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Estimating moose abundance and habitat suitability from satellite-derived indicators

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Background

My educational and professional background in Geomatics and Environmental Sciences has shaped my interest in utilizing Earth observation technologies, to better understand the link between ecological and environmental processes, during my Masters degree in Forestry. In 2005, I completed a degree in Geomatics Technology at Collège Ahuntsic, in Montréal, Québec. After working with various land surveyor offices and Hydro-Québec, I enrolled in an undergraduate program in Applied Environmental Geomatics at the Université de Sherbrooke, in Sherbrooke, Québec. During my B.Sc. degree, I got involved with the Canadian National Forest Inventory program, where I investigated the potential benefits of using very high spatial resolution satellite imagery for updating and assessing existing forest inventory data. This work inspired me to pursue a M.Sc. in September 2009 at the University of British Columbia, in Vancouver, British Columbia, where I am currently using satellite-derived environmental indicators to characterize moose habitat and abundance, and ecosystem variability.

The research presented in this application outlines my findings to date, which will form the basis for a chapter in my thesis. This work was completed during the past year and was presented at the 2010 North American Moose Conference held in International Falls, Minnesota, in June 2010. The findings from my M.Sc. research will be used by the Ontario Ministry of Natural Resources (OMNR) as an additional tool to reliably manage moose populations in the province.

Introduction

Moose *(Alces alces)* are the largest ungulates in the family Cervidae, of which there are four subspecies across North America. Moose are considered to be of high importance for various recreation and economic activities, and because they are a food source for predators and scavengers, such as the black bear (*Ursus americanus*) and timber wolf (*Canis lupus*), can be considered a key species in many forested ecosystems. Moose population densities are variable throughout North America in relation to variation in natural predation, hunting pressure, parasites, disease and habitat availability. Extensive moose aerial surveys are crucial for effectively managing moose and are undertaken annually by the OMNR; however, surveys of ungulate populations are expensive and the ministry would substantially benefit from alternative methods for mapping moose density, such as monitoring key habitat and assessing how it varies through space and time.

Remote sensing has been shown to be a valuable technology for monitoring environmental change at multiple spatial and temporal scales; over the past three decades, scientists have increasingly utilised it for terrestrial habitat mapping. In this study, I propose a statistical model that assesses a remote sensing-derived land cover product to estimate moose habitat and abundance across Ontario. I discuss the model development, and its application to moose aerial survey data throughout Ontario from 2000 – 2005.

Methods

Aerial inventories were undertaken by the OMNR to estimate size, age and sex distribution of the moose population over the Ontario moose range (totalizing 590 000 km^2). Experienced observers were collecting the data by helicopter annually between December and early February, over a period of five years (2000-2005). Land cover classification based on Landsat imagery was provided by the Earth Observation for Sustainable Development of Forests (EOSD) into 23 classes (25 m spatial resolution) that represented land condition circa year 2000.

In order to determine moose habitat quality potential using the existing land cover classification, I developed a suitability mask based on previous studies' findings. This suitability mask was partitioned over the study area in 100 km^2 hexagons using Hawth's tool in ArcGIS 9.3. Within each hexagon plot, land cover types were weighted according to their ability to provide year-round food and/or protection cover (Table 1). In addition to land cover proportion, the spatial organisation of the cover types can influence behavioural strategies of moose. Forest edges are generally preferred by these animals, where they can have access to deciduous forests for browsing and nearby mature, semi-mature coniferous stands for protection from weather and predation. In order to account for interspersion of the food and cover patches, I computed a Largest Patch Index (LPI) over softwood cover using the FRAGSTATS software (Fig. 1). Specifically, this index identified patches of coniferous stands that were of sufficient size to represent a predation and weather refuge. From these patches, the index computes a buffer of 200m which account for area that is easily accessible for foraging.

In summary, the proposed moose habitat suitability index (HSI) has three components: derivation of preferred forage for food (SI_{food}), coniferous stands for weather and predation protection (SI_2) and spatial organisation of forest land cover types from the LPI. We tested existing indices from the literature and the newly developed index (Table 2) using moose aerial inventory data.

Results and Discussion

Preliminary model results suggested that patchworks of land cover types, designated as protection cover and a food source, tended to be highly correlated to moose habitat preferences. T-tests indicated that, from the indices tested, the index HSI 5 provided the best explanation of adult moose spatial density distribution (Fig. 2). Representation of the results for this proposed moose habitat suitability index are presented in Figure 3.

This method is a generalized approach and focuses first on evaluating remotely sensed land cover potential, in order to characterize habitat suitability for moose in Ontario. Preliminary results are promising; however, I hope to improve the model by including auxiliary datasets, which will account for spatiotemporal change in vegetation as well as limitations and regulatory effects of changing environments. I will use a vegetation productivity index derived from the fraction of photosynthetically active radiation (fPAR) time-series of the MEdium Resolution Imaging Spectrometer (MERIS) sensor, elevation from Shuttle Radar Topography Mission (SRTM) and distance from roads and urban areas from Statistics Canada and the National Oceanic and Atmospheric Administration (NOAA).

Conclusion

This research is the basis of ongoing research; once my project is finalized, it has the potential to provide consistent estimation of moose habitat and abundance across a broad scale using free of charge data.

Table 1. Habitat component composition and associated forest cover attributes.

Habitat component	Annual function	Original composition*	Modified for this study	EOSD forest land cover classification
Forage (SI_1)	Food	Shrub or forested cover < 20 years old	Any sparse forest, shrub, grassland, herbs	10-25 % crown closure forests, shrub, grassland, herbs
Softwood Cover (Winter Cover) (SI_2)	Cover	Spruce/fir forest ≥ 20 years old	Coniferous dense or open forest	> 25% crown closure, coniferous trees are 75% or more of total basal area
Hardwood and Mixedwood Cover (Forage/Cover) (SI_3)	Food/Cover	Upland deciduous and Mixed forest ≥ 20 years old	Deciduous and Mixed dense or open forest	> 25% crown closure, coniferous not account for more than 75% of total basal area
Wetlands (Aquatic Forage) (SI_4)	Food (Summer)	Area in riverine, lacustrine, or plaustrine wetlands not dominated by woody vegetation	Herb and shrub wetland	Wetland with majority of herb or shrub as vegetation
Si_{food}	Food	-	Forage, Hardwood and Mixedwood cover	Shrub, grassland, forest stands where coniferous not account for more than 75% of total basal area
Largest Patch Index (LPI)	Spatial organisation	-	Softwood Largest Patch Index	> 25% crown closure, coniferous trees are 75% or more of total basal area

*** Source from Allen, A. W., P. A. Jordan, and J. W. Terrell, 1987.**

Table 2. Habitat Suitability Index equations.

$HSI_1 = (SI_1\ SI_2\ SI_3\ SI_4)^{1/4}$	Original composition following Allen et al. (1987)
$HSI_2 = (SI_1\ (SI_2)^2\ (SI_3)^2)^{1/5}$	Wetland removed and cover weighted more heavily
$HSI_3 = ((SI_1 + SI_3)/2)\ 0.45 + (SI_2)\ 0.55$	Food and cover from Suitability Indexes (SI) weighted following Dussault et al. (2006)
$HSI_4 = (SI_{food})\ 0.45 + (SI_2)\ 0.55$	SI_{food}: (forage + hardwood + mixedwood) and conifer suitability index (SI_2)
$HSI_5 = (SI_{food})\ 0.45 + (SI_2)\ 0.20 + [1-(LPI)]\ 0.35$	SI_{food}, SI_2 and inverted Largest Patch Index (LPI)

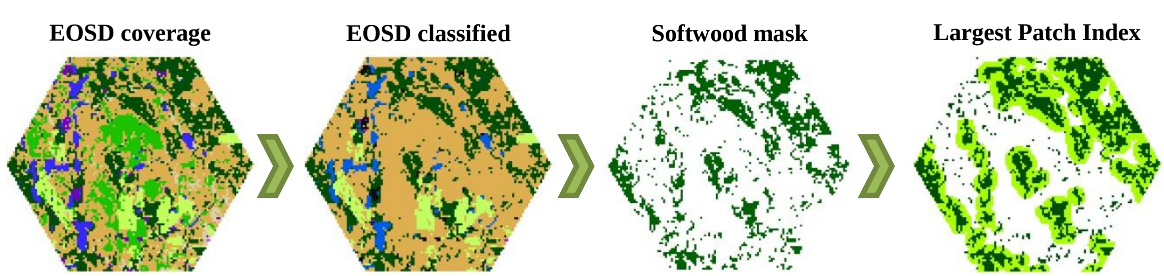

Figure 1. An example of the land-cover classification and large patch index computation for 100km^2 hexagons

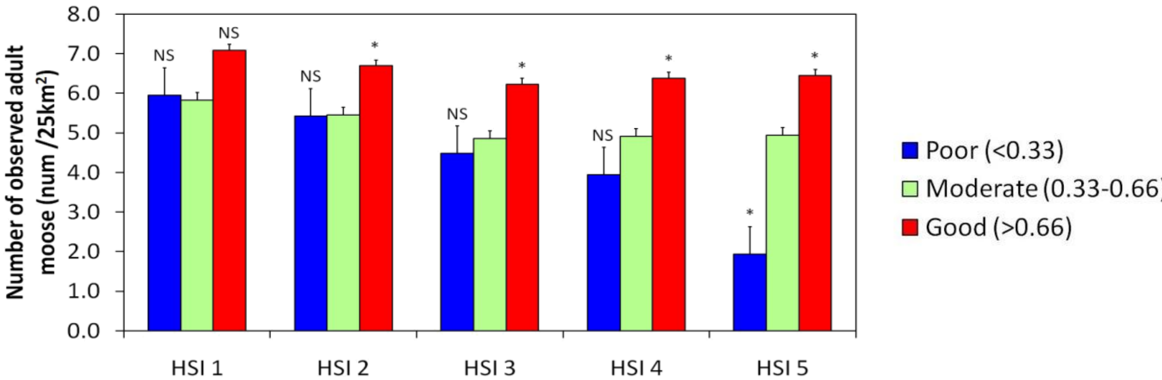

Figure 2. Summary of habitat suitability in Ontario's moose range from 5 experimental equations. Vertical bars show the habitat-selection ratios (mean + SE) for moose in evaluation plots and symbols above the bars indicate if the values differ significantly from the Moderate class (*: $p < 0.01$; NS: non-significant).

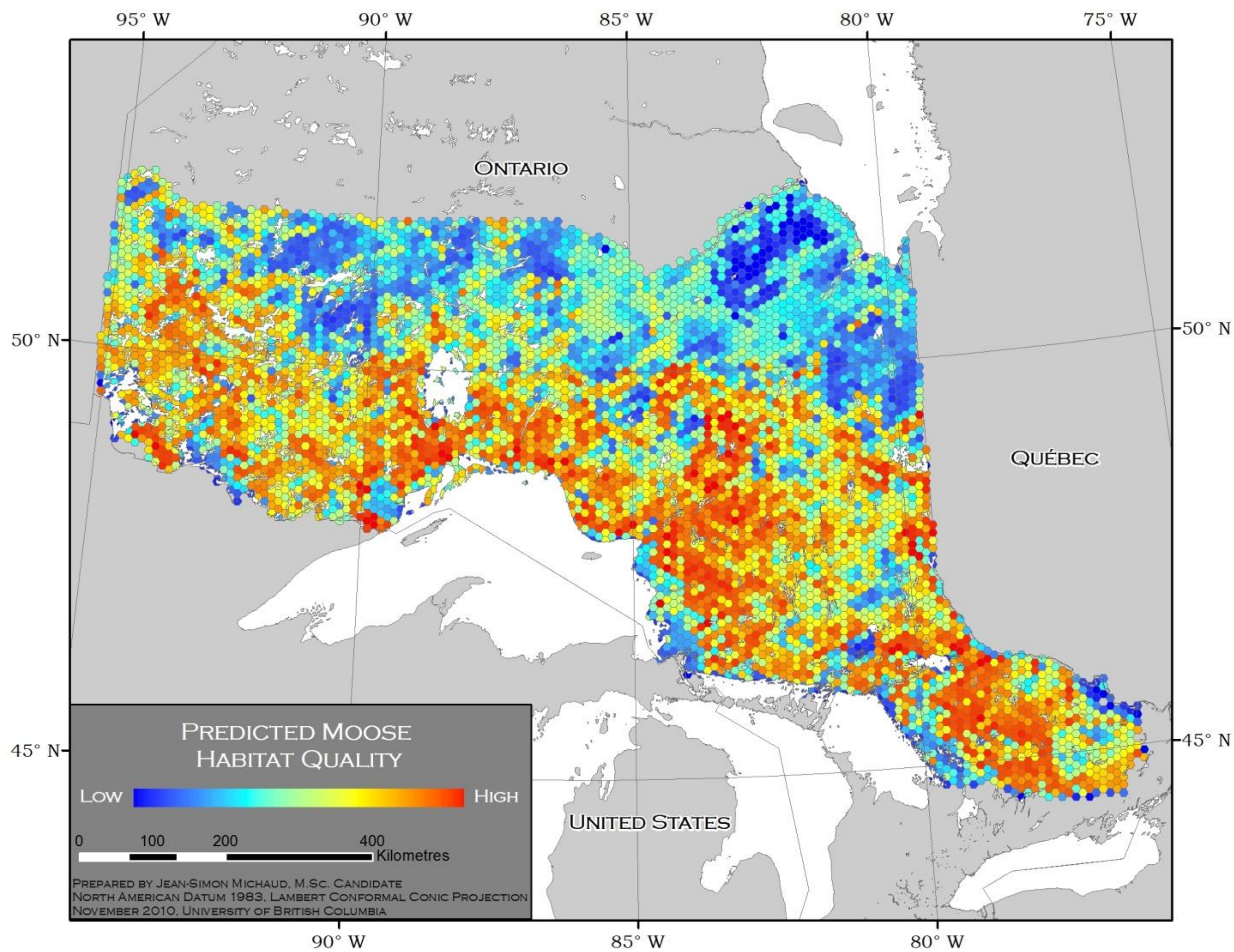

Figure 3. Predicted moose habitat quality computed from the Habitat Suitability Index 5 over the Ontario's moose range.