR spectroscopy, NIR spectroscopy and C and N concentrations using a LECO CNS 2000 analyzer.

In logs of all species, N and lignin concentrations and the alkyl/O-alkyl ratio increased with decay while cellulose and hemicelluloses concentrations and the C/N ratio decreased. A higher proportion of carbonyl compounds was found in aspen logs than in conifer species, whereas conifer species were characterized by a higher proportion of aromatic compounds, including lignins and tannins. In particular, Jack pine logs had the lowest mass loss in this study, and the highest amount of aromatic and alkyl compounds, which are the most stable forms of carbon. Jack pine wood could then enhance carbon retention. The physical structure of CWD and its proportion of aromatic compounds could promote carbon retention in soils for longer periods than leaves.

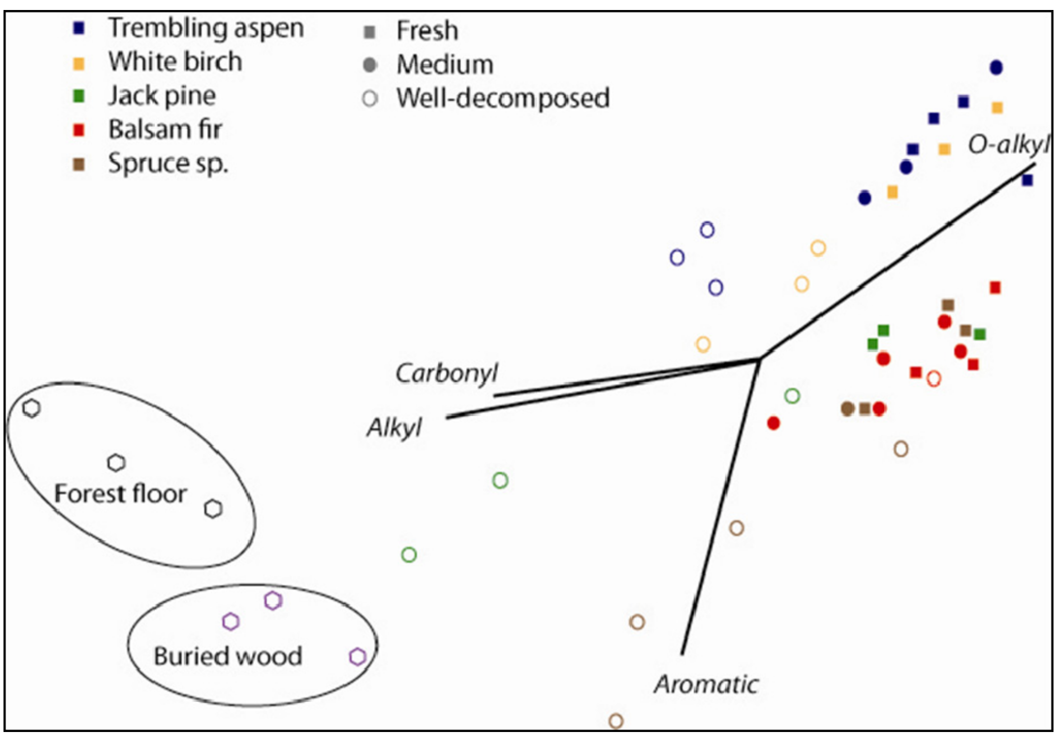

Figure 40. NMS ordination of CPMAS ^{13}C NMR integral areas from decaying logs of five boreal species. Buried wood and forest floor originating from leave litter were also analyzed.

Stop 7 iii) - presented by Manuella Strukelj

Downed deadwood and forest regeneration in the eastern boreal mixedwood

Emilie Robert, Suzanne Brais and Brian Harvey

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Figure 42. Seedlings on a log.

Coarse woody debris has been recognized as a favourable substrate for germination and growth of regeneration in a many forest ecosystems, a quality that has earned it the name "nurse logs". In this study, we took advantage of a mast year in 2006 to compare the establishment and survival of seedlings of five tree species on downed logs and on the forest floor. Seedling surveys were conducted in the fall 2007 and the spring and fall of 2008 in three stand types representing different successional stages: aspen; mixed aspen-fir-spruce; and post-spruce budworm fir-spruce-cedar-birch. Each of the 165 logs was paired with an adjacent equivalent area of forest floor. The following characteristics were measured on each log: decomposition stage, hardness, density, moisture and C:N ratio. Other characteristics measured on logs and on the forest floor included % herbaceous, litter, and moss cover, and thickness of moss and leaves. Data were analyzed using logistic regressions.

Probability of seedling establishment increased with wood moisture content, and decreased with hardness (of logs) whereas probability of survival decreased with hardwood basal area in stands. Our results show that species that produce small seeds, such as white birch and spruce, established preferentially on dead wood, while balsam fir, a larger seeded species, established more frequently on the forest floor. Relatively open stands with high volumes of downed wood provide best conditions for seedling establishment of spruce and birch.

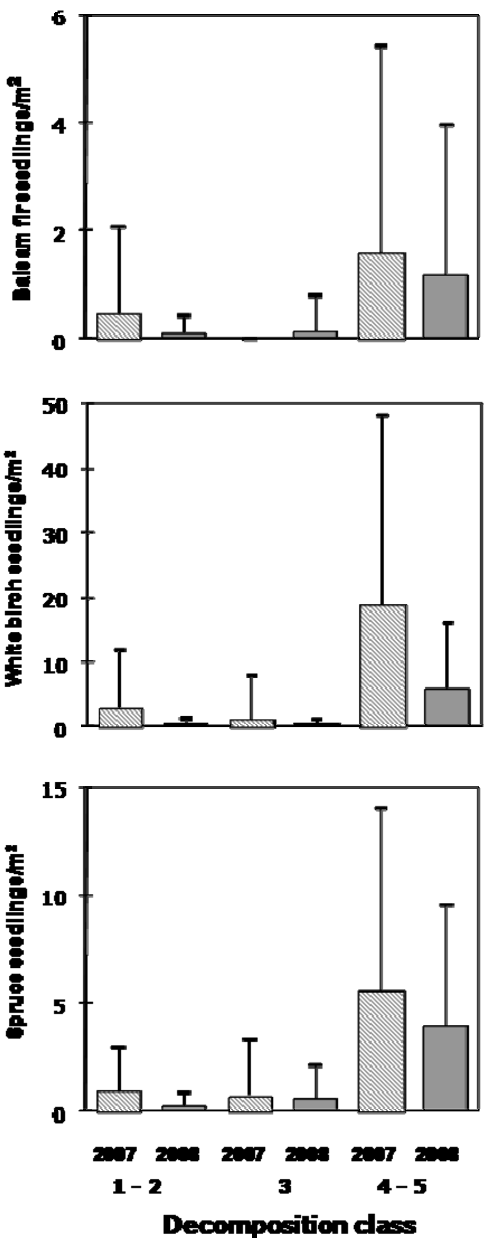

Figure 41. Densities of seedlings observed on logs of varying decay state one and two years following the 2006 mast year.

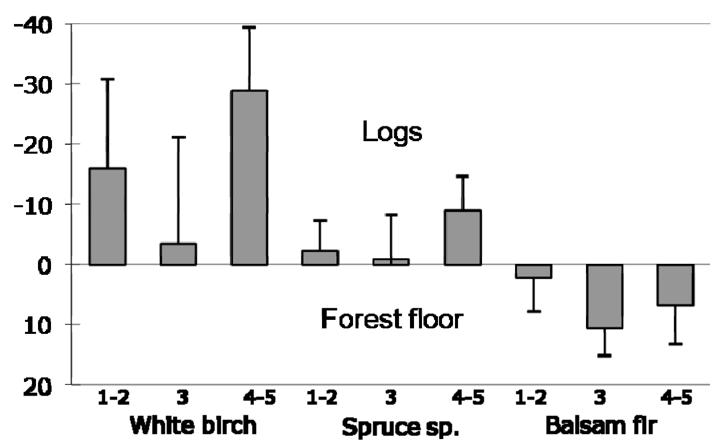

Figure 43. Differences in seedling establishment between forest floor fine litter and logs in boreal mixedwood stands according to log decomposition class.

Stop 8
Partial cutting and biodiversity

Presented by Brian Harvey[1] and Jenna Jacobs[2]

[1]Université du Québec en Abitibi-Témiscamingue, [2]Université du Québec à Montréal

Stop 8a
Maintaining plant biodiversity in managed boreal aspen forests

Prepared by Sybille Haussler

University of Northern British Columbia

Project description

In the winter of 1998-99, two partial harvesting treatments that removed 33% ("1/3") and 61 % ("2/3") of stand basal area were applied to even-aged aspen (*Populus tremuloides* Michx.) stands and compared with control (uncut) stands. Stands in the 1/3 treatment were low thinned with non-vigorous stems removed, while stands in the 2/3 removal were crown thinned with co-dominants and dominants preferentially selected. Coarse woody debris dynamics was assessed during the following 6 years by means of permanent sampling plots and downed wood inventories.

Study objectives

1. To identify important indicators of plant biodiversity in aspen-dominated stands of the southern boreal mixedwood forest.

2. To determine whether SAFE's approach to emulating natural forest dynamics (disturbance and succession) more effectively maintains plant biodiversity than conventional clearcutting practices.

What is "Plant Biodiversity"?

In this study it refers to the plant component of biodiversity, including vascular plants, mosses, liverworts and macro-lichens. It was important to decide whether our objective was to maintain diversity, per se, or to maintain certain species and structural features of boreal plant life that are threatened by short-rotation clearcutting. Evidence from Fenno-Scandia & elsewhere suggests that species dependent on decaying wood, large old trees, and fires are most at risk.

Figure 44. Trembling aspen stand

Methods

We measured plant species composition, structure and diversity at multiple scales (deadwood, tree trunks, microsite, gap, stand, whole experiment) in Phase 1 of SAFE, 3 and 10 years after logging or prescribed fire and compared the results to 105-yr old growth aspen stands and 3 yr old wildfires.

Major findings and interpretations:

1. Aspen stands have diverse, leafy understories that are highly tolerant of disturbance and don't change much as the stand ages. Among vascular plants, most species either tolerate or thrive after clearcutting. The main exception are myco(hetero)trophic herbs that derive energy from mycorrhizae connected to forest trees: orchids, wintergreens and odd plants like Indian pipe, pinesap etc. These sensitive species tend to accumulate as the stand gets older and many are associated with decaying wood. Most will tolerate partial cutting if not directly disturbed or exposed to direct sun.

2. As a group, mosses, lichens and especially liverworts are much more sensitive to clearcutting than vascular plants, but they also have pioneering species that thrive after disturbance and light –so it's difficult to generalize. Liverworts are most sensitive to changes

Figure 45. One-sided wintergreen (*Moneses uniflora*-left) and Indian pipe (*Monotropa uniflora*-centre) are myco-heterotrophic plants that grow on decaying wood in SAFE1, usually near conifer trees. Yellow coralroot (*Corallorhiza trifida*-right*)* is the most common myco-heterotrophic orchid in these aspen stands and can be connected via ectomycorrhizae to aspen, birch, willow or alder trees.

in humidity, and lichens are most strongly associated with larger trees.

3. Large old aspen trees support a tremendous variety of epiphytes that rarely grow on other tree species. These epiphytes take a long time to reappear after wildfire or clearcutting, so partial cutting should be beneficial, provided some trees are retained into old age.

4. SAFE1 partial cuts retained many non-vascular species found in uncut SAFE stands, but after 10 years there was no evidence that partial cutting accelerated the development of the rich non-vascular communities found in old-growth stands.

5. Aspen logs are not particularly rich in epixylic species and decompose rapidly. Large old conifer logs dating from before the 1923 fire are hot spots of epixylic and mycotrophic diversity in SAFE1 –indicating that it is important to retain a supply of large old conifer trees in aspen stands and that periodically cycling from aspen to conifers and back again will enhance biodiversity. These old logs are easily crushed by machinery.

Table 5. Effects of partial cutting on the number of epiphytic species on aspen trunks, 10 years after logging (total of 10 sample trees per stand, n = 3 stands). Differences not significant at $\alpha = 0.10$.

Stand Type	Mosses	Liverworts	Lichens	Total
Uncut mature	18	4	2	24
1/3 partial cut	17	5	2	23
2/3 partial cut	16	4	2	22
Uncut old growth*	20	9	5	34

*Nearby old growth stands were sampled in 2001 (couldn't be resampled because logged by 2008). Results adjusted to account for between-year sampling error.

6. Small patches of conifers within aspen stands promote heterogenous understories (beta diversity) because the species that grow under conifers are usually different than those that grow under aspen.

7. Uniform partial cutting as was done in SAFE1 is not ideal for enhancing diversity and protecting old- forest species: (1) it tends to homogenize the understory, favouring generalist species rather than creating open gaps vs. shady patches that encourage diversity; (2) machinery travelling throughout the stand tends to crush logs and damage residual trees; (3) snags usually have to be removed for safety reasons. Variable retention, leaving behind clumps of varying size, is a better option for biodiversity management.

8. Creating and maintaining a variety of aspen-containing stand types, ages and sizes across the landscape, and a variety of structures and patchiness within aspens stand will best maintain plant biodiversity. Although fire reduces stand-scale diversity in the short run, judicious use of fire can also enhance diversity by promoting fire-maintained species and preventing buildup of mountain maple (Acer spicatum) and other generalists in the understory. It may also slow the decay rate of large old conifer logs and stumps that create understory heterogeneity (Shorohova et al. 2008).

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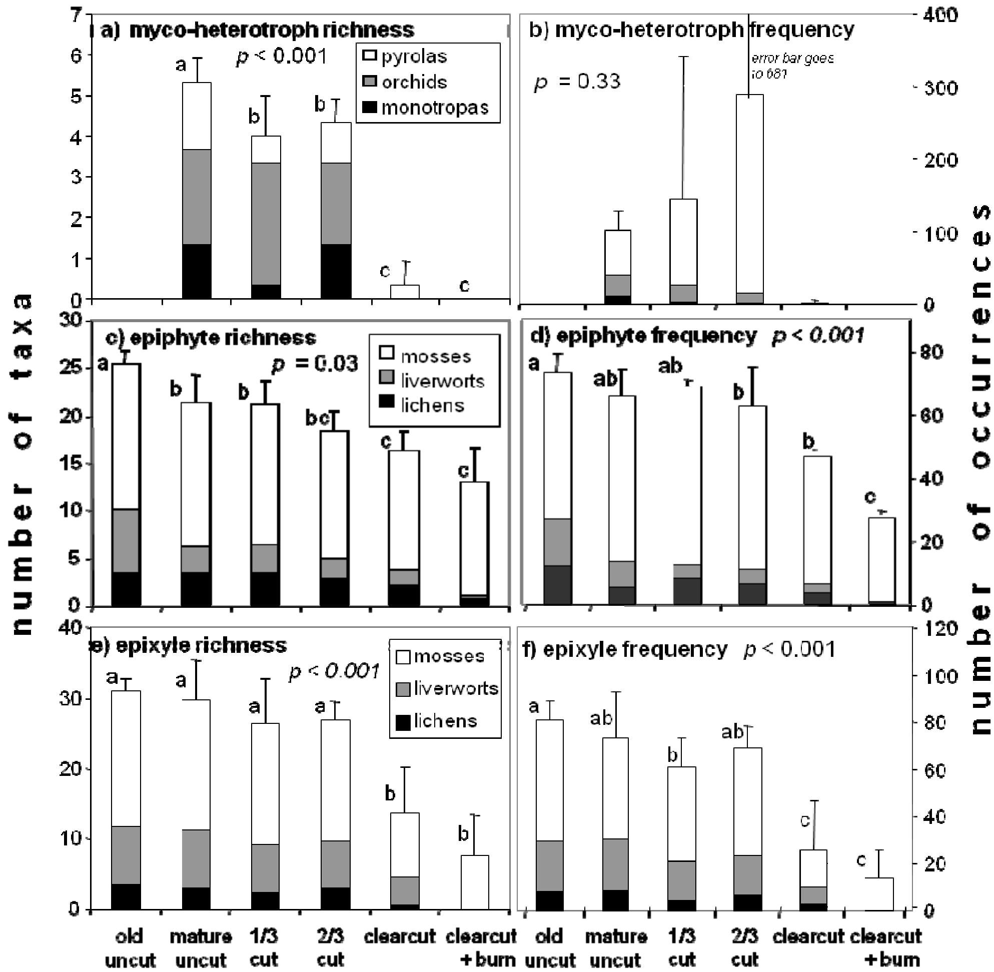

Figure 46. Species richness and abundance of (a-b)myco-heterotrophic herbs, (c-d)epiphytic and (e-f) epixylic mosses, liverworts and macrolichens in aspen-dominated forests of SAFE1, 3 years after treatment, and in nearby 105-yr old uncut aspen stands.

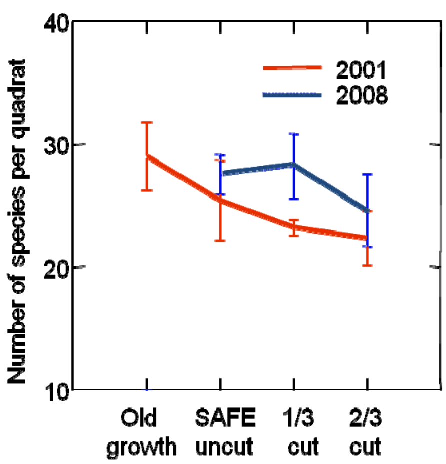

Figure 47. In 2001, 3 years after logging, total plant species richness declined slightly with the degree of disturbance (mostly due to fewer non-vascular species). In 2008, 10 years after logging, neither the uncut nor 2/3 cut had changed significantly from 2001, but the 1/3 cut had recovered to the same level of richness as the uncut. The 2/3 cut remained quite open due to abundant blowdown, and generalist species have fared better than interior forest species (results significant at $\alpha = 0.10$). Old growth stands, located just outside the experimental forest, were logged between 2001 and 2008.

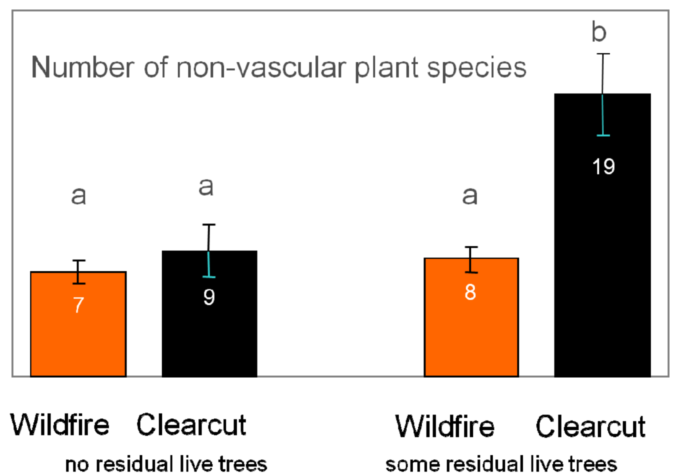

Figure 48. The effect of residual live trees on the mean number of non-vascular plant species (mosses, liverworts, macrolichens growing on all substrates in 2 m^2 subplots) in aspen-dominated boreal stands, 3 years after wildfire and 3 years after clearcutting. The heat of wildfires apparently kills off non-vascular plants, even when some trees remain alive. Results suggest that variable retention logging should allow non-vascular plants to recolonize more quickly than after wildfire.

Stop 8b

Testing the coarse filter approach on invertebrate biodiversity

Timothy Work, Jenna Jacobs, Christopher O'Connor

Université du Québec à Montréal

Introduction

In Canadian boreal forests, efforts aimed at conserving biodiversity have focused largely on coarse filter approaches such as increased green tree retention and partial cutting. The cohort management approach tested in the Lake Duparquet Research and Teaching Forest may be considered a form of retention. Increased levels of retention are meant to maintain stand structures and long-term inputs of legacy elements such as deadwood that serve as both habitat and a resource for resident biodiversity. Using the three phases of the SAFE project, our general working hypothesis is that increased levels of retention, particularly those more than 50%, will maintain arthropod communities consistent with uncut stands and intensive treatments that reduce deadwood availability will create arthropod communities with no natural analogue.

Treatments

The SAFE project focuses on three stand types, which reflect a common successional trajectory in this region (See Table 3, page 25.), from an initial cohort dominated by trembling aspen (cohort 1-SAFE 1), to a mixed cohort where both aspen and balsam fir occupy the canopy (cohort 2-SAFE 3) and a late successional cohort where high densities of balsam fir were killed by spruce budworm and birch and residual softwoods now dominate (cohort 3-SAFE 2). Using this successional template, a variety of silvicultural treatments was applied to each stand type. In addition to standard clearcuts, we also tested the effects of post-harvest prescribed burning and whole tree harvesting in the aspen cohort. Dispersed partial cutting was done in the aspen cohort [33 and 66% retention] and dispersed and 400m^2 gap cutting applied in the mixed cohort [55% retention]. All treatments were replicated 3 times and uncut stands as well as nearby natural fires were used as controls.

In each cohort x treatment combination, epigaeic arthropods were trapped and collected using pitfall traps. These samples were collected 6-7 years following harvest. We identified all carabids and spiders and are in the process of identifying all staphylinids from these collections. We compared composition among each group and the relation with stand structure using multivariate regression trees. [We present just the results for the carabids here.] In the mixed cohort, saproxylic diptera were reared *in situ* from individual aspen and spruce logs in a variety of decay classes using emergence cages. We compared diptera composition between tree species and as a function of decomposition class. This data was used to extrapolate a species accumulation curve based on binomial mixing to estimate changes in species richness as a function of deadwood volume.

Results

We have identified over 14,000 carabid beetles representing 47 species. Overall catch rates decreased with increasing harvesting intensity (Figure 50). The decrease in individuals with harvesting intensity translated into differences in compositional differences between silvicultural treatments as well (Figure 51). Dispersed retention at levels of 33% in aspen and 55% in mixed stands maintained communities more similar to uncut stands than did clearcuts. However, 55% retention in the form of gap cuts was similar to clearcutting in the mixed cohort.

Émilie Robert

Figure 49. *Ellychnia corrusca*

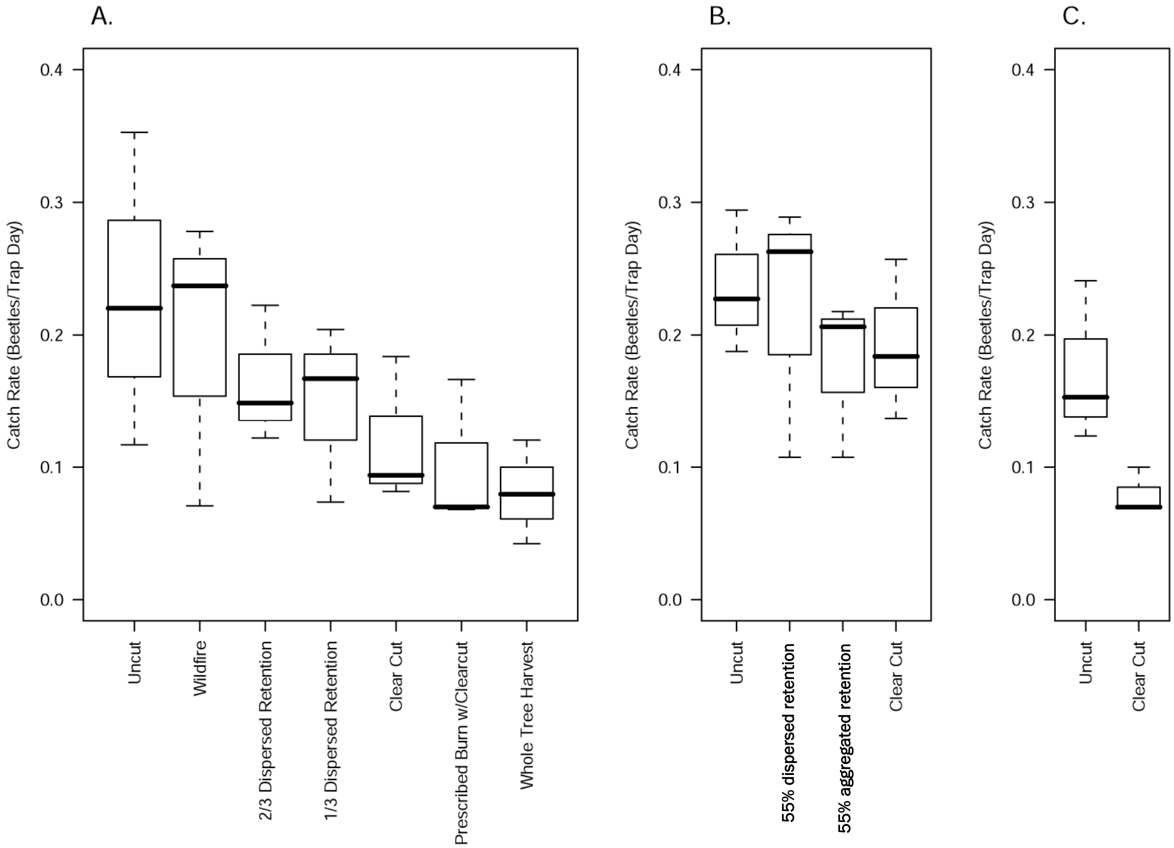

Figure 50. Box and whisker plots of carabid catch rates in A) aspen, B) mixed and C) post-budworm killed stands.

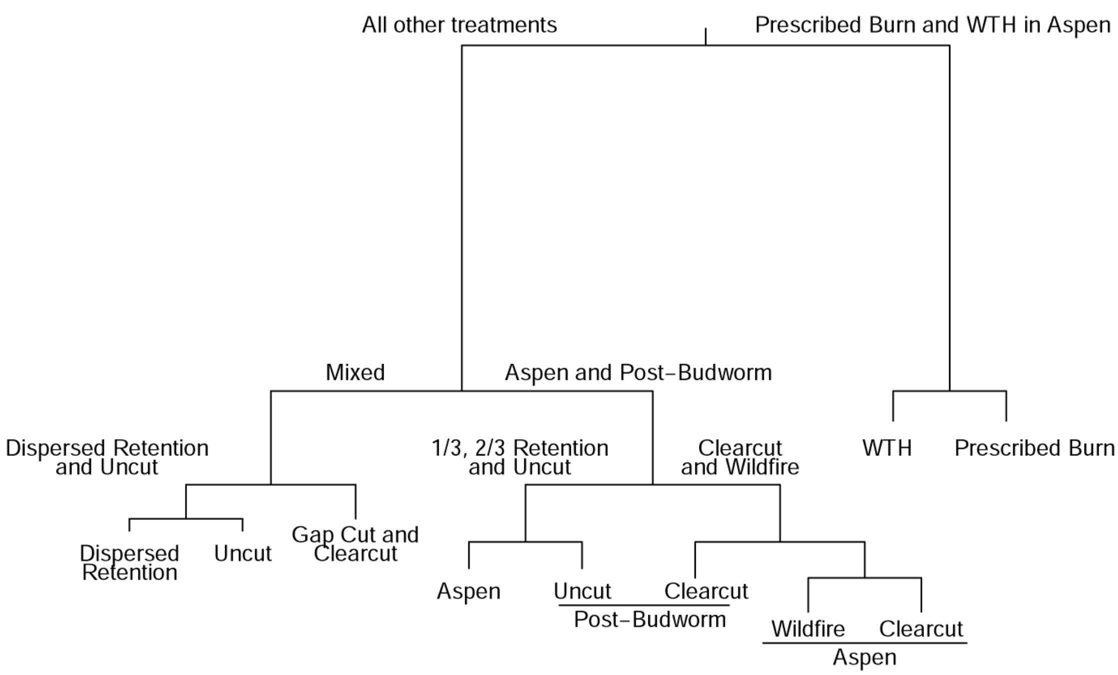

Figure 51. Distance-based multivariate regression tree explaining 71% of the total variance (CV error 63%, SE=0.109). Initial splits divide whole-tree harvest and prescribed burns from all other silvicultural treatments. Secondary splits divide mixed cohorts from aspen and post budworm cohorts. In mixed cohorts, gap cuts and clearcuts had similar effects and were differentiated from mixed sites with more retention. In aspen cohorts, retention greater than 33% maintained communities similar to uncut stands. In aspen and post-budworm stands, more intense disturbances such as wildfire or clearcutting, differed from stands with higher levels of retention.

Testing the coarse filter approach on invertebrate biodiversity (continued)

Timothy Work, Jenna Jacobs, Annie Hibbert

Université du Québec à Montréal

In a second study examining the association of saproxylic diptera with varying stages of decomposition within spruce and aspen logs, we found few differences in the diptera community related to either tree species or decomposition stage. This was related in part to very high spatial turnover in species between logs. We were able however to develop a novel approach to estimate minimum volumes of deadwood necessary to maintain species richness of saproxylic diptera. This approach used estimates of intra-log variation in species similarity to calibrate a species accumulation curve generated from binomial mixing and estimate changes in species richness as a function of deadwood volume (rather than the number of individuals or the number of samples). Our predictions suggest that a minimum of 40m^3/ha are required to maintain diptera communities in these stands (Figure 52). Details on this project will be presented by T. Work during the conference.

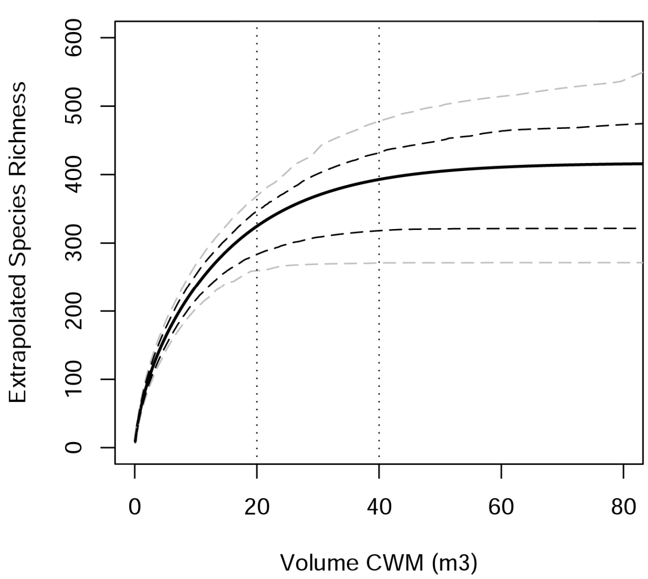

Figure 52. Extrapolated species accumulation curve for saproxylic diptera collected in spruce and aspen logs as a function of stand-level volumes of downed dead wood (CWM).

Notes

Drive through (9)

Variable retention

Claude-Michel Bouchard and Brian Harvey
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Background

Excluding partial cutting treatments aimed at maintaining forest cover or moving "first cohort stands" into stand compositions and structures more characteristic of older stands, clearcutting with variable retention has been practiced in the Lake Duparquet Forest for almost 10 years.

Dispersed retention

Most forest harvesting in the Lake Duparquet Forest is done using multifunctional harvesters. Guidelines and training for dispersed retention are provided to cutting crews prior to harvest. In general, at least 25 stems/ha, representative of the species mix and stem size distribution are left standing on site. Operators are instructed to *high-stump* five deciduous trees and leave five large diameter trees as a retention/harvest compromise. As well, all white spruce and cedar stems < 16 cm DBH are generally retained on site. This "drive through" provides an example of the dispersed variable harvesting practiced here.

Aggregated retention

Sectors designated for aggregated retention within clearcuts are roughly located during the forest harvesting planning stages and flagged at the same time as cut block perimeters. Aggregated retention may be configured as residual islands or peninsulas in cut blocks and are frequently located around wet zones, breaks in topography or other natural barriers and, where possible, in parts of stands containing higher vertical structure. Ideally, aggregated retention contains a dense conifer understory, large snags or wolf trees (usually aspen) and fallen logs. The simple, even-aged structure of the 85 year-old stands at this site does not lend itself particularly well to aggregated retention because the stands generally lack structural complexity and are prone to windthrow. Nonetheless, monitoring here and elsewhere provides evidence that aggregated retention is more windfirm than dispersed retention.


M-Eve Sigouin

Figure 53. Variable retention

Using Imbeau and Desrochers' (2002) stem degradation classification (Fig. 55), we have monitored 20 small aggregations (200-300m2) established in clearcuts in 2002. The forests harvested originated from the same fire in 1923 that affected the SAFE 1 sites and, as such, were essentially mature and even-aged. Figure 2 shows the number of stems (as expressed as a percentage of total standing stems 2 years following har-


Claude-Michel BBouchard

Figure 54. Dispersed retention

vest) in grouped decomposition classes for 2, 4 and 9 years following harvesting. Following a major drop in the number of vigorous stems (classes 1&2) in all species between years 2 and 4, most remaining stems in these classes are still intact at year 9. In year 9, close to 50% of standing stems of birch and spruce are still alive (classes 1-3), compared to about a quarter of aspen and pine stems. Of total standing stems (live and dead) in year 2, downed wood accounted for between 16% (pine) and 31% (birch) in year 9.

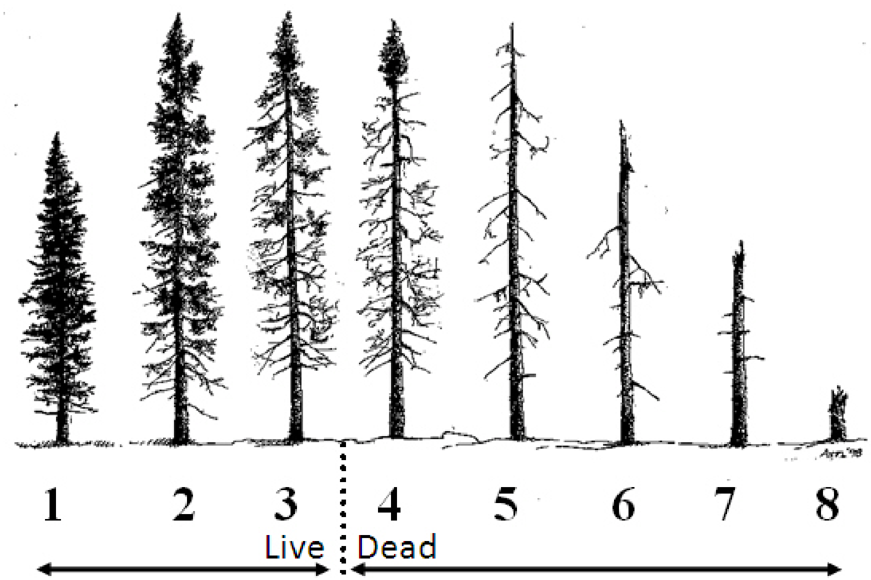

Figure 55. Stem degradation classification used for retention monitoring in the FERLD. (Source: Imbeau & Desrochers 2002).

References

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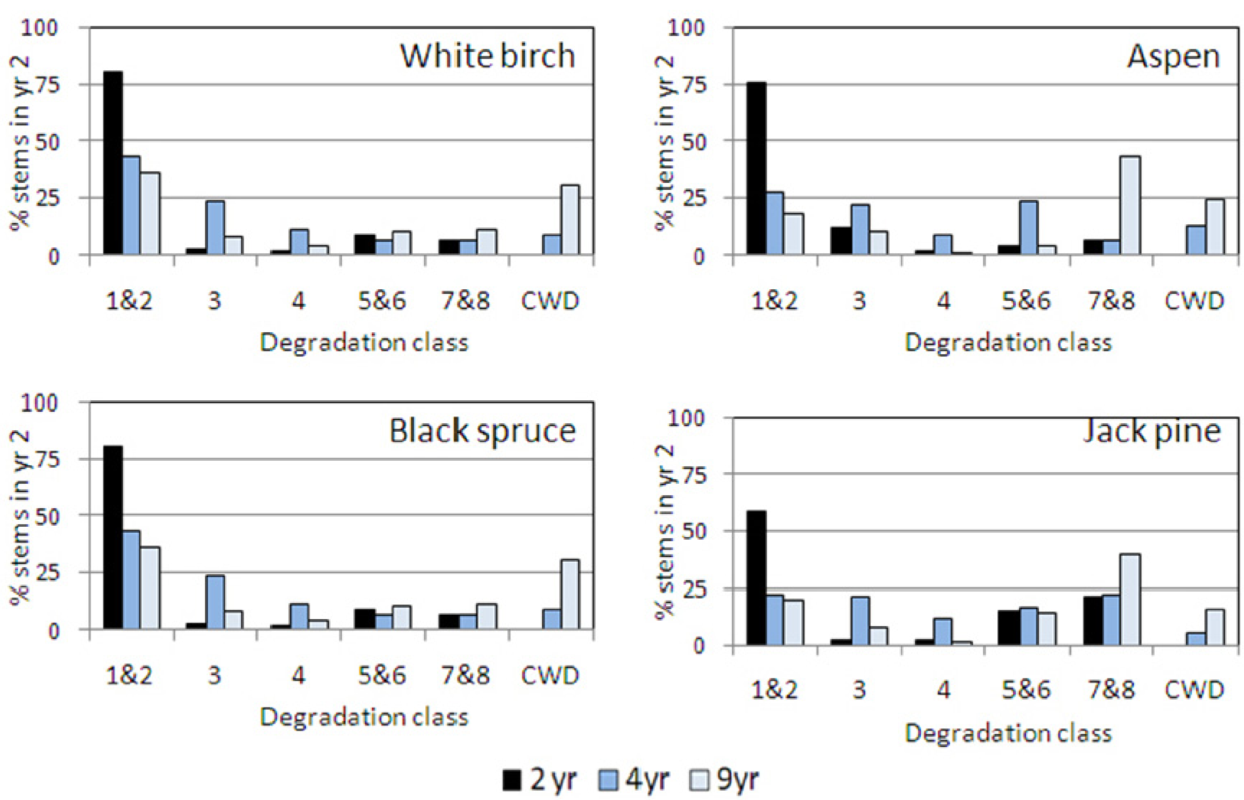

Figure 56. Degradation class distribution of stems in aggregated retention, expressed as a percentage of total stems in each year for each species (see Fig.55 for visual key to degradation classes).

Stop 10

Biomass harvesting

Timothy Work[1], Suzanne Brais[2],

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Introduction

Recent changes in Québec's forest management policy suggest that woody biomass harvesting for bioenergetic applications will become increasingly prominent. These will likely include practices such as post-harvest recovery of residual biomass following clear cutting and partial cutting. While secondary recovery of woody biomass may provide additional material for bioenergetic applications and facilitate some aspects of stand re-establishment such as exposure of microsites for replanting, secondary interventions and deadwood removal may also pose substantial risk for reducing soil quality and biodiversity. If secondary recovery of woody biomass eliminates specific pools of deadwood [ie. early decay classes], this could reverberate through successive decay classes with time creating a traveling 'dirth' of deadwood for saproxylic and soil organisms.

In this experiment, we compare the effects of secondary biomass harvesting in systems where deadwood inputs are expected to be limited [clearcuts] or constant [partial cuts] on both the deadwood profile and abundance and diversity of litter dwelling arthropods. We anticipated that in addition to a reduction of volumes of early decay classes, we would observe the destruction of advanced decay classes as a result of machine traffic during biomass recovery. In clearcuts, where inputs are limited, we anticipate that these initial reductions of deadwood biomass will persist throughout later decay classes.

Harvesting and Biomass Treatments

All post-harvest biomass treatments were applied in 2009 in clearcut and partial cutting treatments of 85 year old jack pine forests [Fig 1]. Within partial cuts, biomass was either collected along harvesting corridors [PC-Path] or left in place as a control [PC-CTRL]. Within clear cuts, we expanded and intensified biomass treatments to include residual biomass from both harvesting corridors and surrounding areas [CC-EXT] in addition to residual biomass from harvesting corridors only [CC-PATH] or experimental units where no additional residual biomass was collected [CC-CTRL].

Figure 57. Biomass harvesting research site.

Sampling

Within each experimental unit, coarse and fine woody material volumes, soil chemistry and epigaeic invertebrates were sampled from triangular plot [30 m on a side] where one side was placed directly on the machine corridor. The remaining sides projected into surrounding areas where residual biomass was generally left intact with the exception of CC-EXT treatments. Volumes of both coarse and fine woody material from five decomposition classes were estimated by counting the number of individual pieces in seven diameter classes [0-0.5 cm, 0.51-1 cm, 1.01-3 cm, 3.01-5 cm, 5.01-7 cm, 7.01-17.5 cm and all pieces >17.5 cm in diameter]. Along each side of the sampling plot, two pitfall traps [10 cm ø] were placed ~12.5 meters apart. Each trap contained 15 ml of propylene glycol as a preservative. All traps were covered with elevated roofs to limit flooding from rain. All traps were collected at 3-week intervals, five times throughout the summer of 2010.

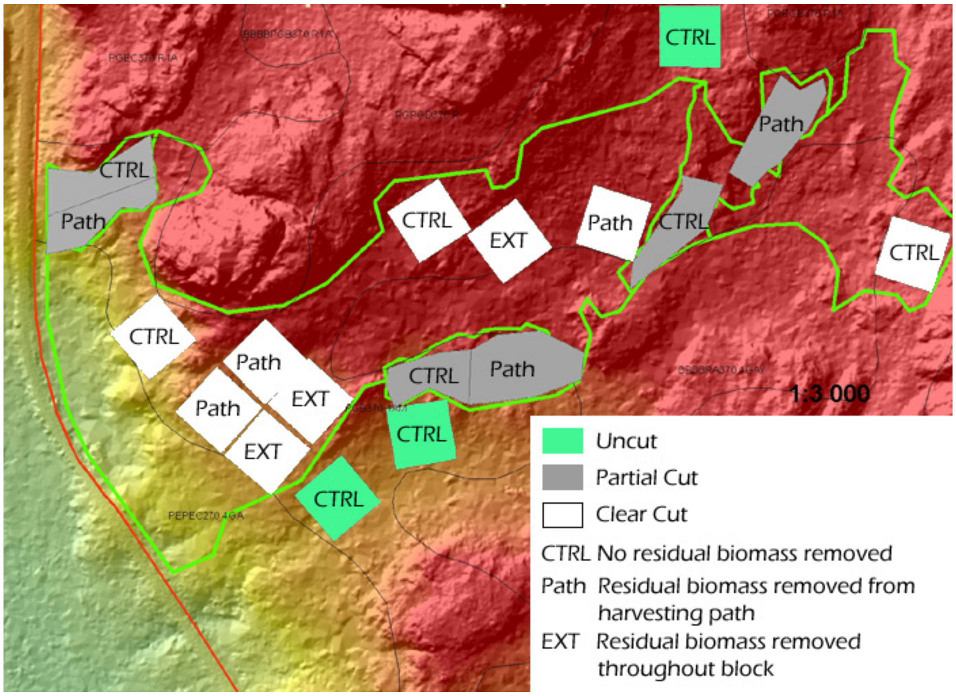

Figure 58. Map of experimental plots used in biomass recovery experiments.

Analysis

We used the volume of deadwood left after harvest and biomass recuperation to model the residency of deadwood in three decay classes [early, middle and late] in clear cuts. These decay classes are defined based on comparisons of visual decay classes and measured wood densities. We specified the three classes with densities 0.55-0.401, 0.4-0.301 and 0.3-0.101 g/cm^3 respectively. Our model allocates the initial biomass across a decay class as unimodal function whereby 99.9% of the mass falls between the upper and lower limit of a decay class. This initial mass is then allowed to transition to later decay classes with time according to a negative exponential function with k=0.02.

Results

Secondary recovery of biomass following harvesting reduced overall volumes of deadwood with experimental plots with increasing intensity of biomass recovery resulting in further reductions of deadwood volumes (Fig. 59). In clear cuts, increased biomass recovery reduced volumes across all diameter classes. In partial cuts, increased biomass recovery reduced volumes primarily between 1-7 cm diameter classes. Biomass recovery had the largest effects on decomposition classes 2 and 3 but also reduced volumes of advanced decomposition classes.

When initial biomass values were extrapolated into successive pools of deadwood, all three biomass scenarios in clearcuts showed similar trends in transitions between deadwood pools. The most obvious difference is related to reduced initial mass that enters the cycle under increasingly intense biomass harvest (Fig.60).

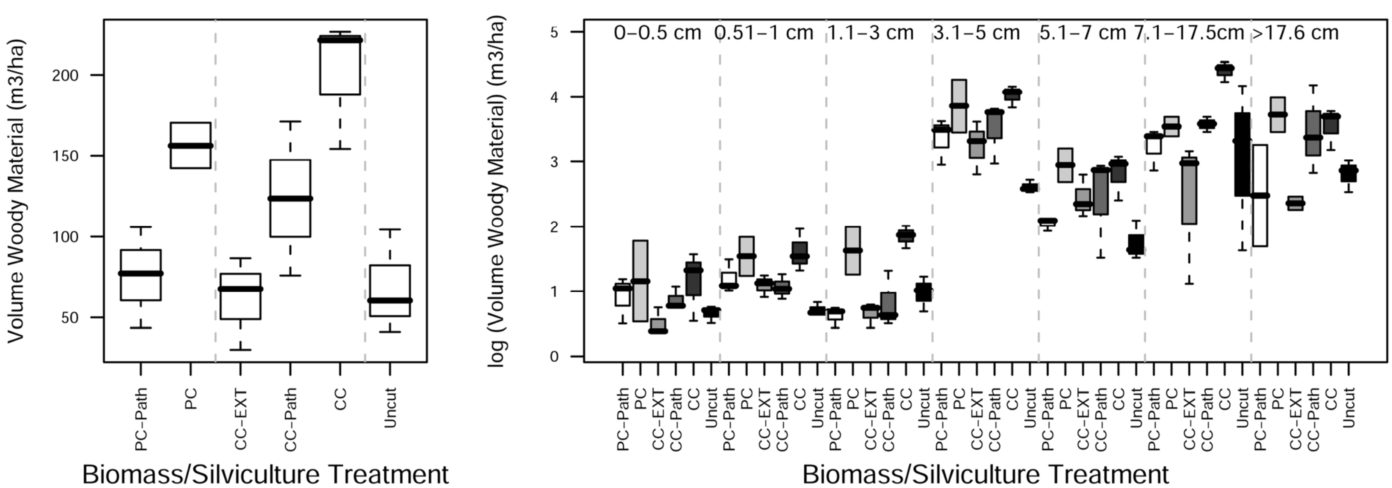

Figure 59. Box-and-whisker plots depicting median and 25-75% quantiles for a) overall volumes of woody material and b) volumes divided by diameter classes measured following biomass removal treatments. PC corresponds to Partial Cuts, CC corresponds to clear cuts, Path refers to biomass recovered from harvesting paths, EXT corresponds to extreme biomass recover collected from both harvesting paths and vegetation strips.

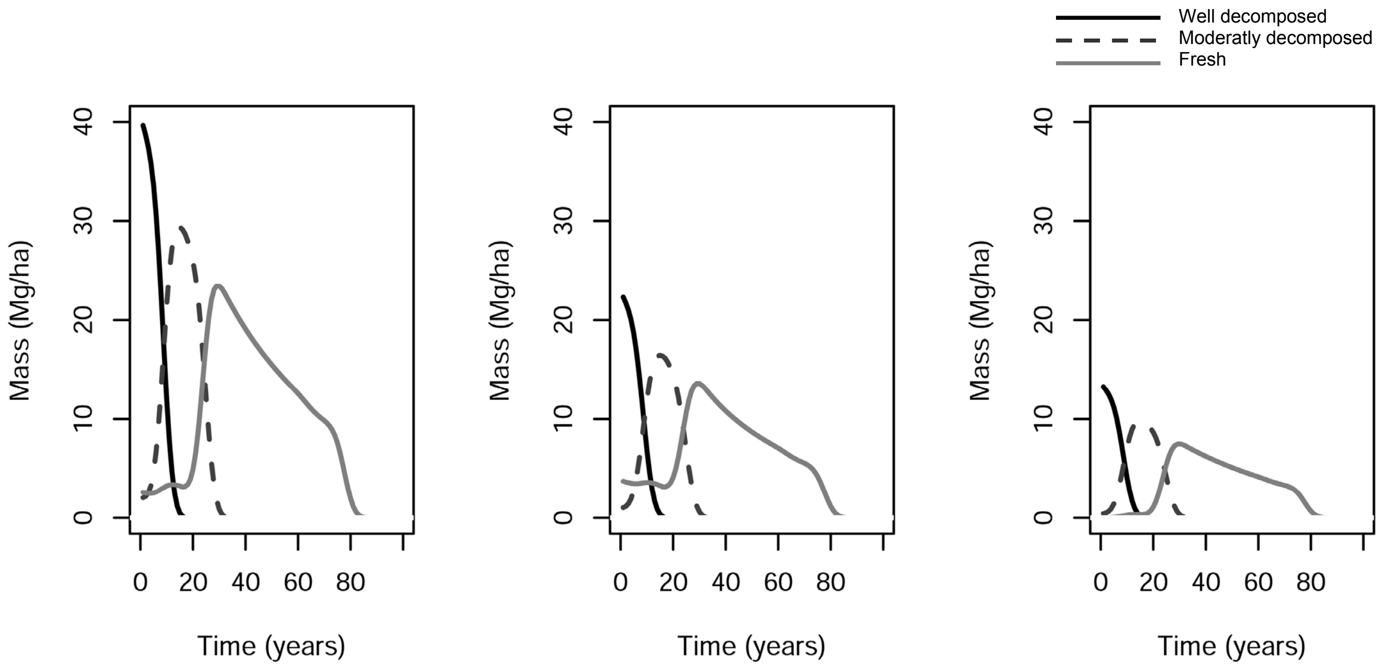

Figure 60. Projected residency times of biomass in three decay classes under a) standard clear cuts with no biomass removal b) CC-Path, where biomass was removed from harvesting paths following clear cuts and c) CC-Extreme where biomass was removed from both harvest paths and vegetation strips following clear cuts.

Notes

Stop 11a

Linear remnant habitat: the role of riparian buffer strips and cut block separators in maintaining cavity and snag-dependant species

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[2]Université du Québec en Abitibi-Témiscamingue

Introduction: Forest regulations concerning cut-block size and residual forest in boreal Quebec

In the last twenty years, forest regulations in Quebec allowed two basic spatial patterns of cutovers in the boreal forest: 1) *aggregated* (a matrix dominated by cutover areas covering up to several hundred km^2) or 2) *dispersed* in a checkerboard pattern ("mosaic cutting"). In landscapes dominated by aggregated clearcutting, 50-200 ha cut-blocks are separated by linear strips or separators. As a result, remnant forests in these landscapes are generally composed of narrow corridors, 20 to 100 m wide, along streams and lakes or between cut -blocks (Fig.X. In dispersed-cut landscapes (10-80 ha cut-blocks), harvesting is limited to 50 % of the mature forest and residual uncut forest blocks have to be equivalent in size to adjacent cut-blocks. At a sub-regional level 30% of productive forest in "*territorial reference units*" (300-500 km^2 in the boreal zone) must remain in height classes > 7m at all times.

Objectives of recent studies conducted in harvested landscapes

1. Evaluate the effects of size, shape and isolation of residual habitat fragments in boreal black spruce forests on eight bird species associated with mature forest and dead wood, in landscapes highly fragmented by logging (Leboeuf 2004).

2. Compare the effects of the spatial organization of residual habitat fragments in boreal black spruce forests on bird species associated with mature forest and dead wood, in landscapes characterized by aggregated vs. dispersed clearcuts (Gagné 2006, Gagné et al. 2007).

3. Characterize the availability of large living and dead trees in remnant old forest stands for large secondary users (Vaillancourt 2007, Vaillancourt et al. 2008).

M-Eve Sigouin

Figure 61. Aggregated clearcut landscape

4. Determine whether remnant linear habitats in even-aged managed (aggregated clearcut) landscapes provide adequate nesting habitats for primary (woodpeckers) and secondary cavity nesters (ducks, owls, passerines, mammals) (Ouellet-Lapointe 2011, Bédard ongoing M.Sc.)

Main findings and interpretation

Bird abundance patterns in remnants

In spruce-dominated forests, the cumulative occurrence of five species associated with old forests and dead wood decreases with increasing distance to large continuous undisturbed forest tracts, and increases with increasing percentage of mature forest cover within a one km radius. Brown Creeper was the most sensitive species to distance from a large continuous undisturbed forest tract (Figure 64).

Although the strength of the effect is weak, the isolation of residual forest habitats within clear-cut areas affects negatively the bird fauna associated with mature and over-mature forests.

Louis Imbeau

Figure 62. Yellow bellied sapsucker.

Pierre Drapeau

Figure 63. Bird's eye view of linear remnant mature forest in managed landscapes characterized by an aggregated clearcut pattern. Riparian buffer strips and cut block separators, 20m to 100 m wide, make up 5 - 10% of the land base.

Spatial organisation of mature remnants matters for forest bird species

Whereas some mature forest associates such as the American Three-toed Woodpecker (*Picoides dorsalis*) and the Boreal Chickadee (*Poecile hudsonicus*) occurred more often in larger forest patches (40-60 ha) of dispersed clearcut areas, large woodpeckers such as the Northern Flicker (*Colaptes auratus*) were significantly more abundant in linear strips (20-100 m width) of aggregated clear-cuts.

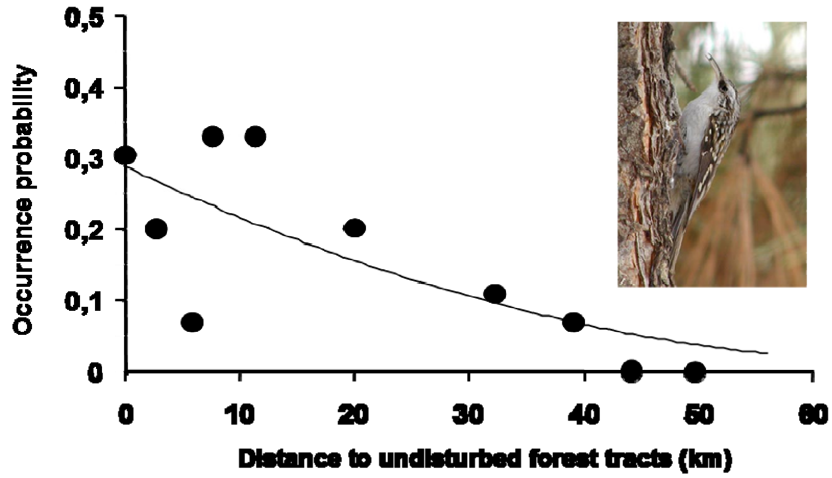

Figure 64. Occurence probabilities for Brown Creeper in residual mature forests after logging, in relationship to distance to undisturbed forest tracts in northwestern Quebec.

Deadwood availability for large cavity nesters in habitat remnants

Large cavity-nesting birds depend on large-diameter trees (> 30 cm dbh) for suitable nest sites. The increased spatial extent of commercial timber harvesting has modified the availability of large trees at the landscape scale. Remnant stands in boreal coniferous forest (*Picea marianna – Abies balsamea*) in eastern Québec showed a much lower availability of large trees when compared with unharvested forests. Current even-aged management practices clearly affect availability and recruitment of large trees. Therefore forest-dwelling wildlife species that rely on these structures for breeding are likely to be affected by large-scale harvesting in coniferous boreal forests.

Cavity nesters breeding activity and productivity in boreal mixedwood forests

Availability of large-diameter trees (>30 cm dbh) was similar (standing dead trees) or higher (live trees) in remnant habitats of managed landscapes than in the continuous forest tracks of the unmanaged forest of Lake Duparquet Research and Teaching Forest. We conducted a study on woodpecker nesting activity that assessed breeding abundance, nesting success and productivity in linear remnants of forests in managed landscapes and compared these parameters with those of breeding woodpeckers in a continuous unmanaged landscape. For most species we found higher or similar nesting abundance in linear remnant habitats compared to continuous forest tracks, as well as comparable nesting success and productivity (Figure 65). These results suggest that linear remnant habitats in even-aged managed landscapes provide quality habitats for some woodpecker species and clearly indicate their high conservation value. Consequently, we recommend that no further harvesting be conducted in these remnant

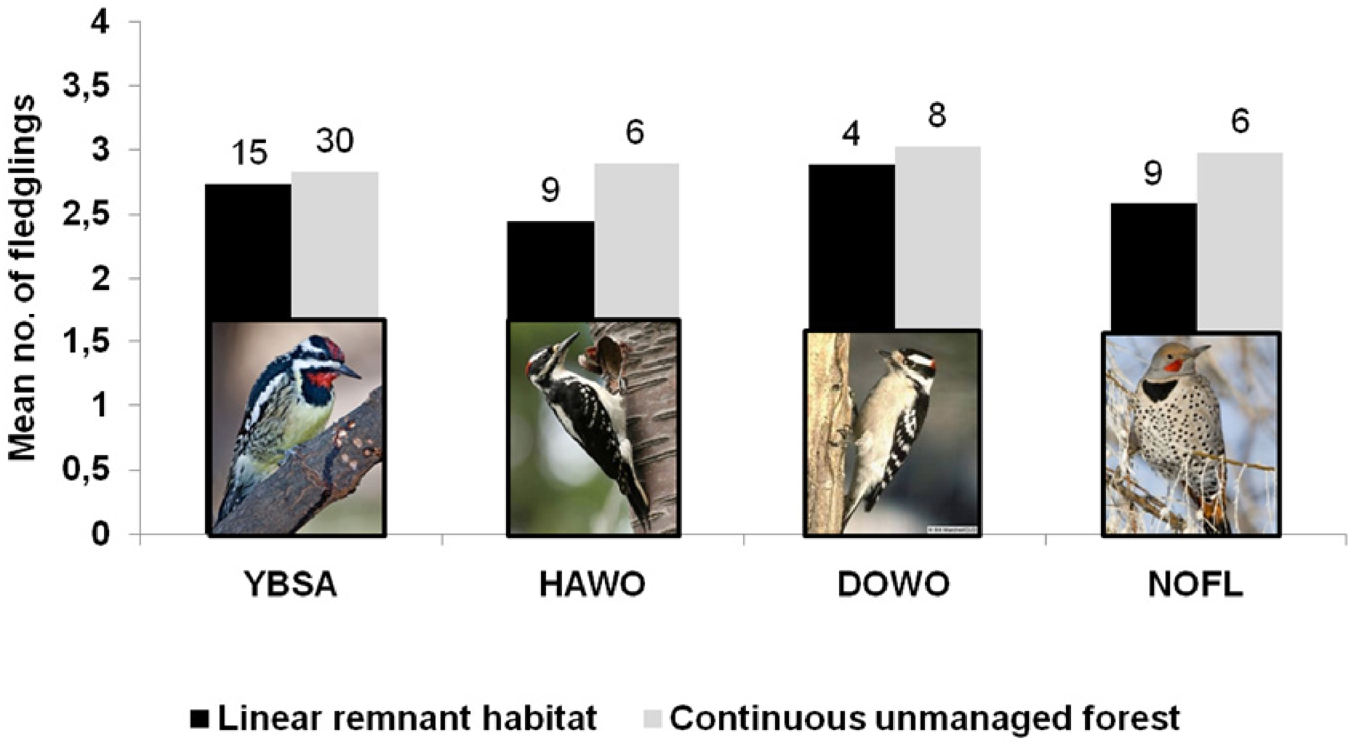

Figure 65. Woodpecker nest productivity in linear remnants vs. continuous forest tracks of managed and unmanaged forest landscapes within and near the Lake Duparquet Research and Teaching Forest (Adapted from Ouellet-Lapointe, 2011, M.Sc. thesis). YBSA: Yellow-bellied sapsucker; HAWO: Hairy woodpecker; DOWO: Downy woodpecker; NOFL: Northern flicker. (Values above bars are numbers of nests monitored).

forests and that they be maintained as permanent retention habitats in even-aged managed landscapes.

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Notes

Stop 11b

Nest webs and nest tree selection by excavators in eastern boreal mixedwood forests

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Study description

The availability of cavity-trees plays an important functional role in maintaining the biodiversity of forest ecosystems. Cavity excavators, mostly woodpeckers, have been found to be architects of cavity nesting communities by providing the vast majority of cavities used by cavity nesting species. Secondary cavity nesters are a more diverse group, composed of passerines, birds of prey, ducks and mammals that cannot excavate their own cavities and therefore depend on the availability of cavities. Weak excavators can excavate their cavities in soft or degraded wood or use existing cavities. A community is formed through the creation of cavities and the competition for them, and is often described as a "nest web", a practical tool to visually highlight the interactions between cavity nesting species and potential interdependencies. All cavity-nesters are dependent on cavity-trees or adequate cavity excavation substrates for nesting and roosting. However, the quality and quantity of these substrates can vary considerably between forest cover types and as the forest ages.

Objectives

1. Using a nest web approach, compare functional structures and network properties of cavity nesting communities along an forest age and compositional gradient of naturally disturbed forest in the boreal mixedwood;
2. Understand nest tree use and selection by cavity excavators.

Field methods

Between 2003 and 2010, twelve 24 to 40 ha plots representing seral stages ranging from 61 to 245 years after fire disturbance were surveyed in the Lake Duparquet Research and Teaching Forest to detect cavities with active nests. All cavities found were inspected using a camera mounted on a telescopic pole (TreeTop Peeper™, Sandpiper Technologies, Manteca, California) to determine the state of the cavity: non-completed excavation, suitable cavity or occupied cavity. This study provides the first comparison of nest webs along a time-since-fire age gradient in a continuous boreal mixedwood setting.

Figure 66. Cavity in large-diameter aspen snag.

Main findings and interpretation

1. Nest webs were composed of 5 primary cavity excavator species (woodpeckers), two weak cavity excavator species (nuthatches, chickadees) and 7 secondary cavity users (squirrels, passerines, ducks, birds of prey). Cavity nesting communities remained similar throughout the age gradient and the deciduous to coniferous cover type transition (Figure 67).
2. Along the age gradient, we found a cavity nesting community mainly structured around trembling aspen and two primary excavators, the Yellow-bellied Sapsucker and the Pileated Woodpecker. In these continuous boreal mixedwood forests, the Northern Flicker was not an important cavity-providing excavator. Trembling aspen harbored 95% of the cavity nests, despite its low availability. Secondary cavity users selected excavated cavities (as opposed to naturally occurring ones) 99% of the time.

3. Cavity excavators selected large diameter trembling aspen in varying stages of degradation. Almost all live aspen nest trees and half of dead aspen nest trees bore fungal conks (Phellinus tremulae) despite their low presence (7%) in aspen stems of >20 cm in DBH.
4. Excavators used large trees: Mean nest tree DBH ranged from 28.8 cm to 45.5 cm. In comparison, available aspen trees had a mean DBH of 22.9 cm (Figure 2). Excavators could be separated into significantly different groups according to their mean nest tree DBH. The Pileated Woodpecker used the largest trees and the Red-breasted Nuthatch and the Downy Woodpecker used the smallest (Figure 68).
5. Nest tree use and selection was similar across forest cover types and forest age. Nest abundances followed the availability of quality excavation substrate, as there seemed to be a modal distribution of nests along the succession, the highest abundance being in old deciduous and mixedwood forests.
6. The presence of large diameter trembling aspen that cover a wide range of degradation stages from senescent to highly degraded trees, is necessary to maintaining cavity excavators in mixedwood boreal forests under natural disturbance regimes.

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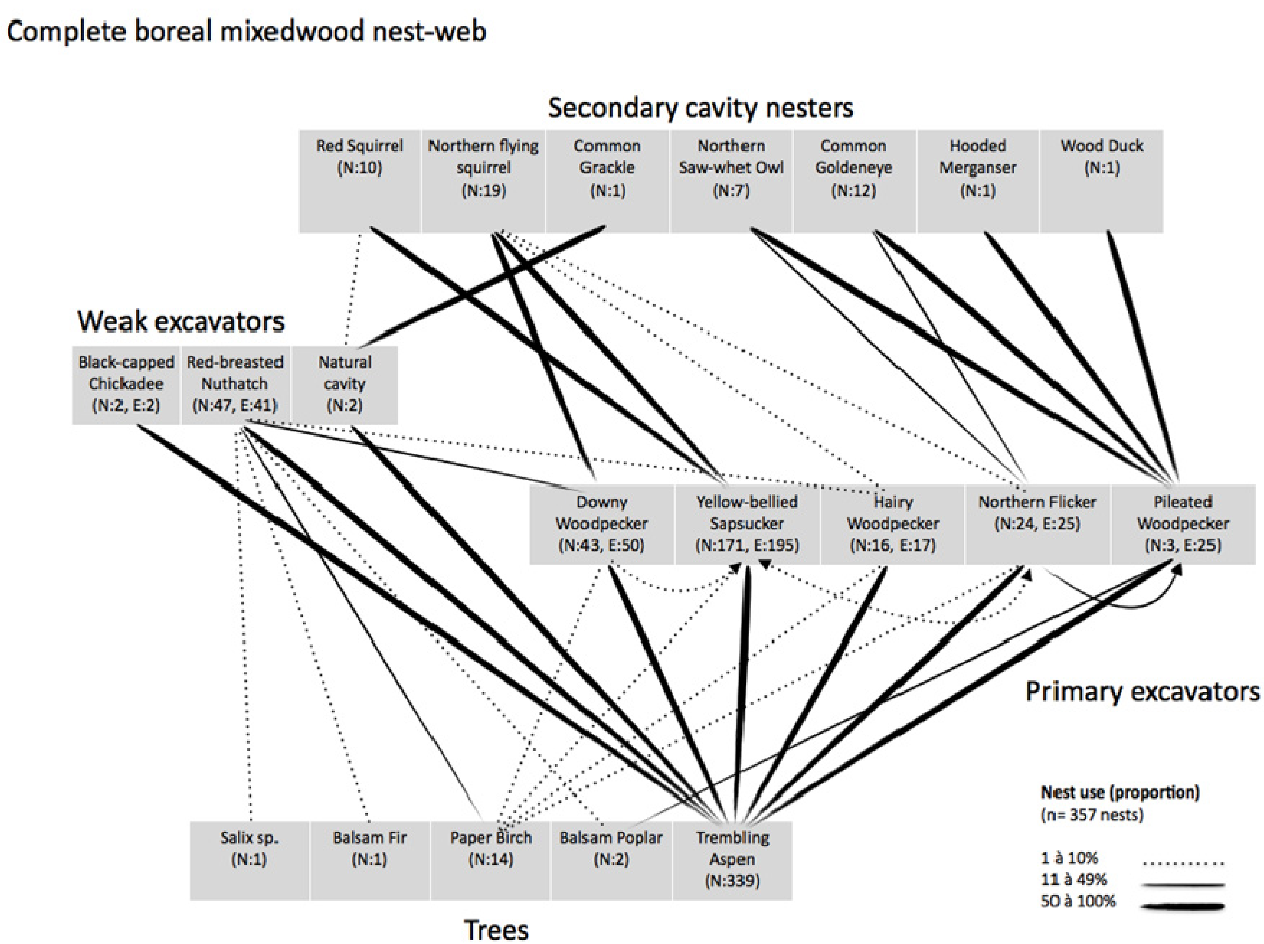

Figure 67. Complete boreal mixedwood nest web in Abitibi, Québec. Lines between species represent the use of cavity resource. N is the number of nests found and E is the number of excavated cavities that were used by the excavator and by other cavity nesters. Links between the excavator level and the tree level represent the proportion of nests found in the tree species and the links between secondary cavity nesters, excavators and natural cavities represent the proportion of nests found in reused cavities.

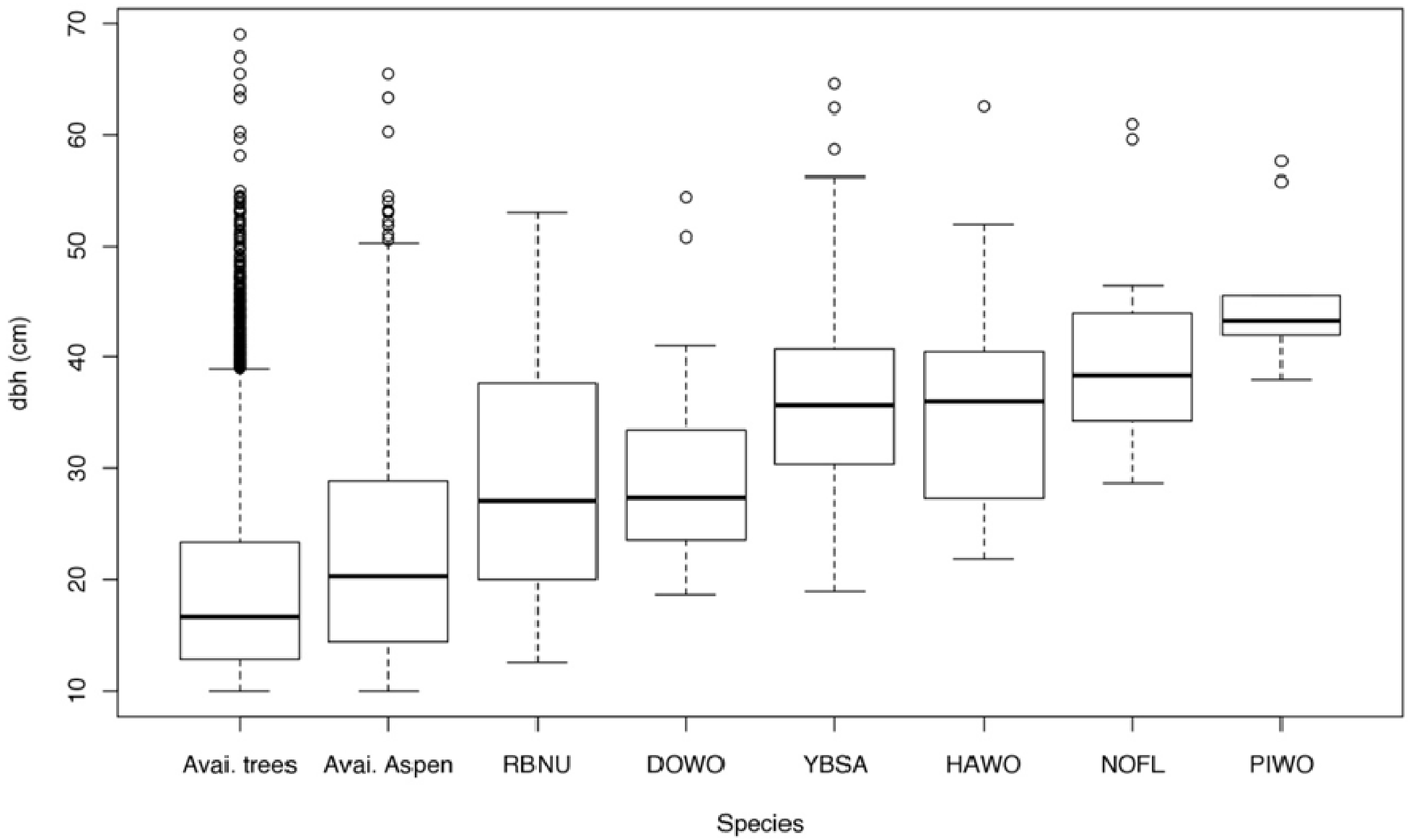

Figure 68. DBH of available trees (all species), available aspen and trees used for nesting by species. Species considered are Red-breasted Nuthatch (RBNU), Downy Woodpecker (DOWO), Yellow-bellied Sapsucker (YBSA), Hairy Woodpecker (HAWO), Northern Flicker (NOFL) and Pileated Woodpecker (PIWO).

Notes

Drive through (12)

Deepwater, wetlands and riparian ecosystems at the Lake Duparquet research and teaching forest

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Study description

Numerous studies have been conducted since the 1980’s in the Lake Duparquet Forest and over 200 articles treating boreal forest ecology have been published. However, few studies have been conducted on the ecology and management of deepwater and wetland ecosystems, despite the fact that the LDRTF is located in one of the regions of Quebec where wetlands are the most abundant. In 2007, the deepwater, wetland and riparian ecosystems of the Lake Duparquet Forest were mapped and classified using aerial photos and a recently developed classification system (Ménard 2007). Considering the importance of beaver dams in this area, research projects were also undertaken on the ecology of this species in order to better understand factors affecting dam construction (Labbé 2009, Tremblay 2010), and the use of small ponds by waterfowl in boreal Quebec (Lemelin 2007, Lemelin et al. 2010).

Figure 69. Beaver dam

Main findings and interpretation

1. Deepwater, wetland and riparian ecosystems are important components of this forested landscape, covering 40.1 % of the LDRTF (93 km²). Deepwater and conifer swamps are the most well represented ecosystems (Meunier et al. 2009, Figure 1).

2. Beaver is abundant within the limits of the LDRTF. A total of 458 beaver dams were located (active/inactive) and found to modify nearly two thirds of the stream ecosystems. However, the modified areas are relatively small (average 0.64 ha). One dam measuring 437 meters long, is (to our best knowledge) the longest beaver dam ever documented in Quebec (Meunier et al. 2009, Figure 1).

3. Factors having a notable effect on beaver occurrence or abundance are stream gradient, watershed size (geomorphological factors) and, to a lesser degree, hardwood cover adjacent to the streams (factor related to food availability). An analysis of dam locations at the provincial scale revealed that food availability had a stronger effect in the boreal region than in the southern regions of Quebec (Labbé 2009).

4. In Quebec, the Abitibi region has a much higher mean density of beaver colonies (5,5/km²) than the provincial average (2,9/km²). Forest road culverts are frequently used by beaver as a structural element on which to build dams, causing frequent road damage. Their likelihood of being used by beaver in this region is always high and we found limited effects of variability in culvert type and surrounding habitat factors (Tremblay 2010). To avoid road damage, pre-dams should be constructed to prevent dam construction directly on culverts.

5. Connected ponds (<8 ha) were highly used and highly selected by all dabbling duck species and by ring-necked duck, hooded merganser, and

common goldeneyes. Isolated ponds were primarily selected by many species, but their use remained negligible. Dabbling duck species and Canada geese made extensive use of streams (25–41% of all pair locations). Half of the species preferentially used shorelines of water bodies <8 ha, whereas all piscivorous species preferred shorelines of larger water bodies.

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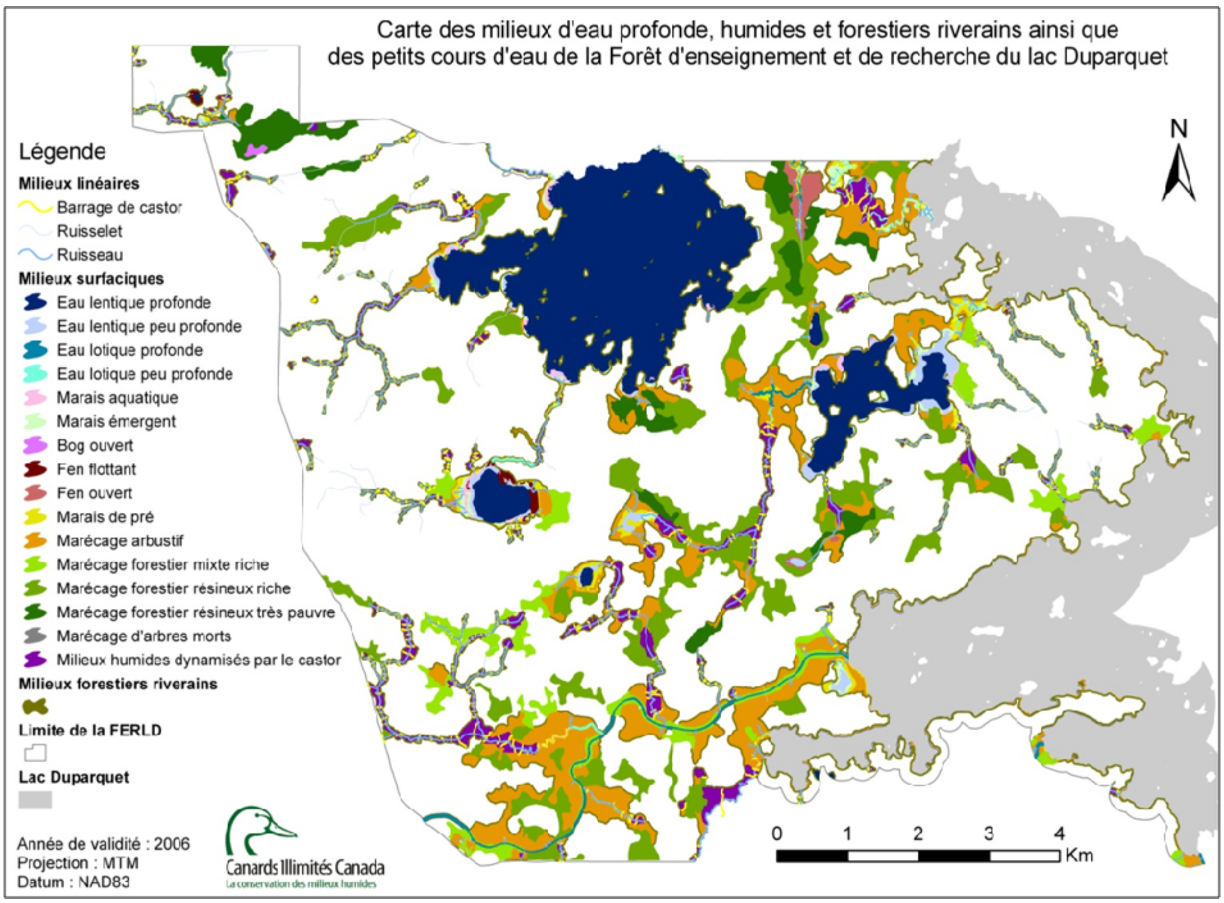

Figure 70. Deepwater, wetland and riparian ecosystems of the lake Duparquet Research and Teaching Forest in Abitibi lowlands, Quebec, Canada (Meunier et al. 2009).

Notes