Development of Seasonal Moose and Elk Habitat RSPF Models (V3)

Proposal for Louisiana Pacific Canada and Manitoba Wildlife Branch

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Project Background and Objectives

Moose and elk are important ungulate species in Manitoba. Moose are found throughout the province of Manitoba ranging south from the U.S border, north to the Nunavut Territory, including the Mountain Forest Section of Manitoba, where moose is an important ungulate species. (Manitoba Moose Fact Sheet). It is valued by almost all people, but in different ways. For example, Indigenous communities have spiritual, social, and economic connections to moose populations. Although the population is relatively stable at the Provincial level, in the Mountain Forest Sections (Duck Mountain (GHA 18-18C), Porcupine Mountain (GHA 13, 13A), Turtle Mountain (GHA 29, 29A), and GHAs 12, 14 and 14A.) a moose conservation closure has been necessary, due to a decline in moose populations. Therefore, all agencies are working to manage moose populations at levels where risk to ecological and socio-economic values are simultaneously minimized.

The Duck Mountains hosts the 2nd largest herd of Elk in Manitoba (Chranowski 2009). Considered one of Manitoba's most valued wildlife resources, this species is an integral part of the landscape for the aspen-parkland and mixed prairie-parkland habitats. Elk are valued by many and provide special enjoyment for viewing and hunting by licensed and rights-based hunters. There are*10 identified populations located in the south central third of the province, including the forest mountain areas of Riding Mountain, Duck Mountain, Porcupine Mountain, and Turtle Mountain.*

Elk populations are driven by a variety of factors, including hunting, predation, disease, and food availability. Elk is an adaptable species and can feed on a variety of herb and forb plant species, depending on their availability throughout the year. Elk habitat is principally found within the northern boreal forest, aspen parkland, bur oak savannah, grasslands, private agricultural lands, and eastern deciduous forest. Important tree species include trembling aspen *(Populus tremuloides),* balsam poplar *(Poplar balsamifera),* white birch *(Betula papyrifera),* white spruce *(Picea glauca),* black spruce *(Picea mariana),* bur oak *(Quercus macrocarpa),* balsam fir *(Abies balsamea),* jack pine *(Pinus banksiana)* and tamarack *(Larix laricana).* (Manitoba Elk Fact Sheet).

Development of seasonal resource selection probability function (RSPF) models to evaluate the importance of various habitat configurations would help in ensuring that appropriate habitat conditions are available for Moose and Elk through development of the 20-Year Forest Management Plan (2020). Although these ungulate populations are driven by multiple factors, it is important that suitable habitat is available to allow ungulate populations to fluctuate at sizes that will minimize risk of local extirpation under multiple sustainable uses. A range of factors influence ungulate habitat including environmental change, fire disturbance, herbivory, and human activity.

RSPF Development Strategy

Hierarchical hypotheses and prior knowledge: Model development will be based on evaluating model support for alternative hypotheses. For moose, initial hypotheses will be based in part on coefficients and/or variables from the General Moose Winter RSF model (Sana Zabihi-Seissan 2018 report), as this model performed the best among the 3 versions assessed in the report. For elk initial hypotheses would be based in part on variables used in the 1998 Elk HSI model and research by Chranowski (2009) and Brook (2010). Three broad research hypotheses, expressed as models, will be evaluated during model development:

1. Ecosite Model (*Ecosite Model*). This is the initial "neutral model", where it is hypothesized that independent of forest vegetation management and road effects, moose and elk habitat is sufficiently defined by the enduring ecosite features of upland and wetland ecosites that provide food, predator escape cover, thermal cover, and wetland vegetation. These ecosites are associated with a range of soil moisture and fertility conditions that affect vegetation composition that are relatively stable over time.

2. Forest vegetation management model (*Ecosite and Forest Model*). In addition to enduring ecosites, it is further hypothesized that it is necessary to understand (model) the effects of overstory composition and age-structured (which is actively managed through forest management) to sufficiently predict habitat use by moose and elk. Forest vegetation management can ensure a continuous supply of young browse in close proximity to predator escape cover. This model will include variables used by Sana Zabihi-Seissan (2018) for the moose model, and variables used by Chranowski (2009) and Brook (2010) for the elk model.

3. Road effects model. (*Ecosites, Forest, and Roads Model*). In addition to ecosite and forest management effects on habitat, it is further hypothesized that it is necessary to understand (model) both the positive and negative influences of large secondary roads and small forest roads to effectively predict moose and elk habitat use. Ungulates may avoid larger, busy secondary roads, but may either be positively associated with smaller forestry roads where active forest management is occurring, or negatively associated with smaller roads when they facilitate wildlife harvest.

Model selection will be hierarchical in nature, where the best of alternative *Ecosite Models* will be selected. Next, the best *Ecosite and Forest Model* will be selected if this improves upon on the *Ecosite Model* (i.e., delta AIC value is > 2). Finally, the best *Ecosite, Forest, and Roads Model* will be selected if this improves upon the *Forest Model*.

Estimated time – 2 days to develop and vet hypotheses for moose and elk

AIC and Model Selection (2 days): We propose to use the Akaike Information Criterion (AIC) for selection of *a priori* defined models (hypotheses). Note that selection of models using AIC is based on performance of the overall model, not assessment of p-values associated with individual variables. AIC provides a penalty for each variable included, and this helps to protect against over specification of the model. This method can evaluate whether the inclusion of additional variables representing more complex models is statistically supported and justified.

Estimated time – 2 to 3 days to assess moose and elk models using AIC

Bayesian Approach to Model Development: The RSPF models will be developed using binary Bayesian logistic regression. This approach allows the model to be initially specified using "priors" based on existing knowledge. Priors can be either exact coefficients, or simply directional coefficients that indicate that relationship with the habitat variable is expected to be positive or negative. Thus the *a priori* hypotheses of high-quality food, food & cover, etc., can be specified using existing knowledge, such as existing HSI model, or selection coefficients determined from previous studies. The Bayesian approach will also allow future refinement of the model after new data is collected (as opposed to developing a new model completely uninformed by the previous model). Similar approach used in Ontario for developing seasonal specific RSPF models for caribou (Hornseth and Rempel 2016).

Estimated time – 3 to 4 days to develop RSPF models for moose and elk

Data Sources and Seasonal Models: Two principal sources of data will be used for model development: accurate locational data of cows using GPS (and possibly VHS) collars, and winter aerial survey data where location of detected animals was recorded. The collar data is collected throughout the year, whereas the aerial survey data is collected only in the winter, as snow covered ground is required for animal detection. A winter RSF model will be developed using a combination of collar and aerial survey data, and a non-winter RSF will be developed using collar data only. Patterns of habitat use will be explored to determine if evident differences occur in habitat use among the non-winter seasons (spring, summer, and fall).

For moose we would use recently collected moose aerial survey data (2019-2020) and moose observations from the aerial transect surveys in 2010, 2012 and 2017. We would eventually include data expected for 2020-2021. Following previous model development approach, we would generate a uniform distribution of points every 600 m along the transect lines to model available points for the RSPF. For elk we would assemble data collected under the Chranowski (2009) and Brook (2010) projects into GIS layers.

Estimated time – 4 to 5 days to assemble and format data for moose and elk

Development of RSPF and Kernel Density: The collar locational data will be processed to create kernel density estimating probability of use. The kernel density estimates (KDEs) will be used to create continuous surfaces that separate high use areas (top 10% of use) from low use areas (bottom 50% of use). This categorization does not imply that data between 10% and 50% is unimportant, rather the categorization is designed to separate the highest use from the lowest use to strength model development. Alternative categorizations may be tested during model development. These surface areas will then be sampled using a point sampling routine to create a data set of selected versus non-selected habitat. Additionally, aerial survey data will be used to determine areas that have been surveyed but where no ungulates have been detected. This will help to strengthen the model's ability to detect avoided habitat (i.e., negative selection).

Estimated time – 2 days to generate KDE surfaces and randomly create point sample data sets for each of moose and elk

K-folds to Improve Model Robustness: Once the best set of model variables has been selected, then further refinement and testing of the model will be conducted using stratified K-folds approach. This approach increases the robustness of the model (i.e., ability of the model to predict habitat-use outside of the data samples used to develop the model) and allows a better assessment of confidence in model predictions. The full data set is divided multiple (K) times into a larger training data set and smaller testing data set. Model development is performed on the training data set, and then tested on the smaller testing data set using area under the ROC curve (see below). Estimated coefficients and model performance are then averaged.

Estimated time – 2 days to generate K-folds data sets for moose and elk

Overall Model Performance and ROC: The overall performance of a binary classification model, such as an RSPF that predicts high-use versus low-use habitat, can be evaluated by plotting 1- model specificity (false positive rate) versus sensitivity (true positive rate). The resulting curve is called the resource operating characteristic (ROC), and the area under the resulting curve allows us to evaluate how successfully the model can discriminate good habitat from poor habitat. The model should have as close to 100% sensitivity (true positive rate) and 100% specificity (true negative rate) as possible.

Estimated time – 2 days to generate ROC curves for moose and elk

Model Performance and Thresholds: Management application of a binary RSPF classification model requires a threshold value that classifies continuous values of predicted use (varying from 0 to 1) into one of the two categories. For an RSPF, any value of predicted high-use above the threshold is classed as high-use, and all others as low-use. Changing the threshold will change the relative occurrence of false-positives (habitat that is predicted as high-use, but is really low-use), and false-negatives (habitat that is predicted as low-use, but is really high-use). There are different approaches to determining the threshold, but for habitat management where false-negatives are as bad as false-positives, we suggest that a strong approach is to balance the occurrence of false-positives and false-negatives (i.e., attempt to maximize both sensitivity and specificity). The consequences of alternative thresholds on management decisions may be explored in future projects.

Estimated time – 2 to 3 days to generate performance statistics and select model thresholds for moose and elk

Habitat Data Structure and Variables: Model habitat layer would be based in part on the same LSL data structure as used in the LP Bird RSPF models (Rempel and Donnelly 2010; Rempel et al. 2016) and that has been used in development of other ungulate models (Elkie et al 2012; Kushneriuk and Rempel 2011; Rempel et al. 1997; Rempel 2011) (Table 1). This is comparable to a moving-window analysis for smoothing data at different spatial scales and would allow integration of biodiversity indicators and maintain linkages with the LP planning tool Patchworks. This could facilitate and expedite biodiversity analysis and application of the model to projected future forest conditions for the FMP's five-year report. This would also facilitate linkage to population dynamic models and population viability assessments (PVAs).

A preliminary list of variables has been suggested for the moose (Table 1) and elk (Table 2) models, but these would be refined through discussions with Manitoba Wildlife Branch and LP staff. Additional variables will be included based on specification of the *a priori* hypotheses related to habitat selection. For example, we would also include density of forestry roads as a possible variable under the *Roads Model.* Distance to road is likely a good predictor for the relationship with large roads and busy highways, as moose will tend to avoid these. However, there may be an opposite relationship with small forestry roads, as these will be associated with younger forest with high levels of aspen browse. Forestry roads may increase hunting pressure, but decommissioned roads less so. Density would be a more informative variable for these smaller forestry roads than proximity measures.

For the ecosite models we would include both wetland and upland ecosites as potential variables. Treed fens (wetland ecosites 11 - 12) and treed bogs and swamps (wetland ecosites 15 - 20) can provide thermal cover for moose, and marshes (wetland ecosites 5 – 6) can provide aquatic food rich in sodium. Upland ecosites could be grouped as conifer-mixed (ecosites 13, 24, 36, 43, and 52) , mixed-wood ecosites (23, 34, 35, 42, and 52) and these can provide escape cover, while aspen-hardwood ecosites (11, 12, 21, 22, 31 – 33, 41, and 51) could provide a good source of browse.

This structure would allow us to conduct multi-scale analysis of habitat selection by integrating local, meso, and regional scale analysis (e.g., proportion of hardwood at 50 ha local scale, proportion of wetland ecosites at 500 ha meso scale, and contrast weighted edge-density between young and old forest at the 5000 ha regional scale).

Habitat data will require assembling inventory data with dates similar to the elk and moose observation data, and processing through LSL.

Estimated time – 2 to 3 days to assemble and process habitat data in LSL

Application of Elk and Moose RSPF models to current inventory: The models will be encoded in the LSL scripting language and applied to the current forest inventory to create maps of expected habitat quality across the landscape. A report on the models and their application will be written

Estimated time – 4 to 5 days to code models, apply to current inventory, generate maps and statistics, write report.

Schedule

It is expected the project will begin after the Forest Management Plan is approved by the Province of Manitoba. These moose and elk RSF analyses will take 4 to 6 months to complete, assuming clean and timely data are provided. In addition, timely responses to decision points in the analyses will assist with project competition.

Responsibilities

Manitoba Wildlife Branch/LPC will provide:

i) All collar locational data for elk and moose;
ii) aerial survey data for elk (2018 plus any new surveys) and moose (2010, 2012, 2017, 2020 and any new surveys);
iii) a separate forest inventory layer for each relevant time period for each survey (see above);
iv) updated roads layer for each relevant time period (as above).

Manitoba Wildlife Branch and LPC will provide timely reviews of the proposed hypotheses, methods, list of potential environmental variables, and model outcomes, as well as participation in milestone conference calls to discuss progress and next steps.

FERIT will provide proposed: i) hypotheses, ii) methods, and iii) list of potential environmental variables. FERIT will deliver i) RSPF models for moose and elk (winter and non-winter seasons), ii) estimates of model performance, iii) implementation in the LSL spatial landscape assessment model and application to the current planning inventory, iv) project report detailing methods and outcomes, and v) structured dataset containing all data used in model development and testing, including appropriate metadata.

Cost Estimate and Terms

Total project cost not to exceed $30,000 (exclusive of GST). Total time and cost may be lower if data assembly and development work goes smoothly. No in-person meetings or travel are included in the cost estimate. Payment will be made upon delivery of the final report and models, to be paid within 30 days from invoice date. The province of Manitoba will be billed for 50% and LPC invoiced for the remaining 50%.

Potential Future Directions

Although not part of this proposal *per se*, data will be structured to facilitate development of models to predict moose and elk abundance and density using Poisson regression, and for developing population dynamic models, PVAs, and scenario analysis for population game management using the ALCES Online cumulative effects modeling environment. Data structure will facilitate incorporation of future data for model updating and refinement.

Table 1. Preliminary list of variables for RSPF development for moose.

LSL Variable	**Possible Association with Moose**
Average Age of Forest (50 ha)	Younger forest has more moose browse; older forest provides lateral cover and snow interception
Age Edge Density (5000 ha)	Food and cover. Moose like young forest in proximity to old forest because the old forest provides predator escape cover
Cover Type Edge Density (5000 ha)	This variable is related to a mixture of deciduous and coniferous. Combination provides food and cover
Percentage of Hardwood (50 ha)	Aspen provide a good source of browse
Mean Average Hardwood Height (50 ha)	Tree height can influence lateral cover from predators and hunters
Mean Average Softwood Height (50 ha)	Height can influence lateral cover from predators and hunters
Mean Crown Closure (50 ha)	High crown closure limits browse, but provides good interception of snow
Water Edge Density (500 ha)	Moose like availability of water
Proportion Open Water (500 ha)	Moose like availability of water
Riparian Ecosites (500 ha)	Moose like availability of water and marsh plants
Wet Soils Ecosites (500 ha)	These ecosites may provide good thermal cover in summer
Shrub Rich Ecosites (500 ha)	These ecosites may provide good sources of browse
Forestry Road Density (500 ha)	Forestry roads may be associated with good sources of browse, but may also cause heightened predation pressure

Proximity to Permanent Roads	Moose may avoid traffic associated with permanent roads
Proportion Agriculture	Moose may avoid agriculture and settled land

Table 2. Potential list of habitat variables for the Elk RSPF across spatial scales. This list will be refined based in part on the 1998 HSI and Chranowski thesis.

LSL Variable	Possible Association with Elk
Average Age of Forest (50 ha)	Younger forest has browse, grasses and forbs eaten by Elk. Older forest provides lateral cover to lower predation risk
Age Edge Density (5000 ha)	Food and cover. Elk like older forest in proximity to young forest (browse), as the old forest provides predator escape cover
Cover Type Edge Density (5000 ha)	This variable is related to a mixture landcover types. Certain combinations provide food and cover. May also evaluate edge between mature forest and grasslands/agriculture;
Percentage of Hardwood (50 ha)	Evaluate importance for Elk
Mean Average Hardwood Height (50 ha)	Tree height can influence lateral cover from predators and hunters
Mean Average Softwood Height (50 ha)	Height can influence lateral cover from predators and hunters
Mean Crown Closure (50 ha)	High crown closure limits browse, but provides good interception of snow
Water Edge Density (500 ha)	Evaluate importance for Elk
Proportion Open Water (500 ha)	Evaluate importance for Elk
Riparian Ecosites (500 ha)	Evaluate importance for Elk
Wet Soils Ecosites (500 ha)	These may be selected or avoided
Shrub Rich Ecosites (500 ha)	These ecosites may provide good sources of browse
Forestry Road Density (500 ha)	Forestry roads may be associated with good sources of browse, but may also cause heightened predation pressure
Proximity to Permanent Roads	Elk may avoid traffic associated with permanent roads
Proportion Agriculture	Elk may select agriculture and settled land

Definitions

AIC - The Akaike Information Criterion (AIC) is an estimator of out-of-sample prediction error and thereby relative quality of statistical models for a given set of data. Given a collection of models for the data, AIC estimates the quality of each model, relative to each of the other models. Thus, AIC provides a means for model selection. (https://en.wikipedia.org/wiki/Akaike_information_criterion)

Bayesian Logistic Regression model – In Bayesian logistic regression you begin with an initial (prior) belief about the distribution of model coefficients. This distribution is updated (posterior) by the likelihood based on data applied to the model. The priors can be absolute coefficients or simply directional beliefs (e.g., the model variable has a positive or negative effect on the outcome).

LSL - Landscape Scripting Language. LSL is a spatial modelling system consisting of a scripting language and Integrated Development Environment (IDE). LSL supports the development and testing of models that calculate habitat and landscape composition and configuration metrics, particularly over multiple spatial scales. By including an integrated reporter LSL facilitates model gaming and efficient round-trip engineering. (Kushneriuk and Rempel, 2011).

ROC – A receiver operating characteristic curve, or ROC curve, is a graphical plot that illustrates the diagnostic ability of a binary classifier system as its discrimination threshold is varied. (https://en.wikipedia.org/wiki/Receiver_operating_characteristic)

RSF/RSPF –Resource selection functions (RSFs) are a class of functions that are used in spatial ecology to assess which habitat characteristics are important to a specific population or species of animal, by assessing the a probability of that animal using a certain resource proportional to the availability of that resource in the environment (Manly et al. 2007). When absolute, rather than relative probabilities of selection are estimated, the function is termed resource selection probability function (RSPF). Clarification of key terms is provided by Lele et al. (2013). (https://en.wikipedia.org/wiki/Resource_selection_function)

K-fold Cross-validation – Cross-validation, sometimes called out-of-sample testing, is any of various similar model validation techniques for assessing how the results of a statistical analysis will generalize to an independent data set. In k-fold cross-validation, the original sample is randomly partitioned into k equal sized subsamples. Of the k subsamples, a single subsample is retained as the validation data for testing the model, and the remaining k − 1 subsamples are used as training data. (https://en.wikipedia.org/wiki/Cross-validation_(statistics)#k-fold_cross-validation)

QGIS - QGIS is a free and open-source cross-platform desktop geographic information system (GIS) application that supports viewing, editing, and analysis of geospatial data. (https://en.wikipedia.org/wiki/QGIS)

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