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Woodland caribou habitat connectivity under different ecosystem-based management scenarios

Highlights

- Spatial-temporal modeling of ecosystem-based management is a useful tool to evaluate the amount and the level of connectivity of woodland caribou habitat in a landscape, over long time periods.
- Harvest cycles have a significant impact on the amount and level of connectivity of woodland caribou habitat.
- The size and number of harvest blocks affect the connectivity of woodland caribou habitat.
- Aggregating harvest blocks to achieve patch sizes similar to those created by fire, is a potential strategy for the conservation of large forest patches preferred by caribou.

Woodland caribou are adapted to forest landscapes structured by forest fires with large forest blocks. Forest harvest over the last century has tended to fragment these historically large forest patches, thereby reducing woodland caribou habitat quality. Currently, half of the herds in Canada are in decline and could disappear over the next 50 years. As a result woodland caribou have been placed on the endangered species list.

Woodland caribou require large patches of forest. In spite of the fact that black spruce forests of western Quebec have historically experienced a much higher fire frecuency compared to current fire patterns, this forest has provided a landscape (created by fire disturbance) in which woodland caribou were able to survive. Current low caribou population levels suggest that contemporary forest management does not create habitat that meets their needs. In an ecosystem-based forest management context where we attempt to emulate natural disturbance regimes, it would be prudent to adjust harvest rates to take into account past and current fire frequencies. In other words, a level of disturbance that is similar to historic fire frequencies can be achieved by taking into account the combined effects of harvests and fire (Figure 1). In doing so, a sufficient amount of old growth forests, essential for the conservation of woodland caribou, can be maintained on the landscape.

Total area harvested is not the only aspect of forest management we addressed for the conservation of woodland caribou in this scenario. The spatial distribution of harvests was considered equally important. One of the strategies adopted in Quebec at the beginning of the 2000s, to address the spatial distribution of harvests, was mosaic forest harvesting (dispersing a variety of harvest areas of different shapes and sizes across a landscape). But it rapidly became apparent that spatially spreading out harvest blocks under this strategy accelerated the fragmentation of remaining forest patches. Additionally, this type of harvest strategy requires rapid construction of new forest roads, facilitating the movement of woodland caribou predators and increasing the level of human disturbance in the landscape.

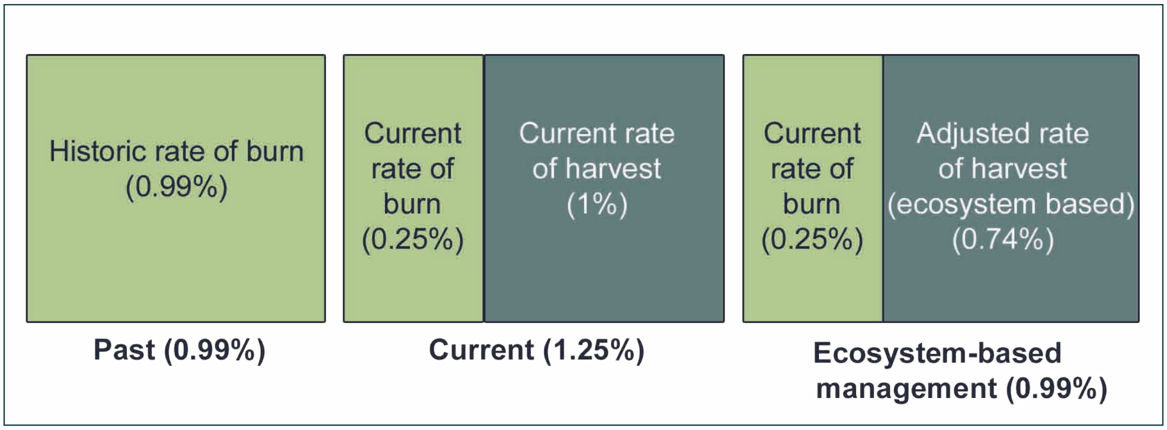

Figure 1. Example of adjusting the annual harvest rate (% area per year) as a function of the historic burn rate. The historic total rate of disturbed area is the same as that under an ecosystem-based management regime, while the total rate of area disturbed is higher under the current management regime.

Aggregating harvest blocks can be adopted to limit the negative impacts of forest removals in a localized area. Concentrating silvicultural activities to a smaller portion of a managed area lowers overall disturbance levels and forest fragmentation. Aggregating harvest blocks also helps to maintain long term habitat availability and connectivity because new forest patches become available to woodland caribou as harvest blocks grow into mature forests. Over the long term this management strategy will tend towards creating a landscape similar to one sculpted by fire.

Spatial-temporal modelling: a decision-making tool

In order to evaluate the potential impacts of ecosystem-based management on woodland caribou habitat, we developed a spatial-temporal model in support of strategic decision-making. Different management scenarios were modelled on the SELES (Spatially Explicit Landscape Event Simulator) computer modelling platform. The simulated landscape corresponds to FMU (Forest Management Unit) 085-51, in north-western Quebec (Figure 2). The Quebec-Ontario Frontier woodland caribou herd inhabits this area. The herd has the largest natural range in Canada (65,000 km^2) and consisted of approximately 500-600 individuals at the beginning of the 2000s. However, population size has declined by 4-5% per year since 2000. Strategic planning is therefore considered very important to create a landscape that ensures the long term survival of this woodland caribou herd.

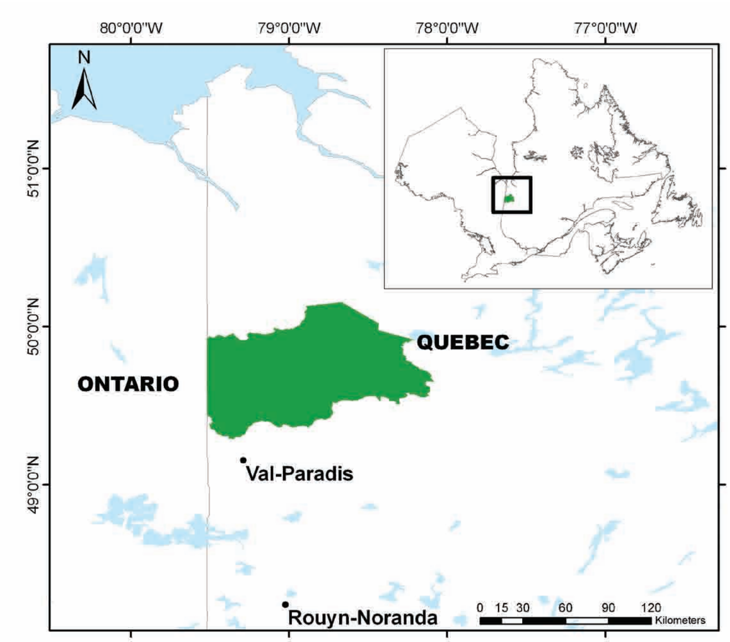

Figure 2. Study area.

The model is characterised by three types of landscape events. Firstly, **forest succession** permits the evolution of forest age, composition and structure through time. Secondly, we integrated **fire events** that randomly (time and space) disturb the landscape. Finally, **forest harvesting** was organised into cutblock aggregations whose arrangement on the landscape was limited by spatial constraints (rotation time, protected areas, etc). We initially placed the largest aggregations first, which optimised the largest blocks of available exploitable forest. Inside harvest aggregations, partial cuts were incorporated at a rate similar to the proportion of forest that is partially burned, e.g. 30%.

Three historic fire cycles (101, 135 and 189 years; Table 1) were modelled in order to determine the harvest cycle that would complement the current fire cycle. When the current fire cycle of 398 years is taken into account, the complementary harvest cycle to achieve the historic fire cycle is 135, 204 and 306, respectively.

Occurence	Historic fire	Current fire	Complementary harvest cycle	Actual total disturbance
Cycle (years) Frequency (%/year)	101 0.99	398 0.25	135 0.74	101 0.99
Cycle (years) Frequency (%/year)	135 0.74	398 0.25	204 0.49	135 0.74
Cycle (years) Frequency (%/year)	189 0.53	398 0.25	360 0.28	189 0.53
References	Bergeron *et al.* 2004; 2006	Bergeron *et al.* 2004	--	--

Table 1. Historic and current fire occurrences used to determine complementary harvest cycles.

In areas where the historic fire cycle has been determined, it is possible to establish harvest aggregation size targets that are based on the pattern that would have been created by fire in the past. Three patch-size distributions were considered for aggregation size (Table 2) corresponding to 9 scenarios; two based on empirical studies, and one (aggregations over 100 km² covering 40% of the harvested area) designed to complete the size gradient.

Disturbance area	Percent of the total disturbed area		
More than 100 km²	40	60	80
10 to 99.9 km²	45	30	15
1 to 9.9 km²	15	10	5
References	--	Bergeron *et al.*, 2004	Perron *et al.*, 2008
Distribution code	A	B	C

Table 2. Percent of the total area harvested for each 25-year period, by aggregation size class. Area burned data are used as targets during the simulations.

Monitoring woodland caribou habitat area through time

The total amount of available woodland caribou habitat is positively correlated with harvest cycle (Figure 3). Spatial patterns from the current management regime require approximately 125 years to overcome – subsequently the scenarios stabilise. Once stability is reached, the scenario with no forest harvest creates twice as much woodland caribou habitat as the 135-year harvest cycle scenario. In order to maintain the current amount of habitat, a harvest cycle of 360 years is required during the next century, i.e., a harvest rate of 0.28%/year.

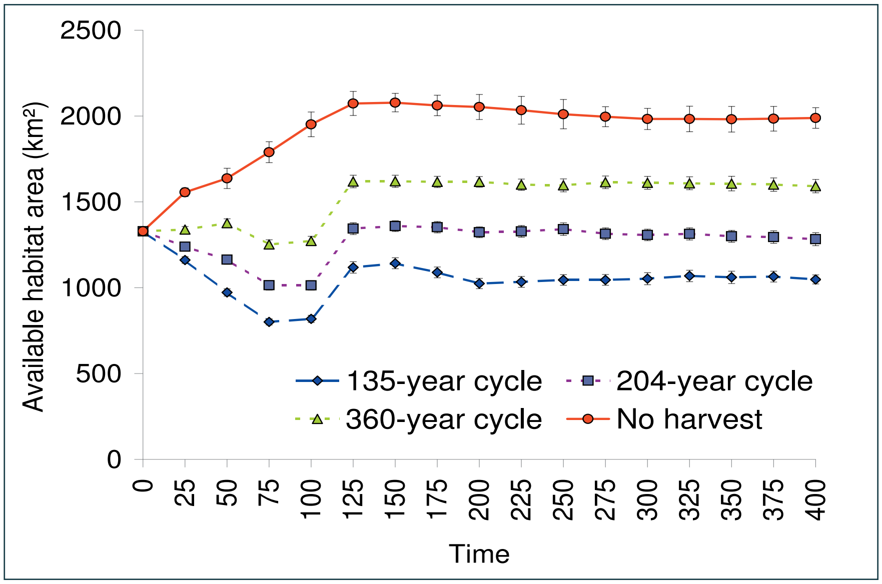

Figure 3. Evolution in the amount of woodland caribou habitat present on the landscape (± 2 SE) over time, based on simultions with different harvest cycles.

Level of connectivity in woodland caribou habitat

Spatial graph theory was used to evaluate connectivity of woodland caribou habitat. This technique creates links between habitat patches, and the landscape is represented as a network of these habitat patches available for dispersing organisms (Figure 5). The Minimum Planar Graph (MPG), a connectivity indicator, was measured at year 400 within the simulations. Figure 4 illustrates that as the proportion of the landscape covered by large harvest aggregations increases, connectivity also increases for a given harvest cycle.

Connectivity, as measured by MPG, increases when habitat patches are larger, and when there are more and shorter connections among them (Figure 5). For woodland caribou, this translates into a landscape with large forest patches that contain all the habitat types necessary for their life cycle. It also means shorter distances between habitat patches. In this situation the forest landscape favours woodland caribou movement without a significant increase in predation risk.

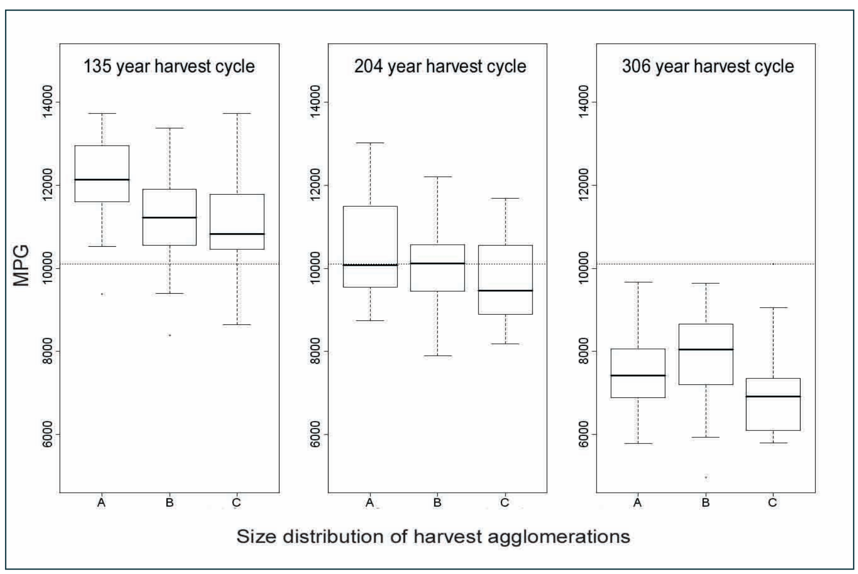

Figure 4. Box-plots of MPG as a function of size distribution of harvest aggregation area (A, B or C; see Table 2) for the three complementary cutting cycles. The dotted line indicates the current level of MPG.

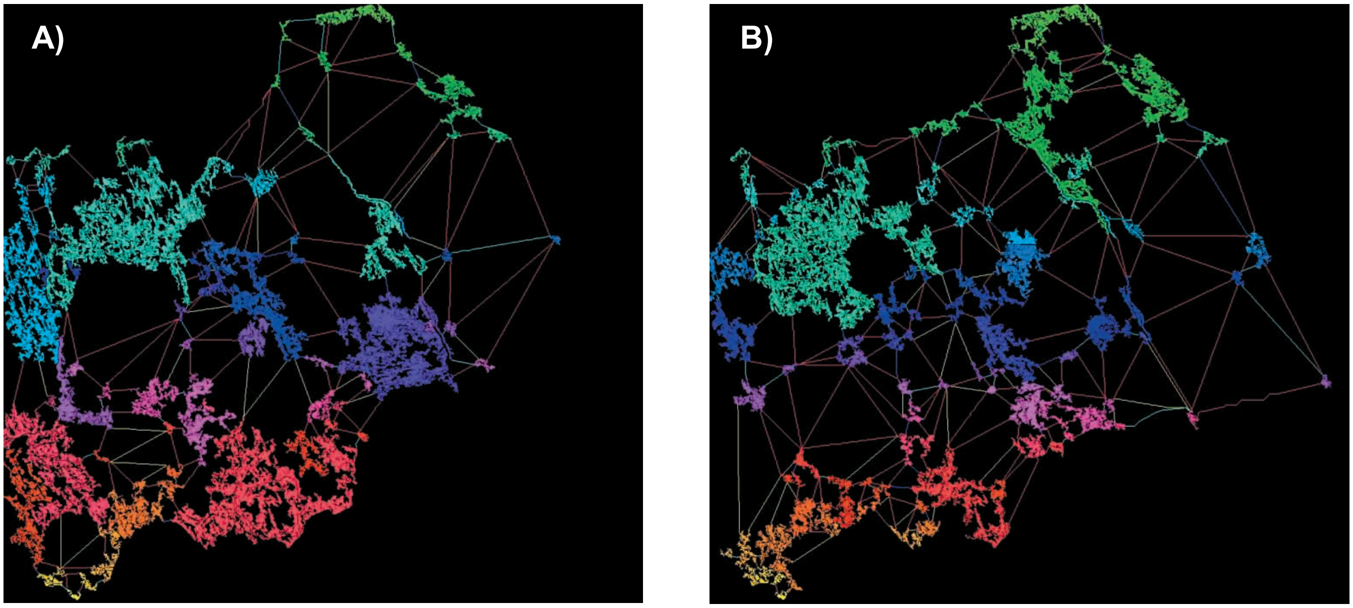

Figure 5. Landscape level connectivity among high quality habitat patches at year 400 with a 204-year harvest cycle, and two size distributions of harvest aggregation: A) smaller harvest aggregations (distribution A) and a MPG of 11,490; B) larger harvest aggregations (distribution C) and a MPG of 8,189.

Further reading

Belleau, A., Y. Bergeron, A. Leduc, S. Gauthier and A. Fall. 2007. *Using spatially explicit simulations to explore size distribution and spacing of regenerating areas produced by wildfires: recommendations for designing harvest agglomerations for the Canadian boreal forest.* For. Chron. 83(1): 72-83.

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Bergeron, Y., S. Gauthier, M. Flannigan and V. Kafka. 2004. *Fire regimes at the transition between mixedwood and coniferous boreal forest in Northwestern Quebec.* Ecol. 85(7): 1916-1932.

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Management Implications

- Long term spatial planning is crucial to determine whether a proposed management plan maintains the level of landscape connectivity required by the most sensitive species.
- Harvest aggregation could maintain the large forest patches within a landscape required by woodland caribou. The size and distribution of harvest aggregations should be based on the underlying fire size distribution.
- Within a single harvest cycle, landscape connectivity can be improved by aggregating harvest blocks. To maximise woodland caribou benefit, these aggregates should be located in forest patches that are the least utilised by the herd.
- The current harvest cycle should take into account the current fire cycle. This should be done in such a way that the total area disturbed does not exceed the historic fire cycle.
- This study suggests that the current harvest cycle should be extended in order to maintain the current level of caribou habitat in the landscape.

Courtois, R., J.P. Ouellet, C. Dussault and A. Gingras. 2004. *Forest management guidelines for forest-dwelling caribou in Quebec.* For. Chron. 80(5): 598-607.

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