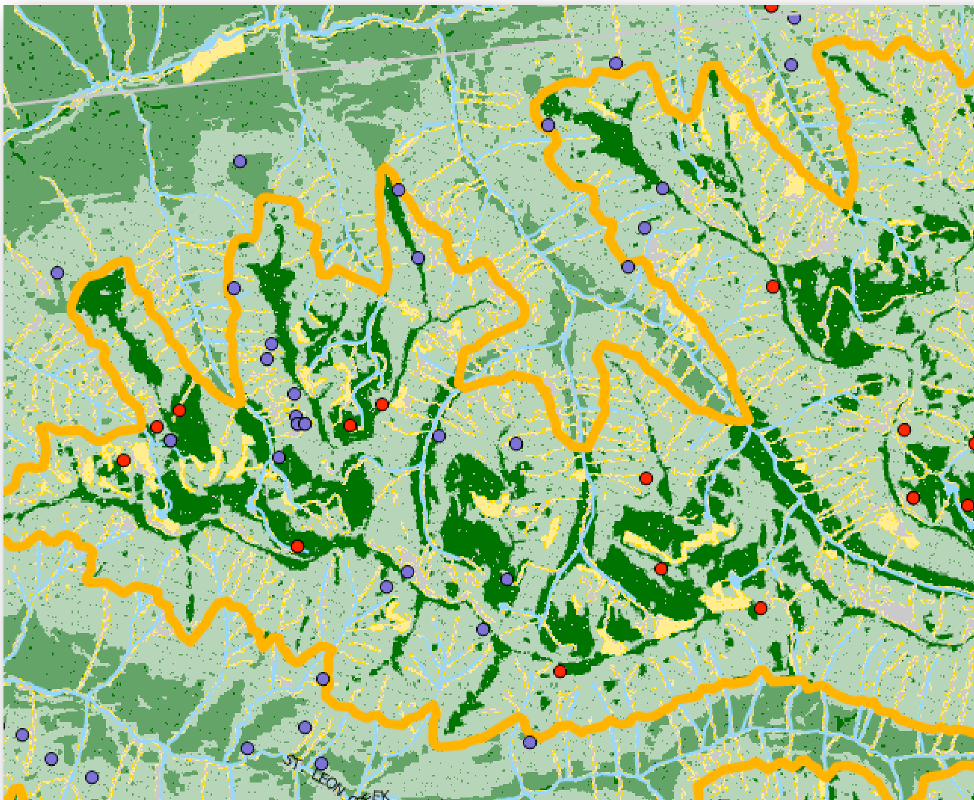
REVISED PREDICTIVE ECOSYSTEM MAP AND WILDLIFE HABITAT MODELS FOR TFL 23



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Executive Summary

The predictive ecosystem map (PEM) developed for TFL 23 is the primary coverage used in strategic, tactical and operational planning for a variety of biodiversity values. We revised both the PEM model and associated wildlife-habitat models for mountain caribou (*Rangifer tarandus*), mule deer (*Odocoileus hemionus*), elk (*Cervis elephanus*) and moose (*Alces alces*). Maps resulting from the update will be incorporated into Pope & Talbot's future biodiversity planning. The revisions included:

- characterizing in the PEM site series for several biogeoclimatic subzone variants that were previously uncharacterized (i.e., high-elevation woodland and parkland variants);
- updating the structural stage component of the PEM model to reflect the current age class distribution on the TFL; and,
- restructuring the wildlife-habitat ratings models for mountain caribou, mule deer, elk and moose into Bayesian belief networks.

These revision resulted in a PEM with a larger spatial coverage, particularly in higher-elevation forests, and a structural stage layer that better reflected current conditions. The restructuring of the wildlife-habitat models resulted in more transparent and defensible ratings, and also provided a foundation for more frequent and less expensive updates, based on new information that might be gathered on the TFL or elsewhere.

We offer the following recommendations arising from this project:

- the updated predictive ecosystem map and related wildlife-habitat suitability and capability ratings for mountain caribou, mule deer, elk and moose should be used for planning purposes related to biodiversity management on TFL 23;
- any field plot work done on TFL 23 should collect basic ecosystem information, including site series calls, which can be used in future to further improve the fit of the PEM;
- the lichen potential submodel of the mountain caribou winter habitat models should be further developed to consider variables influencing stand ventilation and other factors that are practical to model at the landscape scale;
- the PEM should next be updated when new site unit definitions are finalized for the interior wet belt ecosystems found on TFL 23. Further stratification of woodland and parkland ESSF units would further improve the PEM's utility in predicting late-winter mountain caribou habitat suitability; and,
- the submodel predicting forage capability for mule deer, elk and moose should be expanded and made more explicit, linking the abundance of key forage species to correlates of their abundance, throughout the seral trajectory of stands.

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Introduction

The predictive ecosystem map (PEM) developed for TFL 23 is the primary coverage used in strategic, tactical and operational planning for a variety of biodiversity values (e.g., ungulate habitat management, habitat supply modelling). The PEM was first developed in 2001 (Ketcheson et al. 2001) and was extensively updated in 2005 (Wilson 2005). Part of the update involved restructuring the PEM model to allow for more frequent updates as new information becomes available. Since the 2005 update, a basis for classifying site series in previously uncharacterized woodland and parkland units has becomes available (Jones et al. 2006). The wildlife habitat models that are linked to the PEM have not been updated since 2002 (Hamilton and Wilson 2002a, 2002b).

Pope & Talbot Ltd. is committed to continuous improvement of its Sustainable Forest Management Plan. As a result, we revised both the PEM model and associated wildlife-habitat models for mountain caribou (*Rangifer tarandus*), mule deer (*Odocoileus hemionus*), elk (*Cervis elephanus*) and moose (*Alces alces*). Maps resulting from the update will be incorporated into Pope & Talbot's future biodiversity planning.

Methods

Project Area

TFL23 is located in the Arrow-Boundary and southern portion of the Columbia Forest Districts and covers approximately 555,100 ha along the east and west sides of the Arrow Lakes reservoir. TFL 23 is located within the North Columbia Mountains Ecoregion and the South Columbia Mountains, Central Columbia Mountains and Northern Kootenay Mountains Ecosections. The area is characterized by steep, mountainous terrain dominated by mature forest in the Interior Douglas Fir (IDF), Interior Cedar-Hemlock (ICH), Engelmann Spruce-Subalpine Fir (ESSF), and Alpine Tundra (AT) biogeoclimatic zones (Meidinger and Pojar 1991).

Completing the Predictive Ecosystem Map for Previously Uncharacterized Site Series

The previous revision of the PEM for TFL 23 incorporated revised 1:50,000 biogeoclimatic mapping (Braumandl 2000, Wilson 2005); however, at the time there were no site series available for many of the new and existing higher-elevation variants. With the development of a PEM for Revelstoke (Jones et al. 2006), those gaps were addressed for woodland and parkland biogeoclimatic variants common to TFL 23 and Revelstoke. These new site series were applied to the TFL 23 PEM by crosswalking the Ecological Land Units on which the TFL 23 PEM was based, with the Revelstoke PEM entities legend (Table 12 in Jones et al. 2006).

New Plot Data

No new plot data were available for the TFL since the last PEM revision; as a result, the Bayesian Belief Network models were not updated.

Predictive Ecosystem Map Revision

New site series have been defined in draft form for many of the biogeclimatic subzone variants occurring on the TFL, as part of a draft update to the regional field guide. The draft site series were not used to revise the PEM because they are not yet final, and using the new system would require cross-walking previously collected data with the new site series.

The presentation of the PEM was changed to reflect the most probable site series, based on the highest posterior probability of the Bayesian model, rather than presenting three deciles that corresponded to the three most likely site series. This improved the clarity of the final ecosystem map.

Revised Wildlife-Habitat Ratings Models

The wildlife-habitat ratings models were completely revised into Bayesian Belief Network models, using Netica 3.19 (Norsys Software Corp., Vancouver, BC). This was done to make the assignment of ratings much more transparent and easy to update. Each model consisted of "nodes" and relationships that graphically described the inputs, interactions and outputs of the wildlife-habitat ratings model. Behind each node is a table that describes explicitly how variables interact to generate outputs.

Assigned ratings still followed Resources Information Standards Committee methods for wildlife-habitat ratings (Resources Inventory Committee 1999), but the Bayesian belief network method provided a more defensible and transparent way to assign wildlife-habitat ratings to individual site series and structural stages. In parallel with the PEM itself, the structure of the wildlife-habitat models will allow new information to be incorporated more quickly, ensuring that management is always based on the most robust information available.

Contrary to the PEM development, the wildlife-habitat ratings models were not designed to be updated with field data; rather, they were intended to capture the same information that is usually delivered in ratings tables, but to do so in a clearer and more transparent manner.

The model for mountain caribou was based on the lichen submodel currently under development for TFL 23. Only early and winter were considered in the modelling because in these seasons habitat is considered limited. Similarly, only winter was modelled for mule deer, elk and moose.

Results

Revised Predictive Ecosystem Map

Site series for the following biogeoclimatic subzones were updated: ATunp, ESSFdcw, ESSFvcp, ESSFwcp and ESSFwcw. The updated PEM knowledge base was delivered as a table that linked to the map of Ecological Land Units by the KEY field. The new site unit calls are provided in the field SITE_S1 (Appendix).

Mountain Caribou Wildlife-Habitat Ratings Model

Inputs for the early and late winter mountain caribou models (Figures 1 and 2) included:

- biogeoclimatic subzone variant (*BECLABEL*), based on the 1:50,000 revision (Braumandl 2000);
- site series (*SITE_S1*, Braumandl and Curran 2002);
- age class (*AGE2006*), based on 2006 forest cover mapping acquired from Pope & Talbot Ltd. Age class 8 was reclassified as age class 9 to better reflect field observations related to stand age; and,
- slope class (*Slope*), based on the Ecological Land Unit classes of the PEM (Wilson 2005).

Each input variables was summarized in order to stratify the PEM polygons in logical units for rating. All parkland and woodland variants were pooled by broad moisture regime, as were very low (e.g., rock) and non-habitat (e.g., lakes) site units. Age class in the suitability models was reclassified into structural stage based on the general struc-

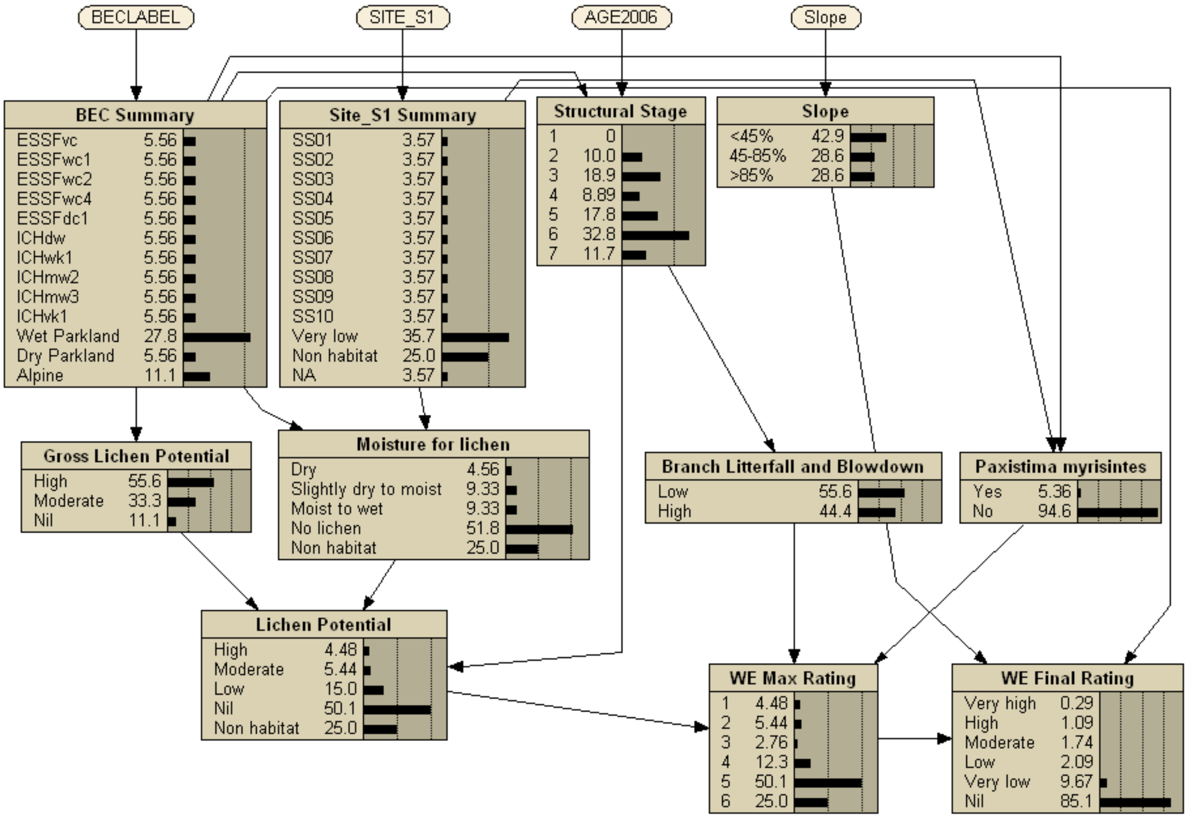

Figure 1. Early winter Bayesian belief network model for mountain caribou habitat suitability on TFL 23. The capability model was the same except that there were no nodes for *Age2006*, *Structural Stage*, *Branch Litterfall and Blowdown*, and Paxistima myrisintes (these were constant in the capability model).

tural characteristics expected at different stand ages, by biogeoclimatic zone (Province of BC 1995, BC Ministry of Environment, Lands and Parks, BC Ministry of Forests 1998). There was no age class or structural stage nodes in the capability models because capability ratings are independent of structural stage.

Lichen potential was based on the gross ability of different subzone variants to produce lichen and the moisture regime of specific site series. Additional variables in the early winter suitability model considered the expected abundance of branch litterfall (classified simply as either *high* or *low* based on structural stage), and the presence of *Paxistima myrisintes*. These three variables determined the maximum early winter rating (Figure 1), while lichen potential alone determined the maximum late winter rating (Figure 2).

The final rating was adjusted for slope (i.e., steeper slopes were stepped down in the ratings, very steep slopes were netted out). Also, habitat above the boundary between the ICH and ESSF biogeoclimatic zones was netted out of the early winter model, while habitat below the boundary was netted out of the late winter model.

The new site series definitions in parkland and woodland biogeoclimatic subzone variants extended the wildlife-habitat model for caribou into these important habitats (Figure 3, Figure 4). Because the models identified early winter caribou habitat only below the ICH-ESSF biogeoclimatic boundary and late winter habitat above the boundary, both early and late winter models could be illustrated on the same map.

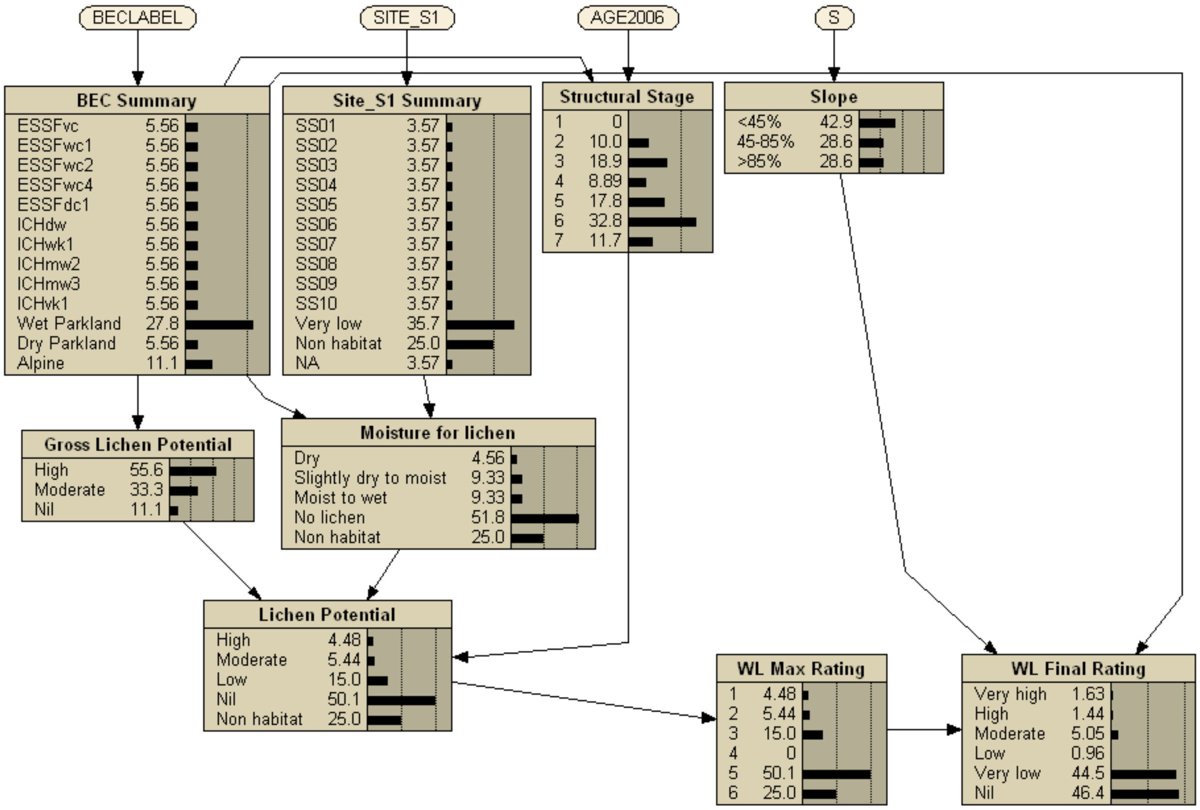

Figure 2. Late winter Bayesian belief network model for mountain caribou habitat suitability on TFL 23. The capability model was the same except that there were no nodes for *Age2006* and *Structural Stage* (these were constant in the capability model).

Mule Deer, Elk and Moose Wildlife-Habitat Ratings Models

Bayesian belief network models developed for mule deer, elk and moose had the identical structure (Figure 5) and used the same inputs as the mountain caribou early and late winter models. The major difference among models was in the definition of *Forage Capability*. Site series were assigned an overall rating for forage capability, based on a review of Braumandl and Curran (2002), as well as a review of ratings developed by Hamilton and Wilson (2002b), which were based extensively on knowledge gained during site investigations on TFL 23. Only ICH and Interior Douglas-fir (IDF) biogeoclimatic zones were considered because deer, elk and moose do not typically winter in higher-elevation zones.

Forage Capability was modified by *Structural Stage* to reflect *Forage Abundance*. In general, shrub forage was considered most abundant before the development of a forest canopy, and again in old forest conditions where a stratified canopy provides conditions suitable for vigorous shrub growth.

Forage Availability was a function of abundance, *Canopy* (closed or open), *Aspect*, and the broad moisture regime of the biogeoclimatic subzone variants. A closed canopy provided better forage availability in wet subzones because of snow interception. This feature was considered less critical in dry subzone variants and on more southerly aspects. *Forage Availability* was also influenced by species. Moose and elk are less-restricted by deep snow and are therefore able to access forage in areas where more snow is expected to accumulate (e.g., cooler aspects and less dense canopy conditions in wet subzone variants).

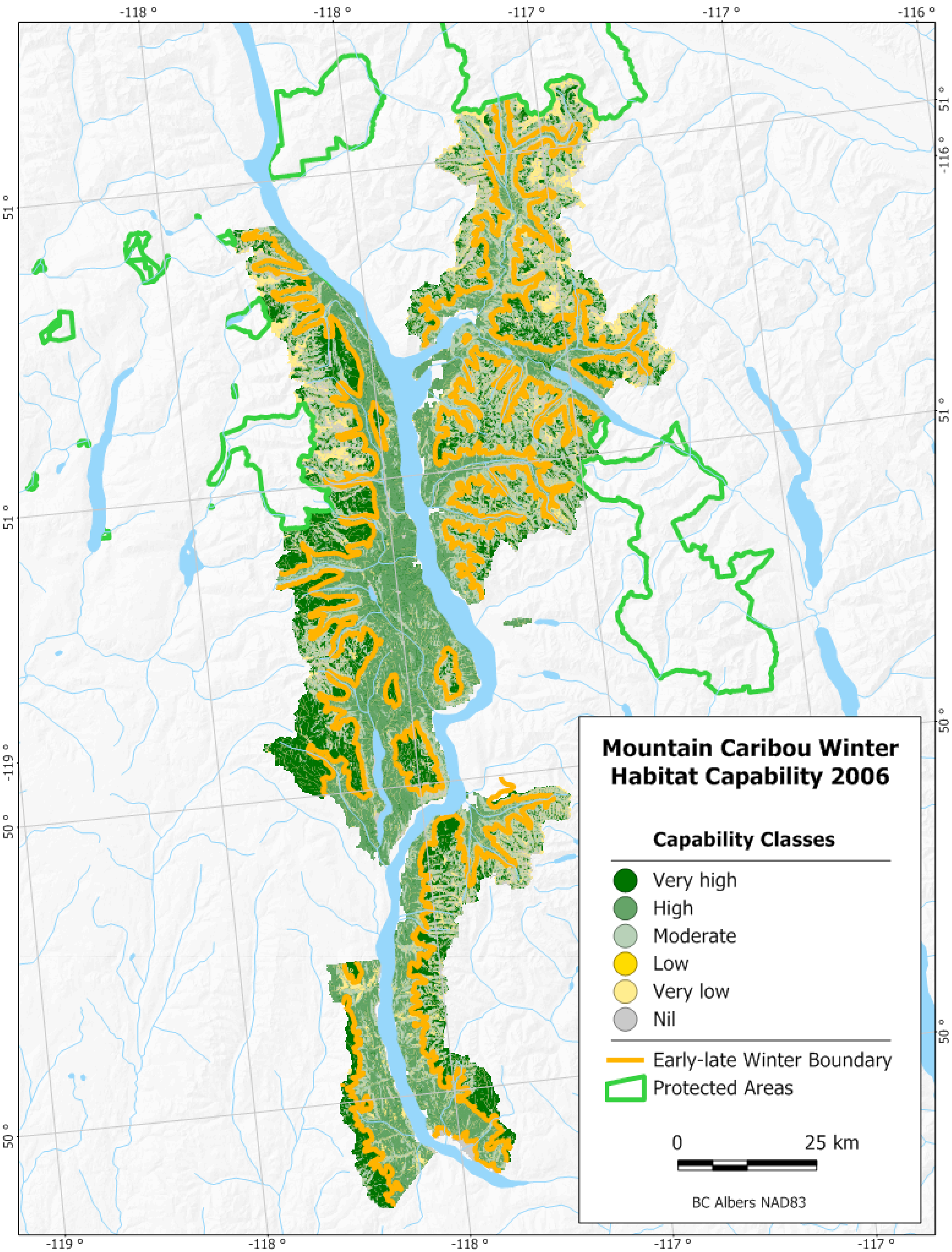

Figure 3. Winter habitat capability for mountain caribou on TFL 23. The orange line denotes the upper elevational limit of early winter habitat and the lower limit of late winter habitat.

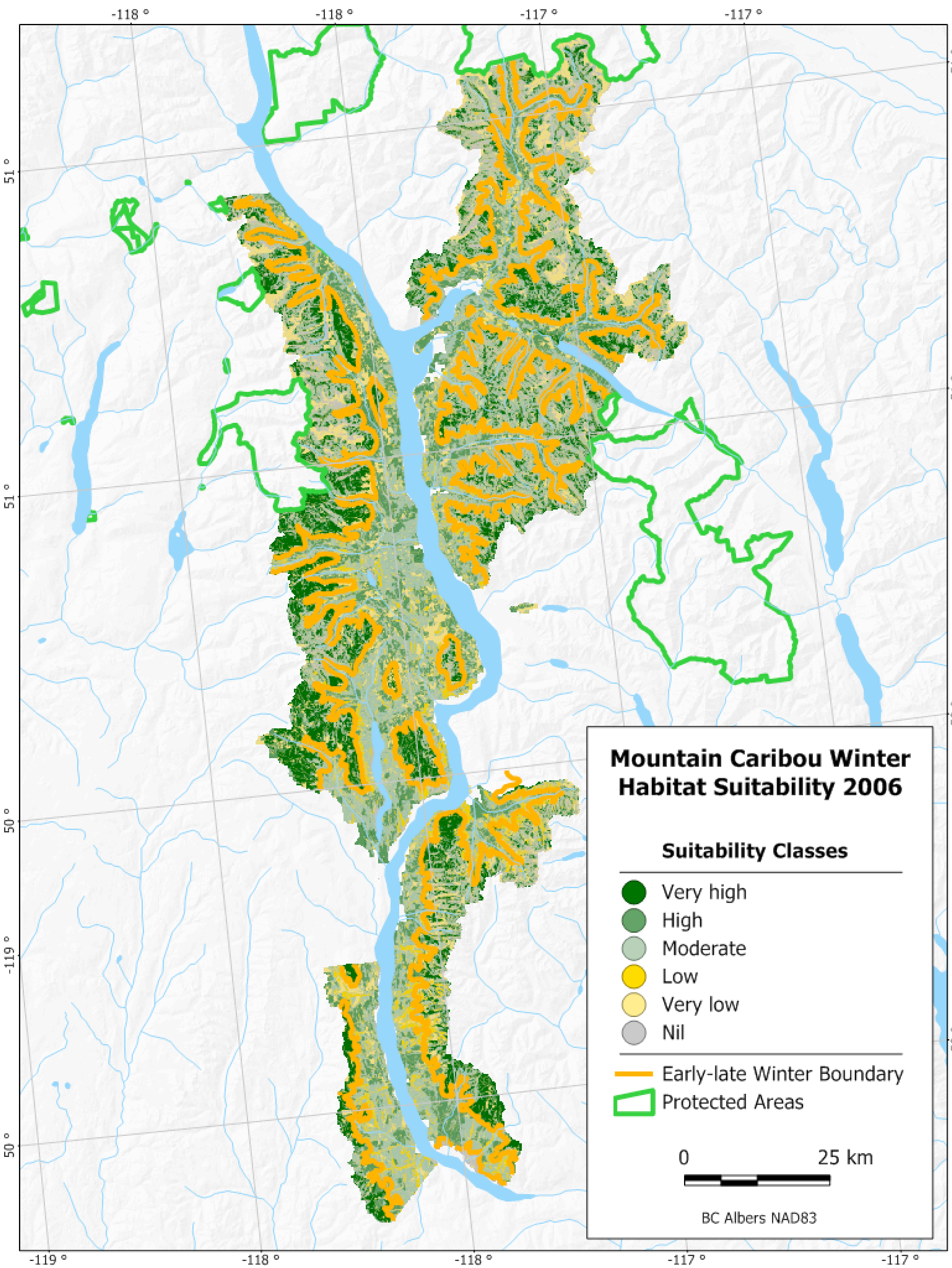

Figure 4. Winter habitat suitability for mountain caribou on TFL 23. The orange line denotes the upper elevational limit of early winter habitat and the lower limit of late winter habitat.

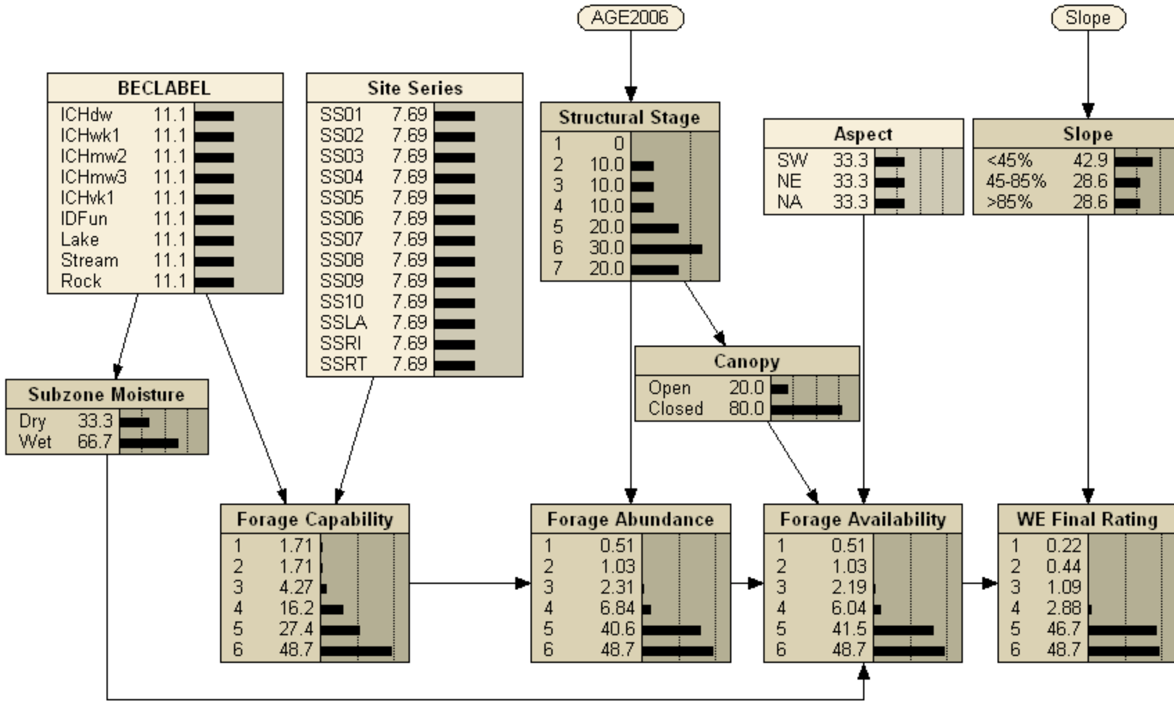

Figure 5. Bayesian belief network model for mule deer, elk and moose winter habitat suitability on TFL 23. The capability model was the same except that there were no nodes for *Age2006*, *Structural Stage* and Canopy (these were constant in the capability model).

The final rating was adjusted for the mobility of animals on steep slopes. Very steep slopes were considered inaccessible, while moderately steep slopes were considered more suited to deer than to elk or moose.

Habitat maps for winter suitability illustrated little high-quality habitat from elk (Figure 6), some areas of relatively high quality moose habitat (Figure 7), and extensive deer habitat (Figure 8).

Discussion

Revised Predictive Ecosystem Model and Map

The addition of previously uncharacterized site series extended the utility of the mountain caribou models into high elevation, forested habitat where some of the best late-winter habitat for mountain caribou occurs (Hamilton et al. 2001). However, the site descriptions were not differentiated among different woodland and parkland habitat (Jones et al. 2006), so there remains room for improvement, both within and between biogeoclimatic subzone variants.

Although new site series definition were available in draft for the wetbelt subzone variants of TFL 23, these were not used in the updated PEM. Doing so would require cross-walking previously collected data into the new site series. Although this should be done in the future, it should not be considered until the new site descriptions are stable and a final, revised guidebook is released.

The PEM continues to be best foundation available for biodiversity planning. As reported by Wilson (2005), the resolution and accuracy of the PEM is limited by the resolution and accuracy of input variables. A digital elevation model derived from 1:20,000 Terrain Resource Information Mapping (TRIM) is the basis for deriving the Ecological Land

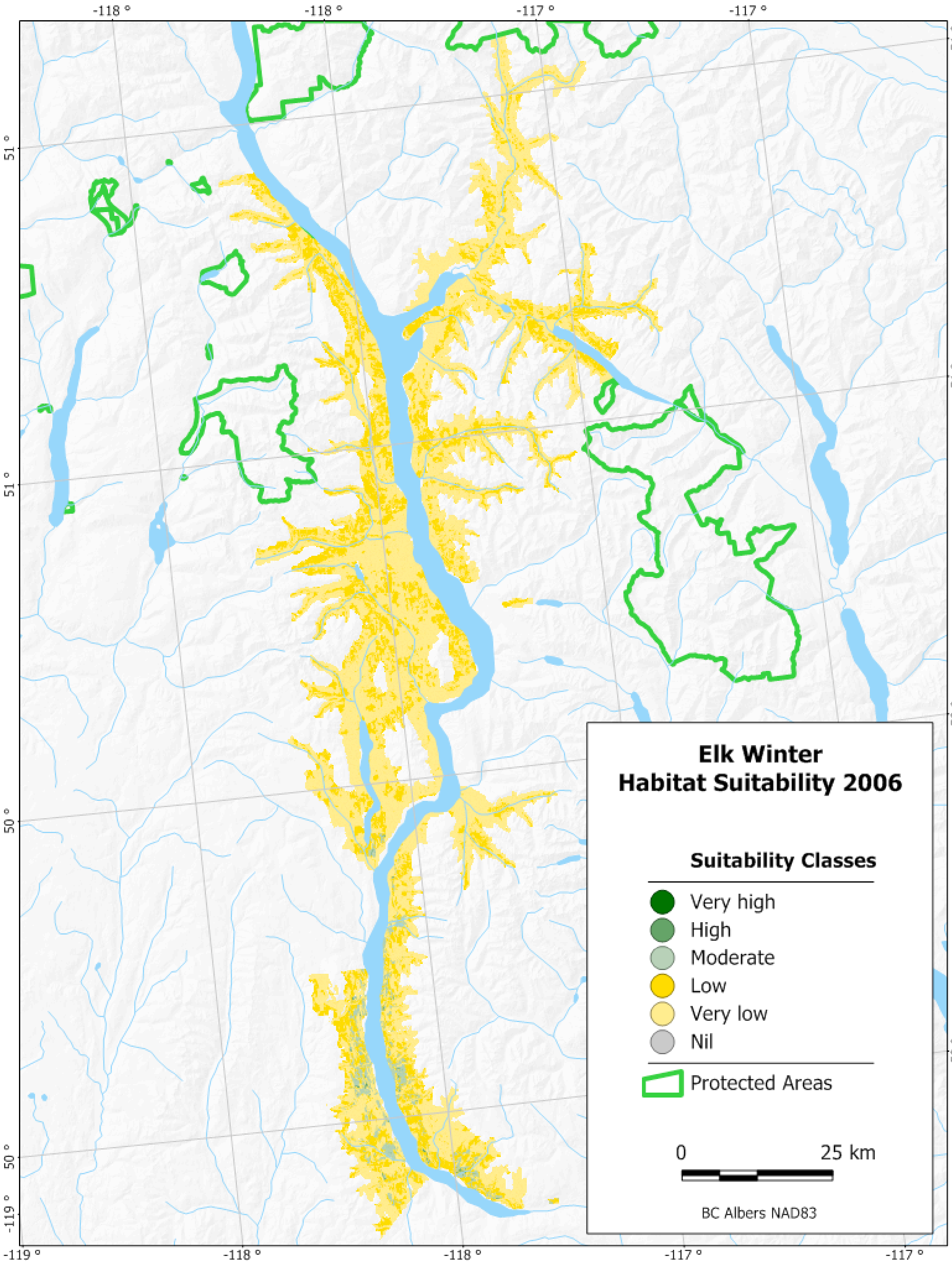

Figure 6. Winter habitat suitability for elk on TFL 23. Only the ICH and IDF biogeoclimatic zones were modelled.

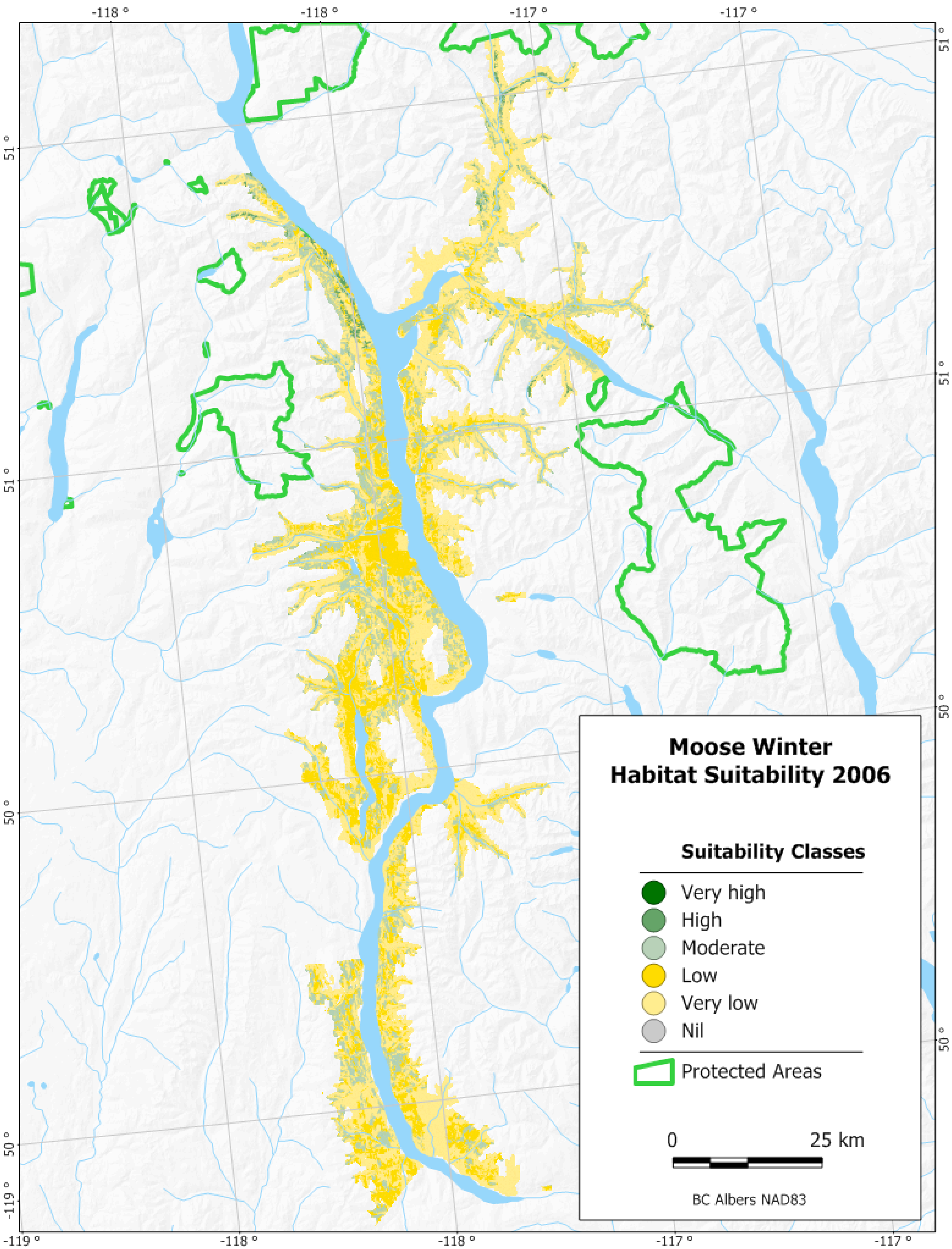

Figure 7. Winter habitat suitability for moose on TFL 23. Only the ICH and IDF biogeoclimatic zones were modelled.

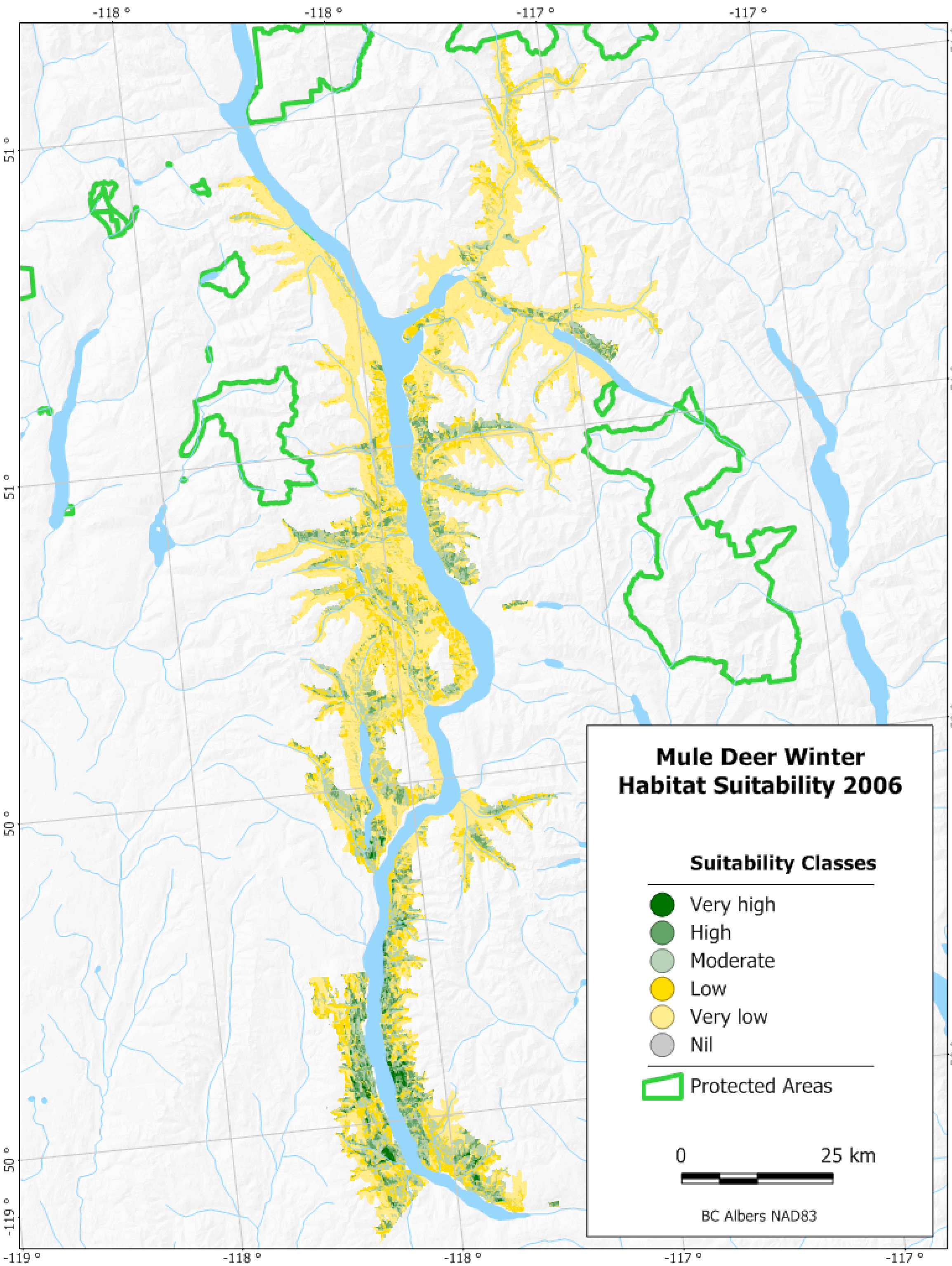

Figure 8. Winter habitat suitability for mule deer on TFL 23. Only the ICH and IDF biogeoclimatic zones were modelled.

Units on which most of the PEM input variables are based. This resolution is insufficient to resolve small landscape features that influence the ecology of sites mapped at the scale of the PEM. In addition, there are other variables that influence influence ecology that are not considered in the PEM model, primarily because landscape-scale maps of these features are unavailable.

Despite these shortcomings, the PEM provides adequate resolution for planning purposes and is inexpensive to develop and update, relative to the alternatives.

Revised Wildlife-Habitat Ratings Models and Maps

Basing the wildlife-habitat models for mountain caribou, mule deer, elk and moose on Bayesian belief networks provided a much more objective basis for assigning ratings, compared to the traditional approach of manually populating ratings tables. The manual approach suffers from a number of drawbacks:

- there is no reliable way of linking an individual rating back to the assumptions and parameters on which it was based, except for the site series and structural stage classification;
- long tables are laborious to populate and inconsistencies are inevitable due to fatigue; and,
- ratings tables are difficult to update as new information becomes available.

Note that the original intent of the wildlife-habitat ratings system was to capture expert knowledge, rather than to explicitly model relationships. In this respect, the manual approach is entirely justified. However, over time it has become evident that the ratings methodology must become more rigorous, transparent and repeatable if it is to be used to map wildlife habitat in relation to ecosystem maps.

The Bayesian belief network models were still based on expert knowledge; however, they had the advantage of explicitly documenting the interactions among variables that were considered in developing the ratings. There is still room to improve the models; for example, forage capability in the deer, elk and moose models was still based entirely on an expert interpretation site series descriptions. This could be made more explicit by incorporating directly into models variables related to key forage species and correlates of their abundance.

For the mountain caribou winter habitat models, a better predictor of lichen potential is required. In this project we used only a rudimentary submodel to predict lichen, which was based on the estimated potential of biogeoclimatic subzone variants to generate lichen, modified by the moisture regime of different site series, and then estimated by structural stage. Lichen abundance is known to be strongly related to stand ventilation, which is a function of stand structure and terrain variables (e.g., Campbell and Coxson 2001, Goward and Campbell 2005). These variables need to be considered in a more robust submodel of potential arboreal lichen abundance. Field verification should also be a component of further model development.

Management Recommendations

We offer the following management recommendations arising from this project:

- the updated predictive ecosystem map and related wildlife-habitat suitability and capability ratings for mountain caribou, mule deer, elk and moose should be used for planning purposes related to biodiversity management on TFL 23;

- any field plot work done on TFL 23 should collect basic ecosystem information, including site series calls, which can be used in future to further improve the fit of the PEM;

- the lichen potential submodel of the mountain caribou winter habitat models should be further developed to consider variables influencing stand ventilation and other factors that are practical to model at the landscape scale;

- the PEM should next be updated when new site unit definitions are finalized for the interior wet belt ecosystems found on TFL 23. Further stratification of woodland and parkland ESSF units would further improve the PEM's utility in predicting late-winter mountain caribou habitat suitability; and,

- the submodel predicting forage capability for mule deer, elk and moose should be expanded and made more explicit, linking the abundance of key forage species to correlates of their abundance, throughout the seral trajectory of stands.

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Appendix

Metadata of digital data delivered with this report:

Name of archive: TFL_23_PEM_update_2007

Description: Update of TFL 23 predictive ecosystem map and related ungulate wildlife-habitat models.

Compiled by: S. F. Wilson, EcoLogic Research, 406 Hemlock Ave., Gabriola BC V0R 1X1, steven.wilson@ecologicresearch.ca

Date: 31 March 2007

Files:

Metadata.txt - this file

\BBNs - Bayesian belief network models, in *Netica* format, limited function software available from www.norsys.com

\BBNs\MRATA_WE_*_*.neta - mountain caribou early winter capability and suitability models

\BBNs\MRATA_WL_*_*.neta - mountain caribou late winter capability and suitability models

\BBNs\MALAL_W_*_*.neta - moose winter capability and suitability models

\BBNs\MCEEN_W_*_*.neta - elk winter capability and suitability models

\BBNs\MODHE_W_*_*. neta - mule deer capability and suitability models

\Maps - GIF images of e-sized capability and suitability maps, following the naming conventions above

PEM_WHR_2007.zip - archive of ESRI shapefile of TFL 23 with new site series calls and wildlife-habitat ratings

PEM_revised_table_Mar_2007.csv - lookup table of new site series linked to Ecological Land Unit code

Wilson and Hamilton. 2007. Revised predictive ecosystem map and wildlife-habitat models for TFL 23. pdf - report