WINTER PRESENCE OF MOOSE IN CLEAR-CUT BLACK SPRUCE LANDSCAPES: RELATED TO SPATIAL PATTERN OR TO VEGETATION?

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ABSTRACT: Winter aerial surveys of moose (*Alces alces*) were completed on 14 landscapes (10–256 km^2) formed of aggregated black spruce (*Picea mariana*) clear-cuts logged 3–9 years ago in southcentral Québec. Moose were present in 8 landscapes (11 yards) and had a mean density of 0.20 moose/10 km^2, which was 50% of the density observed in the same hunting zone with a similar forest composition. Based on previous work, effects of variability in hunting pressure and time since cutting were assumed not to influence distribution and abundance of moose. Browse density did not increase with age of cuts. Moose density was not related to the size of the clear-cut landscapes or the proportion of residual forest (18–40%) within each landscape ($P = 0.14$). Moose yards were not located close to uncut forest surrounding the landscapes and did not have a greater proportion of residual forest than clear-cut landscapes. Moose yards had a denser shrub layer and more browse available than random sites selected in the same landscapes. The presence of moose in large clear-cut black spruce landscapes is related to vegetation characteristics and not the spatial pattern of the forest. The authors propose two strategies to maintain moose populations and moose hunting activity in this type of forest after harvesting.

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Key words: *Alces alces*, black spruce, cover, food, habitat management, *Picea mariana*

RÉSUMÉ: Nous avons réalisé l'inventaire aérien hivernal de l'orignal (*Alces alces*) dans 14 paysages formés de grandes coupes totales agglomérées (10–256 km^2) effectuées au cours des 3 à 9 dernières années au centre-sud du Québec. La forêt d'origine était dominée par l'épinette noire (*Picea mariana*). La présence de l'orignal a été confirmée dans 8 paysages (11 ravages), pour une densité moyenne de 0,20 orignal/10 km^2, soit 50% de celle retrouvée dans cette zone de chasse ayant le même type de forêt. D'après un travail antérieur, nous assumons que la variation de la pression de chasse et le nombre d'années après coupe n'ont pas influencé la distribution et l'abondance de l'orignal. La taille des paysages de coupe totale ou la proportion de forêt résiduelle (18–40%) à l'intérieur de ceux-ci n'a pas influencé la densité ($P = 0{,}14$). Les ravages d'orignaux n'étaient pas situés à proximité de la forêt intacte autour des paysages de coupe et ne contenaient pas davantage de forêt résiduelle que les paysages de coupe. Cependant, les ravages d'orignaux avaient une strate arbustive plus dense et une disponibilité de brout plus grande que des sites aléatoires choisis dans les mêmes paysages. La présence de l'orignal dans des paysages formés de grandes coupes totales en pessière noire est davantage reliée aux caractéristiques de la végétation qu'à la configuration spatiale de la mosaïque forestière. Nous proposons deux stratégies pour favoriser après coupe le maintien de l'orignal et de l'activité de chasse dans ce type de forêt.

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Mots clés: *Alces alces*, aménagement forestier, couvert, épinette noire, nourriture, *Picea mariana*

Although forest logging increases the amount of browse for moose (*Alces alces*), large clear-cuts can have detrimental effects in the short term due to a lack of protective cover (Girard and Joyal 1984, Courtois and Beaumont 2002, Courtois et al. 2002). Clear-cutting, the prevalent harvesting regime in the boreal forest in Canada, remains a controversial issue (Bliss 2000). Provinces have adopted regulations to make this technique more acceptable ecologically and socially. For example, over the past 15 years, regulations in Québec have limited the maximum size of clear-cuts to 250 ha (up to 1995) or 150 ha (since 1996). Uncut forest strips (60–100 m wide) are left between 2 adjacent clear-cut patches. Riparian buffer strips, 20-m wide along lakes and on each side of permanent streams, are also mandatory and can be used to separate adjacent cuts, but their width must then be increased to 60 or 100 m. Aggregating cutover patches, a common management strategy, has resulted in clear-cut dominated landscapes that may exceed tens and even hundreds of km^2. Large clear-cut landscapes are more frequent in black spruce (*Picea mariana*) boreal forests, characterized by a more uniform forest mosaic, than in balsam fir (*Abies balsamea*) or mixed forests.

A previous study in coniferous and mixed boreal forest in south-western Québec has shown that moose seldom use recent clear-cuts, except in areas providing dense high regeneration and where logging is more of a partial type (Courtois and Beaumont 2002, Courtois et al. 2002). Because clear-cut landscapes are larger in black spruce forests, we suspect that the short-term impact of logging might be more severe in this type of forest than where that previous study took place. Traditionally, higher moose densities have been associated with mixed stands (Crête 1988) or areas disturbed by forest fires, insect outbreaks, or logging some 15-40 years ago (Crête 1977, Peek 1998). Rarely has moose abundance been related to the pattern of the forest mosaic, except for the edge between food and cover (Thompson and Stewart 1998, Courtois et al. 2002). The original black spruce forest being a poor habitat for moose (Brassard et al. 1974, Girard and Joyal 1984), recent cutovers in that type of forest must consequently be of very low value for moose. In such clear-cut landscapes, the pattern of the residual forest, such as buffer strips, might play a greater role than vegetation for the persistence of moose in recent cuts.

From 1998 to 2000, we surveyed moose in very large black spruce clear-cuts in central Québec. We hypothesized that clear-cut landscapes constitute poor habitats for moose. To verify this hypothesis, we predicted that (1) moose would be at a lower density in recently clear-cut landscapes, especially the largest ones, than in similar uncut black spruce forests. We also hypothesized that (2) moose yards would be located close to uncut forest surrounding the clear-cut landscapes or in those parts of the landscapes having a higher proportion of residual forest, and that (3) moose yards would be located in parts of the clear-cut landscapes where the shrub layer is more dense and browse more abundant.

STUDY AREA

Aerial surveys were conducted in forest management unit 25-03 (49°02'–50°00' N, 72°31'–74°17' W), located north-west of Lac Saint-Jean, Québec (Fig. 1). We selected all clear-cut landscapes ≥10 km^2 in this unit, within the black spruce–moss ecological zone (Grondin 1996). These 14 landscapes had been clear-cut between 1991 and 1997 and ranged in size between 10 and 256 km^2 (Fig. 2). The proportion of residual forest (uncut) within landscapes ranged between 18 and 40% of the productive area (land area minus wetlands/bogs), with a

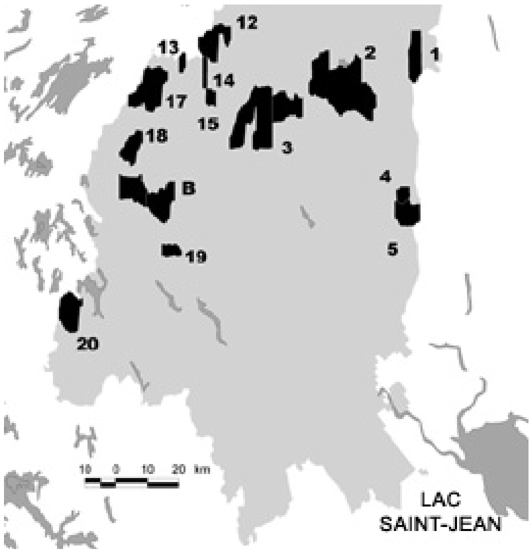

Fig. 1. Location of the 14 aerial survey blocks for moose in forest management unit 25-03 (gray shade) in Québec. Each block corresponds to a clear-cut landscape.

mean value of 30%. The bulk of residual forest was made up of riparian and non-riparian buffer strips, but also included non-commercial forest patches (forests too young or at low density) and commercial forests in inaccessible areas (slope ≥ 40%) in some landscapes. Black spruce was the dominant tree species, with balsam fir, white birch (*Betula papyrifera*), trembling aspen (*Populus tremuloides*), and jack pine (*Pinus banksiana*) being locally present.

The study area is part of hunting zone 18 west, which supports a density of 0.95 moose/10 km^2 (Dussault 1999). In the northern portion of forest management unit 25-03 (black spruce-moss ecological zone), moose density is much lower than in the southern portion (balsam fir–white birch zone) (0.37 vs. 1.26 moose/10 km^2).

METHODS

Aerial Surveys and Habitat Map

Aerial surveys were conducted in January of winters 1998 (1 landscape), 1999 (4), and 2000 (9). We used a Bell 206-B helicopter flying at an altitude of 110 m and a speed of 160 km/hr (Courtois 1991). A navigator and 2 observers were on board. North-south survey lines were spaced 600 m along longitude transects (0.5 min). A 1-km distance was added to the beginning and end of each transect to delineate the survey blocks (Fig. 3). Moose sign was noted on 1:20,000 (1998) or 1:50,000 (1999, 2000) topographical maps showing recent clear-cut patches.

A spatial database was built to produce the aerial survey maps and to analyse the data. The base map was the Québec 1:20,000 topographical map in numeric format. It included watercourses, wetlands/bogs, roads, and elevation contour lines. The delineation of recent cuts was obtained from the industrial forest company Abitibi-Consolidated Inc. We used ArcView 3.2 software and Spatial Analyst extension (ESRI 1996) to manage the database and to analyse the aerial survey data.

The analysis of aerial surveys was done at 2 scales: clear-cut landscapes and moose yards. At the first scale, moose density was computed inside each landscape (excluding the 1-km buffers). We used the Pearson correlation coefficient to test if moose density was related to the size of the landscape or to the proportion of residual forest within

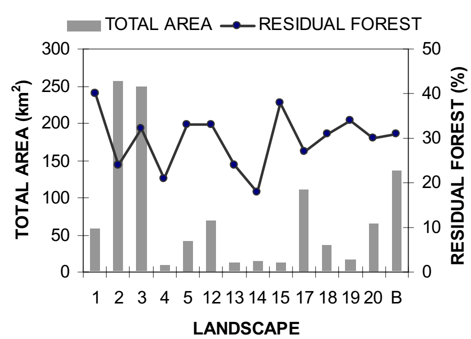

Fig. 2. Total area of the 14 studied clear-cut landscapes and proportion of residual forest (uncut) within each one, expressed as the proportion of the productive area (land area minus WETLANDS/BOGS).

each landscape. We also verified if moose yards tended to be located close to the uncut forest surrounding the landscapes. For that purpose, we generated 500-m buffers inside each clear-cut landscape to evaluate the proportion of the surveyed area occupied by each distance class to surrounding uncut forest. Using a χ^2 test, the actual number of moose yards by distance class was then compared with the theoretical number that corresponded to a distribution proportional to the area surveyed in each class.

At the scale of the yards, we generated a 1-km^2 circle around the center point of moose tracks to approximate the area used by moose. Using fresh moose tracks to delineate yards was not possible because the track network was too small and sometimes consisted of a single linear track. To evaluate habitat selection of moose in cut-landscapes, we computed the Chesson-Manly selection index (Manly et al. 1993) for each yard for 4 habitat classes (WATER, WETLANDS/BOGS, RECENT CUTS, and UNCUT FOREST):

$$\text{CM Index}_i = \frac{U_i / A_i}{\sum U_i / A_i}$$

where U_i = proportion of habitat class i inside the 1-km^2 circle and A_i = proportion of habitat i inside the clear-cut landscape. The Friedman test was applied to this index in order to test the influence of habitat class on moose yard selection (yard = subject, habitat class = treatment).

Vegetation Survey

Time since cutting influences vegetation in cutovers. To account for that variation, we measured habitat variables at 19 sites randomly selected within clear-cut patches of the studied landscapes. We also compared vegetation in moose yards (n = 11) with random sites (n = 11) selected within clear-cuts in the same landscapes. Measurements were made at 6 sampling stations for each random site or yard, systematically distributed (50 × 50 m spacing). Vertical crown closure of the tree (> 4 m) and shrub (1.5-4 m) layers was measured by the presence/absence of canopy over 10 points spaced on a line at a 3-m interval at each station (adapted from Bunnell and Vales 1990). We used a 2× metric prism and DBH measurements to evaluate the basal area and the number of trees > 9 cm DBH (1 point sample per station) (Grosenbaugh 1952). The number of stems in the shrub layer (1–9 cm DBH) was counted inside a 25-m^2 circular plot. The lateral cover was measured on a 2-m profile board at a 15-m distance (2 readings in opposite directions per station) (Nudds 1977). The median height of forest regeneration was estimated visually inside a 15-m radius circle at each station. Browse availability was evaluated by counting stems having at least 1 twig (10 cm long) between 50 and 300 cm from the ground in three 1-m radius circular plots per station. Black spruce was not included as browse because it is seldom used by moose. To compare each variable among cuts of different ages, we used a 1-factor ANOVA. The same test was also applied between moose yards and random sites selected in the same landscapes.

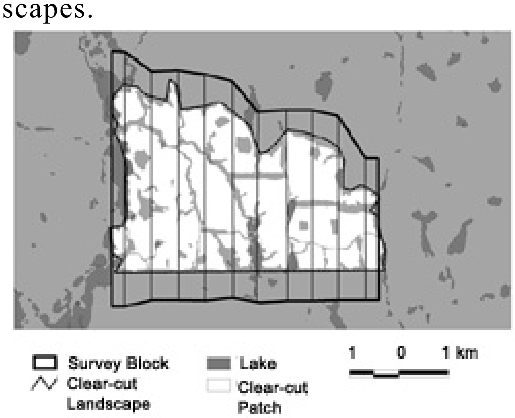

Fig. 3. Aerial survey plan for a clear-cut landscape. North-south transects are spaced 0.5 min of longitude (600 m) apart.

RESULTS

Moose Densities

Snow conditions were very good in all aerial surveys, with 40-80 cm of snow depth, 5-20 cm of fresh dry snow, and absence of crust. Wind was light or absent and a clear sky enabled easy detection of moose tracks in these open landscapes. Moose tracks were detected in 8 landscapes, for a total of 11 yards and 22 moose (4 adult males, 10 adult females, and 8 calves). The overall density for the 14 landscapes (1,089 km^2) was 0.20 moose/10 km^2. There was no significant relationship between moose density by clear-cut landscape and the size of the landscape (r = -0.31, P = 0.14) or the proportion of residual forest within each landscape (r = 0.32, P = 0.14) (Fig. 4).

Moose Yards

The number of moose yards by 500-m distance classes from the uncut forest inside each landscape had a similar distribution to the proportion of the landscape's area by distance classes (χ^2 = 0.02, P = 0.99) (Fig. 5). The 14 clear-cut landscapes contained 4.2% WATER, 7.8% WETLANDS/BOGS, 61.8% RECENT CUTS, and 26.1% UNCUT FOREST. The proportions of these cover types were different between moose yards and landscapes, with moose yards containing less WATER (0.9%) and WETLANDS/BOGS (3.8%) (Friedman test, P < 0.01) (Fig. 6). When testing only for RECENT CUTS and UNCUT FOREST, there was no difference between moose yards and landscapes (P = 0.76).

Vegetation

Vegetation was quite similar among cuts of different ages, with only white birch stems in the shrub layer being more numerous in 8–9 year-old clear-cuts than in younger ones (P = 0.04) (Table 1). Moose yards had quite a different vegetation than the clear-cut landscapes where they were

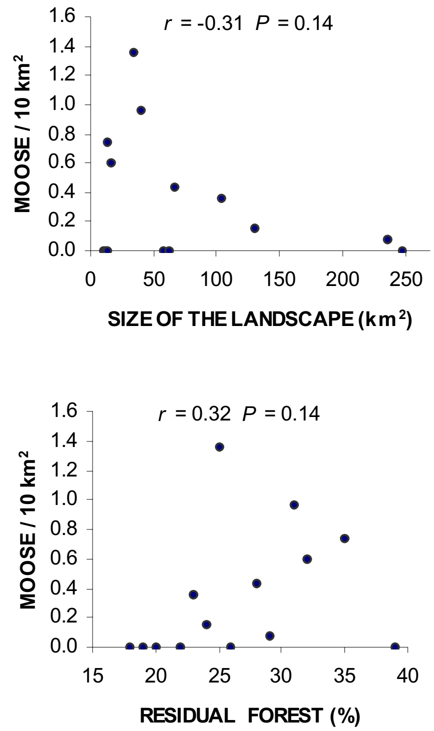

Fig. 4. Relationship between moose density in clear-cut landscapes and the size of the landscape or the proportion of residual forest within each landscape.

located (Table 2). Moose yards had greater vertical cover for the shrub layer (37 vs. 18%, P < 0.01), greater lateral cover (69 vs. 53%, P < 0.01), a more abundant shrub layer (2,600 vs. 1,300 stems/ha, P < 0.01), especially balsam fir (P = 0.02), and 3 times more browse available (23,200 vs. 7,100 stems/ha, P < 0.01). Conversely, black spruce was less abundant in the tree layer (basal area and stems/ha, P = 0.02) and shrub layer (P = 0.01) of moose yards. The height of the regeneration was the same in moose yards and in random sites (2.2 m).

DISCUSSION

Black spruce forests are poor habitats for moose, as opposed to mixed or deciduous stands (Brassard et al. 1974, Girard and Joyal 1984). The general density in this type of forest in the hunting zone was only 0.37

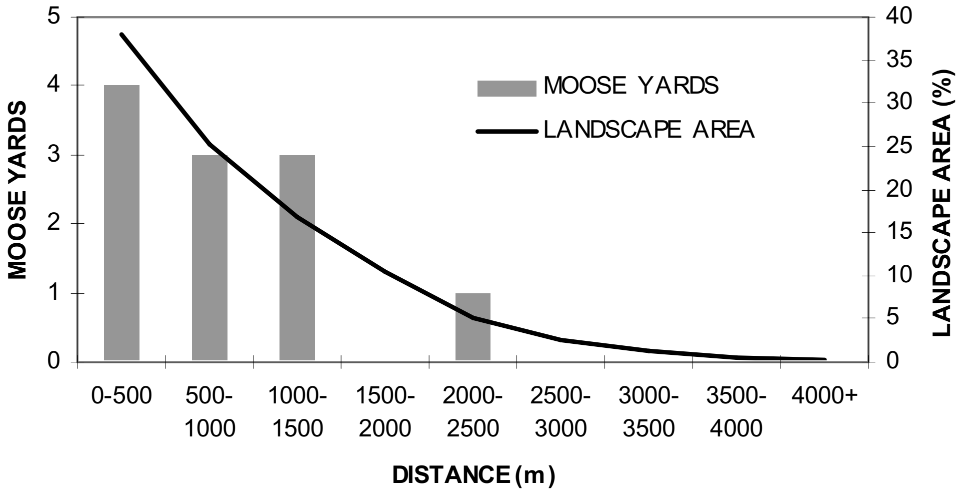

Fig. 5. Distribution of the number of moose yards in relation to the distance from the uncut forest surrounding each clear-cut landscape and proportion of the landscape area by 500-m distance classes.

moose/10 km^2, a low value (Dussault 1999). As expected from our first prediction, moose density was even lower inside our 14 clear-cut landscapes (0.20 moose/10 km^2). However, such density still represents about 50% of the density before cut. In a previous study, Courtois and Beaumont (2002) measured a smaller decrease in moose density (23–30%) in 2 blocks that had been partially clear-cut (29–43% of their total area). In our study, the treatment was more severe because surveys were restricted to clear-cut landscapes instead of larger blocks containing a proportion of uncut forest. In the early 1980s, Girard and Joyal (1984) conducted aerial surveys in an area located at the same latitude as our study area. They reported densities of 0.36 moose/10 km^2 in 60-km^2 plots located in clear-cuts, as opposed to 0.50 moose/10 km^2 in uncut forest. All these results indicate that moose can persist in landscapes that have been recently logged (< 10 years) and where large clear-cuts (= 250 ha) are aggregated. Moose densities in such landscapes are much lower though than in uncut forest. This confirms part of our first prediction. On the other hand, moose density was not higher in the smaller clear-cut landscapes (Fig. 4). While 5 landscapes smaller than 100 km^2 had the highest densities (≥ 0.4 moose/10 km^2), 5 other landscapes in the same area class had no moose.

In Ontario, increase in hunting pressure in logged areas had a negative effect on moose densities (Eason et al. 1981, Eason 1989, Rempel et al. 1997). Conversely, in southwestern Québec, the accessibility offered by new logging roads had a minor impact on harvest rates in blocks recently clear-cut (Courtois and Beaumont 1999). We did not measure hunting pressure in our study but Bertrand and Potvin (2002) analysed moose harvest statistics in those same 14 clear-cut landscapes and in the entire management unit 25-03 from 1981 to 2000. A similar trend between both data sets suggests that the effect of hunting on moose

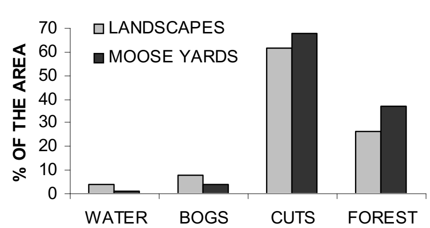

Fig. 6. Cover types of 14 clear-cut landscapes and of 11 moose yards located in the same landscapes.

Table 1. Vegetation ($\bar{x}$ ± SE) of clear-cut black spruce landscapes according to the time since cutting.

Variable	3–4 years (n = 10)	5–7 years (n = 6)	8–9 years (n = 3)	P
Crown closure (%)				
Trees (> 4 m)	2 ± 1	2 ± 1	7 ± 3	0.91
Shrubs (1.5-4 m)	7 ± 1	13 ± 3	24 ± 6	0.25
Tree layer (> 9 cm DBH)				
Basal area (m^2 / ha)				
Black spruce	0.3 ± 0.2	0.9 ± 0.3	0.1 ± 0.1	0.97
Balsam fir	0.0 ± 0.0	0.0 ± 0.0	0.3 ± 0.2	1
White birch	0.1 ± 0.1	0.3 ± 0.2	0.7 ± 0.4	0.96
Total	0.4 ± 0.2	1.4 ± 0.4	1.0 ± 0.6	0.99
Stems / ha				
Black spruce	32 ± 18	87 ± 35	9 ± 9	0.86
Balsam fir	0 ± 0	0 ± 0	18 ± 15	1
White birch	3 ± 2	13 ± 7	18 ± 11	0.85
Total	35 ± 18	120 ± 37	44 ± 25	0.92
Shrub layer (1–9 cm DBH)				
Black spruce	500 ± 110	520 ± 170	170 ± 97	0.91
Balsam fir	93 ± 35	0 ± 0	470 ± 160	0.14
White birch	7 ± 7	89 ± 48	390 ± 170	0.04
Trembling aspen	7 ± 7	480 ± 200	13 ± 13	0.69
Total	610 ± 110	1,200 ± 240	1,300 ± 340	0.22
Lateral cover (%)	42 ± 2	52 ± 4	57 ± 4	0.11
Height of regeneration (m)	1.8 ± 0.1	2.0 ± 0.2	1.8 ± 0.2	0.22
Available browse (stems / ha)	6,200 ± 750	10,700 ± 1,800	11,900 ± 1,900	0.07

abundance was not different in the clear-cut landscapes than outside.

Contrary to our second prediction, spatial analysis was unable to explain the presence or the location of moose yards inside clear-cut landscapes. Moose yards were not located close to the uncut forest surrounding the landscapes and did not have a higher proportion of residual forest. Forest strips between clear-cut patches or riparian buffer strips along streams are not attractive to moose in winter probably because of their small size (60–100 m width) and low browse production (black spruce forest). Furthermore, as suggested by Courtois et al. (2002), cover does not appear to be a major component of habitat for moose even in late winter, at least in regions where snow depth is usually < 90 cm.

In the clear-cut landscapes in general, browse availability and density of the shrub layer were still poor 3–9 years after logging. In moose yards, the vegetation was quite different from that of random sites within the same landscapes in that shrubs and small trees were more abundant, especially balsam fir, and there was greater vertical cover, lateral cover, and more browse. Before conducting the ground survey in recently logged areas, we did not expect to find this type of vegetation, which is more characteristic of balsam fir or mixed

Table 2. Vegetation ($\bar{x}$ ± SE) of moose yards located in clear-cut black spruce landscapes and of random sites selected within clear-cuts of the same landscapes.

Variable	Moose yards (n = 11)	Random sites (n = 11)	P
Crown closure (%)			
Trees (> 4 m)	4 ± 1	5 ± 2	0.83
Shrubs (1.5-4 m)	37 ± 3	18 ± 3	< 0.01
Tree layer (>9 cm DBH)			
Basal area (m^2 / ha)			
Black spruce	0.1 ± 0.1	0.7 ± 0.2	0.02
Balsam fir	0.1 ± 0.0	0.1 ± 0.1	0.56
White birch	0.5 ± 0.2	0.4 ± 0.2	0.91
Total	0.6 ± 0.2	1.4 ± 0.4	0.1
Stems / ha			
Black spruce	10 ± 6	71 ± 25	0.02
Balsam fir	8 ± 5	8 ± 7	0.97
White birch	16 ± 7	14 ± 6	0.82
Total	33 ± 12	100 ± 27	0.02
Shrub layer (1–9 cm DBH)			
Black spruce	240 ± 60	590 ± 130	0.01
Balsam fir	550 ± 160	140 ± 60	0.02
White birch	410 ± 120	150 ± 70	0.07
Trembling aspen	850 ± 280	250 ± 110	0.05
Total	2,600 ± 400	1,300 ± 200	< 0.01
Lateral cover (%)	69 ± 3	53 ± 2	< 0.01
Height of regeneration (m)	2.2 ± 0.1	2.2 ± 0.1	0.8
Available browse (stems / ha)	23,200 ± 2,400	7,100 ± 1,300	< 0.01

forests than of black spruce stands, at such northern latitudes. In conformity with our third prediction, this confirms that food production is the main factor driving habitat selection by moose, as suggested by Crête (1977), Peek (1998), and Courtois et al. (2002).

MANAGEMENT IMPLICATIONS

In black spruce forest, it takes more than 10 years for browse availability to become attractive to moose in recent clear-cuts. In our study, moose density was very low and in most cutovers, even the oldest ones, and food production was much lower in control sites than in moose yards. These observations confirm our hypothesis that clear-cut black spruce landscapes are poor moose habitats. In balsam fir or mixed forests, 10-year cutovers are much more productive (Potvin et al. 2004).

Special measures are therefore needed in the planning process if the goal is to maintain moose populations and moose hunting activity in this type of forest. As proposed by Courtois et al. (2002), there can be 2 strategies: (1) identify stands that have greater value for moose and use silvicultural techniques that will maintain their characteristics, or (2) leave a higher proportion of residual forest (50–60%) by applying a dispersed patch cutting strategy. Since mixed and deciduous stands are rare within the black spruce–moss ecological zone, the first strategy might be implemented as a basic step where moose production is a moderate priority issue. The second strategy is more aimed at maintaining moose hunting activity. Although moose density in our study was not related to the proportion of residual forests, moose hunters have a negative perception of forest harvesting systems (Courtois et al. 2001). They prefer landscapes where residual forests are dominant over those where clear-cut patches are aggregated and narrow uncut strips are the sole residual forest. The second strategy might be suited to areas where moose production is a higher priority (outfitters areas, areas devoted to forest–wildlife integrated management).

In other areas, the goal might be to decrease moose numbers. For example, the conservation of woodland caribou (*Rangifer tarandus*) may be at risk because of predation, if a large moose population exists that can sustain high wolf numbers (Courtois 2003). In this case, caribou habitat management involves preserving large forest blocks (> 250 km^2) interconnected with a corridor network. In order to diminish moose and predator densities, clear-cuts outside preserved areas should aim at regenerating black spruce and very few deciduous species. In this context, stands that may be suitable to moose (e.g., mixed forests) might even be transformed towards coniferous stands.

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