**WILDLIFE INFOMETRICS INC.**

# MODELING

# Reduction and Recalibration of Bayesian Models Used to Assess Mountain Caribou Winter Ranges in British Columbia

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# ABSTRACT

Decisions about habitat conservation within individual herd areas of threatened mountain caribou in British Columbia will be informed by a spatial analysis of seasonal range values. To support that analysis we used standard modeling methods to reduce and simplify previously constructed habitat supply models for early- and late-winter ranges. These reduced models were then applied across the range of mountain caribou to predict current range condition in each herd area.

## ACKNOWLEDGEMENTS

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# INTRODUCTION

The Mountain Caribou Science Team (MCST) developed habitat supply models for seasonal ranges used by all herds of mountain caribou (Rangifer tarandus caribou) that are at risk of becoming locally extirpated in British Columbia (McNay et al. 2006, McNay 2006). We document methods for reduction and recalibration of the Bayesian models with the goal to make the models simpler and more efficient to implement. For the purposes of informing decisions about recovery planning, the Species At Risk Coordination Office (SARCO) restricted this work to those ranges considered most limiting to mountain caribou (i.e., early- and late-winter ranges). Outcomes of this work will lead to a quantitative spatial analysis of range values as a means to enhance the transparency of range conservation targets (i.e., decisions about targets will be directly informed by the best available information about current range conditions in each herd area).

Our specific objectives were to: 1) modify current models of early- and late-winter ranges (Appendix A) by eliminating redundant input data through model sensitivity analyses and by simplifying resulting model structure through "absorption" of summary nodes and 2) construct revised winter range maps for each of the herd areas by reapplying the new reduced models. SARCO further requested that range values be expressed as probable abundance of seasonal forage (i.e., seasonal forage usefulness (SFU)) rather than probable density of caribou. SFU as the resultant implied disregarding components of previous modeling concerning potential disturbance to caribou from anthropogenic activities.

# EARLY WINTER

In general, SFU during early winter was considered to be a function of abundance of available forage and movement costs (Appendix A). The intersection of the two summary nodes was modified when evaluating locations outside current herd areas with a weighted-distance cost surface (i.e., habitat value varied with movement cost and the distance from the current, known herd area). Movement costs were estimated as a function of forest age, terrain steepness, landscape permeability, and forest inventory type group. Abundance of available forage was estimated as a function of tree species forage group, macro-climate snowfall, macro-climate shrubs, soil moisture regime, landscape vegetation potential, forest canopy closure, macro-climate landscape openness, wind potential, and tree crown structure[1].

The original model of early winter range (McNay 2006; Appendix A) was simplified using the following methods[2]:

- Disconnected and deleted the carrying capacity (CC) output node from influencing SFU. This step removed the influence of landscape carrying capacity

[1] For a more complete description of the listed input variables, refer to McNay et al. 2006 and McNay 2006.
[2] Prior to conducting this simplification we amended conditional probability tables in two cases. (1) A coding error was noted in the AAF node in which the pattern of decreasing forage availability with increasing snow accumulation was not adhered to in the state of deepest snow (i.e., >2.5). This pattern in the CPT was amended to a consistent pattern (Appendix B). (2) SARCO reconsidered the strength at which terrain steepness (TS) influenced movement cost and so the conditional probabilities for the movement cost node were adjusted to soften this effect (Appendix C).

(#/1000 kms) and disturbance factors (i.e., from helicopters (heli-skiing), cat-skiing, snowmobiles);
- Disconnected and deleted modifiers based on weighted distances from current herd areas (WD_MC, CIHA);
- Tested sensitivity of findings (i.e., SFU results) to all remaining inputs (n=13) where results are displayed in (Table 1);
- On the basis of sensitivity results, deleted redundant inputs:
  - Inventory type group (ITG) from Forest Permeability (FP);
  - Macro-climate landscape openness (MCLO) and wind potential (WP) from Windblown sites (WS);
  - Interception species group (ISG) from snow interception potential (SIP);
  - Shade/snow interception (SSI) from snow interception potential (SIP) and from terrestrial lichen abundance (TLRA); and
  - Ice and bare sites (IBS) from terrestrial lichen abundance (TLRA);
- Modified movement cost network:
  - Absorbed[3] forest permeability (FP); and
  - Absorbed permeability (P);
- Modified palatable shrub abundance network;
  - Absorbed shrub potential (SP);
- Modified snow accumulation net
  - Absorbed windblown sites (WS); and
  - Absorbed snow interception potential (SIP); and
- Modified abundance of available forage net:
  - Absorbed bryoria abundance (BA);
  - Absorbed palatable shrub abundance (PSA);
  - Absorbed terrestrial lichen relative abundance TLRA); and
  - Absorbed snow accumulation (SA).

Results of the sensitivity analysis indicated that most of the model output was determined from seven of the original inputs: moisture regime (MR), macro-climate snowfall (MCSF), macro-climate shrubs (MCS), tree species group (TSG), forest age effects (FAE), terrain steepness (TS) and landcover permeability (LCP). With the exception of removing the influence of disturbance factors, the elimination of six redundant inputs and absorption of nine summary nodes was not expected to have significantly influenced the inherent function of the model or the results. The early winter model was then depicted in its reduced format (Figure 1).

## LATE WINTER

In general, the late-winter range model had some similarities with the early-winter range model; most notably the estimate of movement cost was the same and the overall

[3] Node absorption is a net transform which removes nodes from a Bayes net or decision net, and makes any necessary adjustments to the resulting net, so that any inference done with it yields the same results as before the nodes were removed (except of course you can't interact with the removed nodes). The local representation is changed, but the global relationships are not changed (as is the case with link reversal). In probability theory this is sometimes loosely called "summing out a variable". It leaves the full joint probability distribution of the remaining nodes unchanged (Norsys 1997).

Table 1. Sensitivity of the early-winter findings node (seasonal forage abundance) to inputs that determine its outcome state.

| Input Factor | Variance Reduction | Cumulative % of Total Variance Reduction | Mutual Information | Variance in Beliefs |
|---|---|---|---|---|
| LCP | 0.00405 | 34.43% | 0.16407 | 0.028883 |
| TS | 0.003778 | 66.55% | 0.15299 | 0.027238 |
| FAE | 0.002125 | 84.62% | 0.063 | 0.007327 |
| MCSF | 0.0008541 | 91.88% | 0.02831 | 0.003643 |
| TSG | 0.0006952 | 97.79% | 0.01876 | 0.002627 |
| MCS | 0.0001262 | 98.86% | 0.00324 | 0.000442 |
| MR | 0.0001017 | 99.73% | 0.00266 | 0.000373 |
| ISG | 1.33E-05 | 99.84% | 0.00038 | 5.57E-05 |
| SSI | 6.02E-06 | 99.89% | 0.00031 | 0.000036 |
| ITG | 5.38E-06 | 99.94% | 0.0003 | 6.95E-05 |
| MCLO | 4.61E-06 | 99.97% | 0.00016 | 2.25E-05 |
| WP | 2.28E-06 | 99.99% | 0.00008 | 1.11E-05 |
| IBS | 6.66E-07 | 100.00% | 0.00006 | 1.9E-06 |

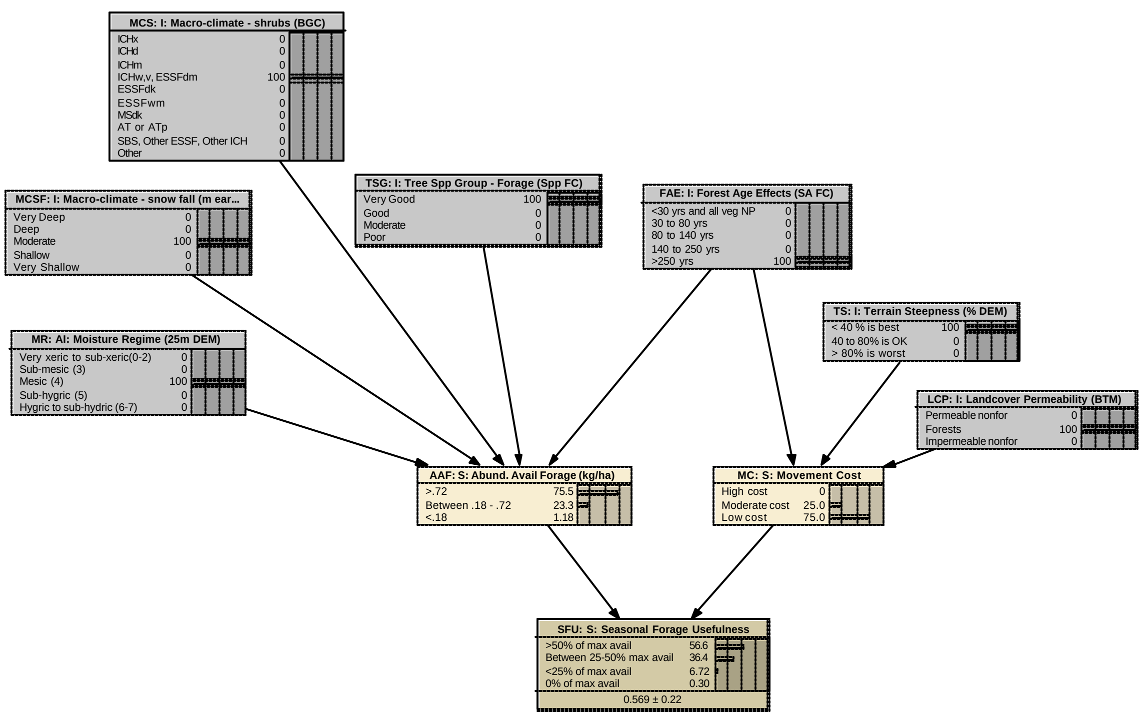


Figure 1. Reduced Bayesian belief network used to predict forage usefulness for mountain caribou during early winter.

estimate of seasonal forage usefulness was similarly based on movement cost and the abundance of available forage. The estimate of forage in this season however was related only to the effects of input variables (forest age, tree species, stand ventilation, and macro-climate lichens) on the estimated abundance of Bryoria.

The original model of early winter range (McNay 2006; Appendix A) was simplified using the following methods:

- Disconnected and deleted the carrying capacity (CC) output node from influencing the seasonal forage usefulness output node (SFU). This step removed the influence of landscape carrying capacity (#/1000 kms) and combined expected displacement factors (i.e., from helicopters (heli-skiing), cat-skiing, and snowmobiles);
- Disconnected and deleted modifiers based on weighted distances from current herd areas (WD_MC, CIHA);
- Tested sensitivity of findings (SFU) to all remaining inputs (n=7) where results are displayed in (Table 2);
- Deleted redundant input layers:
    - Stand Ventilation (SV) from Bryoria Distribution in Canopy (BD); and,
    - Inventory type group (ITG) from Forest Permeability (FP);
- Modified movement cost net:
    - Absorbed forest permeability (FP); and
    - Absorbed permeability (P); and
- Modified abundance of available forage net
    - Absorbed Bryoria abundance (BA); and
    - Absorbed Bryoria Distribution in Canopy (BD);

Results of the sensitivity analysis indicated that most of the model output was determined from five of the original inputs: tree species group (TSG), forest age effects (FAE), macro-climate lichens (MCL), terrain steepness (TS) and landcover permeability (LCP). With the exception of removing the influence of disturbance factors, the elimination of two redundant inputs and absorption of four summary nodes was not expected to have significantly influenced the inherent function of the model or the results. The late winter model was then depicted in its reduced format (Figure 2).

Table 2. Sensitivity of late-winter findings node (seasonal forage abundance) to inputs that determine its outcome state.

| Input Factor | Variance Reduction | Cumulative % of Total Variance Reduction | Mutual Information | Variance in Beliefs |
|---|---|---|---|---|
| LCP | 0.006918 | 36.61% | 0.19358 | 0.026229 |
| TS | 0.006341 | 70.16% | 0.18316 | 0.025542 |
| MCAL | 0.002716 | 84.53% | 0.10154 | 0.012278 |
| FAE | 0.002596 | 98.27% | 0.08244 | 0.00773 |
| TSG | 0.000196 | 99.31% | 0.00408 | 0.000624 |
| SV | 0.000113 | 99.91% | 0.00357 | 0.000512 |
| ITG | 1.78E-05 | 100.00% | 0.00049 | 8.52E-05 |

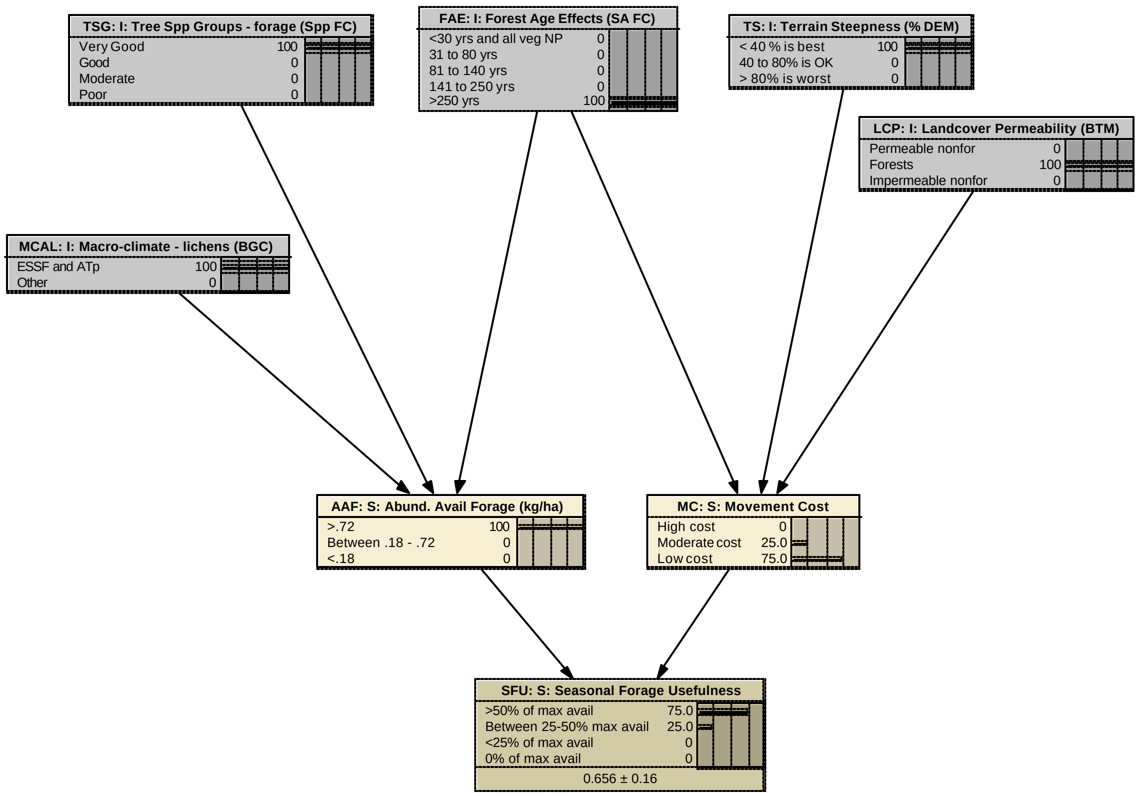


Figure 2. Reduced Bayesian belief network used to predict forage usefulness for mountain caribou during late winter.

## RESULTING INPUT LAYERS

After simplification and reduction of the two seasonal models, inputs were limited to eight different nodes based on four data types as follows:

1. Biogeoclimatic subzone (MCAL stands for Macro-climate Lichens) – was used as a factor to indicate the abundance of palatable shrubs and, in a limited number of cases, terrestrial lichen. Subzones were stratified into two states as indicated in the network (Figure 2).
2. Biogeoclimatic subzone (MCSF stands for Macro-Climate Snowfall) – was used as a factor to indicate the relative amount of snowfall expected in the region. Subzones were stratified into five states as indicated in the network (Figure 1) where the states were determined based on the script in Text Box Macro-Climate Snowfall.
3. Biogeclimatic subzone (MCS stands for Macro-Climate Shurbs) – was used as a factor to indicate the abundance of palatable shrubs and terrestrial lichen. Subzones were stratified into 10 states as indicated in the network (Figure 2).
4. Forest cover (FAE stands for Forest Age Effects) – was used as a factor to indicate forest permeability (ease of movement), snow interception potential, and abundance of bryoria. Age of forest stands was stratified in to five states as indicated in the network (Figure 1).

5. Forest cover (TSG stands for Tree Species Group – Forage) – was used as a factor to indicate relative ability of different species to accumulate arboreal forage lichens. Tree species codes were used to create the four relative states in the network (Figure 1) using the script in Text Box Tree Species Group – Forage.
6. Baseline Thematic Map (LCP stands for landcover permeability) – was used as a factor to indicate relative ease of movement for caribou. Data were stratified into 3 states expressed in Figure 1 and determined according to the script in Text Box Landcover Permeability.
7. Digital elevation model (TS stands for terrain steepness) – was used as a factor to indicate the effect slope has on movement cost. Slope from the DEM was stratified into three states as indicated in the network (Figure 1).
8. Digital elevation model (MR stands for moisture regime) – was used as a factor to indicate relative soil moisture and its effect on terrestrial lichens, potential for forage shrubs, and windblown sites. Moisture regieme was stratified into five states as indicated in the network (Figure 1).

## RESULTING INPUT LAYERS

The reduced seasonal models were applied to the range of mountain caribou, raster data collected for the value of SFU, and digital information was transferred to the MCST for further analysis.

## REFERENCES

McNay, R. S. 2006. Preliminary calibration of a habitat supply model for mountain caribou in British Columbia: Interim Progress Report. Wildlife Infometrics Inc., Mackenzie, BC. Wildlife Infometrics Inc. Report No. 190. 63pp

McNay, R.S., C. Apps, S. Wilson, T. Kinley, D. O'Brien, and G. Sutherland. 2006. Use of habitat supply models to establish herd-based recovery targets for threatened mountain caribou in British Columbia: Year 2 Progress Report. Wildlife Infometrics Inc., Mackenzie, BC. Wildlife Infometrics Inc. Report No. 180. 92pp.

Norsys Software Corp. 1997. Netica application users' guide. Norsys Software Corp., Vancouver, British Columbia, Canada. 91pp.

# APPENDIX A. BAYESIAN BELIEF NETWORKS

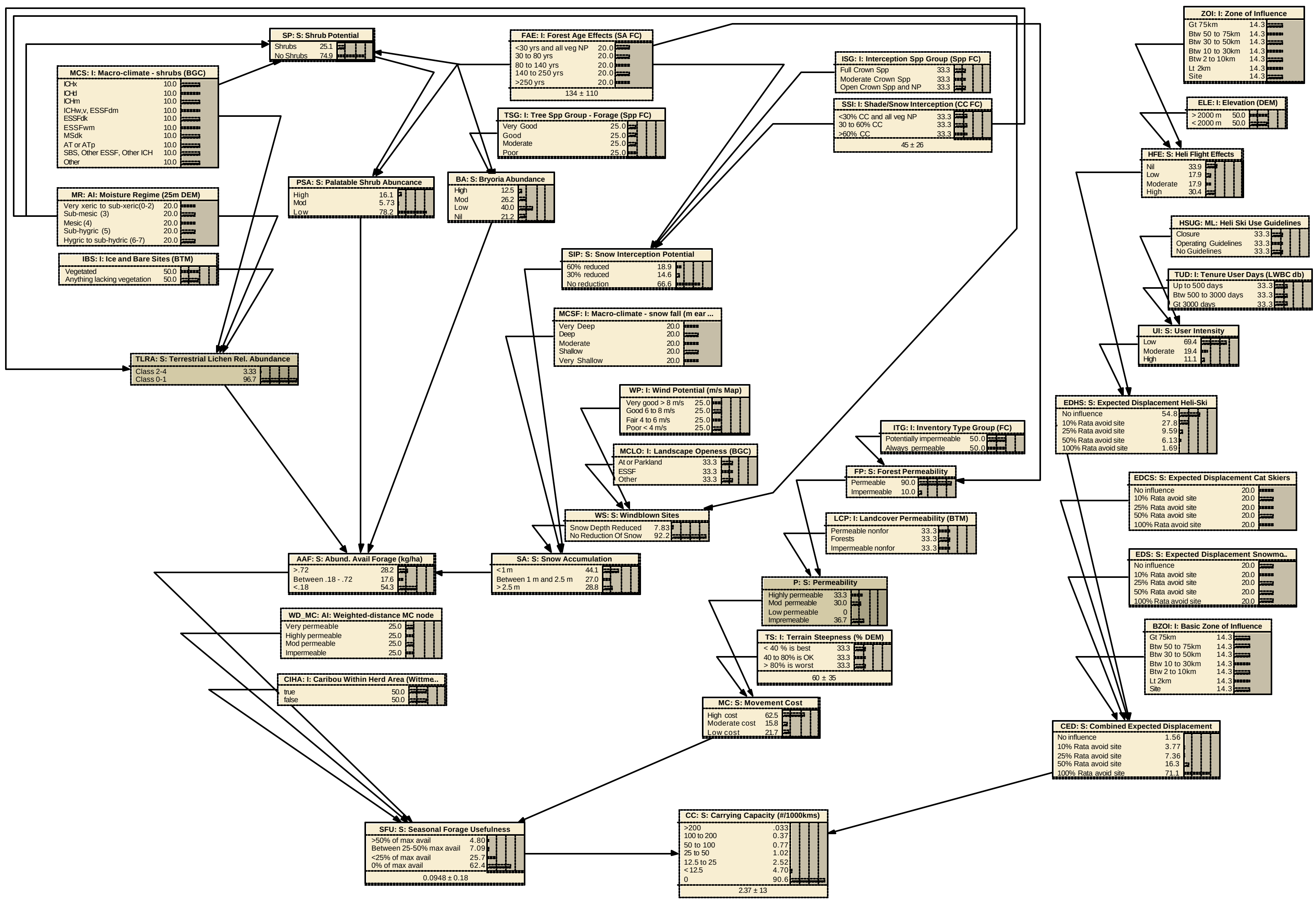


Figure 3. A Bayesian belief network used to predict the carrying capacity of mountain caribou range (prior to accounting for the potential effects of predation) during early winter in southeastern British Columbia.

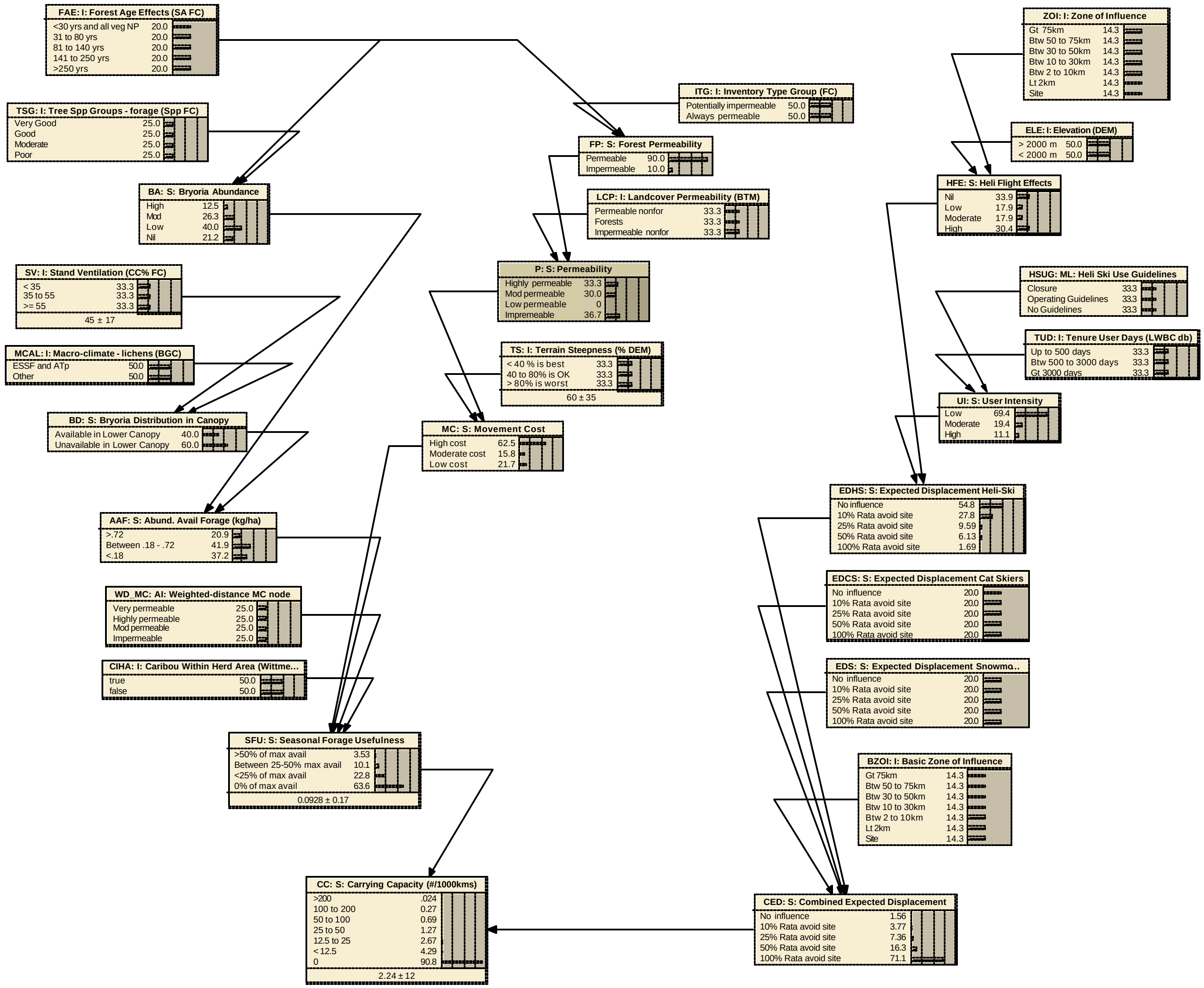


Figure 4. A Bayesian belief network used to predict the carrying capacity of mountain caribou range (prior to accounting for the potential effects of predation) during late winter in southeastern British Columbia.

# APPENDIX B. AMENDED CONDITIONAL PROBABILITIES FOR THE ABUNDANCE OF AVAILABLE FORAGE

| Input Nodes | | | | AAF Conditional Probabilities | | |
|---|---|---|---|---|---|---|
| SA | BA | PS | TL | >.72 | 18-.72 | <.18 |
| <1m | High | High | cl2-4 | 100 | 0 | 0 |
| <1m | High | High | cl0-1 | 100 | 0 | 0 |
| <1m | High | Mod | cl2-4 | 100 | 0 | 0 |
| <1m | High | Mod | cl0-1 | 100 | 0 | 0 |
| <1m | High | Low | cl2-4 | 100 | 0 | 0 |
| <1m | High | Low | cl0-1 | 100 | 0 | 0 |
| <1m | mod | High | cl2-4 | 100 | 0 | 0 |
| <1m | mod | High | cl0-1 | 100 | 0 | 0 |
| <1m | mod | Mod | cl2-4 | 75 | 25 | 0 |
| <1m | mod | Mod | cl0-1 | 75 | 25 | 0 |
| <1m | mod | Low | cl2-4 | 50 | 50 | 0 |
| <1m | mod | Low | cl0-1 | 50 | 25 | 25 |
| <1m | low | High | cl2-4 | 50 | 50 | 0 |
| <1m | low | High | cl0-1 | 25 | 50 | 25 |
| <1m | low | Mod | cl2-4 | 25 | 50 | 25 |
| <1m | low | Mod | cl0-1 | 25 | 25 | 50 |
| <1m | low | Low | cl2-4 | 0 | 50 | 50 |
| <1m | low | Low | cl0-1 | 0 | 0 | 100 |
| <1m | Nil | High | cl2-4 | 0 | 75 | 25 |
| <1m | Nil | High | cl0-1 | 0 | 50 | 50 |
| <1m | Nil | Mod | cl2-4 | 0 | 50 | 50 |
| <1m | Nil | Mod | cl0-1 | 0 | 25 | 75 |
| <1m | Nil | Low | cl2-4 | 0 | 50 | 50 |
| <1m | Nil | Low | cl0-1 | 0 | 0 | 100 |
| btwn1-2.5 | High | High | cl2-4 | 50 | 50 | 0 |
| btwn1-2.5 | High | High | cl0-1 | 50 | 50 | 0 |
| btwn1-2.5 | High | Mod | cl2-4 | 25 | 75 | 0 |
| btwn1-2.5 | High | Mod | cl0-1 | 25 | 75 | 0 |
| btwn1-2.5 | High | Low | cl2-4 | 0 | 100 | 0 |
| btwn1-2.5 | High | Low | cl0-1 | 0 | 100 | 0 |
| btwn1-2.5 | mod | High | cl2-4 | 50 | 50 | 0 |
| btwn1-2.5 | mod | High | cl0-1 | 50 | 50 | 0 |
| btw n1-2.5 | mod | Mod | cl2-4 | 25 | 75 | 0 |
| btwn1-2.5 | mod | Mod | cl0-1 | 25 | 75 | 0 |
| btwn1-2.5 | mod | Low | cl2-4 | 0 | 50 | 50 |
| btwn1-2.5 | mod | Low | cl0-1 | 0 | 50 | 50 |
| btwn1-2.5 | low | High | cl2-4 | 50 | 50 | 0 |
| btwn1-2.5 | low | High | cl0-1 | 50 | 50 | 0 |
| btwn1-2.5 | low | Mod | cl2-4 | 25 | 75 | 0 |
| btwn1-2.5 | low | Mod | cl0-1 | 25 | 75 | 0 |
| btwn1-2.5 | low | Low | cl2-4 | 0 | 50 | 50 |
| btwn1-2.5 | low | Low | cl0-1 | 0 | 50 | 50 |
| btwn1-2.5 | Nil | High | cl2-4 | 0 | 75 | 25 |
| btwn1-2.5 | Nil | High | cl0-1 | 0 | 50 | 50 |
| btwn1-2.5 | Nil | Mod | cl2-4 | 0 | 50 | 50 |
| btwn1-2.5 | Nil | Mod | cl0-1 | 0 | 25 | 75 |
| btwn1-2.5 | Nil | Low | cl2-4 | 0 | 50 | 50 |
| btwn1-2.5 | Nil | Low | cl0-1 | 0 | 0 | 100 |
| >2.5 | High | High | cl2-4 | 0 | 100 | 0 |
| >2.5 | High | High | cl0-1 | 0 | 75 | 25 |
| >2.5 | High | Mod | cl2-4 | 0 | 75 | 25 |
| >2.5 | High | Mod | cl0-1 | 0 | 50 | 50 |
| >2.5 | High | Low | cl2-4 | 0 | 50 | 50 |
| >2.5 | High | Low | cl0-1 | 0 | 25 | 75 |
| >2.5 | mod | High | cl2-4 | 0 | 75 | 25 |
| >2.5 | mod | High | cl0-1 | 0 | 50 | 50 |
| >2.5 | mod | Mod | cl2-4 | 0 | 50 | 50 |
| >2.5 | mod | Mod | cl0-1 | 0 | 25 | 75 |
| >2.5 | mod | Low | cl2-4 | 0 | 25 | 75 |
| >2.5 | mod | Low | cl0-1 | 0 | 0 | 100 |
| >2.5 | low | High | cl2-4 | 0 | 50 | 50 |
| >2.5 | low | High | cl0-1 | 0 | 25 | 75 |
| >2.5 | low | Mod | cl2-4 | 0 | 25 | 75 |
| >2.5 | low | Mod | cl0-1 | 0 | 0 | 100 |
| >2.5 | low | Low | cl2-4 | 0 | 25 | 75 |
| >2.5 | low | Low | cl0-1 | 0 | 0 | 100 |
| >2.5 | Nil | High | cl2-4 | 0 | 50 | 50 |
| >2.5 | Nil | High | cl0-1 | 0 | 25 | 75 |
| >2.5 | Nil | Mod | cl2-4 | 0 | 25 | 75 |
| >2.5 | Nil | Mod | cl0-1 | 0 | 0 | 100 |
| >2.5 | Nil | Low | cl2-4 | 0 | 25 | 75 |
| >2.5 | Nil | Low | cl0-1 | 0 | 0 | 100 |

# APPENDIX C. AMENDED CONDITIONAL PROBABILITIES FOR MOVEMENT COST

| Input nodes | | MC Conditional probabilities | | |
|---|---|---|---|---|
| **Permeability** | **Terrain steepness** | **High cost** | **Moderate cost** | **Low cost** |
| High | < 40% is best | 0 | 0 | 100 |
| High | 40 to 80% is OK | 0 | 25 | 75 |
| High | > 80% is worst | 100 | 0 | 0 |
| Moderate | < 40% is best | 0 | 25 | 75 |
| Moderate | 40 to 80% is OK | 25 | 75 | 0 |
| Moderate | > 80% is worst | 100 | 0 | 0 |
| Low | < 40% is best | 25 | 75 | 0 |
| Low | 40 to 80% is OK | 75 | 25 | 0 |
| Low | > 80% is worst | 100 | 0 | 0 |
| Impermeable | < 40% is best | 100 | 0 | 0 |
| Impermeable | 40 to 80% is OK | 100 | 0 | 0 |
| Impermeable | > 80% is worst | 100 | 0 | 0 |

# APPENDIX D. EXAMPLE SCRIPTS TO PREPARE SPATIAL INPUT DATA

**Landcover Permeability**

```
Select Case !PLU_LABEL                'assign value to LCP landcover permeability node
   Case "FO", "FY", "LOGS"
     strPermeability_State = "#1"      'forests, set to ordinal state 1
   Case "HWY", "LAKE", "WSAL"
     strPermeability_State = "#2"      'lakes, 4-lane highways, and salt water, set to ordinal state 2
   Case "AGR", "AGMX", "ALP", "AVA", "BARE", "BURN", "EST", "ICE", "LOG", "MINE", _
       "NONE", "RANG", "REC", "RIV", "SHRB", "TRAN", "URB", "WET", "WFRE"
     strPermeability_State = "#0"      'all other PLU classes, set to ordinal state 0
   Case Else
     strPermeability_State = "*"  'missing or unexpected value
     booMissingDataFlag = True    'set missing data flag
 End Select
```

**Tree Species Group - Forage**

```
'Assign state value to the TSG forage tree species group node by tallying
'the total amount of spruce and combination of subalpine fir, whitebark pine,
'and douglas fir in all six stand species composition fields in FIP.
'NOTE:  The modeling criteria state that for good and moderate arboreal lichen
'      capability spruce must sometimes be be the leading species with OVER 50%
'      of the stand composition.  Because the model considers spruce to be an
'      amalgamation of all spruce species, leading species is no longer a
'      requirement since an amalgamation of over 50% stand composition from all
'      spruce species will automatically make it the lead species since no
'      other species, or combination of species can exceed the maximum 49% of
'      the stand composition not attributed to spruce.
   intPctBL = 0        'reset/initalize variable value
   intPctPA = 0        'reset/initalize variable value
   intPctFD = 0        'reset/initalize variable value
   intPctHemlock = 0   'reset/initalize variable value
   intPctSpruce = 0    'reset/initalize variable value

   If Not IsNull(!SPC_1) Then
      If (!SPC_1 = "BL") Then
        intPctBL = !SPCPCT_1
      ElseIf (!SPC_1 = "PA") Then
        intPctPA = !SPCPCT_1
      ElseIf (!SPC_1 = "FD") Then
        intPctFD = !SPCPCT_1
      ElseIf (!SPC_1 = "H") Or (!SPC_1 = "HM") Or (!SPC_1 = "HW") Then
        intPctHemlock = !SPCPCT_1
      ElseIf (!SPC_1 = "S") Or (!SPC_1 = "SB") Or (!SPC_1 = "SE") Or _
            (!SPC_1 = "SS") Or (!SPC_1 = "SW") Then
        intPctSpruce = intPctSpruce + !SPCPCT_1
      End If
   Else
     intPctBL = 0
     intPctPA = 0
     intPctFD = 0
     intPctHemlock = 0
     intPctSpruce = 0
   End If

   If Not IsNull(!SPC_2) Then
      If (!SPC_2 = "BL") Then
        intPctBL = intPctBL + !SPCPCT_2
      ElseIf (!SPC_2 = "PA") Then
        intPctPA = intPctPA + !SPCPCT_2
      ElseIf (!SPC_2 = "FD") Then
        intPctFD = intPctFD + !SPCPCT_2
      ElseIf (!SPC_2 = "H") Or (!SPC_2 = "HM") Or (!SPC_2 = "HW") Then
        intPctHemlock = intPctHemlock + !SPCPCT_2
      ElseIf (!SPC_2 = "S") Or (!SPC_2 = "SB") Or (!SPC_2 = "SE") Or _
            (!SPC_2 = "SS") Or (!SPC_2 = "SW") Then
        intPctSpruce = intPctSpruce + !SPCPCT_2
      End If
   End If

   If Not IsNull(!SPC_3) Then
      If (!SPC_3 = "BL") Then
        intPctBL = intPctBL + !SPCPCT_3
      ElseIf (!SPC_3 = "PA") Then
        intPctPA = intPctPA + !SPCPCT_3
      ElseIf (!SPC_3 = "FD") Then
        intPctFD = intPctFD + !SPCPCT_3
      ElseIf (!SPC_3 = "H") Or (!SPC_3 = "HM") Or (!SPC_3 = "HW") Then
        intPctHemlock = intPctHemlock + !SPCPCT_3
      ElseIf (!SPC_3 = "S") Or (!SPC_3 = "SB") Or (!SPC_3 = "SE") Or _
            (!SPC_3 = "SS") Or (!SPC_3 = "SW") Then
        intPctSpruce = intPctSpruce + !SPCPCT_3
      End If
   End If

   If Not IsNull(!SPC_4) Then
```

```
    If (!SPC_4 = "BL") Then
      intPctBL = intPctBL + !SPCPCT_4
    ElseIf (!SPC_4 = "PA") Then
      intPctPA = intPctPA + !SPCPCT_4
    ElseIf (!SPC_4 = "FD") Then
      intPctFD = intPctFD + !SPCPCT_4
    ElseIf (!SPC_4 = "H") Or (!SPC_4 = "HM") Or (!SPC_4 = "HW") Then
      intPctHemlock = intPctHemlock + !SPCPCT_4
    ElseIf (!SPC_4 = "S") Or (!SPC_4 = "SB") Or (!SPC_4 = "SE") Or _
          (!SPC_4 = "SS") Or (!SPC_4 = "SW") Then
      intPctSpruce = intPctSpruce + !SPCPCT_4
    End If
  End If

  If Not IsNull(!SPC_5) Then
    If (!SPC_5 = "BL") Then
      intPctBL = intPctBL + !SPCPCT_5
    ElseIf (!SPC_5 = "PA") Then
      intPctPA = intPctPA + !SPCPCT_5
    ElseIf (!SPC_5 = "FD") Then
      intPctFD = intPctFD + !SPCPCT_5
    ElseIf (!SPC_5 = "H") Or (!SPC_5 = "HM") Or (!SPC_5 = "HW") Then
      intPctHemlock = intPctHemlock + !SPCPCT_5
    ElseIf (!SPC_5 = "S") Or (!SPC_5 = "SB") Or (!SPC_5 = "SE") Or _
          (!SPC_5 = "SS") Or (!SPC_5 = "SW") Then
      intPctSpruce = intPctSpruce + !SPCPCT_5
    End If
  End If

  If Not IsNull(!SPC_6) Then
    If (!SPC_6 = "BL") Then
      intPctBL = intPctBL + !SPCPCT_6
    ElseIf (!SPC_6 = "PA") Then
      intPctPA = intPctPA + !SPCPCT_6
    ElseIf (!SPC_6 = "FD") Then
      intPctFD = intPctFD + !SPCPCT_6
    ElseIf (!SPC_6 = "H") Or (!SPC_6 = "HM") Or (!SPC_6 = "HW") Then
      intPctHemlock = intPctHemlock + !SPCPCT_6
    ElseIf (!SPC_6 = "S") Or (!SPC_6 = "SB") Or (!SPC_6 = "SE") Or _
          (!SPC_6 = "SS") Or (!SPC_6 = "SW") Then
      intPctSpruce = intPctSpruce + !SPCPCT_6
    End If
  End If

  'the next block tests for conditions that will describe forage tree
  'species groupings
  If ((intPctBL + intPctPA) >= 70) Then
    strTSG_State = "#0"    'very good lichen support, set to ordinal state 0
  ElseIf ((intPctBL + intPctPA + intPctFD + intPctHemlock) >= 50) Then
    strTSG_State = "#1"    'good lichen support, set to ordinal state 1
  ElseIf ((intPctBL + intPctPA + intPctFD + intPctHemlock) >= 25) And _
        ((intPctBL + intPctPA + intPctFD + intPctHemlock) < 50) Then
    strTSG_State = "#2"    'moderate lichen support, set to ordinal state 2
  ElseIf ((intPctBL + intPctPA + intPctFD + intPctHemlock) >= 25) And _
        ((intPctBL + intPctPA + intPctFD + intPctHemlock) < 50) And _
        (intPctSpruce > 50) Then
    strTSG_State = "#1"    'good lichen support, set to ordinal state 1
  ElseIf ((intPctBL + intPctPA + intPctFD + intPctHemlock) >= 10) And _
        ((intPctBL + intPctPA + intPctFD + intPctHemlock) < 25) And _
        (intPctSpruce > 50) Then
    strTSG_State = "#2"    'moderate lichen support, set to ordinal state 2
  Else
    strTSG_State = "#3"    'poor lichen support, set to ordinal state 3
  End If

  intPctBL = 0          'reset variable for next loop iteration
  intPctPA = 0          'reset variable for next loop iteration
  intPctFD = 0          'reset variable for next loop iteration
  intPctHemlock = 0     'reset variable for next loop iteration
  intPctSpruce = 0      'reset variable for next loop iteration
```

**Macro-Climate Snowfall**

```
Select Case Trim(UCase(!BGC_SUBZON))    'assign state values to the MCSF macroclimate snowfall node.
    Case "ATUN", "ATUNP", "ESSFDCP", "ESSFDCW", "ESSFDKP", "ESSFDMP", "ESSFMMP", _
        "ESSFMV", "ESSFMVP", "ESSFVC", "ESSFVCP", "ESSFVV", "ESSFVVP", "ESSFWC", _
        "ESSFWCP", "ESSFWCW", "ESSFWK", "ESSFWKP", "ESSFWM", "ESSFWMP", "ESSFWMW"
      strMCSF_State = "#0"          'very deep snowpack, set ordinal state to 0
    Case "ESSFDC", "ESSFDK", "ESSFDKW", "ESSFDM", "ESSFDMW", "ESSFMM", "ICHVK", _
        "ICHWK", "SBSMC", "SBSMM", "SBSMW", "SBSVK", "SBSWK"
      strMCSF_State = "#1"          'deep snowpack, set to ordinal state 1
    Case "BWBSMW", "BWBSWK", "ESSFXC", "ICHMK", "ICHMM", "ICHMW", "IDFDK", _
        "MSDK", "MSDM", "SBPSMK", "SBSDH", "SBSDW", "SBSMH"
      strMCSF_State = "#2"          'moderate snowpack, set to ordinal state 2
    Case "ICHDK", "ICHDM", "ICHDW", "ICHXW", "IDFDM", "IDFMW", "IDFUN", "IDFXH", _
        "PPDH"
      strMCSF_State = "#3"          'shallow snowpack, set to ordinal state 3
    Case "SBSMK"
      If Trim(UCase(!Variant)) = "1" Then
        strMCSF_State = "#1"        'deep snowpack, set to ordinal state 1
      Else
        strMCSF_State = "*"         'otherwise data is missing or is and unhandled BEC variant.
        booMissingDataFlag = True  'set missing data flag.
      End If
    Case Else
      strMCSF_State = "*"           'otherwise data is missing or is and unhandled BEC variant.
      booMissingDataFlag = True     'set missing data flag.
  End Select
```