

Assessing the length of the post-disturbance recovery period for woodland caribou habitat after fire and logging in west-central Manitoba

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Abstract: This study examined the habitat characteristics of areas used by woodland caribou and areas disturbed by fire or logging in the Naosap caribou range in west-central Manitoba. The population inhabiting this area is currently considered to be of high conservation concern. The purpose was to determine how long after disturbance forests again resembled caribou habitat and whether there were differences in the recovery period between fire disturbed and logged areas. Sample transects were located in areas used by caribou and areas disturbed by fire or logging. Previously, it was shown that variables positively associated with habitat suitability in this region were species composition (presence of black spruce), an index of arboreal lichen abundance and tree size, while variables negatively associated with habitat suitability were deadfall abundance and species composition (presence of trembling aspen). It was hypothesized that if disturbed sites had become suitable caribou habitat, then they should be statistically indistinguishable from sites used by caribou based on these variables. Using cluster analysis, it was found that 2 statistical clusters showed the highest level of agreement with sampling clusters, with 88% of plots used by caribou classified into one cluster, and 74% of disturbed plots classified into the other. Although a small proportion (12%) of disturbed plots resembled used plots, 30 years (the age of the oldest disturbed plot) was not enough time, in general, for forest to return to conditions resembling caribou habitat in this region.

Key words: arboreal lichen, coarse woody debris, habitat disturbance, habitat suitability, forest fire, forest management, logging, succession.

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Introduction

A reduction in the historical range of woodland caribou in the province of Manitoba is thought to have occurred (Johnson, 1993) that is similar to trends found elsewhere in Canada (Bergerud, 1974; Schaeffer, 2003). This investigation was conducted between 1998 and 2002 in the Naosap caribou range in west-central Manitoba, Canada (Fig. 1), a population currently considered to be of high conservation concern (Manitoba Conservation, 2005). Caribou in the Naosap area are potentially affected by highway and rail transportation corridors, road development associated with forestry operations, transmission line construction, and habitat disturbance from logging or forest fires. One potential habitat management scheme that could be used to conserve woodland caribou populations involves ensuring that some critical proportion of the landscape remains in conditions that are suitable for woodland caribou. However, it is generally

not known how many years after disturbance that sites return to suitable conditions and if this recovery period is different after fire and logging disturbance.

Differences in post-disturbance pathways following logging and fire have been noted in both a caribou habitat (Coxson & Marsh, 2001) and non-caribou habitat context (Carleton & MacLennan, 1994; Timoney *et al.*, 1997). Logging tends to result in an increase in deciduous habitats (Carleton & MacLennan, 1994) that are more suitable to moose and other ungulates than to caribou (Rettie & Messier, 2000). Similarly, some forest management practices may favour the creation of forest conditions with increased forage availability for other ungulates (Strong & Gates, 2006). While caribou may exist in such forests in the absence of predators, the general result of this is an alteration of predator-prey dynamics

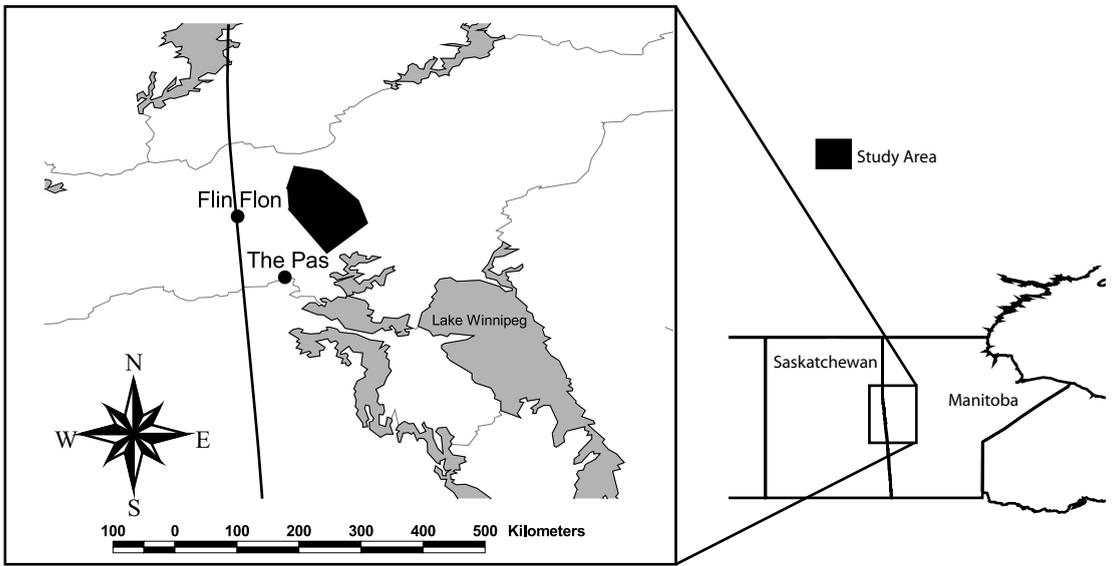


Fig. 1. The location of the Naosap caribou range in west-central Manitoba, Canada.

to the overall detriment of caribou (Bergerud & Elliot, 1986; Seip, 1992).

Most studies of post-disturbance recovery of caribou habitat have focused on lichen regeneration (Webb, 1998; Coxson & Marsh, 2001; Coxson *et al.*, 2003). Fire is generally thought to have detrimental impacts on lichen abundance in the short term (Schaeffer & Pruitt, 1991). However, post-logging lichen regeneration can initially be faster than the post-fire regeneration of lichen and may be augmented by forest management practices like thinning or winter harvesting (Coxson & Marsh, 2001; Coxson *et al.*, 2003; Daintith *et al.*, 2005). Another factor that may be of importance is the post-disturbance accumulation of coarse woody debris. For example, Schaeffer and Pruitt (1991) found that the density of deadfallen trees at burned sites was much greater in 10 year old burns than in mature forests, and postulated that this may represent a significant barrier to movement of caribou. If deadfalls also concurrently represented a barrier to the movement of other ungulates (Cumming, 1980) then this could influence faunal composition of post-fire communities. Coarse woody debris accumulation follows a “U-shaped” successional pattern after fire, with high abundance immediately following fire disturbance, low abundance during mid-successional stages, and increasing abundance again during late-successional stages (Brassard & Chen, 2006). Total accumulations immediately are much lower after logging and the majority of the debris tends to be small diameter downed material and not standing dead trees (Tinker & Knight 2000, Pedlar *et al.* 2002).

This study investigated the micro-habitat characteristics of sites used by caribou in the Naosap range in west-central Manitoba during their annual cycle in relation to the characteristics of areas disturbed by fire or logging. The purpose of the study was to attempt to determine how many years after disturbance a forest becomes caribou habitat in this region and whether there were differences in this time between fire and logging. Previously, it was determined that variables positively associated with micro-habitat suitability in this region were species composition (presence of black spruce), mean tree size, and an index of arboreal lichen abundance. Variables negatively associated with suitability were species composition (presence of trembling aspen) and the density of deadfallen trees (Metsaranta *et al.*, 2003). Here, it was hypothesized that if a disturbed plot had returned to conditions that were suitable for caribou habitat, then it should be statistically indistinguishable from plots used by caribou, based on these variables. Differences between logging and fire disturbed sites for these variables were also investigated.

Material and methods

Study area

The Naosap caribou range (Fig. 1) encompasses the boundary of the Churchill River upland and the mid-boreal lowland ecoregions of the boreal shield and boreal plains ecozones. The boreal shield landscape consists of uplands and lowlands with many bedrock outcrops. This contrasts with the boreal plains landscape, which is topographically level to gently rolling,

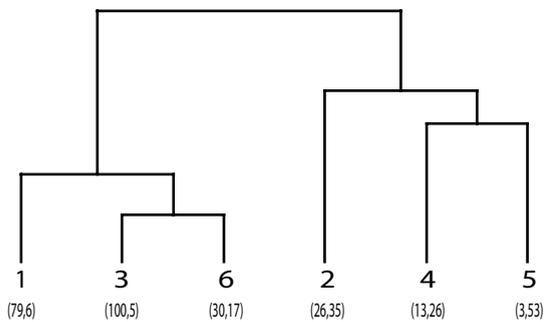


Fig. 2. Classification dendrogram for the 393 caribou habitat plots, based on micro-habitat variables most important to caribou in the Naosap caribou range in west-central Manitoba (arboreal lichen index, deadfall density, tree size, presence of trembling aspen, and presence of black spruce). Number of (used, disturbed) plots in each cluster are in parentheses.

consisting of lacustrine or organic parent materials. Tree species include black spruce (*Picea mariana*), white spruce (*Picea glauca*), jack pine (*Pinus banksiana*), tamarack (*Larix laricina*), trembling aspen (*Populus tremuloides*), and white birch (*Betula papyrifera*). The climate is continental, characterized by short warm summers and cold winters. Mean daily temperatures in the study area range from +17.8 °C in July to -21.4 °C in January. Mean annual rainfall and snowfall range from 323.8 mm and 154.9 cm in The Pas to 339.2 mm and 141.3 cm in Flin Flon. Snow is typically present from mid-November to early April, with maximum monthly mean depths of 30 to 39 cm occurring in January and February.

Data collection

Thirty-eight transects containing a total of 393 plots were sampled during the summer of 1999 and 2000. Twenty-four transects were located in areas used by woodland caribou (6 in each of the 4 calendar seasons), as determined by a telemetry study of habitat selection and population demographics (Metsaranta, 2002). Ten transects were located in logged areas, further classified by decade logged (1970s, 1980s, and 1990s). The oldest logged area was approximately 30 years old. Four transects were located in areas burned in 1989, ten years prior to data collection.

More details on the sampling protocol can be found in Metsaranta (2002) and Metsaranta *et al.* (2003). Briefly, transect start points were randomly selected within 500 m of roads or lakes in order to provide access. Transects were at least 500 m long, with plots located every 50 m. Data collected at each sample plot included habitat index scores (Storey & Storey,

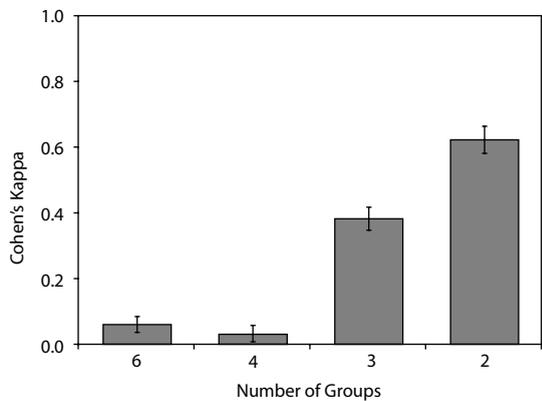


Fig. 3. Cohen's Kappa measure of agreement (+/- S.E.) at four possible levels for grouping caribou habitat plots into statistical clusters or sampling clusters in the Naosap caribou range in west-central, Manitoba. See methods for interpretation of different group memberships.

1980), forest resource inventory characteristics (species composition, age, height, canopy closure, diameter), ecological characteristics (shrub/herb species composition), and other stand attributes thought to be important to caribou (deadfall density, visibility, and arboreal lichen abundance). A number of hierarchical plot sizes were used (2 m x 2 m for herbaceous species composition, 5 m x 5 m for shrub species composition, 10 m x 10 m for forest resource inventory characteristics, and 50 m x 50 m for habitat index scores deadfall density, and visibility). Using a regression analysis approach, it was found that the five variables best describing woodland caribou habitat at these plots were the arboreal lichen index, deadfall density, tree size, the presence of black spruce, and the presence of trembling aspen.

Data analysis

For this analysis, each of 5 variables considered important for describing woodland caribou habitat at each plot were standardized according to the maximum value for that variable. Each plot was then classified using hierarchical cluster analysis (Ward's method with Euclidean distances (Legendre & Legendre, 1998)) into 1 of 2, 3, 4, or 6 statistical clusters. In addition, each plot was also assigned into 1 of 2, 3, 4 or 6 sampling clusters, based on different combinations of plots sampled in habitat used in each of the 4 calendar seasons and plots sampled in each of the 2 types of disturbance. For the sampling clusters, the 2 group level represented used plots and disturbed plots, the 3 group level represented used plots, burned plots, and logged plots, the 4 group level represented plots used in spring/summer, plots used in fall/winter, burned

plots, and logged plots, and the 6 group level represented plots used in each season (spring, summer, fall, and winter), burned plots, and logged plots. The hypothesis was that if disturbed plots had returned to conditions that resemble caribou habitat, then they should be classified into the same groups as plots used by caribou. Furthermore, if these classifications indicated true groupings, then there should be substantial agreement between statistical clusters and sampling clusters at some true level of grouping. Agreement between statistical cluster membership and sampling cluster membership for each plot at each level of grouping was assessed using Cohen's Kappa statistic (Landis & Koch, 1977). Finally, at the level of grouping with the highest level of agreement, the mean difference between the 5 variables based on both statistical clusters and sampling clusters was also assessed to see if the groupings reflected true differences.

Results

The first split in the dendrogram (Fig. 2) essentially subdivided the plots into disturbed and undisturbed groups. Clusters 1, 3, and 6 contained 88% used sampling sites and 12% disturbed sampling sites. Clusters 2, 4, and 5 on the other hand contained 26% used sampling sites and 74% disturbed sampling sites. Cohen's Kappa statistic indicated almost no agreement between true group membership and cluster membership for 4 and 6 groups, moderate agreement for 3 groups, and substantial agreement for 2 groups (Fig. 3). Taken together, these suggest that there are only 2 significant statistical groups in these data: plots used by caribou (clusters 1, 3, and 6 – the used statistical cluster) and plots disturbed by fire or logging (clusters 2, 4, and 5 – the disturbed statistical cluster). The 12% of disturbed sampling sites that were grouped with the used statistical cluster came from burned sites and logged sites of all ages, suggesting that no particular type of disturbed site of any age (5 to 30 years old) was more likely to resemble habitat used by caribou than any other type.

The arboreal lichen index and tree size were significantly higher in the plots in the used statistical clusters than in the plots in the disturbed statistical clusters, while deadfall density was significantly lower (Table 1). On average, used statistical cluster plots had an arboreal lichen index that was 0.9 units higher, had 5.2 less deadfallen trees 50 m^{-1} , and had trees that were 4.2 cm larger in diameter. Trembling aspen was present in 75% of the plots in the disturbed statistical cluster, and was absent from all plots in the used statistical cluster. Black spruce was present in 90% of used statistical cluster plots (including all of

those disturbed sampling cluster plots that were considered members of this group), but only 39% of disturbed statistical cluster plots. These results are nearly identical to those obtained if the 2 group level of the sampling clusters is used to assess the differences between these variables (Table 1). On average, used sampling cluster plots had an arboreal lichen index that was 1.3 units higher, had 5.4 less deadfallen trees 50 m^{-1} , and had trees that were 7.7 cm larger in diameter. Trembling aspen was present in 62% of disturbed sampling plots, but only 11% of used sampling plots. On the other hand, black spruce was present in 94% of used sampling plots, but only 44% of disturbed sampling plots. These similarities between statistical and sampling clusters at the 2 group level further confirm the strong agreement at this level of grouping.

Discussion

The abundance of arboreal lichen, the accumulation of deadfallen trees, and species composition were 3 factors considered important for determining microhabitat suitability for caribou in this region (Metsaranta *et al.*, 2003). All 3 of these variables were significantly different between both the statistical clusters and the sampling clusters at the 2 group level, which had the highest amount of agreement between group memberships in this study. Although a small proportion of disturbed plots (12%) resembled used plots, there were no consistent trends in which plots were misclassified, except that all of these misclassified disturbed sampling cluster plots did have black spruce present. Otherwise, the 12% of disturbed plots that resembled used plots were distributed evenly amongst the categories of disturbed plots that were sampled, meaning that plots of any age sampled (5 to 30 years old) were just as likely to be misclassified. These results indicate that 30 years is likely not enough time for forests to return to conditions which resemble the habitat types used by caribou in this region. This is consistent with observations made by Racey *et al.* (1996), who noted caribou use of a logged area 40 years after disturbance, Dunford *et al.* (2006), who noted that lichen abundance had recovered to maximum levels about 40 years after disturbance, and Joly *et al.* (2003), who noted that caribou avoid all but the periphery of burned areas up to 50 years after fire.

Past studies have shown that post-disturbance regeneration of terricolous lichens after fire and logging appear to be similar (Webb, 1998), particularly after winter harvest (Coxson & Marsh, 2001). This was not the case in this study. The percent cover of terricolous lichens was higher at logged sites (mean 9.8%) than

Table 1. Differences between (A) statistical clusters and (B) sampling clusters at the two group level for three key variables determining habitat suitability for caribou in the Naosap range, west-central Manitoba.

Variable	Mean disturbed cluster value (SD)*	Mean used Cluster value (SD)**	Mean difference (95% CI)	T (P-value)
(A) Statistical Clusters				
Arboreal lichen index	0.38 (0.77)	1.27 (0.91)	0.90 (0.73 to 1.06)	10.57 (<0.001)
Deadfall density (trees 50 m ⁻¹)	9.62 (12.59)	4.45 (5.41)	-5.17 (-7.28 to -3.05)	-4.83 (<0.001)
Mean tree size (cm dbh)	7.05 (7.38)	11.24 (4.77)	4.19 (2.87 to 5.51)	6.28 (<0.001)
(B) Sampling Clusters				
Arboreal lichen index	0.18 (0.51)	1.34 (0.89)	1.16 (1.02 to 1.3)	16.41 (<0.001)
Deadfall density (trees 50 m ⁻¹)	9.96 (13.08)	4.53 (5.31)	-5.43 (-7.69 to -3.16)	-4.73 (<0.001)
Mean tree size (cm dbh)	4.64 (4.69)	12.37 (5.27)	7.73 (6.72 to 8.74)	14.99 (<0.001)

* Mean age 93 years (SD 36 years, $n = 235$).

** Mean age 35 years (SD 39 years, $n = 150$).

at burned sites (mean 1.25%). In addition, only 5.5% of burned sites had an arboreal lichen index greater than 0, while 23.1% of logged sites had an arboreal lichen index greater than 0. Fire and logging also create very different post-disturbance coarse woody debris accumulation patterns (Pedlar *et al.*, 2002; Brassard & Chen, 2006). Accumulations were essentially absent after logging, as it was in this region (Metsaranta *et al.*, 2003). In the case of fire, the minimum value of coarse woody debris abundance at mid-successional stages often appears to correspond to the period of time when lichen abundance has also recovered to at or near pre-disturbance levels after fire (Brais *et al.*, 2005; Dunford *et al.*, 2006; Goward & Campbell, 2005), which may result in confounding effects when examining the effect of these 2 variables. Furthermore, studies have shown that there is a tendency for forests to regenerate to deciduous habitats after logging (Carleton & MacLennan, 1994; Timoney *et al.*, 1997) and these habitats tend to be more suitable for moose than caribou (Rettie & Messier, 2000). In the study area, coniferous regeneration was present in 94.2% of burned plots and in only a slightly smaller percentage (87.7%) of logged plots. However, deciduous regeneration was present in a much greater percentage of logged plots (83.3%) than burned plots (61.5%), indicating that post-logging forests had a much more mixed species composition than post-fire forests in this region.

It is possible that differences in post-disturbance succession can result in differences in the post-disturbance faunal communities. Some studies have suggested that moose appear to avoid areas where coarse woody

debris accumulation appears to be high (Cumming, 1980), and Schaeffer and Pruitt (1991) suggested that accumulation of deadfall could impede caribou movement. In this study area, 2 surveys of moose populations (Cross, 1991; Cross, 2000) failed to detect increases in moose numbers in the large burned areas sampled in this study and areas of high deadfall accumulations had low moose activity (Cross, 2000). Moreover, caribou in the study area continued to be located in lowland habitats within burned areas, but tended to avoid burned upland habitats where presumably deadfall accumulation would be high (Metsaranta, 2002). Thus it seems that coarse woody debris accumulation is potentially an important factor reducing the post-fire habitat suitability for caribou and moose. Fire may under some circumstances create habitat conditions that are equally poor for both species, while logging can tend to create habitat conditions that differentially favour moose over caribou. These differences in post-disturbance successional pathways between logging and fire could result in differential changes in post-disturbance faunal communities that, in the case of logging, work to the detriment of caribou.

Overall, evidence suggests that fire and logging often do not differ in post-disturbance regeneration of lichen (Webb, 1998; Coxson & Marsh 2001; Coxson *et al.*, 2003), but do differ in the post-disturbance accumulation of coarse woody debris (Pedlar *et al.*, 2002; Brassard & Chen 2006) and in the types of forests that tend to regenerate post-disturbance (Carleton & MacLennan, 1994; Timoney *et al.*, 1997). In addition, it will take more than 30 years after

disturbance for forests to return to conditions that resemble caribou habitat in this region. Evidence from previous studies suggests that this value is in the range of 40-50 years (Racey *et al.*, 1996; Joly *et al.*, 2003). Historically, it is likely that populations of moose and caribou have fluctuated in response to variation in habitat characteristics, primarily driven by fire disturbance (Fritz *et al.*, 1993), and thus differences in the post-disturbance successional pathways after fire and logging are of concern to the long-term persistence of caribou populations if these differences tend to favour other ungulates over caribou. Little can be done about the post-disturbance differences in coarse-woody debris accumulation between logging and fire, since fire tends to leave dead trees standing and logging removes trees for processing. However, there may be management steps that can be taken to encourage the regeneration of lichen after logging (Coxson *et al.*, 2003; Goward & Campbell, 2005). In addition, ensuring successful regeneration of coniferous species after logging is an important first step for ensuring the long-term persistence of caribou habitat in this region. This is generally consistent with forest management objectives and was also suggested by Brown *et al.* (2000) as a first step in ensuring the persistence of caribou populations in this region of Manitoba.

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