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Impacts on declining moose populations in southeastern Manitoba

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Abstract

Moose (*Alces americanus*) populations in eastern and central North America have declined in many parts of their southern habitat range. Many potential impacts have been suggested as contributing to moose declines, including changing habitat disturbance regimes and enhanced disease transmission through increasing deer populations. We examined factors affecting moose in Game Hunting Area (GHA) 26 in southeastern Manitoba, an important traditional hunting area where moose populations have declined substantially, by comparing provincial aerial survey data with features of the landscape. Moose were more likely to be found in areas with high logging (>25%) and recent forest fires (within the past 30 years), indicating that moose respond favorably to habitat disturbances. The presence of roads did not affect the likelihood of moose presence; however moose populations were negatively impacted by white-tailed deer (*Odocoileus virginianus*). We used model selection to determine the variables most important for predicting the presence of moose in GHA 26. The best model included the presence of deer, logging, and forest fires. Among the variables considered, deer presence had the highest relative importance. This study suggests that to increase moose numbers, controlled burns and potential logging areas should be considered as ways to produce new habitat and plant growth for moose in southern Manitoba. Managing the deer population may also help control the effect of the deer brain worm (*Parelaphostrongylus tenuis*) on the moose population in GHA 26.

Keywords: *Alces americanus*, forest fire, logging, *Parelaphostrongylus tenuis*, white-tailed deer

Introduction

Moose (*Alces americanus*) are important herbivores in the boreal forest ecosystem and help maintain forest structure by consuming specific plant species (McInnes et al., 1992). Moose are important prey for wolves when smaller ungulates are not available, and moose that are subject to non-predatory mortality are an essential source of food for scavenging wolves and other carnivores (Forbes & Theberge, 1992). Furthermore, moose are important economically, with important consumptive and non-consumptive value to humans. Moose make up a significant portion of people's diets in many regions. In parts of Alaska about 7,300 moose are harvested each year and about 100kg of moose meat is eaten annually per person (Titus et al., 2009). However, moose populations in southern ranges in North America have declined in recent decades, with several explanations proposed for the cause of the decline (Lankester, 2001).

One important factor determining moose abundance and distribution is the white-tailed deer (*Odocoileus virginianus*). White-tailed deer carry a meningeal parasite, the deer brain-worm (*Parelaphostrongylus tenuis*), that also affects moose living in the same area (Schmitz & Nudds, 1994). The deer brain-worm causes neurological diseases in moose, which can be fatal (Gilbert, 1973). Whitlaw and Lankester (1994) found that the density of moose was inversely related to the density of deer in 83 Wildlife Management Units in Ontario. The highest moose densities were found where the deer densities were <4 per km^2 and the lowest moose densities were observed where the highest mean intensity of *P. tenuis* in deer feces was found (Whitlaw & Lankester, 1994). Moose populations may also be affected by major roads, which cause habitat loss, high noise levels and direct moose mortality (Laurian et al., 2008). Moose are known to be attracted to roads to avoid insects and because of sodium rich vegetation that is created by the addition of salt to icy roads (Laurian et al., 2008). Dussault et al. (2007) showed that moose consider areas near highways as low-quality habitat by using moose-vehicle accident data and Global Positioning System (GPS, a satellite-based navigation system that provides time and location information) collars that recorded the number of road crossings for 47 moose. Roads also allow hunters to have access to moose habitats.

Logged forest areas are generally known to have high moose densities because of new forest conditions and growth (Leavesley, 2010). In one Quebec population, moose densities increased by 25% solely because of a logged area that was harvested 10 years prior (Potvin et al., 2005). However, logging also allows road access to hunters, which can increase moose mortality (Crichton et al., 2004). Regions inflicted by forest fires are likely to attract moose as they can forage on new plant growth in the burned areas after a forest fire (MacCracken & Viereck, 1990). In Alaska, areas with high fire frequency had on average a 10% increase in moose density each year within a 10-year period, as heavily burned areas produced a higher amount of new browse (Shenoy et al., 2011).

Southern Manitoba has experienced a dramatic drop in moose numbers in recent years. For example, the moose population in Game Hunting Area (GHA) 26 in southeastern Manitoba has declined by 47 percent over a four year period, from 1,553 individuals (95% CI:1,300 - 1,807) in 2006 to 823 individuals (95% CI: 675 - 972) in 2010 (Leavesley, 2010). To understand the cause of this decline, we examined several factors that possibly affect moose presence in the area, including the presence of deer, roads, logging and forest fires. We predicted the presence of deer and roads would negatively affect the presence of moose, and logging and recent forest fires would positively affect moose populations. We expected deer presence would be particularly important for moose because of the high prevalence of the deer brain-worm in this area; it is estimated that 80% of the deer are infected (Manitoba Conservation, unpubl. data). The declining moose population is a concern because moose are an important ungulate species that regulate boreal habitats and are essential sources of food for many predator species, including humans.

Results

Deer presence and row (i.e., latitude) were highly correlated ($r_s=0.59$, $p<0.0001$), with lower pairwise correlations between all other predictor variables. Moose presence was positively correlated with high logging ($r_s=0.17$, $p=0.0009$) and forest fire presence ($r_s=0.27$, $p<0.001$), negatively correlated with deer ($r_s=-0.45$, $p<0.001$), and unrelated to road presence ($r_s=-0.08$, $p=0.103$) (Figure 3).

The full logistic regression model, including all the predictor variables, was highly significant ($R^2=0.263$, $\chi^2=142.7$, $p<0.0001$) and produced similar results for individual predictors. The presence of deer ($\chi^2=4.60$, $p=0.0320$), high logging ($\chi^2=3.86$, $p=0.0495$) and fire ($\chi^2=3.89$, $p=0.0485$) significantly affected moose presence, as did both row ($\chi^2=21.81$, $p<0.0001$) and column ($\chi^2=29.47$, $p<0.0001$). The presence of roads was unrelated to the presence of moose ($\chi^2=0.82$ $p=0.364$).

The best model for explaining the presence of moose within our study area included the presence deer, logging and forest fire (Table 1). We also found some support (ΔAIC<2) for the full model (with roads), the model with just deer and logging, and the model with just deer and fire (Table 1). Comparing the relative importance of the predictor variables, deer presence had the highest relative importance (0.77), followed by logging (0.69), fire (0.62), and road presence (0.33).

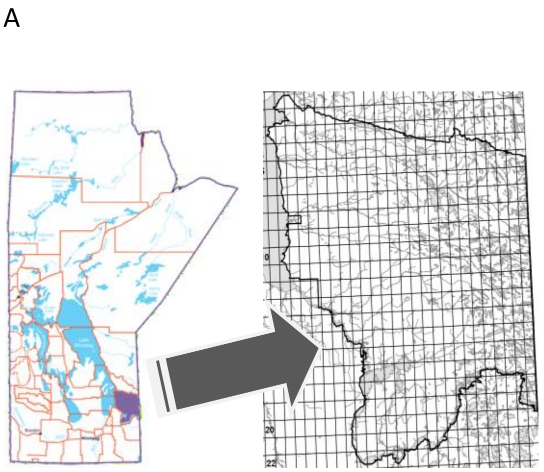

Figure 1. A map of Manitoba with GHA 26 highlighted in purple (left) and a map of GHA 26 with the grid system overlaid onto the region (right)(A).

A

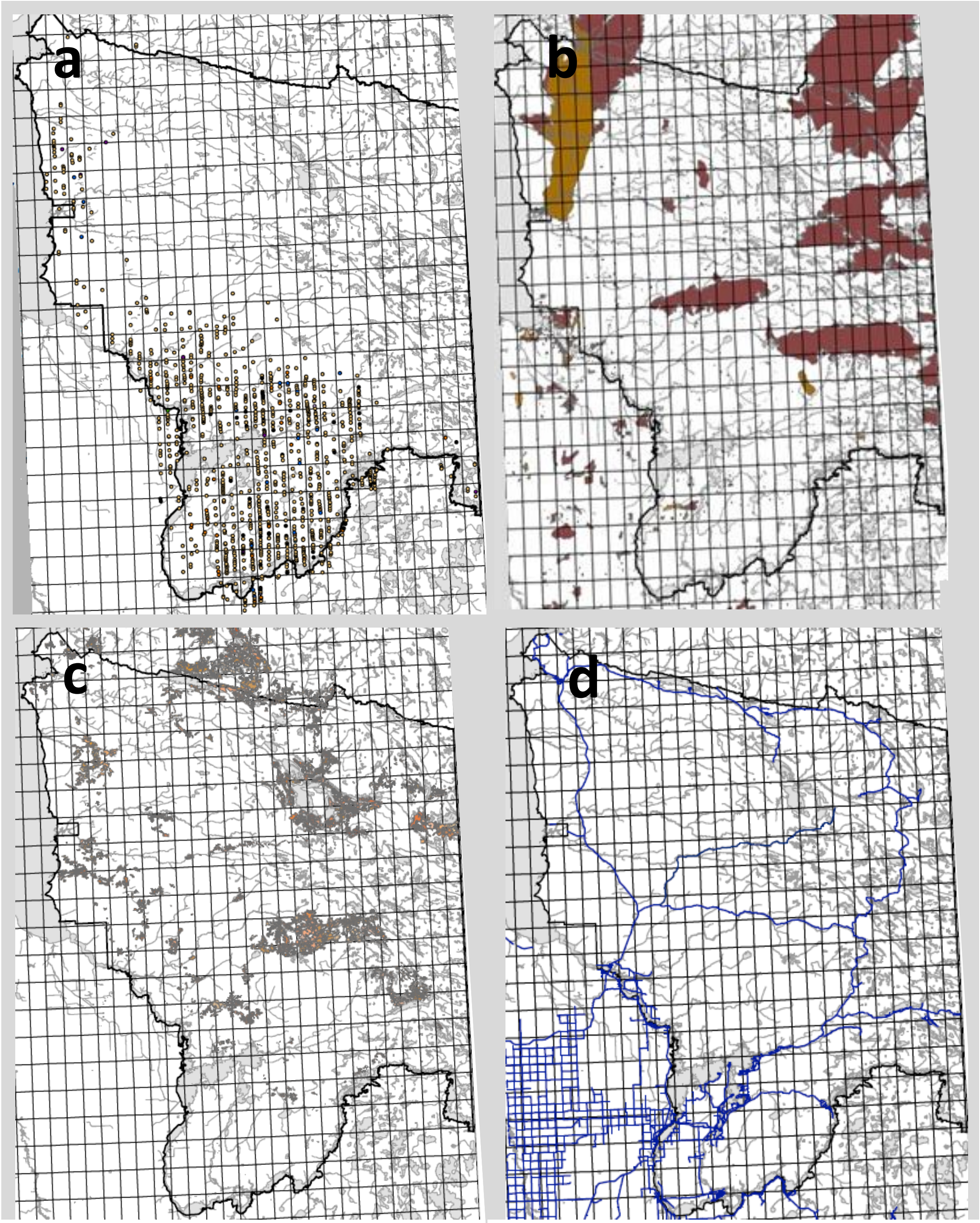

Figure 2. Maps of GHA 26 with the grid system and locations of the four independent variables: a) white-tailed deer (2010), b) forest fires (since 1980), c) logged areas (since 1983), and d) major roads (A).

A

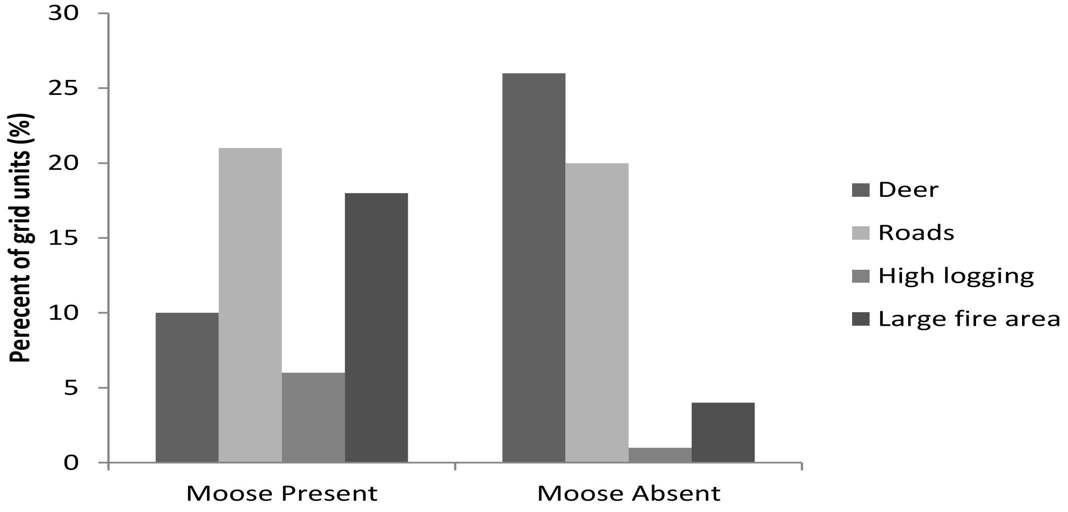

Figure 3. Probability of encountering each predictor variable in grid units with or without moose present (N=397) (A).

Table 1. Comparison of logistic regression models using Akaike's Information Criteria (AIC), showing the top ten models for explaining the presence of moose. Row and column variables were also included in each model to control for spatial autocorrelation. The coefficient of determination (R^2), loglikelihood, sample size (N), number of parameters in the model (K), uncorrected AIC (AIC), delta AIC (ΔAIC), and the probability of each model (weight) are shown (A).

A

Model Variables	R^2	Loglikelihood	N	K	AIC	ΔAIC	Weight
deer, fire, logging	0.2614	200.415	397	7	414.830	0.000	0.2323
deer, roads, fire, logging	0.2630	200.002	397	8	416.005	1.174	0.1291
deer, logging	0.2553	202.084	397	6	416.168	1.338	0.1190
deer, fire	0.2551	202.128	397	6	416.257	1.426	0.1138
fire, logging	0.2531	202.668	397	6	417.337	2.506	0.0663
deer	0.2448	203.851	397	5	417.701	2.871	0.0553
deer, roads, fire	0.2558	201.931	397	7	417.862	3.031	0.0510
deer, roads, logging	0.2558	201.949	397	7	417.897	3.067	0.0501
fire	0.2481	204.041	397	5	418.083	3.253	0.0457
logging	0.2473	204.260	397	5	418.521	3.690	0.0367

Discussion and Conclusion

Moose were more likely to be seen in areas that have been subject to habitat disturbances (logging or fires) and in areas where deer are absent (Figure 3). Whitlaw and Lankester (1994) also showed that moose tend to occupy areas where deer are absent. Additionally, areas that have been logged have seen increased moose presence 10 years after harvesting (Potvin et al., 2005) and annual increases in moose presence have also been noted in severely burned areas (Shenoy et al., 2011), agreeing well with the findings of this study. Contrary to our expectation, however, the presence of a major road was not an important influence on moose presence.

Deer presence had a greater impact on moose presence than any other variable, as predicted. The deer brain worm is thought to strongly impact moose populations (Schmitz & Nudds, 1994), but increasing deer numbers could also introduce other factors such as other parasites and competition for resources (e.g., habitat and food) that could negatively affect moose. Deer presence and moose presence should be examined together in relation to habitat (fields, swamps, forests, etc.) to examine potentially confounding influences on the relationship between these two variables, such as associated habitat types.

It is important to recognize that the stratification data represent a small window of time, and that the visibility of moose and tracks may depend on snow conditions, temperature, weather conditions, and habitat. For example, tracks are easier to see in bright sunlight and moose are easier to see in overcast conditions (K. Leavesley, pers. comm.). Moose also move around more in cold weather to keep warm, making more tracks in the snow. Very thick bush cover can prevent surveyors from sighting animals or tracks located underneath (Gasaway et al., 1986). Moose and tracks are much easier to see in open, post forest fire and logged areas. In 2010, the stratification flights started after a 48 hour fresh snowfall and the weather was mainly clear with a sun and cloud mix, providing good conditions for visibility of both tracks and moose (Leavesley 2010). Furthermore, our study used a very large sample size increasing its reliability, and our results were highly significant based on statistical tests.

Declining moose presence in GHA 26 is a concern because of ecological and predatory relationships. This study demonstrated that deer are likely the key factor affecting moose presence in GHA 26, which suggests that the deer population may need to be controlled to decrease the spread of *P. tenius* to moose. Currently in GHA 26, muzzle loader and rifle deer seasons are extended and extra deer tags are available to hunters to reduce the deer population. Controlled burns in certain regions in GHA 26 would greatly increase the amount of new plant growth available to moose in the area and increase their presence. Potential areas that would be good for logging should be assessed to create new plant growth and habitat for moose. Further studies could also focus on different habitat types, food sources, predators, hunting pressures and weather conditions in GHA 26 that might affect moose presence. This study suggests that conservation measures could help recovery of the declining moose presence in GHA 26.

Materials and Methods

Data on the distribution of moose and deer in the study area were collected by Manitoba Conservation in Lac du Bonnet, Manitoba, using aerial surveys of the 7,702 km^2 study area, employing the Modified Gasaway-Lynch Method (Leavesley, 2010; Gasaway et al., 1986). This technique involved stratification flights flown along prearranged transect lines in a north-south orientation using a Cessna 337 (a safe and efficient aircraft commonly used for wildlife surveys) at ~400ft above the ground and ~90 mph. Surveys for moose and deer were done during winter (February 2010) for greater sightability of the animals and tracks in the snow (Gasaway et al., 1986), and any observed moose or deer sightings, tracks or cratering by deer were noted and recorded as GPS locations (Leavesley, 2010). Moose and tracks could be easily distinguished because moose are much larger and leave a diamond-shaped imprint in light snow, while deer tracks resemble ski tracks and do not leave a diamond shape (Oswald, 1997). Moose overall walking patterns are meandering while deer travel in distinctive directional patterns, leaving paths in the snow (Oswald, 1997). Deer also jump in deep snow, leaving distinct blotch patterns, whereas moose do not (Oswald, 1997).

Locations for major roads were determined using regional highway maps and then shape files were made. Logged areas were determined by taking aerial photos from a fixed wing aircraft and GPS locations were recorded. The photos were used to create shapefiles. Each year a fixed wing aircraft flew the perimeter of recent forest fires to record GPS locations and shapefiles were made. All the GPS locations and shapefiles were superimposed on a map of GHA 26 that was overlaid by a grid in ArcGIS Desktop 10.0, a geographic information system (GIS) commonly used for analysing aerial survey data and producing maps, The grid squares or units were 3.5 x

5.5 km (19.25 km²), with n=397 grid units covering the entire study area (Figure 1).

Five different maps of GHA 26 were created for the study; one for the dependent variable (moose presence) and one for each independent variable (presence of deer, roads, logging and forest fires; Figure 2). For each grid unit we determined if moose were present (a binary variable) based on sightings of either animals or tracks, since thick canopy cover can prevent surveyors from sighting animals underneath (Gasaway et al., 1986). We also determined the presence of each independent variable on each grid unit. For deer presence we included deer sightings and tracks as well as evidence of cratering (digging through the snow to feed on vegetation). Roads were recorded as present if any road ran through any portion of the grid unit. We used logging data collected from 1983-2010 and forest fire data from 1980-2010 because valuable habitat to moose is expected to decline sharply 20-30 years after a disturbance (Manitoba Conservation, pers. comm.). We considered grid units that were highly affected by logging or fires as distinct from grid units that were only slightly affected. Delong and Tanner (1996) considered large fires and logged areas to be greater than five square kilometers. Since 25% of a grid unit was 4.8 km², we considered grid units to have low forest fire or logging presence when < 25% of the grid unit was covered and high forest fire or logging presence when ≥25% of the grid unit was covered.

We used a series of logistic regression models to test which variables best predicted moose presence. To control for spatial autocorrelation we added row and column variables to each model (reflecting latitude and longitude, respectively). First, we used the Spearman's rank order correlation (r_s) to check the predictor variables for multicollinearity. We considered $r_s > 0.7$ or $r_s < -0.7$ as highly correlated. We also examined the correlations between the dependant and independent variables, to understand associations between them. We then ran each logistic regression model and used model selection to rank them based on Akaike's Information Criteria (AIC). We used uncorrected AIC due to the large sample size, and also calculated the Akaikie weight of each model (the probability of being the best model of those considered). Finally, we calculated relative importance of each predictor variable by summing the weights of all models containing that variable to determine which independent variable had the biggest influence on moose presence.

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