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10 RH: Leclerc et al. • Influence of Plantations on Moose Distribution

11 **Influence of Young Black Spruce Plantations on Moose Winter Distribution**

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21 **ABSTRACT** Logging in the boreal forest may benefit moose by increasing food availability.

22 However, the influence of tree plantations on moose behavior, especially on moose spatial
23 ecology, is poorly understood. We assessed the impacts of black spruce plantations on moose
24 winter distribution at a landscape scale in the Bas-Saint-Laurent region (Québec, Canada). We
25 used winter aerial surveys to examine relationships among plantation characteristics and other
26 habitat variables known to affect moose distribution. The total area of plantations positively
27 influenced moose abundance, but highly aggregated plantations resulted in fewer moose. Moose

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1 | Leclerc et al.

28 abundance was also positively associated with food availability and the density of edges between
29 stands providing cover and stands offering high food availability, but moose abundance was
30 negatively associated with road density. Although plantation characteristics were less influential
31 than habitat variables related to foraging and predator avoidance, we demonstrate that the area of
32 black spruce plantations and their configuration should be considered in moose management. We
33 conclude that an integrated management strategy is needed to find a balance between
34 overdeveloped road networks (needed to join homogeneously distributed plantations) and
35 agglomerated plantations in order to mitigate impacts on moose winter distribution.

36 **KEY WORDS** aerial surveys, *Alces alces*, black spruce plantations, limiting factors, moose
37 distribution, Québec.

38 Understanding the effects of human development on wildlife is a central issue of sustainable
39 management of natural resources and biodiversity conservation (Johnson and St-Laurent 2011).
40 In North America, forest harvesting is the primary disturbance in the boreal forest (McRae et al.
41 2001), dominating natural and historical disturbances such as forest fires, defoliating insect
42 outbreaks, and windthrows (Brokaw and Rent 1999, Spies and Turner 1999). Whereas several
43 wildlife species associated with old-growth forests are negatively affected by logging, some
44 associated with early-successional forest stages benefit from the practice (Fisher and Wilkinson
45 2005, St-Laurent et al. 2008), demonstrating that species-specific responses of wildlife to human
46 development are often complex (Johnson and St-Laurent 2011). Among species associated with
47 early-successional forests, moose (*Alces alces*) benefit from logging after a 10-year lag because
48 of increased browse availability and enhanced cover (Peek et al. 1976, Potvin et al. 2005). Forest
49 management and hunting restrictions led to a near doubling of the moose population in the
50 province of Québec (Canada) between 1992 and 2002; the population may have reached
51 approximately 100,000 individuals in the early 2000s (Lamontagne and Lefort 2004). Although

2 | Leclerc et al.

52 increasing moose density is still desirable in some regions of Québec, other parts of the province
53 (e.g., the Bas-St-Laurent and the Gaspésie regions) are now dealing with moose densities near or
54 exceeding the social carrying capacity (Lefort and Huot 2008), forcing wildlife managers to
55 reduce overabundant moose populations in order to limit depredation (McInnes et al. 1992).

56 Plantations are used in several countries and occupy an increasing proportion of the forest
57 landscape (Hartley 2002). In the Canadian provinces, they support regeneration following natural
58 (e.g., fire) or anthropogenic disturbances (e.g., clearcutting), and they promote greater timber
59 yield, resulting in more uniform stocking (Lieffers et al. 2003). In eastern Québec, a severe
60 episode of eastern spruce budworm (*Choristoneura fumiferana*) outbreaks affected almost 100%
61 of balsam fir (*Abies balsamea*) stands between 1974 and 1992 (Boulanger and Arseneault 2004);
62 this led to massive salvage logging operations that resulted in a conversion of balsam fir and
63 white spruce (*Picea glauca*) stands into black spruce (*Picea mariana*) dominated stands.
64 Extensive plantations of the previously uncommon black spruce in southern Québec were
65 promoted to reduce stand vulnerability to future outbreaks and to maximize wood yields
66 (Boucher et al. 2009a, b).

67 Numerous studies have described moose responses to silviculture and associated road
68 networks. Moose responses to human activity included regional increases in density (Potvin et al.
69 2005) and productivity (Courtois and Beaumont 2002) associated with increases in browsing
70 opportunities following intensive clearcutting, road avoidance (Laurian et al. 2008), and increases
71 in movements when moose are forced to cross roads (Dussault et al. 2007). Few studies have
72 explored the effects of conifer plantations on moose behavior (see Peek et al. 1976), instead
73 focusing on the impacts of moose on plantations (Edenius et al. 1993, 2002; Heikkilä and
74 Härkönen 1996; McLaren et al. 2000).

3 | Leclerc et al.

75 Our objective was to quantify the influence of black spruce plantations on the winter
76 distribution of moose at a landscape scale, while considering other relevant habitat variables. We
77 hypothesized that moose distribution would be driven by major ecological constraints at the
78 landscape scale and predicted, according to the Habitat Suitability Index (HSI) developed by
79 Dussault et al. (2006), that moose abundance would be positively related to the proportion of
80 stands offering high food availability and the amount of edges between cover and forage stands.
81 We also predicted that moose abundance would decrease with increased road density (i.e., source
82 of disturbance). We hypothesized that black spruce plantations would influence moose
83 distribution and predicted that moose abundance would be negatively related to the total area and
84 the aggregation of plantations.

85 **STUDY AREA**

86 The Bas-Saint-Laurent region (47° 50' N, 68° 50' W; Fig. 1) covers 22,681 km², of which 50.5%
87 are private lands. This area has a mean elevation of 355 m (range 0–1150 m). Mean annual
88 temperature (1971–2000) varied between –11.7° C (Jan) and 18.2° C (Jul), and mean annual
89 precipitation and snow accumulation were 915 mm and 271 cm, respectively (Environment
90 Canada, <http://www.climate.weatheroffice.ec.gc.ca>). The region is in the eastern subdomain of
91 the balsam fir–yellow birch (*Betula alleghanensis*) domain (Robitaille and Saucier 1998). Balsam
92 fir and yellow birch mostly occur together on mesic sites, whereas sugar maple (*Acer saccharum*)
93 and yellow birch frequently occur together on well-drained and exposed sites. Black spruce and
94 eastern white-cedar (*Thuja occidentalis*) are common on organic soils. At the time of data
95 collection, black spruce plantations represented as much as 12.7% of the forested lands (approx.
96 2,450 km²) in the Bas-Saint-Laurent region and moose were the most abundant large mammal
97 (average density >7 moose/10 km² with some peak densities of 48 moose/10 km²; Lamoureux et
98 al. 2007). Gray wolves (*Canis lupus*) were extirpated from Bas-Saint-Laurent over a century ago.

4 | Leclerc et al.

99 Since then, predation on moose is mostly on calves and is attributed to coyotes (*Canis latrans*)
100 and black bears (*Ursus americanus*).

101 **METHODS**

102 **Aerial Surveys**

103 We estimated moose abundance in February 2005 using aerial surveys conducted by the
104 Ministère des Ressources naturelles et de la Faune du Québec (MRNF) in 41 sampling plots of 60
105 km² (total area surveyed = 2,460 km²; Fig. 1), following the methodology developed by Courtois
106 (1991). Plots were randomly selected in the forests of the Bas-Saint-Laurent region's hunting
107 zone 2 (i.e., excluded agricultural lands and urban areas). Observers attempted to locate moose
108 tracks in the snow from helicopters following transects spaced 500 m apart. If observers located
109 tracks, the pilot returned to the area at reduced airspeed and lower altitude to allow the observers
110 to count moose. Surveys were conducted when snow depth was >70 cm and following a recent
111 snowfall >25 cm to cover older tracks.

112 Previous studies have demonstrated that moose counts obtained via aerial surveys could be
113 biased (Caughley 1974) because of detection bias associated with tree and shrub cover (Anderson
114 and Lindzey 1996). Nevertheless, we did not correct moose counts; we used raw survey data.
115 Doing so, we assumed that detection probability was constant, in accordance with the
116 methodology advocated by the MRNF biologists, following guidelines established for aerial
117 surveys in the Bas-St-Laurent region. Detection probability was empirically estimated previously
118 ($\beta = 0.52$) and tested on 6,000 ha survey plots in different cover classes and is now considered as
119 constant regionally throughout forested lands (see Crête et al. 1986 and Courtois 1991 for more
120 details). In addition, companion studies suggest that forests in the Bas-Saint-Laurent region are
121 relatively homogenous in terms of age (69.9% of forested lands are younger than 60 years old;

5 | Leclerc et al.

122 St-Laurent and Etcheverry 2007) and composition (dominated by mixed forests; Boucher et al.
 123 2009b), a structure resulting from over a century of intensive forestry. With such a dominance of
 124 young forests and considering that moose select edges between stands providing cover (i.e.,
 125 closed canopy stands, lower detectability) and stands with high food availability (i.e., open
 126 canopy stands, greater detectability; Dussault et al. 2006), we were confident that detection of
 127 moose track networks at low altitude was effective.

128 **Variables Describing Habitat, Plantations, and Spatial Structure**

129 To assess the influence of plantations on moose abundance in sampling plots, we quantified a
 130 number of variables using 1:20,000 digitized ecoforest maps of the Bas-Saint-Laurent region
 131 updated in 2005 by the MRNF. Minimum mapping unit size was 4 ha for forested polygons and 2
 132 ha for non-forested areas (e.g., water bodies, bogs). Dussault et al. (2001) empirically
 133 demonstrated that stand age and cover type in the ecoforest maps validated well. Consequently,
 134 we used combinations of these 2 variables to categorize the ecoforest maps according to moose
 135 habitat requirements following Dussault et al. (2005, 2006). We then identified 11 stand types
 136 (Table 1) to calculate a food index. We did not consider area of plantations in the food index in
 137 order to discriminate between the respective influence of plantations and forage stands. For each
 138 sampling plot, we summed the product of each stand proportion by its food value (representing
 139 classes of browse availability; Table 1) as developed by Dussault et al. (2001, 2006) in their HSI:

$$140 \quad \text{Food index} = (M_i10\% + D_t50\% + M_t50\%) \times 1.0 + (D_i50\% + M_i30\%) \times 0.5 + (M_i50\%) \times 0.4 +$$

$$141 \quad (C10\%) \times 0.3 + (C_{fir}30\%) \times 0.15 + (IMP\%) \times 0.1 + (C_{spr}30\%) \times 0.05 + (OTHER\%) \times 0.0$$

142 where $M_i10\%$, $D_t50\%$, $M_t50\%$, $D_i50\%$, $M_i30\%$, $M_i50\%$, $C10\%$, $C_{fir}30\%$, $IMP\%$, $C_{spr}30\%$, and
 143 $OTHER\%$ are the proportion of each stand type in a sampling plot (see Table 1 for stand type
 144 definitions), which are multiplied by their respective food value.

6 | Leclerc et al.

145 We calculated the density of edges between stands offering cover (C_{fir30} , C_{spr30} , M_{i50} ,
146 M_{i30} ; see Table 1) and stands with high food availability (M_{i10} , D_{t50} , M_{t50} ; see Table 1); this
147 variable was recognized as the most influential variable in the HSI developed by Dussault et al.
148 (2006). We included road density in our models because of the known influence of roads on
149 moose behavior (Dussault et al. 2007, Laurian et al. 2008). Finally, we calculated the total area of
150 plantations for each sampling plot, as well as the mean plantation distance by calculating the
151 mean distance between centroids of all the plantations in a sampling plot, as a proxy for
152 plantation aggregation. We conducted these procedures with ArcGIS 9.3.1 (ESRI, Redlands,
153 CA).

154 Because of the spatial structure of our sampling design (i.e., moose abundance increased
155 along a west-east gradient), we expected spatial dependence (i.e., moose abundance spatially
156 structured because it depends upon explanatory variables that are also spatially structured) and
157 spatial autocorrelation (i.e., correlation of moose abundance in adjacent plots) to occur (Legendre
158 et al. 2002). Consequently, we modeled the spatial structure of our dataset, allowing us to adjust
159 statistical analyses and account for the spatial structure in our data (Dale and Fortin 2002). We
160 calculated principal coordinates of neighbor matrices (PCNMs; Borcard and Legendre 2002)
161 from x and y coordinates of plot centroids using the PCNM library of R 2.12.1 software (R
162 Development Core Team 2011). The PCNMs are a spectral decomposition of the spatial
163 relationships among sampling plots, which are used to create variables corresponding to all
164 spatial scales that can be explored in a given dataset (Borcard et al. 2004). These matrices can be
165 incorporated into multiple regressions as independent variables to model the spatial structure of a
166 design (Borcard and Legendre 2002, St-Laurent et al. 2008). Dray et al. (2006) demonstrated that
167 PCNMs can control for the effect of spatial structure on response variables; that they are more
168 flexible, precise, and powerful than commonly used polynomial trend surfaces; and that they can

7 | Leclerc et al.

169 be used at large scales and on experimental designs where sampling plots are not systematically
170 distributed. Based on this analysis, we retained a matrix of 2 significant PCNMs, which we
171 forced into all candidate models.

172 **Statistical Analyses**

173 We analyzed the effects of the food index, density of edges, road density, total area of
174 plantations, and mean distance between plantations on moose counts using multiple linear
175 regressions. We used information theory to determine the best model(s) among a candidate set
176 (Burnham and Anderson 2001). We judged support among candidate models using Akaike's
177 Information Criterion adjusted for small sample size (AIC_c ; Burnham and Anderson 2001). We
178 log-transformed [$\ln(\text{count} + 1)$] moose count data to fulfill regression assumptions because
179 counts were not distributed according to a negative binomial or a Poisson distribution (Cameron
180 and Trivedi 1998); the response variable decreased from 28.1 ± 27.1 to 2.8 ± 1.2 (mean \pm SD)
181 with only 1 null value. An a posteriori analysis based on AIC_c confirmed that a better fit between
182 data and candidate models was obtained with log-transformed data (normal distribution) than
183 with a negative binomial or a Poisson distribution. Prior to analyses, we assessed collinearity
184 among independent variables using the variance inflation factor (VIF), and confirmed that
185 collinearity was absent from our dataset ($VIF < 10$; Graham 2003). Using the best-supported
186 model, we conducted a k-fold cross validation (Pearce and Boyce 2006) by calculating parameter
187 estimates using a subset of 75% of our data and withholding 25% for validation. For each
188 withheld observation, we calculated their estimated value using the model developed with the
189 training data set and calculated a Spearman rank correlation to evaluate model performance using
190 1,000 iterations.

191 To determine which variables had the strongest influence on moose count, we performed a
192 variance partitioning analysis on 3 a priori defined groups of variables: 1) our 2 significant

8 | Leclerc et al.

193 PCNMs (PCNM); 2) food index, road density, and density of edge (habitat); and 3) total area of
194 plantations and mean distance between plantations (plantation) using the adjusted coefficient of
195 determination ($\text{adj-}R^2$; Borcard et al. 1992, St-Laurent et al. 2008). This analysis calculated the
196 pure variance explained by a variable, or a group of variables, and the joint proportion of
197 explained variance shared by 2 or more variables, or groups of variables (Borcard et al. 1992).
198 We conducted all statistical analyses using R 2.12.1 (R Development Core Team 2011).

199 **RESULTS**

200 The best-supported model (smallest AIC_c) was the full model (Table 2). Plantation (mean
201 distance between plantations and total area of plantations; see Fig. 2 for the latter) and 2 of the 3
202 habitat variables (i.e., food index and density of edges) were all positively related to moose count,
203 whereas road density was negatively related to moose count (Table 3). No other candidate models
204 provide substantial support (i.e., ΔAIC_c was always ≥ 2 from the best model) to the data, so we
205 did not performed model averaging (Burnham and Anderson 2001).

206 The full model explained 57.8% of the total variance in moose count and the variance
207 partitioning indicated the plantation variables accounted for 7.5% of the variance, whereas habitat
208 variables accounted for 21.1% and PCNMs accounted for 10.6% (Table 4). The negative
209 intersection of plantation and habitat variables indicated that these groups of variables together
210 explained moose count more effectively than did the sum of their individual effects (Legendre
211 and Legendre 1998). We obtained a Spearman rank correlation of 0.67 ± 0.16 (mean \pm SD) for
212 the k-fold cross validation, which indicated further support for the best-supported model.

213 **DISCUSSION**

214 Understanding how a species uses its environment and reacts to habitat alteration is a central
215 question for both wildlife and forest managers (Johnson 1980, Potvin et al. 2005). According to
216 Rettie and Messier (2000), the relative importance of different limiting factors should be reflected

9 | Leclerc et al.

217 in the scale of resource selection shown by an animal. The major limiting factors for moose
218 populations are, in order of decreasing influence, predation; food availability, quality, or access;
219 climate; parasites; and diseases (Van Ballenberghe and Ballard 1998, Dussault 2002). Coniferous
220 stands are selected by moose for shelter from solar radiation in summer (Dussault et al. 2004),
221 from harsh winter weather (especially snow accumulation; Peek 1998, Dussault et al. 2005), and
222 to avoid predators (White and Berger 2001). However, spruce trees are not eaten by moose
223 (Dodds 1960, Kurttila et al. 2002) who prefer deciduous leaves and shrubs during summer, and
224 twigs and buds of deciduous species, balsam fir, and pine (*Pinus spp.*) during winter (Heikkilä
225 and Härkönen 1996). Consequently, avoiding predators and extreme weather have implications
226 for moose fitness because the habitat providing the best cover usually provides poor foraging
227 opportunities (Dussault 2002, Dussault et al. 2006).

228 Like other studies, we reaffirmed that moose winter distribution is essentially driven by
229 cover and food at a large spatial scale, and more precisely, by their interspersion. Similarly,
230 Dussault et al. (2006) reported that the density of edges between stands providing cover and
231 stands offering high forage availability were one of the best predictors in their HSI. This implies
232 that foraging resources and cover well juxtaposed at small spatial scales favor moose by
233 addressing basic needs, nutrition and predator avoidance (Van Ballenberghe and Ballard 1998).
234 Even though the positive effect of food availability on moose is usually observed at smaller
235 spatial scales (10 ha vs. 500 ha; Dussault et al. 2006, Leblond et al. 2010), we found a positive
236 relationship at the scale of our plots.

237 Black spruce plantations only modestly explained moose winter distribution; despite the
238 lower proportion of variance explained by plantation variables, their influence on moose
239 distribution in winter was not negligible, as including plantation variables (total area of
240 plantations and plantation aggregation) increased model ranking. Unexpectedly, spruce

10 | Leclerc et al.

241 plantations appeared favorable to moose; moose counts were greater in aerial survey plots with
242 greater proportions of plantation. Use of plantations may be associated to their age, which ranged
243 between 15 and 30 years because of extensive salvage logging after the last eastern spruce
244 budworm outbreak (1974–1992). These plantations were old enough to offer suitable cover,
245 while still being young enough to provide forage, such as balsam fir and twigs and buds of
246 deciduous species (Heikkilä and Härkönen 1996, Renecker and Schwartz 1998), an interesting
247 compromise considering that moose daily forage requirements are high, ranging between 3 kg
248 and 8 kg (dry weight; Belovsky and Jordan 1978). The configuration of young black spruce
249 plantations in our study area appeared efficient in providing contiguous cover and forage.

250 We also demonstrated that plantation aggregation (represented by a low mean distance
251 between plantation centroids) decreased moose presence in an area; moose counts were greater in
252 plots where plantations were more homogeneously distributed than where they were aggregated,
253 for a given area of plantations. Past management of Québec's mixed and conifer forests promoted
254 aggregation of clearcuts surrounded by narrow residual stands (strips or blocks, see regulation in
255 article 75, Québec Government 2003); plantations would inevitably be adjacent and concentrated
256 at the landscape scale, leading to less suitable moose habitat by potentially limiting the contiguity
257 of food and cover. Nevertheless, dispersing logging operations also leads to increased road
258 development, which could be detrimental to moose.

259 As expected, we found a negative effect of road density on moose distribution, a common
260 observation in boreal forest (Dussault et al. 2007, Laurian et al. 2008, Bowman et al. 2010). We
261 believe that the negative impact of roads is primarily due to disturbance originating from road
262 traffic (Forman and Alexander 1998, Spellerberg 1998). Cars, trucks, all-terrain vehicles (ATVs),
263 and snowmobiles are numerous and road disturbances affect adjacent habitats (Forman and
264 Deblinger 2000). To a lesser extent, the negative influence of roads on moose distribution might

11 | Leclerc et al.

265 be explained by greater hunting or poaching pressure near roads (Timmermann and Gollat 1982,
266 M.-H. St-Laurent, Université du Québec à Rimouski, unpublished data), although moose hunting
267 and aerial surveys are not conducted in the same season.

268 Precommercial thinning might also influence moose distribution in winter as it removes
269 deciduous stems that have grown in since a plantation of coniferous seedlings was established in
270 order to maximize the growth of conifers. McLaren et al. (2000) suggested that precommercial
271 thinning could influence moose demography in harvested areas, as locally high moose
272 populations may appear healthy for a short time, but could subsequently deplete forage and suffer
273 high mortality, usually in winter. In our study area, we concluded that moose abundance was not
274 influenced by thinning, because a priori analyses revealed that the proportion of plantations
275 treated and untreated by precommercial thinning both had a positive influence on moose counts.
276 Therefore, we grouped these 2 variables and used the total area of plantations in our final
277 analyses. We then concluded that precommercial thinning conducted in young plantations in the
278 balsam fir–white birch domain was not influencing moose winter distribution at a large spatial
279 scale.

280 **MANAGEMENT IMPLICATIONS**

281 Plantations in our study ranged 15–30 years old. Although we did not demonstrate how moose
282 might respond to older plantations, we expect that black spruce plantations will become less
283 suitable for moose as canopy cover becomes denser and browsing opportunities decrease.
284 Consequently, their positive impact on moose winter distribution may only be temporary and we
285 suggest that their influence may need to be periodically re-evaluated. Also, managing plantations
286 requires permanent access to the harvested stands, resulting in conflicting short-term favorable
287 (young plantations) and unfavorable (roads) features for moose in these managed landscapes. We
288 believe that the negative impacts of roads could overcome the benefits associated with plantations

12 | Leclerc et al.

289 because roads are perennial, whereas plantations will inevitably reach a mature, closed-canopy
290 stage. Removing roads and restoring forest in these linear corridors could be suitable, as recently
291 demonstrated for reindeer (Nellemann et al. 2010), but this may prove difficult in the Bas-St-
292 Laurent region because of land use history (colonized over 300 years ago) and intensive forest
293 management which occurred over several decades (Boucher et al. 2009a). An integrated
294 management strategy is needed to achieve a balance between overdeveloped road networks
295 (needed to join homogeneously distributed plantations) and agglomerated plantations in order to
296 mitigate their influence on moose winter distribution.

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14 | Leclerc et al.

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20 | Leclerc et al.

Figure caption

Figure 1. Location of the study area and aerial survey plots ($n = 41$) distributed in forests of the Bas-Saint-Laurent region's hunting's zone 2 (which essentially overlaps the western part of the administrative region boundaries; Québec, Canada) used for moose sampling in 2005.

Figure 2. Relationship between the area of a survey plot (6,000 ha) covered by black spruce plantations and the estimated moose count (full black line) based on the best supported model for the 2005 survey conducted in the Bas-St-Laurent region (Québec, Canada). Dashed lines refer to 90% confidence intervals.

21 | Leclerc et al.

Table 1. Descriptions of the 11 different stand types and their associated food value according to Dussault et al. (2001, 2006). Food values represent classes of browse availability in each stand type. Food index was calculated by summing the products of stand proportion and food value for each stand type. No food value was attributed to plantations in order to discriminate their respective influence from the food index on moose count.

Name	Description	Food value
M _i 10	Deciduous or mixed regenerating stands (< 10 years old) recently disturbed (natural or anthropogenic disturbances)	1.00
M _i 30	Mixed with shade-intolerant deciduous trees 30 years old	0.50
M _i 50	Mixed with shade-intolerant deciduous trees 50 years old	0.40
M _t 50	Mixed with shade-tolerant deciduous trees 50 years old	1.00
D _i 50	Deciduous with shade-intolerant trees 50 years old	0.50
D _t 50	Deciduous with shade-tolerant trees 50 years old	1.00
C _{fir} 30	Coniferous with balsam fir 30 years old	0.15
C _{spr} 30	Coniferous with spruce 30 years old	0.05
C10	Coniferous in regeneration	0.30
IMP	Unproductive areas (e.g., bogs, fens, alder stands)	0.10

22 | Leclerc et al.

OTHER	All other weakly represented forest or non-forest polygons (e.g., water bodies)	0.00
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23 | Leclerc et al.

Table 2. Candidate models used in multiple regression predicting moose counts ($n = 41$) from environmental covariates in the Bas-St-Laurent, Québec, Canada.

Model ^a	K^b	AIC_c^c	ΔAIC_c^d
PCNM + EDGE + FOOD + ROAD + AREA _p + DIST _p	8	111.65	0
PCNM + EDGE + FOOD + ROAD	6	115.08	3.43
PCNM + EDGE + FOOD	5	117.41	5.76
PCNM	3	121.37	9.72

^a PCNM: principal coordinates of neighbor matrices, EDGE: density of edges between stands providing cover and stands offering high food availability, FOOD: food index, ROAD: road density, AREA_p: total area of black spruce plantations, DIST_p: mean distance between plantations.

^b Number of parameters in the model.

^c Akaike's Information Criterion adjusted for small sample size.

^d Difference between the AIC_c value of the model to the best supported model.

24 | Leclerc et al.

Table 3. Variable coefficients (β) and 90% confidence intervals (90% CI) for the most parsimonious candidate model explaining variation in moose counts ($n = 41$) in the Bas-St-Laurent region in 2005. The model explained 57.8% (adjusted- R^2) of the total variance in moose count.

Variable coefficients ^a								
	β_0	EDGE	FOOD	ROAD	AREA _P	DIST _P	PCNM ₁ ^b	PCNM ₃ ^b
β	0.847	0.011	2.099	-0.0152	0.00044	0.00040	-1.109	0.928
90% CI	±2.771	±0.010	±3.472	±0.0086	±0.00037	±0.00055	±0.633	±0.917

^a β_0 : intercept, EDGE: density of edges between stands providing cover and stands offering high food availability, FOOD: food index, ROAD: road density, AREA_P: total area of black spruce plantations, DIST_P: mean distance between plantations, PCNM₁ and PCNM₃: principal coordinates of neighbor matrices #1 and #3 found to be significant.

^b PCNM coefficients and 90% confidence intervals were multiplied by 100,000 to simplify the table.

25 | Leclerc et al.

Table 4. Respective portion of the total explained variance (based on adjusted- R^2) in moose counts of 3 groups of variables: PCNM, habitat (FOOD, ROAD, EDGE), and plantation (AREA_P, DIST_P), and their intersections following variance partitioning. Negative intersection means that these variables together explained more than the sum of their individual effect (Legendre and Legendre 2001) on the dependant variable (i.e., moose counts).

Partitioning	Groups of variables	Variables considered ^a	% explained variance
Simple	PCNM	PCNM ₁ + PCNM ₃	10.6
	Habitat	FOOD + ROAD + EDGE	21.1
	Plantation	AREA _P + DIST _P	7.5
Double	PCNM + Habitat	PCNM ₁ + PCNM ₃ + FOOD + ROAD + EDGE	24.2
	PCNM + Plantation	PCNM ₁ + PCNM ₃ + AREA _P + DIST _P	5.4
	Habitat + Plantation	FOOD + ROAD + EDGE + AREA _P + DIST _P	-6.9
Triple	PCNM + Habitat + Plantation	PCNM ₁ + PCNM ₃ + FOOD + ROAD + EDGE + AREA _P + DIST _P	-4.1
	Explained variance		57.8
	Unexplained variance		42.2

26 | Leclerc et al.

^a PCNM₁ and PCNM₃: principal coordinates of neighbor matrices #1 and #3 found to be significant, FOOD: food index, ROAD: road density, EDGE: density of edges between stands providing cover and stands offering high food availability, AREA_p: total area of black spruce plantations, DIST_p: mean distance between plantations.

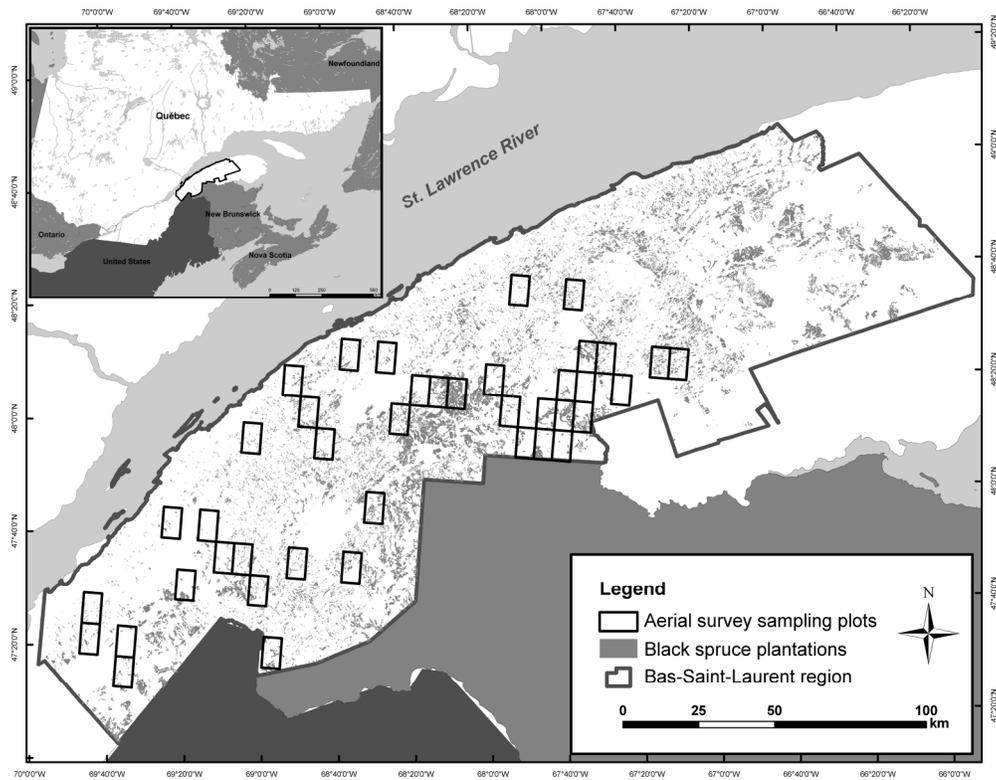


Figure 1. Location of the study area and aerial survey plots (n = 41) distributed in forests of the Bas-Saint-Laurent region's hunting's zone 2 (which essentially overlaps the western part of the administrative region boundaries; Québec, Canada) used for moose sampling in 2005.
215x166mm (300 x 300 DPI)

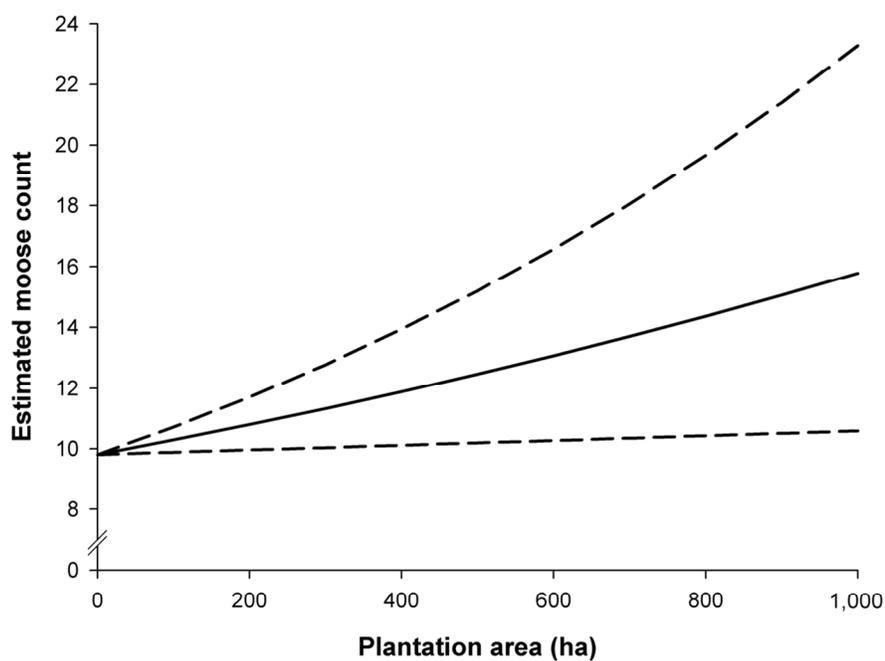


Figure 2. Relationship between the area of a survey plot (6,000 ha) covered by black spruce plantations and the estimated moose count (full black line) based on the best supported model for the 2005 survey conducted in the Bas-St-Laurent region (Québec, Canada). Dashed lines refer to 90% confidence intervals.
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