Fish & Wildlife Compensation Program Project 16.W.COM.02
Development of a Roosevelt Elk Habitat Model for the South Coast Region
Project BAPID 6480

for:

Trevor Oussoren, Coastal Program Manager
Fish and Wildlife Compensation Program

by:

MADRONE ENVIRONMENTAL SERVICES LTD.
1081 Canada Avenue, Duncan, BC V9L 1V2

March 31, 2016

PREPARED WITH FINANCIAL SUPPORT OF THE FISH AND WILDLIFE COMPENSATION PROGRAM ON BEHALF OF ITS PROGRAM PARTNERS BC HYDRO, THE PROVINCE OF BC, FISHERIES AND OCEANS CANADA, FIRST NATIONS AND PUBLIC STAKEHOLDERS

MADRONE ENVIRONMENTAL SERVICES LTD.

1081 CANADA AVENUE • DUNCAN • BC • V9L 1V2

TEL 250.746.5545 • FAX 250.746.5850 • WWW.MADRONE.CA

DOSSIER: 15.0052

EXECUTIVE SUMMARY

Madrone Environmental Services Ltd., (Madrone) was awarded funding through the Fish and Wildlife Compensation Program (FWCP) to develop a Roosevelt elk habitat capability/suitability model for the South Coast region of British Columbia, prioritizing the Clowhom watershed and adjacent areas of the Sunshine Coast TSA. A secondary goal was to complete this mapping for all BC Hydro watersheds within the South Coast region for which ecosystem mapping exists, including the Stave, Coquitlam and Cheakamus watersheds. The development of habitat models supported recommended actions in numerous FWCP Action Plans related to habitat enhancement, critical habitat mapping, and riparian forest conservation for Roosevelt Elk (summarized in Table 1).

Terrestrial ecosystem data was compiled and collated for the project area, and populated with forest age, structural stage, slope/aspect modifiers, snowpack zone and solar radiation information to form an Operational Data geodatabase to be used for Roosevelt elk habitat capability/suitability models for Living in Winter and Growing Season Forage.

Roosevelt elk habitat capability and suitability models for Living in Winter and Growing Season Forage life requisites were completed for the South Coast Region as an expansion of a 3-year habitat model development project in the adjacent Strathcona TSA. Consistent habitat ratings assumptions and logic were applied across both regions after extensive review by species experts. South Coast habitat models provided 519,863 ha of total coverage, equivalent to approximately 23% of the total project area (Figure 1). The area of model coverage was limited by the availability of Terrestrial Ecosystem Mapping (TEM). Complete model coverage has been mapped for the Clowhom watershed, a high priority area for FWCP (Figures 2-5).

The habitat model and map products developed in this project provide a sound basis for habitat enhancement and conservation in FWCP watersheds. Populations of Roosevelt elk can be limited by the availability of high quality winter range, and opportunities for protection of high quality winter range can be identified from suitability maps (e.g., in the upper Clowhom watershed, Fig. 3). Capability maps identify candidate areas for enhancement (Fig. 2). Furthermore, the habitat ratings developed for each ecosystem unit in this project can be applied to new TEM is completed in future. The seamless ecosystem map coverage for areas with ecosystem mapping (TEM) produced for this model can also be

used as the basis for wildlife habitat ratings projects for other FWCP priority species on the South Coast (e.g., Western Screech-owl, Grizzly Bear, Mountain Goat).

The complete logic and assumptions used to rate habitat values for Roosevelt elk are described in Appendix 1. Description of the development of the Operational Data is found in Appendix 2, with a detailed description of the snowpack zone and solar radiation models in Appendix 3. Finally, Appendix 4 provides a description of Python scripts used to develop and populate information in the WHR models.

The Roosevelt elk habitat models completed for the South Coast project area have not undergone extensive validation by local experts, and this step is strongly recommended to improve confidence in model outputs for use in strategic decision-making.

Disclaimer

This product is meant for use of habitat supply at the TSA level and provides one dataset for comparison of predicted habitat values across a large area. Prior to application at a watershed or stand-level, further refinement of the model through incorporation of site-specific information and/or improved baseline data may be necessary (especially for areas of the model where baseline data is viewed as less reliable).

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

Key Elements of Project

Element	Description	Source
Digital Elevation Model (DEM)	A 25 m resolution DEM (25 m x 25 m grid cells/rasters) was produced for use with this project.	Stored in raster format
Ecosystem Mapping - Spatial Data and Geodatabase	All original ecosystem spatial data was obtained from the MoE TEIS file geodatabase for the province.	Terrestrial Ecosystem Information System (TEIS)
Forest Age Data	VRI release date of January 2015 (projected age is January 2014).	File geodatabase format (FGDB)
Look-up Table	The “look-up table” (LUT) was created in Excel that lists all of the unique BEC-Mapcodes (ecosystem/habitat types) for the purposes of conversion and capture of attributes associated with Stand Age, Structural Stage, and Stand Composition. The LUT is used as a “data dictionary” for the application of specific Python scripts developed for this project and run in ArcGIS.	Excel format
Model Output – Results	A script was developed to summarize the total hectares by habitat class for capability and suitability, for each season and life requisite. Results were exported as Excel files. Another script was developed to “read” results for Highest Value, Weighted Average, and Maximum Area and produce a consistent figure layout to depict the CAPSU results for review.	Excel files of results Feature class in FGDB PDF maps of results for visual review of output.
Python Scripts	Programs (scripts) written for this project to perform a series of rules to efficiently populate, summarize, and link various sources of data. Python scripts were used to link age data to map units (via the use of the look-up table as a data dictionary); to link RRM results to spatial data; to produce summaries of results, etc.	Refer to Appendices 2 and 4
RRM Tool and Associated Models	Excel add-in used to calculate RSI values for each ecosystem unit-model attribute combination	http://www.env.gov.bc.ca/wildlife/whr/rrm_tool.htm
Snowpack Model	Predicted snowpack by elevations within each BEC variant. Refined from previous coastal models that assigned one, generic snowpack zone to each biogeoclimatic subzone variant.	Refer to Appendix 3. Output in raster format by letter block for coastal BC
Solar Model	Produced in ArcGIS 10.1, using ESRI “Solar Radiation Tool”	Refer to Appendix 3. Output in raster format by letter block for coastal BC
Operational Data	The feature class created by combining ecosystem mapping information into a seamless layer, with each polygon assigned a value for forest age, snowpack zone, solar radiation class, and wildlife habitat rating from the RRM model output	Feature class in FGDB

Fish & Wildlife Compensation Program Project 16.W.COM.02
Development of a Roosevelt Elk Habitat Model for the South Coast Region
Project BAPID 6480

1 Introduction

Roosevelt Elk (*Cervus elaphus roosevelti*) is a hunted species of high importance to Provincial government and First Nations. It is a species of conservation concern in coastal BC because of vulnerability to unregulated hunting and habitat loss, resulting in its Provincial Blue-listed status (Special Concern; BC CDC 2014), and its priority status within the BC Conservation Framework (2014) with recommendations for habitat restoration and protection.

Roosevelt elk are identified as a Medium-High, High, or Very High Priority species in eight of the BC Hydro Watersheds found in the Coastal Region of the FWCP (Table 1). Most of these Watershed Action Plans have recommended habitat conservation and enhancement actions for Roosevelt Elk, including the mapping and identification of critical winter range and riparian habitats. These recommendations from the Watershed Action Plans underscore the major need for habitat suitability mapping for Roosevelt Elk across their range in BC.

Table 1. FWCP Watershed Action Plans, Roosevelt Elk Priority Rank within Watershed/Species Action Plans, and recommended actions relevant to habitat modeling.

Priority area for habitat model development	Watershed	Name of Action Plan	Roosevelt Elk FWCP Rank/Priority	Relevant recommended action(s)
1	Clowhom	Clowhom Watershed Plan	High	Habitat enhancement and conservation; Critical habitat capability/suitability mapping.
2	Stave	Stave Watershed Species of Interest Action Plan	High	Riparian forest conservation
2	Coquitlam	Coquitlam/Buntzen Watershed Species of Interest Action Plan	High	Riparian conservation

Priority area for habitat model development	Watershed	Name of Action Plan	Roosevelt Elk FWCP Rank/Priority	Relevant recommended action(s)
2	Cheakamus	Cheakamus Watershed Plan	Med-High	Restoration and securement of critical winter range and riparian habitats
2	Alouette	Alouette Watershed Plan	n/a	Potential for winter range land securement
3	Ash	Ash Watershed Species of Interest Action Plan	Very High	Not completed for this Action Plan
3	Campbell	Campbell River Watershed Species of Interest Action Plan	Med-High	Winter range conservation and securement
3	Puntledge	Puntledge River Watershed Species of Interest Action Plan	High	Habitat suitability modeling of Cruikshank River Population; preserving riparian habitats
3	Jordan	Jordan Watershed Plan	High	Conduct habitat assessment to determine relative abundance of key habitat requirements (forage, cover, winter habitat)

Unfortunately, there is a lack of species habitat supply information that covers large areas of BC (e.g., entire forest districts) in a standardized, seamless map product at a useful scale (1:20 000) for stand level management decisions. Recent updates to ecosystem map products for the province, however, now make it possible to apply habitat ratings to entire forest districts at a 1:20 000 to 1:50 000 scale. Standardized terrestrial ecosystem classification and wildlife habitat ratings (WHR) methods provide the project framework for map production and application of the habitat ratings (Resources Inventory Committee (RIC) 1998a, 1998b, 1998c, 1999a, and 1999b; Resources Information Standards Committee (RISC) 2000a, 2000b, 2002, 2004a, 2004b, and 2010; Ministry of Forests and Range (MoFR) and Ministry of Environment (MoE) 2010; MoE 2011a and 2011b).

Wildlife habitat ratings are used to define the relative importance of various ecological units to wildlife. The ratings reflect a habitat's potential to support a particular species by comparing it to the best available for that particular species in the province (benchmark habitat). Once habitat values are linked to the ecosystem mapping, habitat supply can be quantified based on current conditions, and projected into the future.

A Roosevelt Elk habitat model was developed in 2014 as part of a Wildlife Habitat Supply modeling project for the Timber Supply Review of the Strathcona Timber Supply Area (TSA) on Vancouver Island and the South Mainland Coast (Button and Tripp, Eds. 2014), and was tested in the McNab watershed on the Sunshine Coast. The habitat model was developed using a Wildlife Habitat Rating (WHR) species account with review and input from regional Ministry of Environment (MoE), and Ministry of Forests Lands and Natural Resource Operations (FLNRO) staff, along with species expert Kim Brunt.

In 2015 and 2016, Madrone Environmental Services Ltd. (Madrone) worked with MFLNRO and MOE staff to improve the Strathcona TSA habitat models for Roosevelt Elk, and expanded the model areas to the Sunshine Coast Project Area with a focus on the Clowhom Watershed. There is a strong need for habitat capability/suitability mapping to support conservation and enhancement goals for both FWCP Watershed Plans and MFLNRO Elk Population Unit management objectives (MFLNRO 2014).

2 Goals and Objectives

The goal of this project was to apply the wildlife habitat model concepts developed for Roosevelt Elk in the Strathcona TSA to the Sunshine Coast TSA and additional BC Hydro watersheds on the South Mainland Coast where Roosevelt Elk has been identified as a priority species for management.

Objectives of the project were to develop:

1. A seamless ecosystem mapping product for the Sunshine Coast populated with attributes that could be used for WHR for Roosevelt elk and other species.
2. A Living in Winter Habitat Capability/Suitability model (to identify important winter range for Roosevelt elk).
3. A Growing Season Forage Habitat Capability/Suitability model for Roosevelt elk.

3 Study Area

The study area boundary follows the Sunshine Coast TSA , containing the Clowhom Watershed, and additional BC Hydro watersheds on the South Mainland Coast: Cheakamus, Stave, Alouette, and Coquitlam (see Figure 1 in Results). Ecosections included in model coverage are listed in Table 2.

Table 2. Ecosections of the South Coast Project Area.

Abbreviation	Ecosection Name
EPR	Eastern Pacific Ranges
GEL	Georgia Lowland
NPR	Northern Pacific Ranges
SOG	Strait of Georgia
SPR	Southern Pacific Ranges

4 Methods

The Roosevelt elk habitat models for capability and suitability were developed using a standardized Wildlife Habitat Rating (WHR) approach (RIC 1999) that is based on a combination of existing ecosystem mapping (Terrestrial Ecosystem Mapping or Predictive Ecosystem Mapping) and expert opinion. The WHR method has been widely used for habitat rating for many species across BC, because of its advantages in terms of cost-efficiency to cover large areas and because the logic-based rating system provides easily interpreted rationale for ratings decisions that can be consistently applied.

The following is a summary of steps completed in the model development process:

1. Compile best available ecosystem mapping across the study area and collate mapping into a seamless layer based on the quality and standards of each mapping project; clean applicable ecosystem data, removing overlaps between adjacent projects
2. Development of a look-up table encompassing all of the unique ecosystem/habitat types within the study area for the purposes of conversion and capture of attributes associated with Stand Age, Structural Stage, and Stand Composition;
3. Create an Operational Data feature class using cleaned ecosystem mapping data, and updating/adding structural stage/age data, stand composition modifiers and slope aspect modifiers;
4. Assign snowpack and solar radiation values to Operational Data
5. Complete Wildlife Habitat Ratings, including all ecosystem assumptions, using the Resource Ratings Tables for Roosevelt Elk: Living in Winter and Growing Season Forage;
6. Complete habitat suitability and capability results linked to the ecosystem coverage;
7. Provide a species account as per the RISC standards; and
8. Provide summary documentation of project methods (this report).

4.1 Ecosystem Data Compilation

The following 14 TEM datasets (non-overlapping) were exported from the TEIS Master Long Table feature class to create the South Coast WHR feature class. Refer to Appendix 2 for more detailed descriptions of Operational Data development, and to Appendix 4 for technical details on scripts applied to complete this process.

Table 3. TEM datasets compiled to create the basis for WHR attributes in the South Coast Project Area.

BAPID	Original Project Name
1073	Hope IFPA TEM
4006	Mission TEM
4517	Callaghan LU TEM
4518	Mamquam LU TEM
4519	Lower Squamish LU TEM
4522	CDFmm TEM
4677	Chapman LU TEM
4678	Sechelt LU TEM
4684	Howe LU TEM
4904	Powell River Block 1 TEM
4913	Jervis LU TEM
4914	Salmon LU TEM
4915	Brittain LU TEM
5638	Sunshine Coast TSA Haslam LU TEM
5640	Sunshine Coast TSA Bunster LU TEM
5666	Soo TSA Whistler LU
6118	Narrows LU TEM
6122	Lois Lake West TEM
6123	Lois Lake East TEM

In the combined "seamless" (i.e. non-overlapping) feature class, only the attribute fields pertaining to ecosystem classification were retained. Attributes describing terrain, geomorphological processes, and so on, which are not generally used in assessing wildlife habitat suitability or capability, were dropped. The ecosystem attributes in the TEIS Master Long Table formed the template for the WHR "base" feature class, to which additional attributes were then added.

4.2 Development of the Operational Data for WHR models

The following is a list of attributes assigned to each polygon for use in the habitat models for the South Coast project area:

- Ecosection
- BEC zone, subzone, variant (BGC)
- Ecosystem type (mapcodes from the approved mapcode list including non-vegetated and anthropogenic codes)

- Structural Stage: as interpreted from the most recent available VRI forest age released in January 2015, cross-referenced to structural stage look-up table by mapcode
- Stand composition (Broadleaf, Mixed or Coniferous)
- Site modifier(s) were assigned based on a Digital Elevation Model: e.g., flat, steep warm/cool, or very steep warm/cool slope aspect modifiers as per ecosystem mapping standards[1]
- Snowpack Zone
- Solar Radiation Code

The database format used for the ecosystem mapping and WHR application is flexible and allows for the future addition of other landscape and stand level data for a given species life requisite.

4.3 Look-up Table

A key component of the data development is a structural stage "look-up table"; based on the unique list of all biogeoclimatic zones/subzones/variants and ecosystems contained within the dataset. The look-up table contains basic ecosystem description information such as name, assumed situation, assumed modifiers, typical soil moisture regime (SMR), climax structural stage, as well as, typical understorey vegetation. This information is useful for wildlife biologists to reference when assigning values to the wildlife ratings.

The look-up table also provides structural stage values that cross-walk to a common reference year[2]. This information is used to populate missing or incomplete structural stage information using various age input layers including Vegetation Resources Inventory (VRI) projected age values. The final version of the look-up table produced for this project is in contained within the RRM model files (excel file) under the "Ecosystem Descriptions" tab.

4.4 Assigning Age Data

A script was developed to apply age information to each ecosystem polygon for the project area (refer to Appendix 2 and 4 for technical details). The process of assigning age information to ecosystem polygons is based on an overlay of ecosystem polygons with VRI polygons. This overlay results in a situation where a given ecosystem polygon contains

[1] https://www.for.gov.bc.ca/hts/risc/pubs/teecolo/tem/tem_man.pdf (see Table 3.2)

[2] For the most recent run of the age to structural stage model, the reference year was January, 2014 (this VRI data was released in January of 2015, but the projected age is based on January 2014)

multiple fragments of VRI age polygons. Each VRI age polygon is assigned an absolute age value ("Projected Age") expressed in a number of years.

In order to arrive at a "summary" age for the polygon, we could not take a simple weighted average age value, because it could have resulted in an age value that doesn't exist in the ecosystem polygon at all. For example, if half of the ecosystem polygon was occupied by an age polygon with age 2, and the other half by an age polygon with age 300, we wouldn't want to assign an age value of 151 to the ecosystem polygon.

We also couldn't use the single age value that occupies the largest portion of the eco polygon. For example, a polygon may be 10% occupied by an age polygon with age 15, and 9% each by 10 other age polygons with all different ages somewhere between 101 and 120 but never the same exact number twice. In this case, we wouldn't want to conclude that the age for the polygon is 15.

As a viable solution (after reviewing many approaches and outputs), the project team decided to reclassify each age value into standard age classes, and determine the area-dominant **age class** found within the eco polygon. That age class was then assigned to the ecosystem polygon rather than an age value in years. This approach provides a more accurate result, but at the loss of the more detailed information of the absolute age value. For example, a "40" means that the eco polygon was occupied mostly by age polygons with age values from 21 to 40 (Appendix 2).

4.5 Assignment of Structural Stage

Structural stage (STS) values ranging from 0 to 7b were assigned for a series of age ranges within the look-up table for each unique BEC-mapcode as per provincial, standardized definitions (MoFR and MoE 2010; Table 4).

Table 4. Structural Stage Definitions (As per Land Management Handbook 25: Field Manual for Describing Terrestrial Ecosystems, 2010).

Structural Stage	Description
Post-disturbance stages or environmentally induced structural development	
1 Sparse/ cryptogam	Initial stages of primary and secondary succession; bryophytes and lichens often dominant, can be up to 100%; time since disturbance less than 20 years for normal forest succession, may be prolonged (50–100+ years) where there is little or no soil development (bedrock, boulder fields); total shrub and herb cover less than 20%; total tree layer cover less than 10%.
1a Sparse	Less than 10% vegetation cover;
1b Bryoid	Bryophyte-dominated communities (greater than ½ of total vegetation cover).
1c Lichen	Lichen-dominated communities (greater than ½ of total vegetation cover).
2 Herb	Early successional stage or herbaceous communities maintained by environmental conditions or disturbance (e.g., snow fields, avalanche tracks, wetlands, grasslands, flooding, intensive grazing, intense fire damage); dominated by herbs (forbs, graminoids, ferns); some invading or residual shrubs and trees may be present; tree layer cover less than 10%, shrubby layer cover less than or equal to 20% or less

Structural Stage	Description
	than 1/3 of total cover; time since disturbance less than 20 years for normal forest succession; may herbaceous communities are perpetually maintained in this stage.
2a Forb-dominanted	Herbaceous communities dominated (greater than ½ of the total herb cover) by non-graminoid herbs, including ferns.
2b Graminoid-dominated	Herbaceous communities dominated (greater than ½ of the total herb cover) by grasses, sedges, reeds, and rushes.
2c Aquatic	Herbaceous communities dominated (greater than ½ of the total herb cover) by floating or submerged aquatic plants; does not include sedges growing in marshes with standing water (which are classed as 2b).
2d Dwarf shrub	Communities dominated (greater than ½ of the total herb cover) by dwarf woody species such as Phyllodoce empetriformis, Cassiope mertensiana, Cassiope tetragona, Arctostaphylos arctica, Salix reticulata, and Rhododendron lapponicum. (See list of dwarf shrubs assigned to the herb layer in the Field Manual for Describing Terrestrial Ecosystems).
3 Shrub/Herb	Early successional stage or shrub communities maintained by environmental conditions or disturbance (e.g., snow fields, avalanche tracks, wetlands, grasslands, flooding, intensive grazing, intense fir damage); dominated by shrubby vegetation; seedlings and advance regeneration may be abundant; tree layer cover less than 10%; shrub layer cover greater than 20% or greater than or equal to 1/3 of total cover.
3a Low shrub	Communities dominated by shrub layer vegetation less than 2 m tall; may be perpetuated indefinitely to environmental conditions or repeated disturbance; seedlings and advance regeneration may be abundant; time since disturbance less than 20 years for normal forest succession.
3b Tall shrub	Communities dominated by shrub layer vegetation that are 2–10 m tall; may be perpetuated indefinitely by environmental conditions or repeated disturbance; seedlings and advance regeneration may be abundant; time since disturbance less than 40 years for normal forest succession.
4 Pole/ Sapling	Trees greater than 10 m tall, typically dense stocked, have overtopped shrub and herb layers; younger stands are vigorous (usually greater than 10–15 years old); older stagnated stands (up to 100 years old) are also included; self-thinning and vertical structure not yet evident in the canopy – this often occurs by age 30 in vigorous broadleaf stands, which are generally younger than coniferous stand at the same structural stage; time since disturbance ins usually less than 40 years for normal forest succession; up to 100+ years for dense (5,000 - 15,000+ stems per hectare) stagnant stands.
5 Young Forest	Self-thinning has become evident and the forest canopy has begun differentiation into distinct layers (dominant, main canopy, and overtopped); vigorous growth and a more open stand than in the pole/sapling sate; time since disturbance is generally 40–80 years but may begin as early as age 30, depending on tree species and ecological conditions.
6 Mature Forest	Trees established after the last disturbance have matured; a second cycle of shade tolerant trees may have become established; understories become well developed as the canopy opens up; time since disturbance is generally 80–250 years for stands within the CWH.
Old-growth stage	
7 Old Forest	Stands of old age with complex structure; patchy shrub and herb understories are typical; regeneration is usually of shade-tolerant species with composition similar to the overstorey; long-lived seral species may be present in some ecosystem types or edaphic sites. Old growth structural attributes will differ across biogeoclimatic units and ecosystems.
7a Old Forest	Stands with moderately to well developed structural complexity; stands composed mainly of shade-tolerant and regenerating tree species, although older seral and long-lived trees from a disturbance such as fire may still dominate the upper canopy; fire-maintained stands may have a 'single-storied' appearance; time since stand replacing disturbance generally greater than 250 years for stands within the CWH.
7b Very Old Forest	Very old stands having complex structure with abundant large-sized trees, snags and coarse woody debris; snags and coarse woody debris in all stages of decomposition; stands are comprised entirely of shade-tolerant overstorey species with well-established canopy gaps; time since stand replacing disturbance generally greater than 400 years for stands within the CWH.

High elevation, parkland forests, as well as lower elevation bog forests tend to have stunted structure regardless of how old they are; due to site factors such as shorter growing season, harsh winter conditions, and/or poor soil nutrients. The old growth state of these sites is very different from the classic, large, old forests that we tend to picture. From a wildlife habitat model perspective, this is an important consideration, especially for species that require large wildlife trees and large coarse woody debris that are typically associated with mature and old structural stages.

In order to differentiate the stunted forest types from other, more productive, forest types, a generic “7” was assigned to them; with “productive” forest units assigned structural stages 7a and 7b (Table 4).

Non-forested units typically defaulted (via the values assigned in the look-up table) to their structural stage condition at climax (structural stage 1, 2 or 3). Refer to the look-up table for the logic applied to “age” structure over time for each unique BEC-mapcode (see RRM models – Ecosystem Descriptions tab).

4.6 Slope/Aspect Site Modifiers

For consistency, and to populate missing information, warm and cool slope/aspect site modifiers (w, k, z, q) were modeled based on a 25 m raster digital elevation model (DEM) (Table 5).

Table 5. Ecosystem Site Modifiers Available for the Species-Habitat Models (Modified from Standard for Terrestrial Ecosystem Mapping in BC - RISC, 1998).

Modifier	Description
	Blank indicates “gentle” slopes of <35%
k	cool aspect (285 – 135°) slope (35% – 100%)
q	very steep (>100%) cool aspect (135 – 285°) slope
w	warm aspect (135 – 285°) slope (35% – 100%)
z	very steep (>100%) warm aspect (135 – 285°) slope

4.7 Stand Composition

Stand composition that corresponds with the structural stage climax condition and age for the forested units was assigned according to the look-up table (refer to Appendix 3) (Table 6).

Table 6. Stand Composition Definitions as Available for Species-Habitat Models.
(Modified from *Land Management Handbook 25: Field Manual for Describing Terrestrial Ecosystems*, 2010)

Stand Composition	Description
A description of the leaf-types of trees in a stand (only for structural stages 3-7)	
C	Coniferous (>75% of total tree cover is coniferous)
B	Broadleaf (>75% of the total tree cover is broadleaf)
M	Mixed (neither coniferous or broadleaf account for >75% of the total tree cover)

4.8 Species Account

Roosevelt elk models were created using the Wildlife Habitat Rating method (RIC 1999), and were guided by detailed assumptions to reduce subjectivity, to rate the value of ecosystem units for different life requisites of each species. As an essential component of this project, the species account for Roosevelt elk documents the assumptions used for assigning values to each ecosystem unit (Resource Suitability Index), and setting the Initial Attribute Values (IAV) for structural stage, snowpack and solar radiation values. The species account also includes logic to describe how site modifiers, stand composition, structural stage, solar radiation and snowpack zone interact and influence the value of habitat for elk.

4.9 Habitat Ratings

A 6-Class rating scheme of high (1), moderately high (2), moderate (3), low (4), very low (5), and nil (6) was used for this project due to a substantial level of knowledge on habitat use by Roosevelt Elk. This rating scheme is defined in Table 7, and is suggested by RIC (1999) for use at the 1:20 000 map scale. This rating scheme is used when assigning habitat ratings to the ecosystem units present within the project area. The habitat ratings express the ability of the units to fulfil habitat requirements for the specific life requisites and seasons rated. On completion of the models to assign the associated habitat values, habitat supply could then be quantified.

Table 7. Habitat Capability and Suitability 6-Class Rating Scheme (from RIC 1999); relative quality classes for assessing quality relative to the best in B.C.

Class Code	% of Provincial Best (upper and lower limit)	Description	RSI Value	Quality
1	100% - 76%	High	0.751 – 1	Equivalent
2	75% - 51%	Moderately High	0.501 – 0.75	Slightly less
3	50% - 26%	Moderate	0.251 – 0.50	Moderately less
4	25% - 6%	Low	0.051 – 0.25	Substantially less
5	5% - 1%	Very Low	0.001 – 0.05	Much less
6	0%	Nil	0	Habitat or attribute is absent

4.10 Ratings Model

Habitat ratings were generated using the Resource Ratings Modeling (RRMs) program, version 3.xx (www.env.gov.bc.ca/wildlife/whr/rrm_tool.html) by running the RRM (an "Add-In" for MS Excel®) on the ratings table. The first step in developing a model for the season and life requisite was to summarize what was mapped by BEC (Bgc_zone, Bgc_subzon, and Bgc_vrt) and ecosystem unit (site mapcode).

Values were then assigned for the initial attribute values (IAV) columns resulting in an initial RSI (Resource Suitability Index) based on the best potential for a given mapcode (ecosystem unit) for each species life requisite and season rated. The RRM program uses an RSI index of 0.0 to 1.0, with 1.0 being the best or 100%.

Subsequent RSI and AVE (Attribute-Value Effects) tables were then produced to adjust the best case scenario for a given ecosystem unit due to the influence of:

- BEC zone, subzone, variant
- Mapcode (forested site series, non-forested units, non-vegetated units, and anthropogenic codes)
- Structural Stage and Structural Stage Modifier
- Stand Composition
- Site modifier(s)
- Snowpack Zone (Shallow, Moderate, Deep and Very Deep)
- Direct Solar Radiation (This model is a stand-alone product at this time. It ranks solar values by 1, 2, 3 and 4 with 1 indicating sites that receive the most sun during the winter months of December through February on the coast. See Appendix 3.)

In the model equation, each of the selected RSI and AVE values were then multiplied to produce a final RSI for each unique ecosystem label mapped for a given area. As per the RRM standards, the multiplicative approach was selected because the effect of an attribute tends to change resource values in proportion to the magnitude of the original value. "In the real world it is often difficult (perhaps impossible) to determine whether multiplicative or additive effects are the correct relationship between attributes. Our inability to determine the correct relationship may indicate that it does not matter what relationship is used. The final results may still provide sufficient accuracy to support informed land management decisions." www.env.gov.bc.ca/wildlife/whr/rrm_tool/discussion

Within the RRM program, there is the potential to apply a number of model equations for max or min values, or to scale attributes to emphasize ones that have a greater influence than others. For this project, the default RRM equation (multiplicative) for living in winter (LIW) was applied as follows:

- Final RSI = Bgc_mapcode*Variation in Structural stage values for forage production*Site Modifiers*Influence of structural stage and solar radiation by snowpack zone (this last one addresses access/availability of forage)

The equation used to rate forage values in the growing season was:

- Final RSI = Bgc_mapcode*Variation in structural stage values for forage production*Influence of stand composition on forage values*Site modifier to account for influence of shallow, steep and very steep slopes on warm and cool aspects

A more detailed example of the winter forage model is provided in Appendix 1. The final RSI results are then converted into a 6-scale rating scheme (Table 6). These values were then linked to the ecosystem polygon spatial data, which allowed for visual depiction of results.

4.11 Depicting Model Results for Capability and Suitability

One of the challenges in building habitat models based on ecosystem mapping is how to display the results. This particular challenge is due to the fact that many ecosystem polygons can contain a combination, or complex of multiple ecosystems. For example, a predominately mesic (01 site series) forest on a moderate slope interspersed with sections of richer (e.g., 05 site series) forest growing adjacent to a series of ephemeral streams. There are a number of methods to display habitat Capability and/or Suitability themes, with the most commonly applied consisting of:

- weighted average (WA),
- highest value (HV), and
- largest area (also referred to as maximum area in some habitat supply projects "MA").

The tendency within habitat supply projects is to use the Weighted Average method to display CAPSU themes. When presenting the results for a given species season, life requisite, the maps are accompanied by a summary table of total hectares by habitat class.

The following are more detailed descriptions of the three potential methods of displaying CAPSU results, as adapted from the MoE website[3].

[3] http://www.env.gov.bc.ca/wildlife/whr/erm_mt/vw_create_txt.html

4.11.1 Weighted Average (or Averaged)

With averaged, the ratings for each component are averaged over a polygon. For example, if the six-class scheme is being used, and if a polygon is composed of 50% with a rating of 2 (midpoint = 63), 30% with a rating of 4 (midpoint = 16), and 20% with a rating of 1 (midpoint = 88), then the final value assigned to the polygon is calculated as follows:

- final value = (5 * 63 + 3 * 16 + 2 * 88) / (5 + 3 + 2); final value = 54 %

Because 54 % falls within class 2, the polygon will be depicted by the colour representing class 2.

Using Averaged to display habitat will tend to hide high value habitats. However, averaged gives a good quantitative measure of the amount of habitat within a polygon.

4.11.2 Highest Value

With highest value, the value assigned to a polygon is equivalent to the percentage that represents the rating of the component with the highest rating. For example, if the six-class rating scheme is being used, and if a polygon is composed of two components, and the deciles for each component are 6 and 4, and the ratings for each component are class 4 and 2 respectively, then the percentage assigned to the polygon will be 63%. The polygon will be depicted by the colour representing 63% (i.e. class 2).

4.11.3 Largest Area or Maximum Area

With largest area, the value assigned to a polygon is equivalent to the percentage representing the rating that covers the largest area. For example, if the WHR standard four-class scheme is being used, and if a polygon is composed of three components, and the deciles for each component are 4, 3, and 3, and the ratings for each component are H, L, and L respectively, then the value derived for the polygon will be 13% (midpoint of class L). The polygon will be depicted by the colour representing L because 60% of its area is rated as a Low.

4.12 Snowpack and Solar Data

In a separate project, snowpack and solar radiation models were developed for coastal BC (Tripp and Eade, 2014; Appendix 3). The Snowpack and Solar models, were completed for 13 coastal letter blocks (1:250 000 mapsheets), starting from the NW with 102P, 92M, 92N, 92O, 102I, 92L, 92K, 92J, 92E, 92F, 92G, 92C and 92B.

The impetus of this project was to produce a snowpack and solar dataset that could be used as an overlay in assessment of ungulate winter range habitat. The vision was to eventually be able to incorporate this dataset in with other site attribute information within ecosystem spatial data (polygons) where wildlife habitat models were being developed to predict ungulate winter ranges. However, the information in the Snowpack-Solar model for the coast has the potential to be combined, adjusted and examined in a variety of resource management applications and analyses for a multitude of wildlife species.

The 2014 coastal snowpack model was based on a 25 m Digital Elevation Model (DEM). Each 25 m raster was assigned a value for biogeoclimatic classification (BEC), as well as average slope, aspect, and elevation. Values within each of these features were then grouped into a series of classes (represented by numeric codes) for use with wildlife habitat models. The most up-to-date provincial BEC coverage available in 2013 for the coast (BECv8) was applied in raster format to assign BEC data. Details on the methods applied to determine snowpack are provided in Appendix 3.

In addition to snowpack, the amount of sun that a site receives in the winter can influence the quality (capability/suitability) of a site for ungulate winter habitat. Favourable solar conditions have thermal benefits (less energy spent to stay warm), and more importantly, better access to forage via reduced snowpack. Shading from adjacent hillsides is also a critical factor influencing winter range suitability for ungulates. The more shaded, the less valuable the area, regardless of whether-or-not the site is located on a south-facing slope.

To account for solar values in the winter (as well as topographic shading from nearby mountains and ridges), a Direct Solar Radiation model was run for the project area. The platform that the direct solar radiation model in the winter was created/run in is Arc 10.1. The various iterations that were tested, as well as the final "baseline" input values run in the final solar model are provided in Appendix 3, Table B. An introduction to how the model is run is provided in detail by ESRI:
http://resources.arcgis.com/en/help/main/10.1/index.html#//009z000000t9000000

Solar values were assigned a four-class code, based on amount of sunshine a site receives, with 1 = High amount of direct solar radiation during the winter months (December-March), and 4 = little to know solar energy reaches the site.

5 Results

Habitat capability and suitability models were completed for both Living in Winter and Growing Season Forage for Roosevelt Elk. The model rated 489 unique ecosystem units occurring within the project area. Complete model coverage was developed for the Clowhom watershed, which was the focal area for the study. Within the entire study area, a total area of 519,863 ha of model coverage was completed (Figure 1). This area is approximately 23% of the total area contained within the project boundary (Sunshine Coast TSA and additional BC Hydro watersheds on the South Mainland Coast). The main limitation to expanding model coverage within the project area is the lack of ecosystem mapping in other areas of the Sunshine Coast TSA.

Detailed maps of habitat ratings results for Roosevelt Elk in the Clowhom watershed are included in Appendix 1 (Figures 2-5).

In addition to the Roosevelt Elk habitat models, a seamless ecosystem map coverage has been produced for areas with Terrestrial Ecosystem Mapping (TEM) within the project boundary. This Operational Data (file geodatabase) has been populated with additional attributes such as snowpack zone, solar radiation, standardized slope/aspect modifiers based on a 25 m digital elevation model, and forest age information. This product can be used as basis for other WHR projects for species of concern within BC Hydro watersheds and across the project area (e.g., Western Screech-Owl, Grizzly Bear, and Mountain Goat). A Grizzly bear WHR model has already been developed using the Operational Data from this project to assist with WHA effectiveness monitoring on the Sunshine Coast (Carolyn Churchland, pers. comm.).

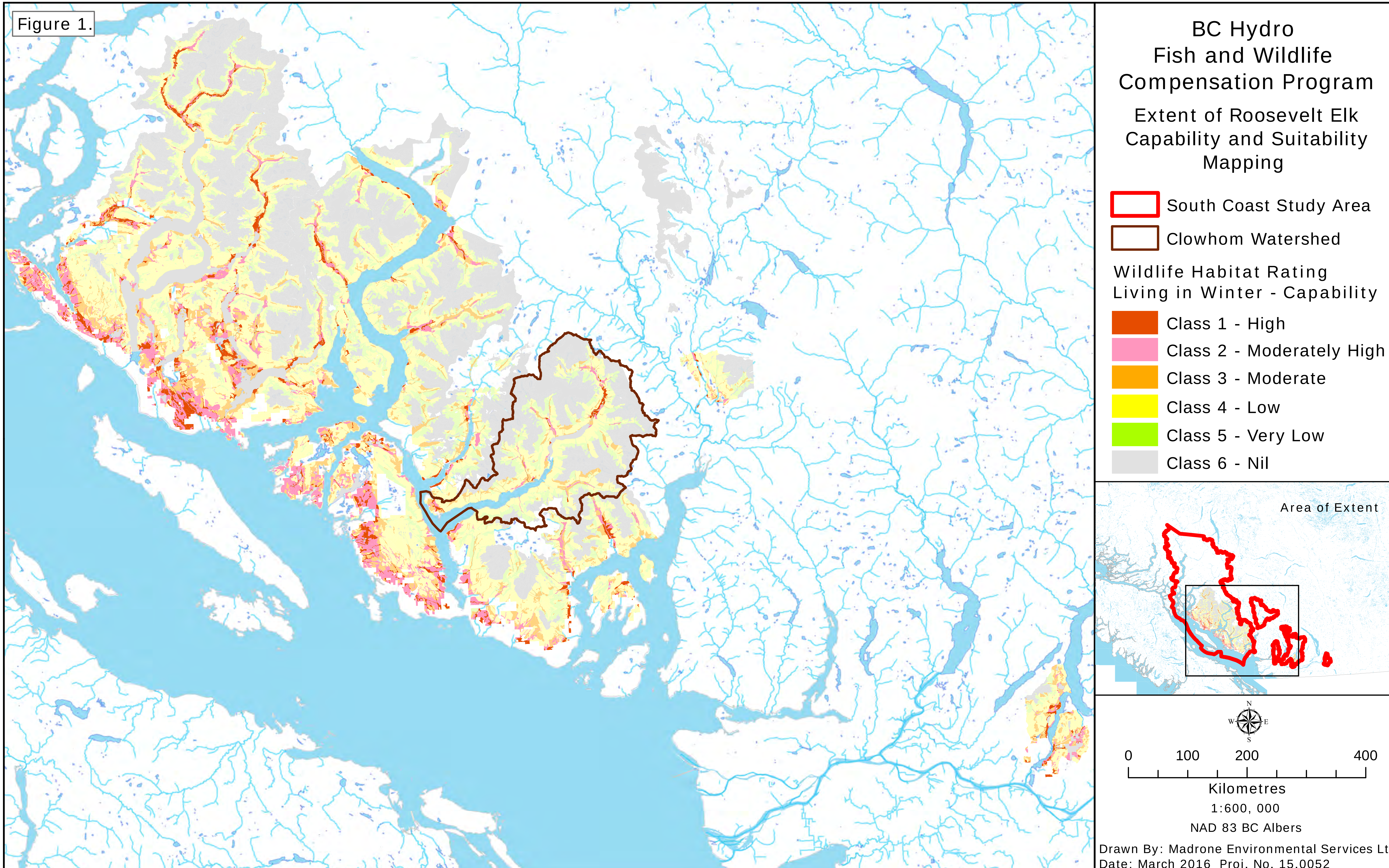


Figure 1.
BC Hydro
Fish and Wildlife
Compensation Program
Extent of Roosevelt Elk
Capability and Suitability
Mapping
South Coast Study Area
Clowhom Watershed
Wildlife Habitat Rating
Living in Winter - Capability
Class 1 - High
Class 2 - Moderately High
Class 3 - Moderate
Class 4 - Low
Class 5 - Very Low
Class 6 - Nil
Area of Extent
N
W
E
S
0
100
200
400
Kilometres
1:600, 000
NAD 83 BC Albers
Drawn By: Madrone Environmental Services Ltd.
Date: March 2016 Proj. No. 15.0052

6 Discussion

The models should be viewed as hypotheses of species-habitat relationships rather than statements of proven cause and effect. Their value is to serve as a basis for improved decision making and increased understanding of habitat relationships and habitat supply analyses over multiple landscape units.

Appropriate model applications include the identification of potential Ungulate Winter Ranges (UWR) for Roosevelt Elk, determining relative risks to Roosevelt Elk populations based on habitat availability and capability by EPU (Elk Population Unit), and identification of habitat enhancement opportunities. The habitat models will also contribute to better range-wide strategic decision-making for Roosevelt elk in B.C., particularly for initiatives such as Cumulative Effects Framework Value assessments.

6.1 Other Landscape Factors to Consider

A number of factors that were not considered in these models may be important to consider when determining overall habitat suitability. For example, topographic heterogeneity ("benchiness") is preferable to a uniform slope. Overstorey heterogeneity (variations in canopy closure) provides enhanced forage production and thickets for hiding in open canopy areas, and greater snow interception in areas of more closed canopy. Gullies, wetlands, and hummocky terrain also increase value of elk winter range. Other important landscape level considerations affecting the relative value of an area as elk winter range include the following:

- Position in the watershed – winter range requirements are more critical in areas of higher snowfall that are further from marine influences;
- Distance to other winter ranges - greater distances between winter ranges increases their individual importance;
- Adjacency to high quality spring and summer range;
- Availability of vegetated rock outcrops that provide topographic security cover (vantage points), favourable thermal conditions on sunny days, and areas that lose snow more readily during snow ablation periods;
- Suitability of adjacent areas to satisfy elk habitat requirements; and
- Other factors affecting local climatic conditions such as exposure to dominant winds or marine influences.

These considerations should be applied whenever model results are factored into operational decision-making processes such as proposal of UWRs.

7 Recommendations

The Roosevelt elk capability/suitability models have been developed based on logic that has been thoroughly reviewed by regional biologists and elk biologists for its application on Vancouver Island, but map products for the Sunshine Coast have not received a detailed analysis to validate model outputs for this region. It is strongly recommended that model outputs be reviewed by local biologists and experts who can provide feedback to improve model performance based on local knowledge.

An additional opportunity for model validation is available for the Sunshine Coast, based on point locations from Roosevelt elk GPS collars that have been deployed by MFLNRO (Darryl Reynolds, pers. comm.). It is recommended that future model validation include an analysis of location data relative to habitat classification for each season.

8 Acknowledgements

Funding to complete this work was provided by the Fish and Wildlife Compensation Program. Additional funding was provided by BC Ministry of Environment to assist with ecosystem data compilation for the Sunshine Coast. In-kind support was provided by the Ministry of Forests, Lands and Natural Resource Operations through review of habitat model logic and assumptions by ministry staff. This project also relied on input data sources (BC coastal snowpack model and solar radiation model) that were produced for and with funding from MOE and MFLNRO. Review of model logic and assumptions was provided by MFLNRO and MOE staff Ron Diederichs, Janice Anderson, Linda Sinclair, Dave Donald, Tony Button and Darryl Reynolds; and by species expert Kim Brunt.

In addition to in-house GIS support throughout the project by Anna Jeffries, GIS support was provided by CloverPoint, Victoria (Jeff Kruys and Erin Philip) for the ecosystem spatial data, Python scripts, layer files, and products produced with Python scripts (see Appendix 4).

GIS support for the snowpack and solar models was provided by George Eade (Geo Tech Systems, Victoria), with logic for applicability to ungulate winter ranges by Tania Tripp. The snowpack and solar models and visual output were reviewed in ArcGIS 10.1 by Tania Tripp and Kim Brunt and Lisa Nordin (MFLNRO, Bella Coola). Data development documentation relevant to this project is provided as Appendix 2.

Literature Cited

B.C. Conservation Framework. 2014. Conservation Framework Summary: *Cervus elaphus roosevelti*. B.C. Ministry of Environment. Available: http://a100.gov.bc.ca/pub/eswp/ (accessed Oct 27, 2014).

B.C. Conservation Data Centre. 2014. Species/Community Summary: *Cervus elaphus roosevelti***.** B.C. Ministry of Environment. Available: http://a100.gov.bc.ca/pub/eswp/ (Oct 2014).

Brunt, K.B. 1991. Testing models of the suitability of Roosevelt Elk seasonal ranges. M.Sc. Thesis, University of Victoria, Victoria, BC. 157 pp.

Button, T. and T. Tripp (Eds.). 2014. Strathcona Timber Supply Area Wildlife Habitat Assessment for the Timber Supply Review. Species Accounts, Habitat Models and Digital Data Prepared for and with the Ministry of Environment and the Ministry of Forests, Lands and Natural Resource Operations, Victoria and Nanaimo, BC.

Fish and Wildlife Compensation Program (FWCP). 2011. Alouette Watershed Plan.

Fish and Wildlife Compensation Program (FWCP). 2011. Ash Watershed Species of Interest Action Plan.

Fish and Wildlife Compensation Program (FWCP). 2011. Campbell River Watershed Species of Interest Action Plan.

Fish and Wildlife Compensation Program (FWCP). 2011. Cheakamus River Watershed Plan.

Fish and Wildlife Compensation Program (FWCP). 2011. Clowhom Watershed Plan.

Fish and Wildlife Compensation Program (FWCP). 2011. Coquitlam/Buntzen Watershed Species of Interest Action Plan.

Fish and Wildlife Compensation Program (FWCP). 2011. Jordan River Watershed Plan.

Fish and Wildlife Compensation Program (FWCP). 2011. Puntledge River Watershed Species of Interest Action Plan.

Fish and Wildlife Compensation Program (FWCP). 2011. Stave River Watershed Species of Interest Action Plan.

Luttmerding, H. A., D. A. Demarchi, E. C. Lea, D. V. Meidinger, and T. Vold. (Eds.) 1990. Describing Ecosystems in the Field, 2nd Ed. MOE Manual 11. B.C. Min. Environment, Lands and Parks and B.C. Ministry of Forests, Victoria, B.C.

Ministry of Forests and Range (MoFR) and Ministry of Environment (MoE). 2010. Field Manual for Describing Terrestrial Ecosystems: Land Management Handbook 25 - 2nd Edition. Victoria, B.C.

Ministry of Environment (MoE). 2011a. Wildlife Habitat Ratings (WHR). http://www.env.gov.bc.ca/wildlife/whr/index.html

Ministry of Environment (MoE). 2011b. User's Guide for Ecosystem-Based Resource Mapping (ERM) Ratings Table Tool. http://www.env.gov.bc.ca/wildlife/whr/erm_rtt/index.html

Ministry of Forests, Lands and Natural Resource Operations (MFLNRO). 2014. A management plan for Roosevelt elk in British Columbia. Unpubl. BC Min.For. Lands and Nat. Res. Ops. 42 pp. http://www.env.gov.bc.ca/fw/wildlife/management-issues/docs/roosevelt_elk_management_plan_draft_July_2014.pdf

Nyberg, J. B. and D. W. Janz, technical Eds. 1990. Deer and Elk Habitats in Coastal Forests of Southern British Columbia. Ministry of Forests, Special Report Series 5, Research Branch, Victoria, B.C.

Resources Inventory Committee (RIC). 1998a. Standard for terrestrial ecosystem mapping in British Columbia. Province of British Columbia, Ecosystems Working Group, Terrestrial Ecosystems Task Force, Victoria, B.C. 110 pp.

Resources Inventory Committee (RIC). 1998b. Field manual for describing terrestrial ecosystems. Province of British Columbia, Ecosystems Working Group, Terrestrial Ecosystems Task Force, Victoria, B.C.

Resources Inventory Committee (RIC). 1998c. Standardized Inventory Methodologies for Components of British Columbia’s Biodiversity #21: Inventory Methods for Bears. Wildlife Branch, Ministry of Environment, Lands and Parks, Victoria, B.C.

Resources Inventory Committee (RIC). 1999a. British Columbia Wildlife Habitat Rating Standards – Version 2.0. Ministry of Environment Lands and Parks, Resource Inventory Branch, Terrestrial Ecosystems Task Force, Victoria, B.C.

Resources Inventory Committee (RIC). 1999b. Standards for Predictive Ecosystem Mapping – Inventory Standard – Version 1.0. Terrestrial Ecosystem Mapping Alternatives Task Force, Victoria, B.C.

Resources Inventory Committee (RIC). 2000a. Standard for Terrestrial Ecosystem Mapping (TEM) – Digital Data Capture in British Columbia – Version 3.0. Ecological Data Committee, Ecosystems Working Group, Terrestrial Ecosystems Task Force, Victoria, B.C.

Resources Inventory Committee (RIC). 2000b. Standards for Predictive Ecosystem Mapping (PEM) – Digital Data Capture: Predictive Ecosystem Technical Standards and Database Manual - Version 1.0. PEM Data Committee, Terrestrial Ecosystem Mapping Alternatives Task Force, Victoria, B.C.

Resources Information Standards Committee (RISC). 2002. The Vertebrates of British Columbia: Scientific and English Names: Version 3.0.

Resources Information Standards Committee (RISC). 2004a. Standard for Terrestrial Ecosystem Mapping (TEM) – Digital Data Capture in British Columbia – Version 3.0: Errata No. 1. Ministry of Sustainable Resource Management, Victoria, B.C.

Resources Information Standards Committee (RISC). 2004b. Standards for Predictive Ecosystem Mapping (PEM) – Digital Data Capture - Version 1.0: Errata No. 1. Ministry of Sustainable Resource Management, Victoria, B.C.

Resources Information Standards Committee (RISC). 2010. Terrestrial Ecosystem Information Digital Data Submission Standard – Draft for Field testing: Database and GIS Data Standards – Version 1.0. Ministry of Environment, Ecosystems Branch, Victoria, B.C.

Appendix 1
Roosevelt Elk Habitat Model

Project Details

Project Name: Development of a Roosevelt Elk habitat Model for the South Coast Region – Applicable to the Clowhom, Stave, Coquitlam and Cheakamus Watersheds associated with BC Hydro Facilities.

The following species account for Roosevelt Elk outlines the logic and assumptions made in the preparation of the habitat ratings (model). The habitat model was developed concurrently with a habitat model for the Strathcona Timber Supply Area and uses the same logic and assumptions, that were extensively reviewed in the Strathcona TSA.

The information provided in this species account is an amalgamation of sources. The species account was edited and updated by Jenna Cragg of Madrone Environmental Services (2016) and was based in part on previous accounts produced by Madrone (2014, 1999a, 1999b). Information relevant to coastal BC was used as much as possible in developing this account and was supplemented with additional data where required and/or applicable. This species account has been reviewed by species expert Kim Brunt.

Disclaimer: This product is meant for use as a strategic planning tool, and provides one dataset for comparison of predicted habitat values across a large area. Prior to application at a watershed or stand-level, further refinement of the model through incorporation of site-specific information and/or improved baseline data may be necessary (especially for areas of the model where baseline data is viewed as less reliable).

Model Version: The logic outlined in the assumptions tables, result tables, and associated figures reflect the March 2016 version of the habitat model (Version 3.0, with Version 2.0 completed in 2015 and Version 1.0 completed in 2014).

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

Common Name: Roosevelt Elk
Scientific Name: Cervus elaphus roosevelti
Species Code: M-CEEL_RO
B.C. Status: Blue-listed
Identified Wildlife Status: N/A
COSEWIC/SARA Status: N/A

Introduction

Throughout North America, elk (*Cervus elaphus*) are an important species to numerous coastal and interior First Nations, as well as to hunters, guide outfitters, naturalists, and tourism in general. They are also a key component of ecosystem function as a prey species in systems that include large predators (bears, wolves, and cougars), such as the South Coast of BC. Elk were historically wide-spread across southern Canada in Ontario, the Prairie Provinces and BC; and in the United States from the Appalachian Mountains to the Pacific Coast, except in the deserts of the southwest (Murie 1951). Historically there were six subspecies of elk in North America of which only four remain. Roosevelt elk (*C. e. roosevelti*) is one of two subspecies of elk that occur in BC. It is confined to Vancouver Island and parts of the South Coast (RIC 1997a).

In coastal BC, Roosevelt Elk inhabit forest and river valley habitat during the winter (McTaggart and Guiguet 1965). Winter range has been identified as an important component of forest management in BC (Nyberg and Janz 1990). These areas provide critical refugia for Roosevelt elk during typical and severe winters, through a combination of slope, aspect, forest cover, and topography. Access to high quality early spring and summer forage is also considered essential to the success of local elk populations.

Roosevelt elk numbers have been increasing steadily over the last 40 years in coastal BC, in part due to the success of transplant efforts in the South Coast Region (MFLNRO 2014) (Table 1).

Table 1. Estimated population size of Roosevelt Elk in British Columbia by Region (MFLNRO 2014).

Year	West Coast Region	South Coast Region	BC (approximate)
1986	2,500	<50	2,550
2001	3,400	<400	3,800
2014	5,300	1,600	6,900

The increase in elk is also reflected in the increased interest that has been focused on management of elk on forestry and agricultural lands, with particular attention to crop damage and safety (vehicle collisions).

Distribution

At the time of this review, elk are known to occur throughout the Sunshine Coast, with a patchy distribution in other areas of the South Coast. The relative abundance of elk on the South Coast is highly variable; ranging from no elk in some areas, to high densities (>1 elk per 2.5 km^2) in areas such as the Sechelt Peninsula where elk have been successfully reintroduced (MFLNRO 2014) (Figure 1).

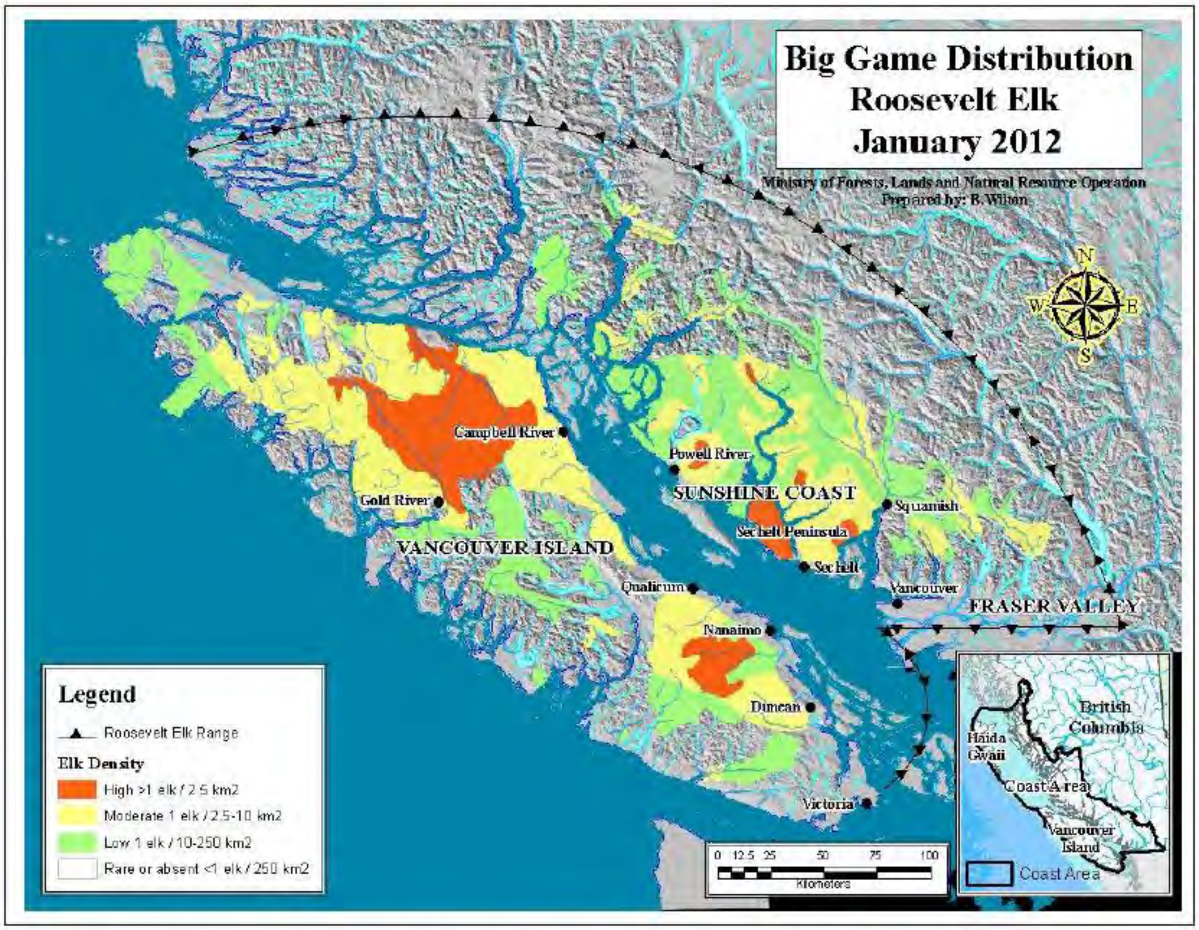


Figure 1: Estimated Distribution and Population Density of Roosevelt Elk in BC (from MFLNRO 2014).

Roosevelt elk can occur from sea level to higher elevations over 1,500 m. Some populations - which are considered resident, or non-migratory - will remain in lower elevation habitats all year, while others have seasonal migrations to higher elevation areas that are occupied during the summer and fall months. Low and mid-elevation valley bottoms, however, will receive the greatest use by this species all year long.

Lower elevation sites are especially important habitat for elk during the winter months due to relatively shallower snowpacks and therefore increased forage opportunities and favourable thermal conditions. A combination of slope, aspect and elevation are key components to determining winter habitat values for this species (Brunt 1991, Campbell 1995). Elevation ranges are also reflected in the biogeoclimatic zone classification system applied to terrestrial ecosystem mapping in BC.

Roosevelt elk can occur within all of the biogeoclimatic (BEC) zones, subzones and variants that occur in the study area at least during part of the year. The main BEC zone occupied by Roosevelt elk in the Sunshine Coast study are is the Coastal Western Hemlock (CWH) zone. Elk are expected to be most abundant within the low elevation CWHdm, vm, and xm subzones (Henigman *et al.* 2005). Generally, elk are not found in the higher elevation alpine (AT/CMA) and parkland (MHmmp) biogeoclimatic zones of the area in the winter, as deep to very deep snowpack results in lack of access to forage, and can impede movement.

Table 2 summarizes expected Roosevelt Elk potential by BEC Zone, Subzone and Variant, and is based on the 1:250,000 Broad Ecosystem Inventory Project (BEI) conducted in the late 1990's and 2004.

Table 2. Potential Occurrence of Roosevelt Elk within the BEC Zones, Subzones and Variants in the Project Area and Associated Snowpack Zones.

BEC Variants	Subzone/Variant Description	General Snowpack Level	Winter Snow Interception	Winter Feeding	Summer Feeding
AT	Alpine Tundra	Very Deep	•	•	P
CMA	Coast Mountain Alpine	Very Deep	•	•	P
MHmmp	Windward Moist Maritime Parkland	Very Deep	•	•	P
MHmm1	Windward Moist Maritime	Deep to Very Deep	• P	• P	P
MHwh	Wet Hypermaritime	Moderate to Deep	• P	• P	P
CWHdm	Dry Maritime	Moderate to Deep	P	P	P
CWHvm2	Montane Very Wet Maritime	Moderate to Deep	P	P	P
CWHxm1	Western Very Dry Maritime	Shallow to Deep	P	P	P
CWHxm2	Eastern Very Dry Maritime	Shallow to Deep	P	P	P
CWHvm1	Submontane Very Wet Maritime	Shallow to Moderate	P	P	P
CWHvh1	Southern Very Wet Maritime	Shallow	P	P	P

(Legend: P = Potential Range; • = essentially absent)

Habitat Requirements

Habitat requirements described below focus on those seasons and life requisites included in the habitat model for this project. It does not mean that other habitat requirements, such as security habitat for reproduction (birthing of calves in the spring), are less important. However, the seasons and life requisites modeled (namely winter habitat requirements) are thought to be the most limiting and therefore critical to the population success of this species.

Seasonal habitat use patterns are variable, with some Roosevelt Elk moving seasonally to high-elevation summer ranges, others moving between low-elevation seasonal ranges, and still others remaining in year-round ranges (Brunt 1990, Shackleton 1999). The primary characteristics of elk habitat are the requirements for forage associated with security cover and thermal cover. Generally, foraging habitat is located in open habitats, security cover in dense forests often with well-developed shrub layers, and thermal cover (snow interception) in coniferous forest stands.

The focal life requisites of the habitat supply model for this project are forage values in the winter, forage values in the spring/summer, and snow interception. The combination of snow interception, shallow to moderate snowpack zones, and association with high winter forage values, are the attributes associated with high value winter range. Table 3 summarizes the life requisites and seasons rated for elk, and their associated months of use in coastal BC. Although we originally proposed a winter habitat model made up of two components (winter forage and winter snow interception), it became clear during model development that a combined Living in Winter habitat model incorporating both components would improve the final product. First, a single model coverage for winter range capability/suitability can be more easily applied and interpreted, rather than having to overlay two maps with different ratings to identify areas of matching high quality. Second, combining winter forage and snow interception into one model facilitates model review and updates.

Table 3. Summary of Seasons and Life Requisites Rated (Modeled) for Roosevelt Elk in the South Coast Project Area.

Rated Life Requisites and Seasons	Code	Months of Use
Living in Winter	LIW	November - March
Growing Season Feeding	G_FD	April - October

Feeding Habitat

Key yearlong feeding habitats include open conifer stands, deciduous-dominated stands, and non-forested units including marshy meadows, wetlands, seepage sites, and estuaries (Nyberg and Janz, 1990). Riparian areas adjacent to lakes, streams, and floodplains of major river valleys also have very high value (Nyberg and Janz 1990). The moist, rich soils that typically occur in these areas provide abundant sources of preferred forage species.

The diet of Roosevelt elk consists primarily of grasses, ferns, shrubs, forbs, and conifers in varying seasonal proportions. A detailed account of feeding habitat is provided in Nyberg and Janz (1990) and synthesized below. Table 4 summarizes the important forage species for Roosevelt elk on Vancouver Island, which has similar ecology to the South Coast study area. For the purposes of this habitat model, similar habitat on the coastal mainland is assumed to provide the same forage species and habitat values.

Winter - Forage

During winter, forage is scarce and of poor quality, energetic demands are high, and snow restricts movement. Elk must rely on fat reserves built up over the previous summer and fall. Adult bulls, weakened by the fall rut, and calves are the most susceptible to malnutrition and winter mortality because of their small fat reserves. High quality winter range is therefore considered to be the most critical habitat for elk, and is of greater importance for herds that occupy areas associated with deep snowpack. Important, high value winter range includes floodplains and other riparian areas, and mature and old forests on warm aspect slopes with reduced snowpack levels that provide enhanced access to forage and reduced energy expenditure associated with travel through snow.

During mild winters, important forage species include grasses, sedges, deer fern, twinflower, willows, devil’s club, salal, dull Oregon-grape, red huckleberry, and oval-leaved blueberry. Under heavy snow conditions, when many low-growing species of plants are not accessible due to snow cover, elk will shift their diet to include more browse species such as Western hemlock, Western redcedar, and tall shrubs.

Spring/Summer - Forage

During the spring, the diet consists mainly of shrubs, ferns, and grasses. Deer fern is a very important forage species at this time, in addition to salmonberry, bunchberry, sword fern, grasses and sedges, and young skunk cabbage. In summer, shrubs and herbs are more heavily used, including salmonberry, red elderberry, and bunchberry, with ferns and moderate amounts of grasses and sedges also eaten.

Table 4: Key Forage Species for Roosevelt Elk on Vancouver Island.

(Adapted from Nyberg and Janz (1990). The most important or preferred species are in **bold** type)

	Winter forage	Spring forage	Summer forage
TREES:	amabilis fir Douglas-fir western hemlock western redcedar	amabilis fir Douglas-fir western hemlock	amabilis fir western hemlock western redcedar
SHRUBS:	devil's club dull Oregon-grape Pacific ninebark red elderberry *Rubus* spp. (salmonberry, blackberry, thimbleberry, raspberry, bramble) salal twinflower *Vaccinium* spp. (blueberry, huckleberry, cranberry) willow spp.	devil's club hardhack Pacific ninebark salmonberry	bunchberry devil's club dull Oregon-grape Pacific ninebark red elderberry salmonberry twinflower
FERNS:	deer fern lady fern sword fern	deer fern sword fern	deer fern lady fern sword fern
HERBS:	grass spp. sedge spp. skunk cabbage	bunchberry grass spp. sedge spp. skunk cabbage	grass spp. sedge spp. skunk cabbage wall lettuce

Winter Range and Snow Interception

Suitable winter range for elk in coastal BC is generally found in low elevation river valleys and the lower part of watersheds where snow depths tend to be shallow. During mild winters or in the shallow snowpack zone, elk use wetlands, clearcuts, and open forests to forage, generally in rich, moist sites (Nyberg and Janz 1990). When deep or crusted snow conditions preclude feeding in more open areas, elk will move into densely canopied forests or onto moderately steep southerly slopes where snow packs are lower (Nyberg and Janz 1990). Snow depths of more than 60 cm reduce mobility, forcing elk to move to lower elevation forested habitats or warm aspect sites (south and southeast facing slopes) with low snow accumulations (Skovlin 1982, RIC 1997a).

In the winter, the level of snow interception of various forest types (dry, mesic, and wet) and ages (young to old) influences elk use. Higher snow interception allows for reduced snowpack in the understorey, which can allow for improved access to forage and reduced energy output for travelling through shallow snowpacks compared to moderate or deep snowpacks. Sites with high snow interception can also provide enhanced thermal values, which can further reduce energy expenditure.

Forest cover influences snow depth, density and surface hardness (Nyberg and Janz 1990), and elk typically expend most energy walking through dense, deep snow (i.e., sinking depths greater than 25 cm). Conditions that produce favourable snow conditions include dense young-growth (>10 m tall) and old-growth forests (Nyberg and Janz 1990). Forests greater than 10 m in height may provide sufficient snow interception in low snowpack zones, but only old growth is capable of providing sufficient snow interception in moderate and deep snowpack zones (Nyberg and Janz 1990).

Canopy closure (crown completeness in trees of suitable size) exerts the most influence on snow interception. Stand conditions that provide 60-80% canopy closure can provide ideal (High value) snow interception for elk. Sites with good snow interception are also associated with thermal benefits. Winter thermal cover requirements are met by coniferous stands with a minimum height of 10 – 12 m and canopy closure of at least 70% (Thomas *et al.* 1979).

Security

In summer, elk may bed wherever they are finished feeding, but always in close proximity to cover (Collins and Urness 1983). Minimum security cover for elk has been defined as vegetation capable of concealing 90% of a standing elk from view at a distance of 61 m or less (Thomas *et al.* 1979). The stand's density and diameter of trees and the density of understorey vegetation, determine its value as security cover; topographical features may also enhance security cover for elk (Nyberg and Janz 1990, Thomas *et al.* 1979). Most forested stands greater than approximately 3 m in height provide security cover. Stands with deciduous overstories often provide abundant forage and adequate security cover.

Female elk give birth in seclusion and birthing takes place in late May to early June (Boyd 1978). Cover is an important habitat feature for young calves. They will blend in with tall grasses and low or tall shrub cover. Therefore, habitats such as floodplains and riparian zones, or grassy meadows on the edges of forests provide suitable cover for cows and calves during the calving period. On Vancouver Island, cows were noted to give birth - and subsequently rear their calves for up to several weeks - on small flat areas among relatively steeper terrain (Nyberg and Janz 1990).

Interspersion of Habitat Types

Good interspersion of feeding areas and cover is important to elk. Optimal habitat consists of relatively open foraging areas interspersed with patches of cover in the form of trees or dense shrubs. Elk are often found in edge habitats between open foraging areas and forested cover areas, and most use of open areas is within 80 m of cover (Nyberg and Janz 1990). As well, habitat complexes of stands with high snow interception interspersed with rock outcrops on warm aspect slopes also provide important winter habitat. These habitat complexes are often important in early spring as well for access to the first flush of high value herbaceous forage (early vegetation green up) (Brunt 1991, Nyberg and Janz 1990).

Ecosystem and Site Attributes

A number of relationships between habitat use and ecosystem attributes can be assumed for Roosevelt elk based on research conducted in coastal BC and local knowledge of Regional Biologists and species specialists. Often the habitats used most frequently are associated with specific ecosystem and site attributes. The habitat model, also referred to as the Resource Ratings Model (RRM), accounts for these site attributes when calculating a Resource Suitability Index (RSI).

The RSI is rated on a 0 to 1.0 index, and consists of unique mapcodes (ecosystems) by each Biogeoclimatic subzone variant in the study area, as well as site modifiers for a slope/aspect combination, stand composition, structural stage, snowpack zone, and solar radiation class. The combination of these attributes in an ideal assemblage (initial attribute values - IAVs) for each BEC_Mapcode combination are rated, with attribute value effects (AVE) tables applied to adjust initial habitat values based on changes to the ideal condition. For example, AVE tables can be used to adjust the value of habitat to reflect current conditions (e.g., structural stage 7 for forage production and snow interception compared to the same site as recently harvested structural stage 3). Table 5 summarizes the ecosystem attributes that were considered in the Resource Ratings Model.

Table 5. Terrestrial Ecosystem Mapping (TEM) relationships for the life requisites for Roosevelt elk.

Life Requisite	Ecosystem/Mapcode Attribute
Living in Winter (LIW)	• Forage value of vegetation: rated based on site series (mapcode), understorey forage species, structural stage • Access to forage: based on factors affecting snow depth. Snowpack zone (Biogeoclimatic zone, elevation), site modifier based onslope and aspect, effect of solar radiation on snow depth (solar radiation class), snow interception based on structural stage
Growing Season_Feeding (G-FD)	• Site influence on forage value: BEC/Elevation, site modifier base on slope/aspect • Forage value of vegetation: based on site series (mapcode), understorey forage species, structural stage, stand composition

Ratings

Rating Scheme

A 6-Class rating scheme of high (1), moderately high (2), moderate (3), low (4), very low (5), and nil (6) is employed due to the substantial level of knowledge on habitat use of this species. This rating scheme is suggested by RIC (1999) for use with Roosevelt Elk at the 1:20 000 map scale and is defined in Table 6. This rating scheme is used when assigning habitat ratings to the ecosystem units present within the project area. The habitat ratings express the ability of the units to fulfil habitat requirements for the specific life requisites and seasons rated for Roosevelt Elk for this project.

Table 6. Habitat Capability and Suitability 6-Class Rating Scheme (from RIC 1999).

% of Provincial Best	Rating	Class Code	RSI Value
100% - 76%	High	1	0.751 – 1
75% - 51%	Moderately High	2	0.501 – 0.75
50% - 26%	Moderate	3	0.251 – 0.50
25% - 6%	Low	4	0.051 – 0.25
5% - 1%	Very Low	5	0.001 – 0.05
0%	Nil	6	0

Provincial Benchmarks

Provincial benchmark habitat for this species as identified by Demarchi and Demarchi (2003), based on Broad Ecosystem Inventory (BEI) is found within the Northern Island Mountains (NIM) Ecosection of Northern Vancouver Island. The following ecosystems were used as benchmarks for Roosevelt Elk from which all other life requisites and ecosystems were compared:

Ecosection: Northern Island Mountains (NIM)

Biogeoclimatic Zone: Very Dry Maritime Coastal Western Hemlock Variant 2 (CWHxm2)

Habitat: Sitka Spruce - Black Cottonwood Riparian (SR)

Site Modifier: Slope and aspect

Stand Structure: Old Forest seral stages (greater than 140 years old), in the BEI classification system (Ecosystems Working Group 2000) (equivalent to structural stage 6 and 7a/b in TEM Standards).

A number of habitat units mapped within the South Coast project area have been rated on par with the best habitat (an RSI rating of up to 1.0).

Ratings Assumptions

In developing habitat interpretations, assumptions were based on information found in published and unpublished literature supplemented with local knowledge (Table 7).

Table 7. Habitat Rating Assumptions for the South Coast - Roosevelt Elk Winter Range – Living in Winter (LIW).

Attribute	Assumptions
General	The winter habitat model for elk is based on an extreme winter (a 1 in 100 year event) where snowpack could be limiting to elk even within the Shallow Snopack zone (<150 m elevation). The focus of the model is on accessible forage in the winter, which varies by snowpack zone and other site conditions (attributes). During the winter, forage values are greatest in areas with little to no snowpack. Where local populations occupy moderate to very deep snowpack zones, access to high-value forage and forest with good snow interception are of increased importance.
Ecosection	The NIM (Northern Island Mountains) Ecosection has been identified as containing provincial benchmark (Class 1) habitat for this species. All other Ecosections within the project area have been ranked against the benchmark. Benchmark habitat can occur outside of the NIM, but may not support the same number of animals or may have no elk use at this time. .
BGC Unit	Biogeoclimatic zones are accounted for in the snowpack model, that breaks up each BEC unit by elevation ranges associated with Shallow to Very Deep snowpack zones. The deeper the snowpack, the more important the mature and old forests become for providing snow interception. All biogeoclimatic (BGC) units were rated for potential forage values. Accessibility to forage was adjusted using the snowpack model. For example, the Alpine Tundra (AT) (now mapped as the Coast Mountains Alpine - CMA) and Mountain Hemlock parkland (MHmmp) come out with a rating of 0.0 for suitable/accessible forage because of their associated Very Deep snowpack. The Coastal Western Hemlock (CWH) dm, vm1, vm2, and xm subzone, variants all contain ecosystems associated with winter forage values rated up to 1.0 (Class 1 habitat).
Snowpack Zones	The following are broad level assumptions related to snowpack. Refer to Table 9 for detailed assumptions related to the influence of snowpack on winter habitat for elk. **Shallow Snowpack** varies by BEC, but typically 0-150 m elevation; always <250 m for this model. Rated up to 1.0, Very High for winter habitat; snow interception is important in an extreme winter, and therefore, only mature and old forest units associated with high or very high forage values can be rated up to 1.0 (Class 1). In the Shallow Snowpack, high forage values associated with non-forested units (i.e., wetlands and swamps) are limited to an RSI of 0.80 (Class 2) at best; recent cutblocks (structural stages 3) are limited to an RSI of 0.30 (Class 4) at best. **Moderate Snowpack** varies by BEC, but typically 250-500 m elevation; always <550 m for this model. Only mature and old forest can be rated up to 0.80 (Class 1) for winter habitat. In the Moderate Snowpack zone, high forage values associated with non-forested units (i.e., wetlands and swamps) are limited to an RSI of 0.50 (Class 3) at best; recent cutblocks (structural stages 2b to 3b) are limited to an RSI of 0.20 (Class 4) at best for winter habitat. **Deep Snowpack** varies by BEC, but typically 550-800 m; always <900 m for this model. Only mature and old forest associated with decent forage values (Class 1-3) are considered suitable for winter habitat. **Very Deep Snowpack** varies by BEC, but always >900 m with many >1600 m such as alpine areas. The snowpack in this zone is too deep to provide any accessible forage. Therefore, the Very Deep Snowpack zone (regardless of solar values) is rated Nil 0.0 (Class 6) for winter habitat for elk in this model.
Ecosystem Units (Mapcodes)	Ecosystem units (mapcodes) were rated for winter forage values. Wetlands, floodplains, clearcuts, and open forests, generally in rich, moist sites are rated up to 1.0 for forage values. Understorey compositions were ranked according to their relative amounts of sword fern, skunk cabbage, deer fern and salmonberry, as they are associated with rich moist sites that produce the best forage for elk. The initial attribute values (IAV) in the RRM model are based

Attribute	Assumptions
	on all forage values being equally accessible to elk, and are subsequently adjusted for predicted "accessibility" in the winter based on Structural Stage, Snowpack, and Solar values.
Structural Stage	All non-vegetated and anthropogenic units (mapcodes) with a structural stage of 0 to 1 (no structure) are rated Nil (0.0) for food and snow interception. All non-forested units (typically structural stages 2b, 3a, and 3b) are rated Nil (0.0) for snow interception, but are often associated with high forage values in the winter where the snowpack is not too deep. Snow interception values are not achieved until forested sites reach structural stage 4. Structural stages >5 are best for snow interception with structural stages 7a and 7 b (old growth) rated the highest. See Table 8, and refer to Appendix A for structural stage descriptions.
Stand Composition	In general, ecosystem units associated with a broadleaf (B) or mixed (M) stand composition are associated with higher winter forage values than coniferous stands (C). Broadleaf components are typically associated with floodplain units, which are high elk use areas throughout the year. However, where these stands occur in Deep and Very Deep snowpack zones, the forage values are reduced (not accessible), and the snow interception provided by mature and old coniferous stands becomes increasingly important for living in the winter.
Direct Solar Radiation (Solar Code)	The following are broad level assumptions related to solar values that have been classificed into four categories (very high, high, moderate and low to no direct solar radiation in the winter for a given site). Refer to Table 9 for detailed assumptions related to the influence of solar conditons on winter habitat for elk. Solar Code 1 indicates a "High" amount of sun is received by a given site in the winter. These sites are typically located on steep, warm slopes (south facing) or heights of land where no topographic shading occurs. These sites can be highly favourable to ungulates in the winter in the Shallow, Moderate and Deep snowpack zones because they are typically associated with reduced snowpack. However, elk favour valley bottom habitat in the Shallow Snowpack, where forage values are concentrated. Therefore, solar codes were not given a strong influence on winter habitat for elk witihin the Shallow Snowpack zone. Solar values were most important within the Moderate and Deep Snowpack zones. Favourable adjustments are made based on Solar Codes 1 and 2 (High and Moderate solar values).
Site Modifiers (slope/aspect as per TEM standards) and solar radiationl	Adjustments (AVEs) using the slope/aspect site modifiers were applied to flat valley-bottom (Shallow snowpack) units to increase the value of these productive areas in spite of their potentially poor snow interception (flat units were multiplied by 1.5 for shallow snowpack and by 1.25 for moderate snowpack). Adjustments were also made for "Site Selection" based on avoidance of steep slopes by elk in the winter. The steep and very steep site modifiers "k, w, q and z" were used for the site selection adjustment**. Steep slopes (>35% but <100%) were reduced in value by a greater amount for cool aspect than warm aspect slopes for shallow and moderate snowpacks (0.75 and 0.50 adjustments, respectively). In the Deep snowpack, warm aspect slopes were not adjusted downward, to reflect the importance of warm aspect slopes in shedding snow; however, cool aspect steep slopes were adjusted by a factor of 0.1 in the Deep snowpack (Class 4 at best). Very steep slopes >100% were adjusted to Very Low at best (0.05 - Class 5) due to the known lack of use of these sites by elk in the winter. **Ideally, a series of ungulate appropriate slope modifiers would be developed for this model for future refinement in future iterations.
Adjacency	Juxtaposition, of high quality food and cover – while known to be very important in determining overall habitat suitability (Nyberg and Janz 1990) – was not addressed in these models. For example, in all subzones and variants, sparsely or unvegetated units (CL, ES, TA and especially RO) may be important on warm aspects for absorbing solar radiation in late winter resulting in early spring green up. Because spatial analyses for adjacency have not been conducted at this time, where other site attributes indicate Moderate to Very High potential winter forage, individual ecosystem polygons can be queried to see when these non-vegetated units occur in complex or adjacent to them.

Table 8. Habitat Rating Assumptions Related to Structural Stage and Forage Production for the South Coast - Roosevelt Elk Winter Range.

Winter Forage Value Assumptions and Adjustments by Structural Stage (STS)

Structural stages 2 (herbaceous) and 3 (shrub/herb) are rated up to an RSI value of 1.0, as they are assumed to produce the highest quantity of forage. Structural stage 4 forests generally have very poor year round foraging value as these stands are typically dense, and forage has been shaded out. However, structural stage 4 in low bench and medium bench riparian forest provides high quality forage (0.8-1.0) of similar value to structural stage 3b because these units age differently from other coniferous forest (having more broadleaf and herbaceous components at STS 4) .Mature and old forest (stages 6 and 7) are rated up to 0.6 and 0.8, respectively (40-20% less productive than herbaceous or shrub dominant conditions, because litterfall is an important winter source of food in mature and old forests, especially in the deep snowpack zone).
Below is a matrix that indicates the assumptions applied to forage production and structural stage in the model. The first column indicates the initial attribute value (IAV), ideal STS condition for a given BEC_Mapcode unit; the top row indicates the actual structural stage conditions (current or potential). Where the ideal and actual are one and the same, the adjustment value is 1.0 (multiply by 1.0 = no adjustment from IAV value).

The following summarizes the assumptions of how structure affects forage values.

	ACTUAL STRUCTURAL STAGE (CURRENT OR POTENTIAL CONDITIONS)												
Ideal STS	**1**	**1a**	**1b**	**2/2a**	**2b**	**2d**	**3/3a**	**3b**	**4**	**5**	**6**	**7**	**7a/7b**
3a/3b[1]	0.05	0.05	0.1	1.0/0.8	1.0	0.5	1.0	1.0	1.0	1.0			
7[2]	0.05	0.05	0.1	1.0/0.8	1.0	0.5	1.0	1.0	0.6	0.8	1.0	1.0	
4[3]	0.05	0.05	0.1	1.0/0.8	1.0	0.5	1.0	1.0	1.0	0.8	0.8		
3[4]	0.05	0.05	0.1	1.0/0.8	1.0	0.5	1.0	1.0	0.1	0.2	0.6		0.8

A shaded cell indicates that the structural stage change does not apply or is not allowed.

[1]There are a number of wetland and shrub units that remain in the younger structural / seral stages over time; they do NOT 'grow' past structural stage 3b; or beyond "5" for the low and mid-bench floodplain units. Refer to the RRM model, ecosystem descriptions tab for information on each BEC_Mapcode Unit and its associated (allowed) structural stages as per BC Provincial Standards for ecosystem mapping.

[2]A structural stage "7" was used to indicate non-productive forested units such as swamp and high elevation, parkland forest. These sites are typically not logged, and it is assumed that forage values would not change as much within these units if disturbed as they would with productive forested units.

[3]Forested floodplain units age differently from other coniferous forested units, with structural stage 4 having similar forage values to structural stage 3b in other forest types. An initial attribute value of 0.8-1.0 for structural stage 4 is only applied to forested floodplain units.

[4]A generic, structural stage"3" is used to indicate that a productive forested unit (typically the 01, 03-08 site series) has been logged. This was the default structural stage assigned to indicate the ideal condition for maximum forage production.

Structural stage in combination with snowpack was then used to adjust the initial attribute values (IAV) for accessibility to forage (Table 9). For example, when snow accumulations are low, herb, shrub and young regenerating forest (structural stages 2, 3a and 3b) may be available to elk, but snow will preclude access to these sites more so than in mature and old forest.

Table 9. Habitat Rating Assumptions for the South Coast - Roosevelt Elk Winter Range - Snowpack Zone Adjustments by Solar Class and Structural Stage.

Snowpack/Solar Radiation/Structural Stage Assumptions and Adjustments

This information is used to adjust/correct the forage values assigned for mapcodes whose accessibility will be affected by snow depth. An AVE table based on a combination of snowpack zone, solar radiation and structural stage was developed for this model based on input from Regional Biologists and species specialists. The assumptions table shows how forage values are affected within each snowpack zone based on the solar radiation class and structural stage.

Although the snowpack model used BEC and elevation, it did not account for favourable solar conditions (slope, aspect, and topographic shading). The solar model accounts for these additional site attributes. Within a given snowpack zone, areas with greater solar radiation (class 1 having the highest solar radiation and class 4 the lowest) will have shallower snow depths and less persistent snow, providing better access to forage. Therefore, AVEs for solar class 1 are higher than for solar class 4 (darker areas with less solar radiation will have a greater reduction in forage access). While snow is not considered a major limiting factor affecting access to forage in the Shallow snowpack zone, adjustments have been applied to structural stages 0-5 to reflect the reduced access to forage that would occur during extreme conditions (e.g. a 1 in 100 year snowfall event).

Across all snowpack zones, the ecosystem's structural stage will affect snow interception and hence, access to forage. For example, a structural stage 7 ecosystem will have better snow interception than a structural stage 3, and therefore the AVE for structural stage 7 will always be higher than for structural stage 3, indicating that the effect of snow depth is less important in older forests. In deeper snowpack zones, the effect of structural stage on overall access to forage becomes more pronounced, with the greatest differences in value between structural stage 3 and 7 occurring in the Deep and Very Deep snowpack zones. See figures in Appendix B for a visual representation of the influence of structural stage and solar radiation on access to forage within each snowpack zone.

Roosevelt elk have slightly lower AVEs (5% lower or 0.05) for structural stages 7a, 7b and 5 in the Deep Snowpack Zone (Solar Class 1 & 2) than Columbian black-tailed deer. This reflects their general preference for foraging at lower elevations relative to deer during winter, and greater avoidance of deep snow.

Shallow Snowpack

Structural Stage (STS)	Solar 1	Solar 2	Solar 3	Solar 4
0	0.00	0.00	0.00	0.00
1	0.20	0.20	0.20	0.10
1a	0.20	0.20	0.20	0.10
1b	0.20	0.20	0.20	0.10
2	0.20	0.20	0.20	0.10
2a	0.20	0.20	0.20	0.10
2b	0.20	0.20	0.20	0.10
2d	0.20	0.20	0.20	0.10
3	0.30	0.30	0.30	0.20
3a	0.30	0.30	0.30	0.20
3b	0.30	0.30	0.30	0.20
4	0.60	0.60	0.60	0.50
5	0.80	0.80	0.80	0.70
6	0.95	0.95	0.95	0.90
7	0.80	0.80	0.80	0.70
7a	1.00	1.00	1.00	1.00
7b	1.00	1.00	1.00	1.00

Moderate Snowpack				
Structural Stage (STS)	**Solar 1**	**Solar 2**	**Solar 3**	**Solar 4**
0	0.00	0.00	0.00	0.00
1	0.10	0.10	0.10	0.05
1a	0.10	0.10	0.10	0.05
1b	0.10	0.10	0.10	0.05
2	0.10	0.10	0.10	0.05
2a	0.10	0.10	0.10	0.05
2b	0.10	0.10	0.10	0.05
2d	0.10	0.10	0.10	0.05
3	0.20	0.20	0.20	0.10
3a	0.20	0.20	0.20	0.10
3b	0.20	0.20	0.20	0.10
4	0.40	0.40	0.40	0.30
5	0.50	0.50	0.50	0.40
6	0.70	0.70	0.70	0.60
7	0.50	0.50	0.50	0.40
7a	0.80	0.80	0.80	0.70
7b	0.80	0.80	0.80	0.70
Deep Snowpack				
Structural Stage (STS)	**Solar 1**	**Solar 2**	**Solar 3**	**Solar 4**
0	0.00	0.00	0.00	0.00
1	0.05	0.05	0.00	0.00
1a	0.05	0.05	0.00	0.00
1b	0.05	0.05	0.00	0.00
2	0.05	0.05	0.00	0.00
2a	0.05	0.05	0.00	0.00
2b	0.05	0.05	0.00	0.00
2d	0.05	0.05	0.00	0.00
3	0.10	0.05	0.00	0.00
3a	0.10	0.05	0.00	0.00
3b	0.10	0.05	0.00	0.00
4	0.20	0.10	0.05	0.00
5	0.40	0.30	0.15	0.05
6	0.60	0.50	0.25	0.10
7	0.30	0.20	0.10	0.05
7a	0.70	0.60	0.40	0.20
7b	0.70	0.60	0.40	0.20

<table>
<tr><th colspan="6">Very Deep Snowpack</th></tr>
<tr><th>Structural Stage (STS)</th><th>Solar 1</th><th colspan="2">Solar 2</th><th>Solar 3</th><th>Solar 4</th></tr>
<tr><td>All (0-7b)</td><td>0.00</td><td colspan="2">0.00</td><td>0.00</td><td>0.00</td></tr>
<tr><td>Structural Stage "7"</td><td colspan="5">The generic "7" is used in the ecosystem model to indicate forested ecosystems that are less productive such as swamp and parkland forests. These sites are adjusted differently than the productive forested site series.</td></tr>
<tr><td>Structural Stage “3”</td><td colspan="5">The generic “3” is used to indicate productive forested ecosystems in a recently harvested seral / structural stage.</td></tr>
<tr><th>Solar Class</th><th>Description</th><th>Value Range</th><th>Units</th><td colspan="2" rowspan="5">For the months of Dec/Jan/Feb for the South Coast of BC (other latitudes must be adjusted and tested accordingly)</td></tr>
<tr><td>1</td><td>High</td><td>1,167 to 1,556</td><td>WH/m^2</td></tr>
<tr><td>2</td><td>Moderate</td><td>778 to 1,166</td><td>WH/m^2</td></tr>
<tr><td>3</td><td>Low</td><td>389 to 777</td><td>WH/m^2</td></tr>
<tr><td>4</td><td>Very Low to Nil</td><td>0.4 to 388</td><td>WH/m^2</td></tr>
</table>

Table 10. Habitat Rating Assumptions for the South Coast – Forage in the Growing Season (G_FD).

Attribute	Assumptions
General	Open sites such as wetlands, riparian forest, deciduous-dominated stands, and vegetated slides around rock outcrops are favoured forage sites, and are especially important in the spring. Therefore, this model focuses on forage potential and availability during the spring. Many of the forage values, however, will also be applicable to the summer and early fall.
BGC Unit	Biogeoclimatic zones were treated as on par with each other; with the parkland having high forage potential in the summer due to delayed phenology. However, in general, the low elevation BGC units such as the CWHvm1 and xm1 are considered to have the best forage potential due to accessibility throughout the year.
Site Series (Mapcodes)	The focus of forage values was at the site series/mapcode unit level based on interpretations of Brunt (1991) understorey forage values cross-walked to ecosystem mapcodes. Wetlands, riparian areas, open deciduous stands, and clearcuts are all rated up to high (Class 1) for forage in the spring, which would also be rated the same for the summer and early fall months.
Structural Stage (STS)	See Table 12, and refer to Appendix A for structural stage descriptions
Stand Composition	Broadleaf and mixed stands are rated as the most favourable stand compositions for forage production. These sites are typically associated with rich, valley bottom and floodplain units where high quantities of preferred forage are available. Applied adjustments consist of a decrease in value for sites mapped as “C” Coniferous that could occur in a “M” Mixed or “B” Broadleaf condition. The decrease in forage value is 40% for “B” to “C”; and 20% decrease in habitat potential for conditions going from “B” to “M”.
Site Modifiers (Slope/Aspect)	Up to this point the habitat model has not distinguished forage availability in the spring versus the summer. Early spring forage is considered to be of higher importance (critical habitat) than summer forage, which is much more readily available. By applying adjustment ratings for warm, south-facing, steep (35-100%) slopes, the early spring bias is introduced. If this attribute is excluded from the model, a generic "Growing Season" forage potential will result. The adjustments applied for access to early spring forage include a 50% (RSI multiplied by 0.5) reduced habitat potential for “k” (cool, steep slopes); 75% (0.25) reduction for “q” (cool, very steep slopes) these conditions are assumed to be associated with persistent snowpack in the spring;

Attribute	Assumptions
	relative applicability; even when no snow – frost and significantly delayed; and a 20% (0.8) reduction for "z" (warm, very steep slopes) due to lack of access.
Canopy Closure	More open canopies are assumed to be associated with higher understorey productivity. At this time, structural stage is used to reflect this variable and canopy closure per se is not included in the model. It has been recommended for inclusion as an attribute within this model when the VRI data is updated and reliable information is available consistently across the landbase.

Table 11. Habitat Rating Assumptions Related to Structural Stage and Forage Production for the South Coast - Roosevelt Elk Spring/Summer/Fall (Growing Season) Forage.

Growing Season (Spring/Summer/Fall) Forage Value Assumptions and Adjustments by Structural Stage (STS)

Forage production typically peaks in recent clearcuts (structural stages 2 to 3a). Canopy closure in dense regenerating stands of structural stage 3b and 4 tend to shade out the understorey, and forage production declines dramatically during these stages. As stands continue towards maturity (structural stages 5 through 7), self-thinning and higher canopies typically result in more light reaching the understorey and increased forage production returns.

Structural stages 2 (herbaceous) and 3 (shrub/herb) are rated up to an RSI value of 1.0, as they are assumed to produce the highest quantity of forage. Structural stage 4 forests generally have very poor year round foraging value as these stands are typically dense, and forage has been shaded out. Old forests (stage 7) are rated up to 0.5 (50% less productive than herbaceous or shrub dominant conditions) compared to only 20% less productive for winter forage in old forests due to the importance of litterfall during the winter.

Below is a matrix that indicates the assumptions applied to forage production and structural stage in the growing season forage model. The first column indicates the initial attribute value (IAV), ideal STS condition for a given BEC_Mapcode unit; the top row indicates the actual structural stage conditions (current or potential). Where the ideal and actual are one and the same, the adjustment value is 1.0 (multiply by 1.0 = no adjustment from IAV value).

The following summarizes the assumptions of how structure affects forage values.

	ACTUAL STRUCTURAL STAGE (CURRENT OR POTENTIAL CONDITIONS)											
Ideal STS	**1/1a**	**1b**	**2/2a**	**2b**	**2d**	**3/3a**	**3b**	**4**	**5**	**6**	**7**	**7a/7b**
3a/3b[1]	0.05	0.1	0.8	1.0	0.5	1.0	1.0	1.0	1.0			
7[2]	0.05	0.1	0.8	1.0	0.5	1.0	1.0	0.5	0.8	1.0	1.0	
3[3]	0.05	0.1	0.8	1.0	0.5	1.0	1.0	0.1	0.2	0.4		0.5
	A shaded cell indicates that the structural stage change does not apply or is not allowed. For example, STS "1" applies to units such as "Rock" or "Road Surface", which do not typically change in structure.											

[1]There are a number of wetland and shrub units that remain in the younger structural / seral stages over time; they do NOT 'grow' past structural stage 3b; or beyond "5" for the low and mid-bench floodplain units. Refer to the RRM model, ecosystem descriptions tab for information on each BEC_Mapcode Unit and its associated (allowed) structural stages as per BC Provincial Standards for ecosystem mapping.

[2]A structural stage "7" was used to indicate non-productive forested units such as swamp and high elevation, parkland forest. These sites are typically not logged, and it is assumed that forage values would not change as much within these units if disturbed as they would with productive forested units.

[3]A generic, structural stage"3" is used to indicate that a productive forested unit (typically the 01, 03-08 site series) has been logged. This was the default structural stage assigned to indicate the ideal condition for maximum forage production.

Ratings Model

The habitat ratings were generated using the Resource Ratings Modeling (RRMs) program, version 3.xx (www.env.gov.bc.ca/wildlife/whr/rrm_tool.html) by running the RRM (an "Add-In" for MS Excel®) on the ratings table. The first step in developing a model for the season and life requisite was to summarize what was mapped by BEC (Bgc_zone, Bgc_subzon, and Bgc_vrt) and ecosystem unit (site mapcode).

Values were then assigned for the initial attribute values (IAV) columns resulting in an initial RSI (Resource Suitability Index) based on the best potential for a given mapcode (ecosystem unit) for each species life requisite and season rated. The RRM program uses an RSI index of 0.0 to 1.0, with 1.0 being the best or 100%.

Subsequent RSI and AVE (Attribute-Value Effects) tables were then produced to adjust the best case scenario for a given ecosystem unit due to the influence of:

- BEC zone, subzone, variant
- Mapcode (forested site series, non-forested units, non-vegetated units, and anthropogenic codes)
- Structural Stage and Structural Stage Modifier
- Site modifier(s) (Warm, Cool, or none)
- Snowpack Zone (Shallow, Moderate, Deep and Very Deep)
- Direct Solar Radiation (This model is a stand-alone product at this time. It ranks solar values by 1, 2, 3 and 4 with 1 indicating sites that receive the most sun during the winter months of December through February on the coast.)

In the model equation, each of the selected RSI and AVE values were then multiplied to produce a final RSI for each unique ecosystem label mapped for a given area. As per the RRM standards, the multiplicative approach was selected because the effect of an attribute tends to change resource values in proportion to the magnitude of the original value. "In the real world it is often difficult (perhaps impossible) to determine whether multiplicative or additive effects are the correct relationship between attributes. Our inability to determine the correct relationship may indicate that it does not matter what relationship is used. The final results may still provide sufficient accuracy to support informed land management decisions." www.env.gov.bc.ca/wildlife/whr/rrm_tool/discussion

Within the RRM program, there is the potential to apply a number of model equations for max or min values, or to scale attributes to emphasize ones that have a greater influence than others. For this project, the default RRM equation (multiplicative) for living in winter (LIW) was applied as follows:

- Final RSI = Bgc_mapcode*Variation in Structural stage values for forage production*Site Modifiers*Influence of structural stage and solar radiation by snowpack zone (this last one addresses access/availability of forage)

The equation used to rate forage values in the growing season was:

- Final RSI = Bgc_mapcode*Variation in structural stage values for forage production*Influence of stand composition on forage values*Site modifier to account for influence of shallow, steep and very steep slopes on warm and cool aspects

A more detailed example of the winter forage model is provided in Table 12. The final RSI results are then converted into a 6-scale rating scheme. These values were then linked to the ecosystem polygon spatial data, which allowed for visual depiction of results.

Table 12. Example Habitat Model Equation for Roosevelt Elk - Living in Winter -Strathcona TSA Project Area.

Table Type	Column Heading	Attribute	Value	Description
RSI	BGC_ Mapcode	CWHxm2 RS 3	0.8	Initial Attribute Value (IAV) (Tab #1 of the Excel RRM Model) that assigns the highest RSI value that the specific BGC_Mapcode and specified combination of site attributes and conditions can achieve. An RSI value of 0.8 is equivalent to Class 1 habitat. CWHxm2 3, forested unit "RS" (Western redcedar - Sword fern; site series 05) with an ideal structural stage 3 (recently cleared forest)
AVE	STS	3a 7b 4	1.0 0.8 0.10	This attribute value effect (AVE) table indicates how different structural stages influence the amount and quality of winter forage. Note that for Winter Forage Values, recently cleared forest was rated slightly higher than old forest as indicated by a multiplication factor (AVE) of 1.0 (no change from the IAV_RSI value of 0.8). Old forest has an AVE of 0.8 to reflect the slightly lower forage production due to partial shading by the canopy. Structural stage 3a is predominately shrub and regen, less than 2 m in height (typically 2-4 years after harvesting). If this ecosystem was mapped as structural stage "4" (dense regen), an AVE value of 0.10 would be applied. The 0.10 adjustment means that 90% of the potential forage value would not be there compared to ideal conditions.
AVE	Solar_ Snowpack_S TS	3a in the Deep Snowpack, Solar Class 3 7b in Deep Snowpack, Solar Class 3	0.00 0.40	The Solar_Snowpack_STS adjusts for accessible winter forage. It is assumed that deeper snowpack impacts younger structural stages more so than older forest. The persistence of the snowpack, as influcenced by solar radiation, also affects access to forage. Therefore, in areas with in the deepest snowpack zone with the lowest solar radiation, structural stage will have the greatest influence on access to forage. For a structural stage 3a, despite high initial forage values, a reduction of 100% is applied in the deep snowpack zone (solar class 3) to indicate the lack of access to this forage. If the same ecosystem unit was in old forest condition (7b), the adjustment value would be only 0.40 (reduction of 60%) to reflect the snow interception capacity of the canopy.
AVE	Site_ modifier	none	1.50	Adjusts for the high value of flat valley-bottom habitats within the shallow and moderate snowpack zones (for all solar radiation classes) by inflating the value of these areas relative to all other slope/aspect combinations and snowpack zones. All other site modifiers are adjusted

<table>
<tr><th>Table Type</th><th>Column Heading</th><th>Attribute</th><th>Value</th><th>Description</th></tr>
<tr><td></td><td></td><td></td><td></td><td>downward, except for warm slope aspect in the Deep Snowpack which is given a value of 1.0 (no change).</td></tr>
<tr><td colspan="5">(CWHxm2, RS, 3 * STS of 3a * 3a in the Deep Snowpack, Solar Class 3 * warm slope aspect in the Deep Snowpack)
Equation = 0.8*1.0*0.00*1.0 = Final RSI value of 0.0 (Class 6 habitat = Nil)
(CWHxm2, RS, 3 * STS of 7b * 7b in the Deep Snowpack, Solar Class 3 * warm slope aspect in the Deep Snowpack)
Equation = 0.8*0.8*0.4*1.0 = Final RSI value of 0.26 (Class 3 habitat = Moderate)</td></tr>
</table>

Limitations

At this time, habitat interpretations for elk are thought to have a moderate to high reliability within the MFLNRO timber supply review (TSR) area of the TSA. Due to lack of up-to-date age data for TFL areas (outside of the scope of the MFLNRO TSR), suitability results in these areas should be used with extreme caution and be viewed as having low reliability. However, for the purpose of Capability mapping, the results from the Strathcona TSA WHR project are thought to be a reliable reference for the TFL areas because the model rates everything under ideal conditions (the best that it can be) regardless of current condition.

The models should be viewed as hypotheses of species-habitat relationships rather than statements of proven cause and effect relationships. Their value is to serve as a basis for improved decision making and increased understanding of habitat relationships and habitat supply analyses over multiple landscape units.

The availability and interspersion of preferred habitat types across the landscape has a substantial effect on overall elk habitat values (Nyberg and Janz 1990, Brunt 1991). The habitat values produced for the purposes of this project are rated on an individual polygon basis. More detailed analyses need to be undertaken on the spatial relationships between different ecosystem units and structural stages, e.g. the proximity of warm rock outcrops to forests with high food availability and thermal cover.

In addition, during review of the snowpack model, it was pointed out that marine influence was not adequately reflected in the results. Adjustments to account for marine influence should be taken into consideration when interpreting the results.

The amount of shading from adjacent hillsides is a critical factor influencing winter range suitability for ungulates. The more shaded, the less valuable the area, regardless of whether-or-not the site is located on a south-facing slope. To account for this factor, a separate solar model (Direct Solar Radiation) was run for the project area.

Other Landscape Factors to Consider

A number of factors that were not considered in these models may be important to consider when determining overall habitat suitability. For example, topographic heterogeneity ("benchiness") is preferable to a uniform slope. Overstorey heterogeneity (variations in canopy closure) provides enhanced forage production and thickets for hiding in open canopy areas, and greater snow interception in areas of more closed canopy. Gullies, wetlands, and hummocky terrain also increase value of elk winter range. Other important landscape level considerations affecting the relative value of an area as elk winter range include the following:

- Position in the watershed – winter range requirements are more critical in areas of higher snowfall that are further from marine influences;
- Distance to other winter ranges - greater distances between winter ranges increases their individual importance;
- Adjacency to high quality spring and summer range;
- Availability of vegetated rock outcrops that provide topographic security cover (vantage points), favourable thermal conditions on sunny days, and areas that lose snow more readily during snow ablation periods;
- Suitability of adjacent areas to satisfy elk habitat requirements; and
- Other factors affecting local climatic conditions such as exposure to dominant winds or marine influences.

Literature Cited

B.C. Conservation Data Centre. 2013. *Rare Vertebrate Animal Tracking List (Sorted Phylogenetically Within Each Taxonomic Group).* September 24, 2013.

B.C. Ministry of Environment. 2013. *Vertebrate Red and Blue Lists*. Wildlife Branch, Victoria, B.C.

Boyd, R.J. 1978. American Elk pp. 11-29. In: Schmidt, J.L. and D.L. Gilbert (eds.). Big game of North America, ecology and management. Stackpole Books, Harrisburg. 494 pp.

Brunt, K.B. 1990. Ecology of Roosevelt Elk. Ch. 3 in J.B. Nyberg and D.W. Jan zeds. Deer and elk habitats in coastal forests of southern British Columbia. B.C. Ministry of Forests, Victoria, BC.

Brunt, K.B. 1991. Testing models of the suitability of Roosevelt Elk seasonal ranges. M.Sc. thesis, University of Victoria, Victoria, BC. 157 pp.

Campbell, K.L. 1995. Testing habitat suitability models for Roosevelt elk. M.Sc. thesis, University of British Columbia, Vancouver, BC. 60 pp.

Collins, W.B. and P. J. Urness. 1983. Feeding Behaviour and Habitat Selection of Mule Deer and Elk on Northern Utah Summer Range. J. Wildlife Management 47: 646-663.

Demarchi, D. and D. Demarchi. 2003. Species accounts for Roosevelt Elk based on 1:250,000 Broad Ecosystem Inventory Habitat Mapping. Prepared for Resources Inventory Branch, Ministry of Sustainable Resource Management, Victoria, B.C.

Ecosystems Working Group. 2000. Standards for Broad Ecosystem Classification and Mapping for British Columbia: Classification and Correlation of the Broad Habitat Classes Used in the 1:250,000 Ecological Mapping. Version 2.0.Terrestrial Ecosystems Task Force, Resources Inventory Committee, Victoria, BC. 212 pp.

Fish, Wildlife and Habitat Protection Department. 1994. *Wildlife Distribution Mapping, Big Game Series.* 16 maps, 1:2,000,000. Ministry of Environment, Lands and Parks, Victoria, B.C.

Henigman, J., J. Turner, and K. Swift. 2005 Coast Forest Region: Roosevelt Elk Wildlife Habitat Decision Aid. BC Journal of Ecosystems and Management 6(1):51–53. URL: www.forrex.org/jem/2005/vol6/no1/vol6_no1_art5.pdf

Luttmerding, H. A., D. A. Demarchi, E. C. Lea, D. V. Meidinger, and T. Vold. (Eds.) 1990. *Describing Ecosystems in the Field, 2nd Ed.* MOE Manual 11. B.C. Min. Environment, Lands and Parks and B.C. Ministry of Forests, Victoria, B.C.

Madrone Consultants Ltd. 1999a. Interim Report – *Clayoquot Sound Year 3 Wildlife Report Addenda*. Madrone Consultants, for Ministry of Forests, Port Alberni, Vancouver Island.

Madrone Consultants Ltd. 1999b. Preliminary Wildlife Interpretations of Terrestrial Ecosystem Mapping: Gold River Area (Compartments N, Z and Q). Madrone Consultants, for Western Forest Products, Vancouver Island.

McTaggart, I.C. and C.J. Guiguet. 1965. *The Mammals of British Columbia.* BCRM, Department of Recreation and Conservation. Handbook #11, Victoria, B.C.

MoFLNRO. 2014. A management plan for Roosevelt elk in British Columbia. Unpubl. BC Min.For. Lands and Nat. Res. Ops. 42 pp. http://www.env.gov.bc.ca/fw/wildlife/management-issues/docs/roosevelt_elk_management_plan_draft_July_2014.pdf

Murie, O. J. 1951. The elk of North America. University of Michigan. Stackpole Co. 376 pp..

Nyberg, J. B. and D. W. Janz, technical Eds. 1990. *Deer and Elk Habitats in Coastal Forests of Southern British Columbia.* Ministry of Forests, Special Report Series 5, Research Branch, Victoria, B.C.

Quayle, J.F. and K.R. Brunt. 2003. Status of Roosevelt Elk (Cervus elaphus roosevelti) in British Columbia. B.C. Ministry of Sustainable Resource Management., Conservation Data Centre, and B.C. Ministry of Water, Land and Air Protection, Biodiversity Branch, Victoria, BC. 31 pp.

Resources Inventory Committee (RIC). 1999. British Columbia Wildlife Habitat Ratings Standards. Version 2.0. BC Ministry of Environment, Lands and Parks, for the Terrestrial Ecosystem Task Force, Resources Inventory Committee. Victoria, BC. 97 pp.

Resources Inventory Committee (RIC). 1997. *Standardized Inventory Methodologies for Components of British Columbia's Biodiversity: Aerial-based Inventory Techniques for Selected Ungulates - Bison, Mountain Goat, Mountain Sheep, Moose, Elk, Deer, and Caribou*. Version 1.1 - January 1997. Wildlife Branch, Ministry of Environment, Lands and Parks, Victoria, B.C.

Ross, S. 1996. *Roosevelt Elk Inventory Project in Clayoquot Sound.* Unpubl. WILCON, Wildlife Consulting Ltd. Report to Ministry of Environment, Lands and Parks, Vancouver Island Regional Office, Nanaimo, B.C.

Shackleton, D. 1999. Hoofed mammals of British Columbia. Royal British Columbia museum handbook. University of British Columbia Press, Vancouver, Canada. 268 pp.

Skovlin, J.M. 1982. Habitat requirements and evaluations. Pages 369-414 *In* Thomas, J.W. and D.E. Toweil (eds.) Elk of North America: Ecology and Management. The Wildlife Management Institute. Washington, D.C.

Thomas, J. W., H. Black, R. J. Scherzinger, and R. J. Pedersen. 1979. *Deer and Elk*. In Wildlife Habitats in Managed Forests: the Blue Mountains of Oregon and Washington. J. W. Thomas (tech. editor). U. S. Dept. Agric. For. Ser., Agric. Handb. 553. Chap.8. pp 104-127. - def'n of security cover.

Wilson, S. 2012. Roosevelt Elk Management in British Columbia A discussion paper. Prepared for Ministry of Forests Lands and Natural Resource Operations, Nanaimo, B.C.

Wisdom, M.J., L.R. Bright, C.G. Carey, W.W. Hines, R.J. Pedersen, D.A. Smithey, J.W. Thomas, and G.W. Winter. 1986. A model to evaluate elk habitat in Western Oregon. USDA For. Serv., Portland. 36 pp.

Appendix A: Structural Stage Definitions

(As per *Land Management Handbook 25: Field Manual for Describing Terrestrial Ecosystems*, 2010)

Structural Stage	Description
Post-disturbance stages or environmentally induced structural development	
1 Sparse/ cryptogam	Initial stages of primary and secondary succession; bryophytes and lichens often dominant, can be up to 100%; time since disturbance less than 20 years for normal forest succession, may be prolonged (50–100+ years) where there is little or no soil development (bedrock, boulder fields); total shrub and herb cover less than 20%; total tree layer cover less than 10%.
1a Sparse	Less than 10% vegetation cover;
1b Bryoid	Bryophyte-dominated communities (greater than ½ of total vegetation cover).
1c Lichen	Lichen-dominated communities (greater than ½ of total vegetation cover).
Stand initiation stages or environmentally induced structural development	
2 Herb	Early successional stage or herbaceous communities maintained by environmental conditions or disturbance (e.g., snow fields, avalanche tracks, wetlands, grasslands, **flooding**, intensive grazing, intense fire damage); dominated by herbs (forbs, graminoids, ferns); some invading or residual shrubs and tress may be present; tree layer cover less than 10%, shrubby layer cover less than or equal to 20% or less than 1/3 of total cover; time since disturbance less than 20 years for normal forest succession; may herbaceous communities are perpetually maintained in this stage.
2a Forb-dominanted	Herbaceous communities dominated (greater than ½ o the total herb cover) by non-graminoid herbs, including ferns.
2b Graminoid-dominated	Herbaceous communities dominated (greater than ½ of the total herb cover) by grasses, sedges, reeds, and rushes.
2c Aquatic	Herbaceous communities dominated (greater than ½ of the total herb cover) by floating or submerged aquatic plants; does not include sedges growing in marshes with standing water (which are classed as 2b).
2d Dwarf shrub	Communities dominated (greater than ½ of the total herb cover) by dwarf woody species such as *Phyllodoce empetriformis, Cassiope mertensiana, Cassiope tetragona, Arctostaphylos arctica, Salix reticulata*, and *Rhododendron lapponicum.* (See list of dwarf shrubs assigned to the herb layer in the *Field Manual for Describing Terrestrial Ecosystems*).
3 Shrub/Herb	Early successional stage or shrub communities maintained by environmental conditions or disturbance (e.g., snow fields, avalanche tracks, wetlands, grasslands, **flooding**, intensive grazing, intense fir damage); dominated by shrubby vegetation; seedlings and advance regeneration may be abundant; tree layer cover less than 10%; shrub layer cover greater than 20% or greater than or equal to 1/3 of total cover.
3a Low shrub	Communities dominated by shrub layer vegetation less than 2 m tall; may be perpetuated indefinitely to environmental conditions or repeated disturbance; seedlings and advance regeneration may be abundant; time since disturbance less than 20 years for normal forest succession.
3b Tall shrub	Communities dominated by shrub layer vegetation that are 2–10 m tall; may be perpetuated indefinitely by environmental conditions or repeated disturbance; seedlings and advance regeneration may be abundant; time since disturbance less than 40 years for normal forest succession.
4 Pole/Sapling	Trees greater than 10m tall, typically dense stocked, have overtopped shrub and herb layers; younger stands are vigorous (usually greater than 10–15 years old); older stagnated stands (up to 100 years old) are also included; self-thinning and vertical structure not yet evident in the canopy – this often occurs by age 30 in vigorous broadleaf stands, which are generally younger than coniferous stand at the same structural stage; time since disturbance ins usually less than 40 years for normal forest succession; u to 100+ years for dense (5,000 - 15,000+ stems per hectare) stagnant stands.

Structural Stage	Description
5 Young Forest	Self-thinning has become evident and the forest canopy has begun differentiation into distinct layers (dominant, main canopy, and overtopped); vigorous growth and a more open stand than in the pole/sapling sate; time since disturbance is generally 40–80 years but may begin as early as age 30, depending on tree species and ecological conditions.
Understorey reinitiation stage	
6 Mature Forest	Trees established after the last disturbance have matured; a second cycle of shade tolerant trees may have become established; understories become well developed as the canopy opens up; time since disturbance is generally 80–250 years for stands within the CWH.
Old-growth stage	
7 Old Forest	Stands of old age with complex structure; patchy shrub and herb understories are typical; regeneration is usually of shade-tolerant species with composition similar to the overstorey; long-lived seral species may be present in some ecosystem types or edaphic sites. Old growth structural attributes will differ across biogeoclimatic units and ecosystems.
7a Old Forest	Stands with moderately to well developed structural complexity; stands composed mainly of shade-tolerant and regenerating tree species, although older seral and long-lived trees from a disturbance such as fire may still dominate the upper canopy; fire-maintained stands may have a 'single-storied' appearance; time since stand replacing disturbance generally greater than 250 years for stands within the CWH.
7b Very Old Forest	Very old stands having complex structure with abundant large-sized trees, snags and coarse woody debris; snags and coarse woody debris in all stages of decomposition; stands are comprised entirely of shade-tolerant overstorey species with well-established canopy gaps; time since stand replacing disturbance generally greater than 400 years for stands within the CWH.

Appendix B: Adjustments to forage values based on solar radiation-snowpack zone-structural stage combinations

The following figures provide a visual representation of adjustment values listed in Table 9.

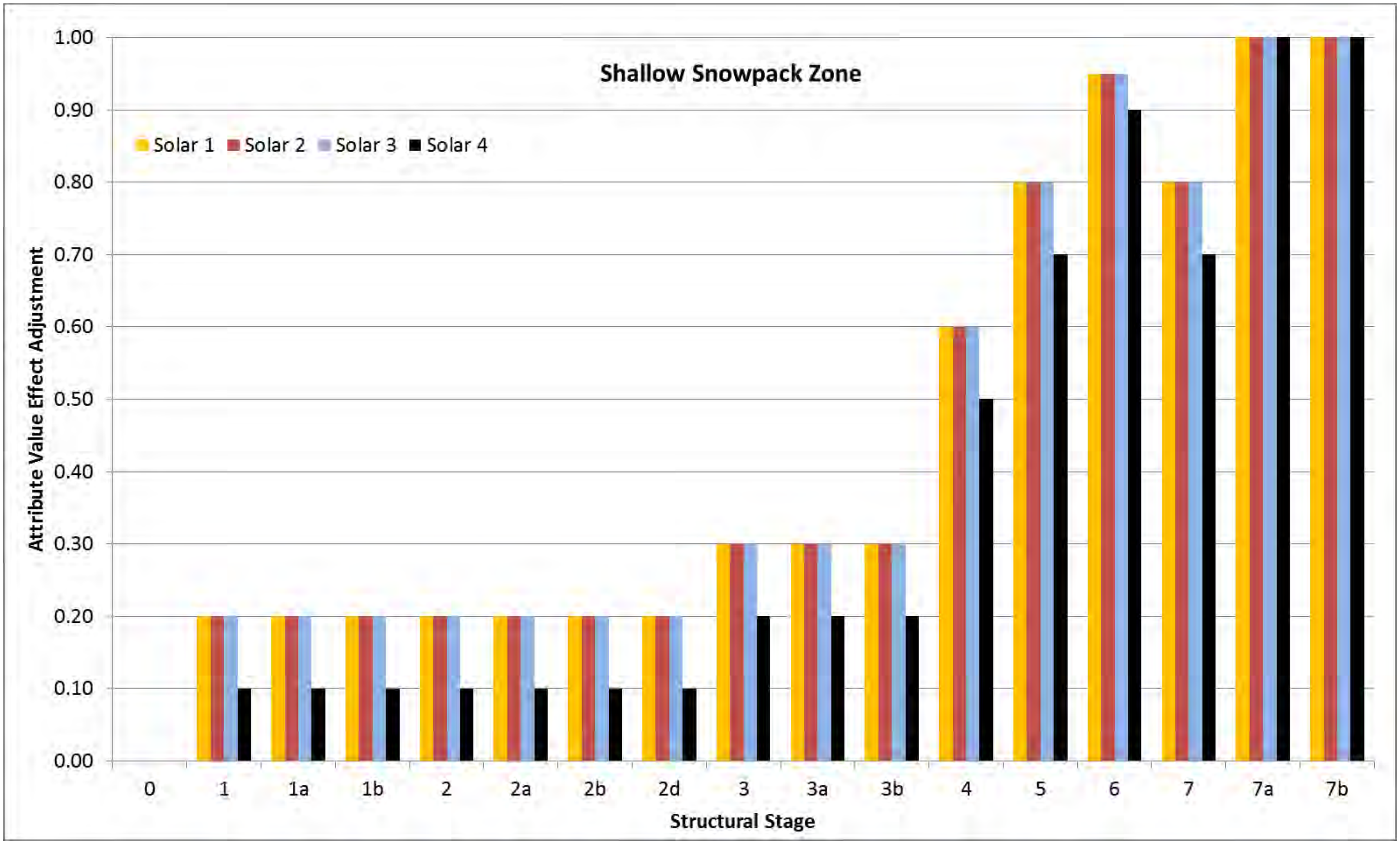


Figure 1. Attribute Value Effect adjustments to forage values based on solar radiation class for each structural stage within the Shallow Snowpack zone.

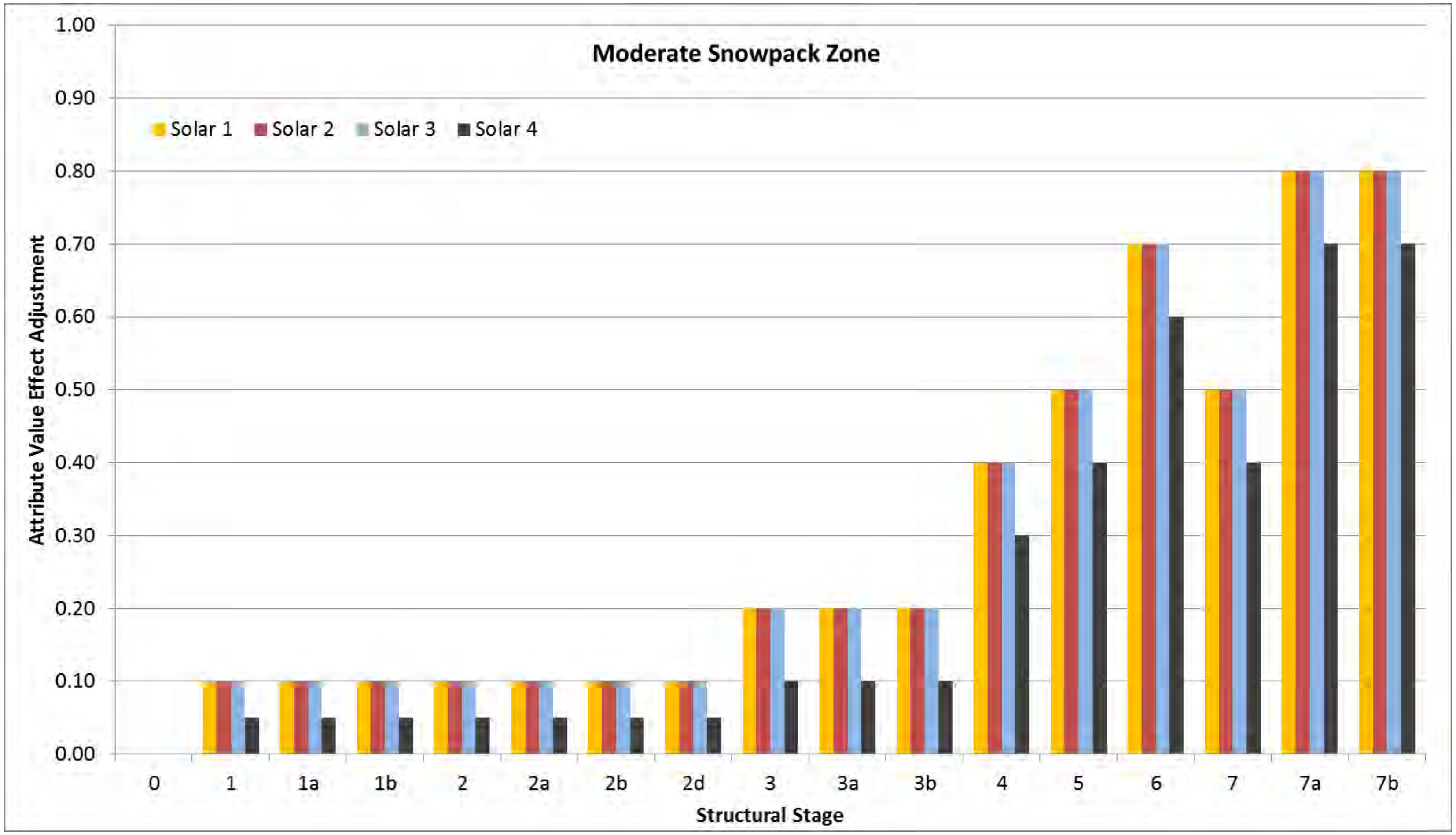


Figure 2. Attribute Value Effect adjustments to forage values based on solar radiation class for each structural stage within the Moderate Snowpack zone.

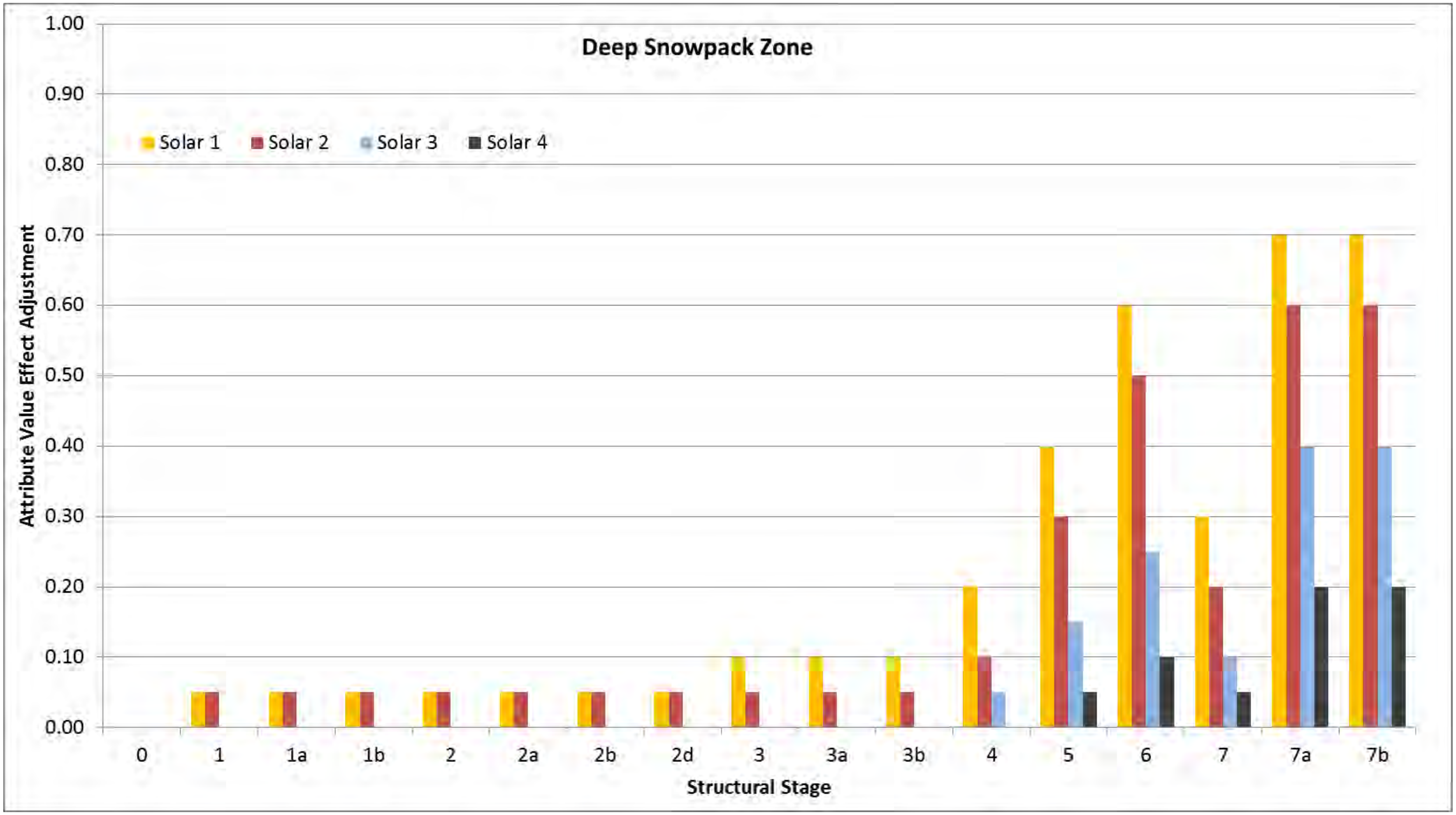
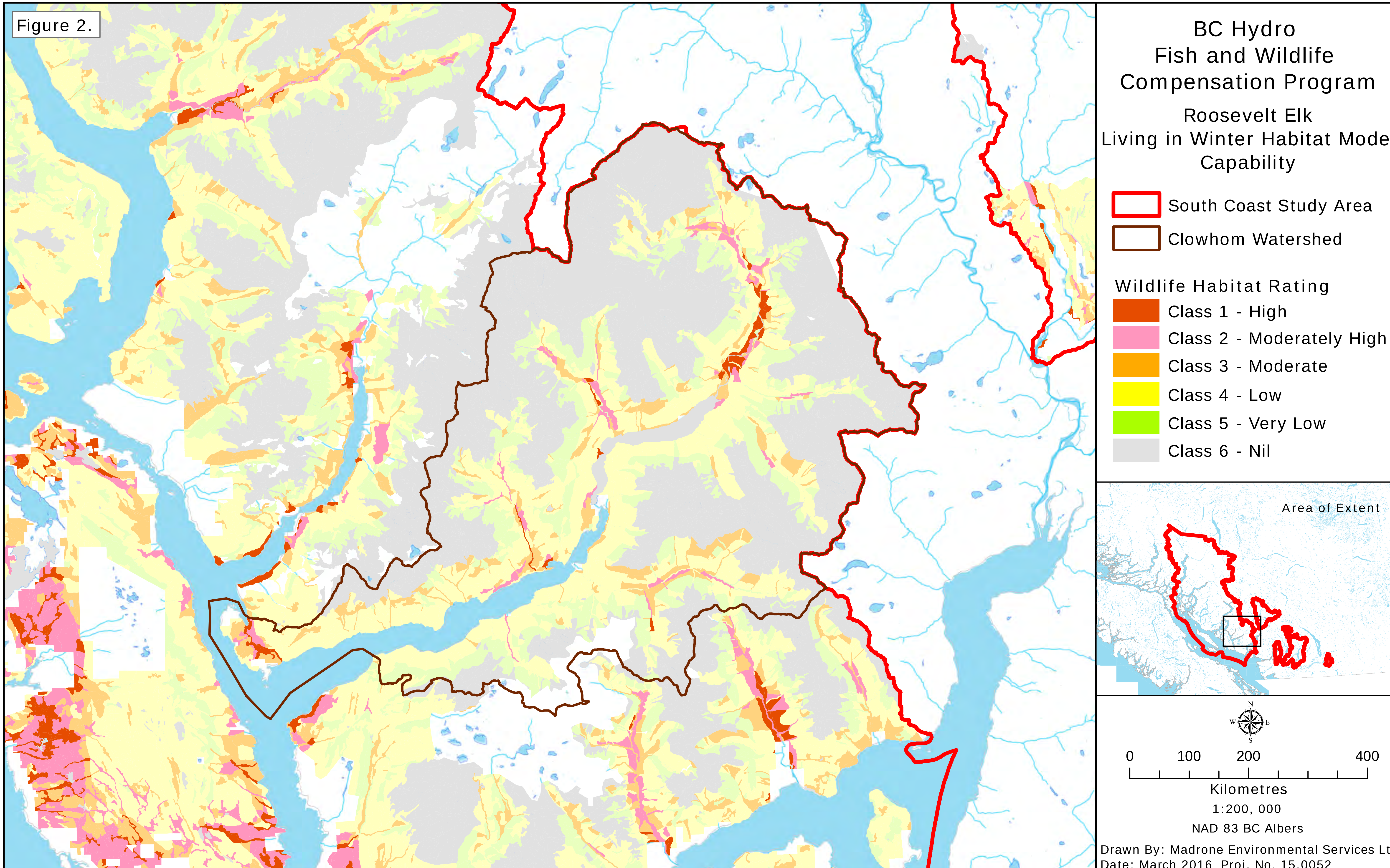


Figure 3. Attribute Value Effect adjustments to forage values based on solar radiation class for each structural stage within the Deep Snowpack zone.

APPENDIX C

Model results maps of habitat capability and suitability values by weighted average for Roosevelt Elk Living in Winter and Growing Season Forage.



BC Hydro
Fish and Wildlife
Compensation Program
Roosevelt Elk
Living in Winter Habitat Model
Capability
South Coast Study Area
Clowhom Watershed
Wildlife Habitat Rating
Class 1 - High
Class 2 - Moderately High
Class 3 - Moderate
Class 4 - Low
Class 5 - Very Low
Class 6 - Nil
Area of Extent
N
W
E
S
0
100
200
400
Kilometres
1:200, 000
NAD 83 BC Albers
Drawn By: Madrone Environmental Services Ltd.
Date: March 2016 Proj. No. 15.0052

Figure 2.

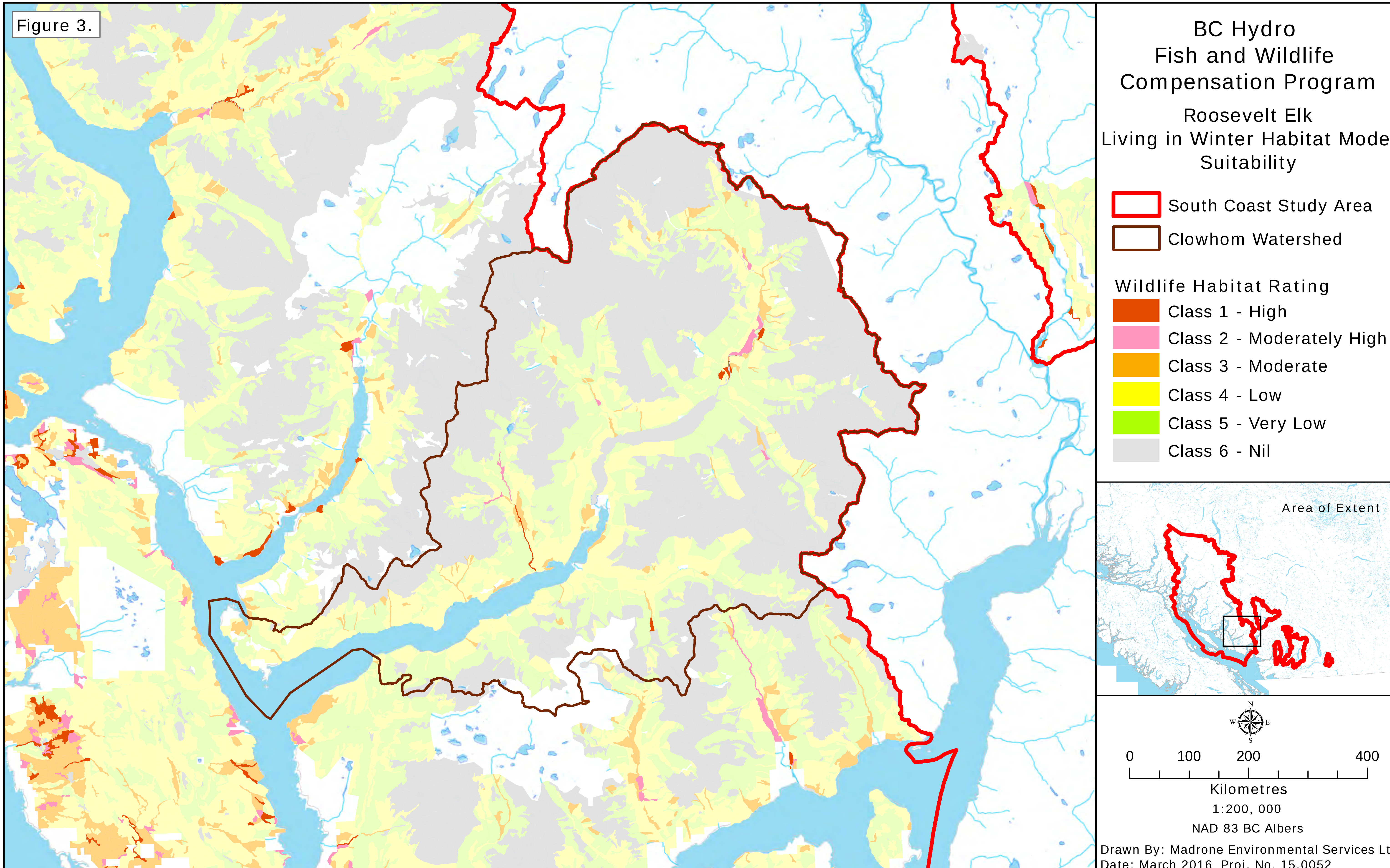


Figure 3.
BC Hydro
Fish and Wildlife
Compensation Program
Roosevelt Elk
Living in Winter Habitat Model
Suitability
South Coast Study Area
Clowhom Watershed
Wildlife Habitat Rating
Class 1 - High
Class 2 - Moderately High
Class 3 - Moderate
Class 4 - Low
Class 5 - Very Low
Class 6 - Nil
Area of Extent
0
100
200
400
Kilometres
1:200, 000
NAD 83 BC Albers
Drawn By: Madrone Environmental Services Ltd.
Date: March 2016 Proj. No. 15.0052

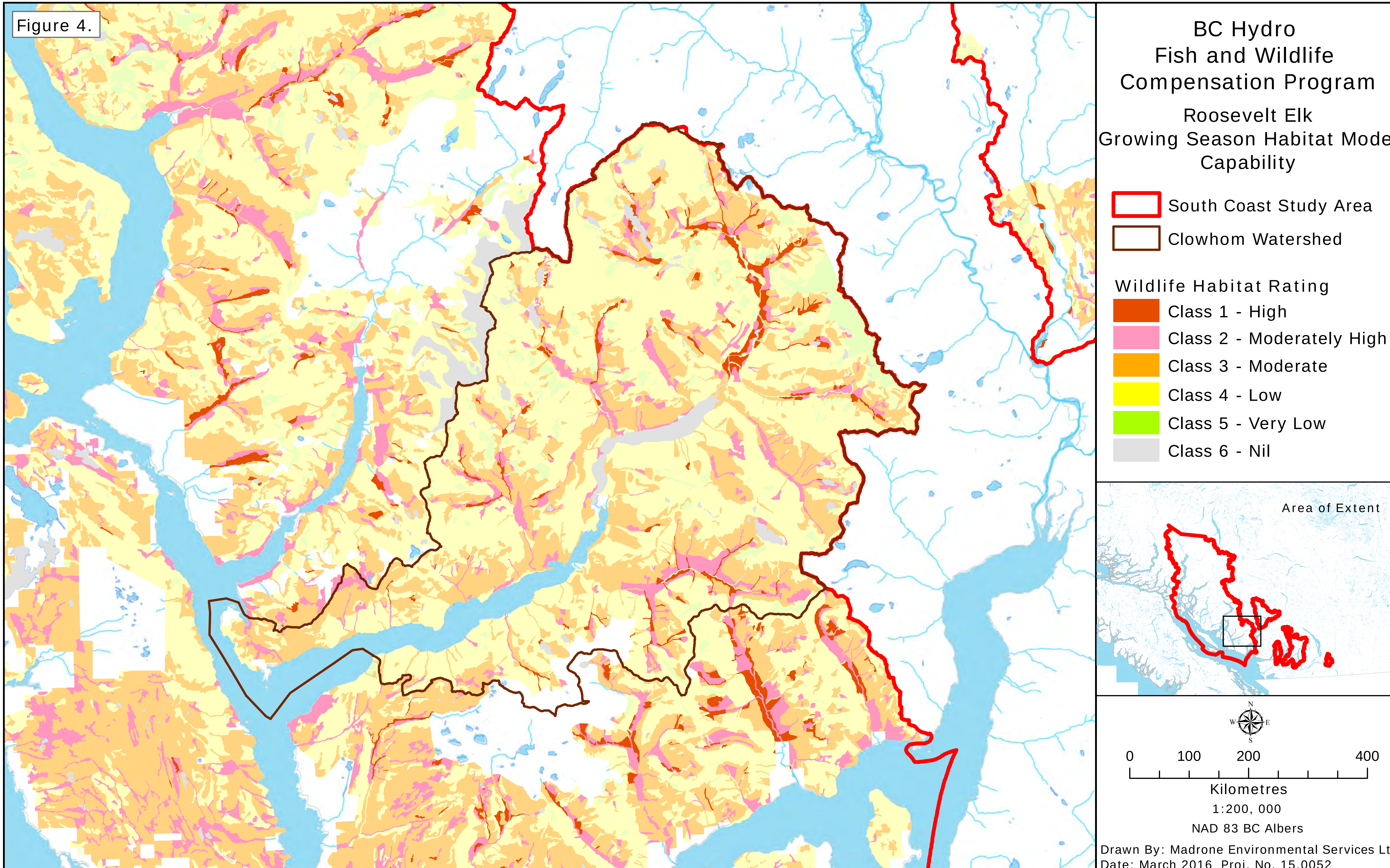


Figure 4.
BC Hydro
Fish and Wildlife
Compensation Program
Roosevelt Elk
Growing Season Habitat Model
Capability
South Coast Study Area
Clowhom Watershed
Wildlife Habitat Rating
Class 1 - High
Class 2 - Moderately High
Class 3 - Moderate
Class 4 - Low
Class 5 - Very Low
Class 6 - Nil
Area of Extent
0
100
200
400
Kilometres
1:200, 000
NAD 83 BC Albers
Drawn By: Madrone Environmental Services Ltd.
Date: March 2016 Proj. No. 15.0052

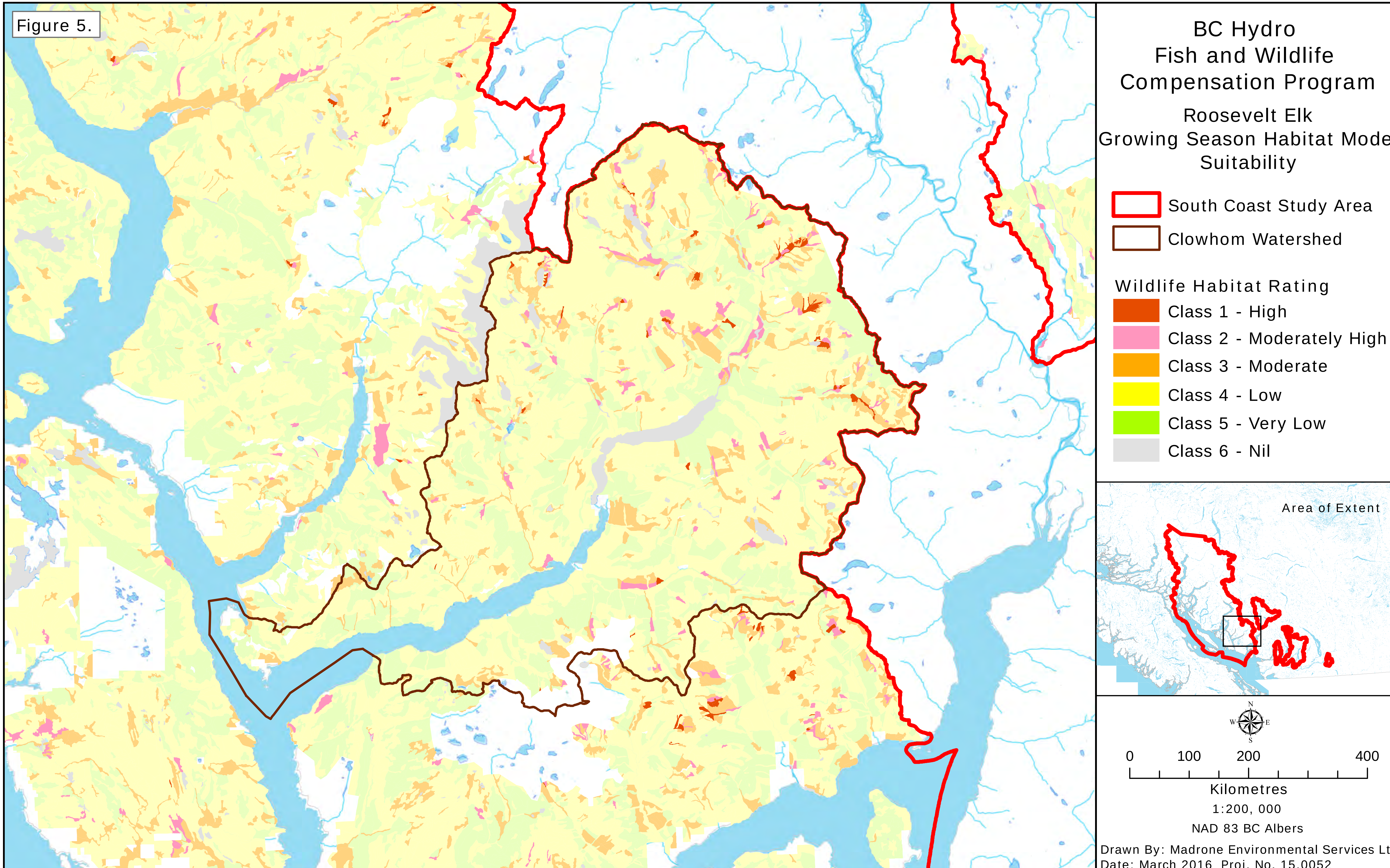


Figure 5.
BC Hydro
Fish and Wildlife
Compensation Program
Roosevelt Elk
Growing Season Habitat Model
Suitability
South Coast Study Area
Clowhom Watershed
Wildlife Habitat Rating
Class 1 - High
Class 2 - Moderately High
Class 3 - Moderate
Class 4 - Low
Class 5 - Very Low
Class 6 - Nil
Area of Extent
0
100
200
400
Kilometres
1:200, 000
NAD 83 BC Albers
Drawn By: Madrone Environmental Services Ltd.
Date: March 2016 Proj. No. 15.0052

MADRONE
environmental services ltd.

APPENDIX 2

South Coast WHR Data Development Documentation – Creation of the Ecosystem and WHR Spatial Data

Appendix 2

Expansion of Roosevelt Elk Habitat Model to Sunshine Coast - Data Development Process

Version 1.0 – March 31, 2016

Tania Tripp and Jenna Cragg – Madrone Environmental Services Ltd., based on
Original “Strathcona TSA WHR” Version 1.0 by Jeff Kruys - CloverPoint - March 26, 2014

Table of Contents

Step 1: Extraction of TEIS Data

The following, 14 TEM datasets (non-overlapping) were exported from the TEIS Master Long Table feature class to create the Sunshine Coast WHR feature class.

BAPID	Original Project Name
1073	Hope IFPA TEM
4006	Mission TEM
4517	Callaghan LU TEM
4518	Mamquam LU TEM
4519	Lower Squamish LU TEM
4522	CDFmm TEM
4677	Chapman LU TEM
4678	Sechelt LU TEM
4684	Howe LU TEM
4904	Powell River Block 1 TEM
4913	Jervis LU TEM
4914	Salmon LU TEM
4915	Brittain LU TEM
5638	Sunshine Coast TSA Haslam LU TEM
5640	Sunshine Coast TSA Bunster LU TEM
5666	Soo TSA Whistler LU
6118	Narrows LU TEM
6122	Lois Lake West TEM
6123	Lois Lake East TEM

Where mapping was already edge matched (i.e., completed by the same company, Timberline, from 2007-2009 for many of the landscape units included in this merged coverage), no overlap decisions were necessary.

In the combined "seamless" (i.e. non-overlapping) feature class, only the attribute fields pertaining to ecosystem classification were retained. Attributes describing terrain, geomorphological processes, and so on, which are not generally used in assessing wildlife habitat suitability or capability, were dropped. The ecosystem attributes in the TEIS Master Long Table formed the template for the WHR "base" feature class, to which additional attributes were then added.

Step 2: Data Cleanup and Creation of Structural Stage Lookup Table

An automated process read the WHR "base" feature class and created a list of all the unique combinations of ecosystem codes that were found. The output of this tool was first used in an iterative process of correcting errors in the ecosystem attribute values.

After all such errors were eliminated, the output table from this automated process was used as a basis for creating the Structural Stage Lookup Table. The Structural Stage Lookup Table is used in various ways throughout the remainder of the WHR data development process. Most importantly, it allows us to look up what the structural stage code would be for a given ecosystem unit at a given "age" (i.e. number of years since the last disturbance).

Step 3: Addition of Supporting Attributes for WHR

Several non-standard attributes were added to the WHR feature class, via manual geoprocessing and/or custom scripted processes. The RRM Tool was then configured to use these additional attributes in calculating wildlife habitat ratings.

Field Name	Value Domain	Description	Data Source	Calculation of Values
ASPECT	0-359	Aspect, in degrees azimuth	BC 25m DEM (2012)	Aspect raster converted to point feature class and overlaid with polygons; ASPECT attribute receives value of "circular average" of aspect values of all points that lie within the polygon, or, if no points lie within the polygon, the aspect value of the point that lies closest to the centroid of the polygon.
SLOPE	0-90	Slope, in degrees	BC 25m DEM (2012)	Slope raster converted to point feature class and overlaid with polygons; SLOPE attribute receives value of average of slope values of all points that lie within the polygon, or, if no points lie within the polygon, the slope value of the point that lies closest to the centroid of the polygon.
SLOPE_MOD	k, q, w, z	Site modifier code for steep slopes	Derived from ASPECT and SLOPE values Note: Rule changes for slope >25% versus >35% depending on BEC subzone variant. In general, interior BEC use >25% as significant slope; while >35% is applied to coastal ecosystems.	If BGC_ZONE = "CWH" or "CDF" or "MH" or "AT" or "CMA": "k" if ASPECT is 285-134 and SLOPE is 35 to 100 "q" if ASPECT is 285-134 and SLOPE > 100 "w" if ASPECT is 135-284 and SLOPE is 35 to 100 "z" if ASPECT is 135-284 and SLOPE > 100 If BGC_ZONE is not "CWH" or "MH" or "CDF" or "AT" or "CMA" : "k" if ASPECT is 285-134 and SLOPE is 25 to 100 "q" if ASPECT is 285-134 and SLOPE > 100 "w" if ASPECT is 135-284 and SLOPE is 25 to 100 "z" if ASPECT is 135-284 and SLOPE > 100

Field Name	Value Domain	Description	Data Source	Calculation of Values
VRI_AGE_CL_STS	-1, 1, 4, 10, 20, 40, 60, 80, 100, 120, 140, 250, 399, 9999	The area-dominant age class (for structural stage lookup) according to current VRI age raster layer.	VRI dataset (2015)	Age raster is reclassified as follows: 1 if original value is 0 or 1 4 if original value is 2 to 4 10 if original value is 5 to 10 20 if original value is 11 to 20 40 if original value is 21 to 40 60 if original value is 41 to 60 80 if original value is 61 to 80 100 if original value is 81 to 100 120 if original value is 101 to 120 140 if original value is 121 to 140 250 if original value is 141 to 250 399 if original value is 251 to 399 9999 if original value is 400 or higher Reclassified raster is converted to a polygon feature class and overlaid with WHR polygons; VRI_AGE_CL_STS attribute is assigned the value of the area-dominant age class value, or -1 if the polygon entirely occupies an area where no age data is available.
VRI_AGE_CL_STAND	-1, 15, 30, 50, 80, 9999	The area-dominant age class (for stand composition lookup) according to current VRI age raster layer.	VRI dataset (2015)	Age raster is reclassified as follows: 15 if original value is 0 to 15 30 if original value is 16 to 30 50 if original value is 31 to 50 80 if original value is 51 to 80 9999 if original value is 81 or higher Reclassified raster is converted to a polygon feature class and overlaid with WHR polygons; VRI_AGE_CL_STAND attribute is assigned the value of the area-dominant age class value, or -1 if the polygon entirely occupies an area where no age data is available.

Field Name	Value Domain	Description	Data Source	Calculation of Values
MARVIN_AGE_CL_STS	-1, 1, 4, 10, 20, 40, 60, 80, 100, 120, 140, 250, 399, 9999	The area-dominant age class (for structural stage lookup) according to Marvin Eng's 2012 age raster layer.	VRI dataset (2015) (Projected Age is Jan 2014)	Age raster is reclassified as follows: 1 if original value is 0 or 1 4 if original value is 2 to 4 10 if original value is 5 to 10 20 if original value is 11 to 20 40 if original value is 21 to 40 60 if original value is 41 to 60 80 if original value is 61 to 80 100 if original value is 81 to 100 120 if original value is 101 to 120 140 if original value is 121 to 140 250 if original value is 141 to 250 399 if original value is 251 to 399 9999 if original value is 400 or higher Reclassified raster is converted to a polygon feature class and overlaid with WHR polygons; MARVIN_AGE_CL_STS attribute is assigned the value of the area-dominant age class value, or -1 if the polygon entirely occupies an area where no age data is available.
MARVIN_AGE_CL_STAND	-1, 15, 30, 50, 80, 9999	The area-dominant age class (for stand composition lookup) according to Marvin Eng's 2012 age raster layer.	VRI dataset (2015) (Projected Age is Jan 2014)	Age raster is reclassified as follows: 15 if original value is 0 to 15 30 if original value is 16 to 30 50 if original value is 31 to 50 80 if original value is 51 to 80 9999 if original value is 81 or higher Reclassified raster is converted to a polygon feature class and overlaid with WHR polygons; MARVIN_AGE_CL_STAND attribute is assigned the value of the area-dominant age class value, or -1 if the polygon entirely occupies an area where no age data is available.

Field Name	**Value Domain**	**Description**	**Data Source**	**Calculation of Values**
LU_STS1	1, 1a, 1b, 2, 2a, 2b, 2c, 2d, 3, 3a, 3b, 4, 5, 6, 7, 7a, 7b	Looked-up Structural Stage code for ecosystem component 1	Age class of highest precedence; Structural Stage Lookup Table; or the code given in STRCT_S1 [[Use the LUT if no other age or Structural stage data is available (apply climax value if forested = “N” or forested = “Y” and operable = “N”) Operable, forested sites with no info from VRI_Age = stay blank]]	LU_STS1 is assigned the structural stage code from the Structural Stage Lookup Table using the BEC unit and first component ecosystem codes and the age value of highest precedence. The age value of highest precedence found in the VRI_AGE_CL_STS field is used; if that is -1, then the age value found in the MARVIN_AGE_CL_STS field is used; if that is -1, then if the unit is forested and operable, we use the existing value in the STRCT_S1 field (even if it is empty); but if the unit is forested and not operable, we use the existing value in STRCT_S1 if it is non-null or the climax structural stage for the unit if the value in STRCT_S1 is null; if the unit is not forested and not operable, we use the climax structural stage for the unit. Note: Use the LUT if no other age or Structural stage data is available (apply climax value if forested = “N” or forested = “Y” and operable = “N”). Operable, forested sites with no info from age layer stay blank.
LU_STS2	1, 1a, 1b, 2, 2a, 2b, 2c, 2d, 3, 3a, 3b, 4, 5, 6, 7, 7a, 7b	Looked-up Structural Stage code for ecosystem component 2	Age class of highest precedence; Structural Stage Lookup Table; or the code given in STRCT_S2	Similar to LU_STS1 above, but using the second ecosystem component codes, and the original STRCT_S2 value if applicable.
LU_STS3	1, 1a, 1b, 2, 2a, 2b, 2c, 2d, 3, 3a, 3b, 4, 5, 6, 7, 7a, 7b	Looked-up Structural Stage code for ecosystem component 3	Age class of highest precedence; Structural Stage Lookup Table; or the code given in STRCT_S3	Similar to LU_STS1 above, but using the third ecosystem component codes, and the original STRCT_S3 value if applicable.

Field Name	Value Domain	Description	Data Source	Calculation of Values
LU_STAND1	B, C, M	Looked-up Stand Composition code for ecosystem component 1	Age class of highest precedence; Structural Stage Lookup Table	If the value assigned to the LU_STS1 attribute begins with 1-3 or is null, LU_STAND1 is assigned a null value; if LU_STS1 begins with 4-7, LU_STAND1 is assigned the stand composition code from the Structural Stage Lookup Table using the BEC unit and first component ecosystem codes and the age value of highest precedence. The age value to be used is VRI_AGE_CL_STAND if it is not -1; if it is -1, then MARVIN_AGE_CL_STAND is used; if that is -1, if both of these age class values are -1, then, if the ecosystem unit is operable according to the Structural Stage Lookup Table, we use the original value in the STAND_A1 attribute (even if it is null); if the ecosystem is not operable, we use the original value in the STAND_A1 attribute if it is non-null, or if STAND_A1 is null, we use the climax stand composition code for the ecosystem unit according to the Structural Stage Lookup Table; if the ecosystem operability is unknown, LU_STAND1 is assigned a null value.
LU_STAND2	B, C, M	Looked-up Stand Composition code for ecosystem component 2	Age class of highest precedence; Structural Stage Lookup Table	Similar to LU_STAND1 above, but using the second ecosystem component codes, and the original STAND_A2 value if applicable.
LU_STAND3	B, C, M	Looked-up Stand Composition code for ecosystem component 3	Age class of highest precedence; Structural Stage Lookup Table	Similar to LU_STAND1 above, but using the third ecosystem component codes, and the original STAND_A3 value if applicable.

Field Name	Value Domain	Description	Data Source	Calculation of Values
AGE_FROM_STS	Integer value greater than 0	Derived age value, in cases where no other age data was available, and the original STRCT_S1 code was used	Structural Stage Lookup Table	For polygons where all both of the age class attributes (VRI_AGE_CL_STS and MARVIN_AGE_CL_STS) were assigned a value of -1 (i.e. “no data”), but the LU_STS1 was assigned a non-null value (i.e. the original value in the STRCT_S1 field or the climax structural stage code for the ecosystem unit), the AGE_FROM_STS attribute is assigned a value that represents the midpoint of the age range for which the structural stage code in LU_STS1 would apply to the first component ecosystem unit according to the Structural Stage Lookup Table. If the LU_STS1 attribute value is null, the LU_STS2 value is considered, and if it is null, the LU_STS3 value is considered.

Field Name	Value Domain	Description	Data Source	Calculation of Values
SNOWPACK	1, 2, 3, 4	Snowpack Zone	Derived from BGC Unit and ELEVATION values	Snowpack class is represented by the following values: 1 if snowpack is considered "Shallow" 2 if snowpack is considered "Moderate" 3 if snowpack is considered "Deep" 4 if snowpack is considered "Very Deep" The SNOWPACK attribute receives the snowpack class value in each polygon derived from snowpack model rasters. The snowpack is assigned based on a combination of BEC, elevation, slope, and solar radiation. This process was completed in a separate model for coastal mapsheets (letter blocks). The solar radiation code = Value given to each ecosystem based on the number of watt hours per square meter (WH/m2) during the winter months (Dec-Feb), where (1) receives the greatest amount of solar radiation and (4) receives the least. These are defined as (measured in WH/m2): 1 if 1,167.30 to 1,556.27 2 if 778.33 to 1,167.30 3 if 389.37 to 778.33 4 if 0.40 to 389.37
SOLAR_CODE	1, 2, 3, 4	Solar Code		Derived directly from the SR_CODE values in the Solar Radiation Model rasters .

Step 4: Reduction of WHR Attribute Table to Unique Values for RRM Tool

An automated process read the WHR feature class attribute table and produced a CSV file that was a list of all unique combinations of values found among all individual ecosystem components. This CSV file was imported into a worksheet of the Microsoft Excel file with the RRM Tool set up. The RRM Tool was then executed for each Roosevelt elk life requisite for which ratings were required. The setup and execution of the RRM Tool is outside the scope of this document.

All of the ratings columns calculated by the RRM Tool were compiled into a single table and exported to a CSV file, which was then read by subsequent automated processes in the WHR Data Development Process.

For the Sunshine Coast WHR project, the added WHR fields in the RRM Tool output table were as follows:

Rating Field	Description (Species, Life Requisite, Equation)
MCEEL_GFD_CAPSU_E1_6C	Roosevelt Elk, Food Values in Summer, Equation 1, 6-class ratings
MCEEL_LIW_CAPSU_E6_6C	Roosevelt Elk, Food and Snow Interception Values in Winter (Winter Range), Equation 6, 6-class ratings

The “equations” listed in the table above refer to combinations of input attributes that were considered when calculating the rating. For the Strathcona TSA WHR project, the equations were as follows:

Equation	Input Attributes
Equation 1	BGC Unit, Site Series Mapcode, Structural Stage, Stand Composition, Site Modifier
Equation 6	BGC Unit, Site Series Mapcode, Structural Stage, Site Modifier, Snowpack Code, Solar Radiation Code

Step 5: Calculation of Summarized Wildlife Habitat Ratings for Map Products

The WHR polygon feature class and the associated habitat ratings needed to be depicted on map products. Each WHR polygon contains up to three ecosystem components and therefore up to three separate WHR values for each species and life requisite for either suitability or capability. We needed to calculate summarized ratings that combine these (up to) three values for each polygon in order to display WHR information on maps for a given species and life requisite. For each species and life requisite, the following summarized ratings were calculated:

Summarized Rating	Description
Max Area (Capability)	The capability rating of the first ecosystem component (first decile)
Highest Value (Capability)	The highest capability rating among the three ecosystem components
Weighted Average (Capability)	The average capability rating of the three ecosystem components (weighted by decile value)
Highest Value (Suitability)	The highest suitability rating among the three ecosystem components
Weighted Average (Suitability)	The average suitability rating of the three ecosystem components (weighted by decile value)

Maps could then be created depicting any one of these summarized ratings.

It has not yet been decided which, if any, of these attribute fields should be saved permanently in the WHR feature class when it is stored on the Ministry servers.

Step 6: Creation of LYR files for Map Products

Map products were required to depict the state of wildlife habitat quality during the year 2015. A custom scripted process was created which added new attribute fields to store the weighted average (WA) and highest value (HV) ratings. The LYR files created from this process are as follows:

LYR Filename	Symbolized attribute field
Roosevelt Elk - Food Values - Summer - Capability - Weighted Average.lyr	MCEEL_GFD_CAP_E1_6C_WA
Roosevelt Elk - Food Values - Summer - Suitability - Weighted Average.lyr	MCEEL_GFD_SU_E1_6C_WA
Roosevelt Elk - Food Values - Summer - Capability – Highest Value.lyr	MCEEL_GFD_CAP_E1_6C_HV
Roosevelt Elk - Food Values - Summer - Suitability –Highest Value.lyr	MCEEL_GFD_SU_E1_6C_HV
Roosevelt Elk - Food Values - Winter - Capability - Weighted Average.lyr	MCEEL_LIW_CAP_E6_6C_WA
Roosevelt Elk - Food Values - Winter - Suitability - Weighted Average.lyr	MCEEL_LIW_SU_E6_6C_WA
Roosevelt Elk - Food Values - Winter - Capability – Highest Value.lyr	MCEEL_LIW_CAP_E6_6C_HV
Roosevelt Elk - Food Values - Winter - Suitability – Highest Value.lyr	MCEEL_LIW_SU_E6_6C_HV

APPENDIX 3

Data Development Documentation – Direct Solar Radiation (Solar) and Snowpack Models

Version 1.0 - March 30, 2014. GIS scripts for the data development process of creating and running the solar and snowpack models was conducted by George Eade (Geo Tech Systems, Victoria) and Jeff Kruys (CloverPoint, Victoria; initial snowpack model), with guidance for relevance to ecosystem classification, elevations, and snow depth thresholds as they relate to coastal ungulate winter range by Tania Tripp (Madrone Environmental Services Ltd.).

Version 2.0 – March 30, 2015. The main change in 2015 was in how the snowpack and solar model products produced by George Eade were applied to the ecosystem mapping (attributes assigned to each polygon) for inclusion in the ungulate winter range models run with the RRM tool. This process was completed by Jeff Kruys of CloverPoint and Anna Jeffries of Madrone, with direction of the process provided by Tania Tripp, and review of the logic by Kim Brunt, Tania Tripp and Jenna Cragg.

Note: No changes were made to the final snowpack and solar models produced in 2014 by George Eade, but the adjusted snowpack value was dropped in favour of including the initial snowpack and solar codes in the 2015-2016 ungulate winter range models. This allowed full flexibility in adjusting the winter range model for warm or cool slope/aspect/solar combinations within each of the snowpack zones.

Methods Summary:

Snowpack and solar radiation models were developed for coastal BC. The Snowpack and Solar models, were completed for 13 coastal letterblocks (1:250 000 mapsheets), starting from the NW with 102P, 92M, 92N, 92O, 102I, 92L, 92K, 92J, 92E, 92F, 92G, 92C and 92B.

The impetus of this project was to produce a snowpack and solar dataset that could be used as an overlay in assessment of ungulate winter range habitat. The vision was to eventually be able to incorporate this dataset in with other site attribute information within ecosystem spatial data (polygons) where wildlife habitat models were being developed to predict ungulate winter ranges. However, the information in the Snowpack-Solar model for the coast has the potential to be combined, adjusted and examined in a variety of resource management applications and analyses for a multitude of wildlife species.

Snowpack Model

The 2014 coastal snowpack model was based on a 25 m Digital Elevation Model (DEM). Each 25 m raster was assigned a value for biogeoclimatic classification (BEC), as well as average slope, aspect, and elevation. Values within each of these features were then grouped into a series of classes, ranges, or codes for use with wildlife habitat models. For example, there are 14 unique BEC/Subzone/Variant combinations in total for the project area; assigned 1 through 14 as a unique BEC_Code ID for use in the snowpack raster model. The most up-to-date provincial BEC coverage available in 2013 (BECv8) was applied in raster format to assign BEC coverage. The benefit of working with the larger BEC polygons in place of TEM polygons were two-fold: 1) reduced processing time, and 2) in theory should have captured current BEC classification (as many of the ecosystem map inputs were based on older versions of BEC).

The provincial BEC layer was used as the base, and then it was overlaid with the reclassified elevation polygons. This process split the larger BEC polygons into small polygons based on elevation zones. A Slope and Aspect classification were then applied using the same 25 m DEM and classification scheme used for assigning attributes to the ecosystem spatial data (a separate process as described in Appendix 3: Strathcona TSA WHR Data Development – Creation of Ecosystem and WHR Spatial Data). The intent was to produce something similar to the results from the ecosystem spatial data development process.

A recent (September 2015) review of the Initial Snowpack assignment based on BEC and Elevation Codes indicates that the provincial BEC coverage does not necessarily have the best data available. Specifically, a series of polygons in the Power Landscape Unit (western Vancouver Island; NW boundary of the project area) were assigned snowpack codes based on provincial BEC coverage assigning a significant portion of the LU as CWHvh1. However, the TEM and elevations support that there are at least 4 BEC subzone variants in the area (as indicated in the ecosystem mapping).

The following is a summary of the elevation ranges assigned from DEM, and their associated codes.

Table 1. Elevation ranges and associated elevation codes applied to the coastal snowpack model.

Elevation Range (meters)	Elevation Code
0-150	1
151-200	2
201-250	3
251-300	4
301-400	5
401-450	6
451-500	7
501-550	8
551-650	9
651-700	10
701-750	11
751-850	12
851-900	13
901-9999	14

For snowpack zone, a total of four (4) Classes were assigned based on a combination of elevation and BEC that indicated whether the site conditions were likely to be associated with a Shallow, Moderate, Deep or Very Deep snowpack as described below.

Table 2. Snowpack Zones, Associated Code (ID) and Descriptions for the Coastal BC Snowpack Model.

ID	Snowpack Zone	Description
1	Shallow	Snow occasionally deep enough to inhibit movements (several days or less). Snow rarely reaches critical depth (several days or less)
2	Moderate	Snow reaches depths sufficient to inhibit movements for periods of days to weeks most winters. Snow occasionally reaches critical depth (several days or less).
3	Deep	Snow reaches critical depth for a period of weeks to months every year
4	Very Deep	Snow reaches beyond critical depth for deer and elk for a period of weeks to months every year

Elevation ranges within each BEC Zone were examined and split to follow snowpack levels outlined in Nyberg and Janz (1990) for elk and deer, and by Brunt (1991) for elk. For the coastal snowpack model, the provincial BEC layer (Version 8) was used as the reference source for BEC information.

Table 3. Snowpack Elevations and Associated Descriptions as per Nyberg and Janz (1990).

Nyberg and Janz 1990 (Elk and Deer)	Snowpack Zone	Description
0-300	Shallow	Usually shallow (<30 cm) and ephemeral. Critical snowpacks occur less than once in 15 years
200-600	Moderate	Usually shallow (30-60 cm) but persistent for up to 2 weeks. Critical snowpacks occur every 5-15 years on average.
500-900	Deep	Often deep (>60 cm) and persistent for 2 weeks or more. Critical snowpacks occur every 3-10 years on average.
>800	Very Deep	Usually more than 60 cm deep and persistent for most of the winter

Table 4. Snowpack Elevation-Slope Combinations as per Brunt (1991).

K. Brunt Thesis 1991 (Elk)	Snowpack Zone	Flat	South	West	North	East
0-350	Shallow	1	1	0.8	0.6	0.8
351-550	Moderate	0.8	0.8	0.6	0.4	0.6
551-1050	Deep	0.6	0.6	0.4	0.2	0.4
>1050	Very Deep	0	0	0	0	0

After each 25m raster cell was assigned a unique code for BEC and Elevation, the two codes were combined to represent a series of unique combinations of elevation-based snowpack (BEC_Elevation) (Table 5). These values were assigned to each raster cell based on majority of area (whichever snowpack ID represented >50% of the polygon).

Table 5. BGC-Elevation Snowpack Zones Applied to WHR Project Spatial Data.

BGC	Generic BGC Elev Range (for Reference)	Total Mean Annual Snowfall - range (cm) (Green and Klinka 1994; Banner et al 1993)	Max. expected Snowdepth (cm) (KWR 2005)	Elevation (m)*	Snowpack Zone (BGC/Elevation) 2014
CWHvh1	0-200	25-272		0-300	Shallow
CWHvm1	0-650	20-548	141	0-150	Shallow
				151-300	Moderate
				301-650	Deep
				>650	Very Deep
CWHvm2	450-800	552-605	226	<300	Moderate
				301-650	Deep
				>650	Very Deep
CWHxm1	0-450	26-234	153	0-254	Shallow
				255-334	Moderate

BGC	Generic BGC Elev Range (for Reference)	Total Mean Annual Snowfall - range (cm) (Green and Klinka 1994; Banner et al 1993)	Max. expected Snowdepth (cm) (KWR 2005)	Elevation (m)*	Snowpack Zone (BGC/Elevation) 2014
CWHxm2	0-700	26-234		0-280	Shallow
				202-500	Moderate
				>500	Deep
CWHdm	0-650 (above CWHxm if present)	45-177	141	0-200	Shallow
				201-500	Moderate
CWHmm1	450-700			115-260	Shallow
				200-556	Moderate
				423-650	Deep
CWHmm2	700-1100	snowpack persists throughout winter		440-540	Moderate
				500-651	Deep
				>652	Very Deep
MHwh	500-900	intermediate heavy snowpack (<0.5m) (50 cm)		400-650	Moderate
				>650	Deep
MHmm1	800-1350	816-820 / up to 3 m snowpack	311	318(500)-650	Deep
				>650	Very Deep
MHmmp	1350-1600			Any	Very Deep
CMA	>1600	1816 (ref stn)	372	Any	Very Deep

In addition to BEC and Elevation, a total of three slope classes were also assigned (<35%, 35-100%, and >100%). Slope classes were included for likelihood of elk to use a given site. The slope breaks followed coastal ecosystem mapping standards for slope modifiers (TEM Standards, RISC 1998).

Table 6. Slope breaks and associated codes for terrestrial ecosystem mapping in coastal BC.

Slope (%)	Slope (degrees)	Slope Code
35-100	19-45	1
>100	>45	2
<35	0-19	3

The Slope and Aspect polygons were then intersected with the points generated from the reclassified slope and aspect rasters. Then a circular average was applied on all the points in each polygon. The result was a series of final polygons with an elevation class, BEC label, Slope class, and Aspect Class. The logic (provided by the lead project biologist) in the script then created a combined snowpack code from these values.

Direct Solar Radiation Model – Winter

The reason for including a sunlight (direct solar radiation) component in ungulate winter range models is to account for insufficient sunlight due to shading from nearby mountains and ridges. The amount of shading from adjacent hillsides is a critical factor influencing winter range suitability for ungulates. The more shaded, the less valuable the area, regardless of whether-or-not the site is located on a south-facing slope. To account for this factor, a separate solar model (Direct Solar Radiation) was run for the project area.

The platform that the direct solar radiation model in the winter was created/run in is Arc 10.1. The various iterations that were tested, as well as the final "baseline" input values run in the final solar model are outlined in the appended Table A. An introduction to how the model is run is provided by ESRI:

http://resources.arcgis.com/en/help/main/10.1/index.html#//009z000000t9000000

In ArcMap (or ArcCatalog) click on the Help menu, click on ArcGIS Help, click on the Search tab and enter "solar radiation area", then click "Ask". There are a number of relevant topics including "Area Solar Radiation (Spatial Analyst)" that explains all the parameters. There is also a very technical document "How Solar Radiation is Calculated" that explains, in detail, the formulas used to create the outputs.

The basis of the solar radiation model is a Digital Elevation Model (DEM) because solar radiation is largely affected by topology and other surface features. Solar radiation can be calculated two ways by Area or Point. Points are more accurate but only give you a small study area. For the coastal solar models, an "Area Solar Radiation" was calculated. The following are the steps that are taken to create a Solar Radiation Model (SRM):

1. A calculation of an upward-looking hemispherical view shed based on topology. This calculates areas of 'visible sky' based on surrounding topology and features.
2. Overlay of the viewshed (created in step 1) with a direct sunmap to estimate direct solar radiation. This maps out direct radiation based on the sun track and sun position.
3. Overlay of the viewshed on a diffuse skymap to estimate diffuse radiation. This calculates a raster showing values of diffused radiation
4. Repeating the process for every location of interest to produce an insolation map.

The Skymap, Viewshed and Sunmap are all overlaid and solar radiation is calculated by summing direct and diffuse insolation originating from the unobstructed sky directions.

The following section summarizes notes that were maintained during the application and review of the initial and final run of the solar model.

ESRI Area Solar Radiation Tool and Model Parameter Notes

Prior to running the solar model for the entire BC Coastal area, a series of detailed test runs were conducted on a small area (for quick processing time to compare outputs). The test area used was the Salmon River watershed that is located within the Strathcona TSA. During this process, a set of 4 for each run with different parameters, and another set of 4 each with values converted to kJ/m2/day (in an attempt to compare the results of this SRM to similar projects in BC). The default settings were used as the baseline for comparison of adjustments to 4 parameters.

The 4 outputs included:

1. GloRad - this is the total global radiation - this is the default output from the tool with the total solar radiation value
2. DirRad - this is the direction radiation output raster
3. DifRad - this is the diffuse radiation output raster
4. DirDur - this is the direct duration radiation output raster (value is in hours)

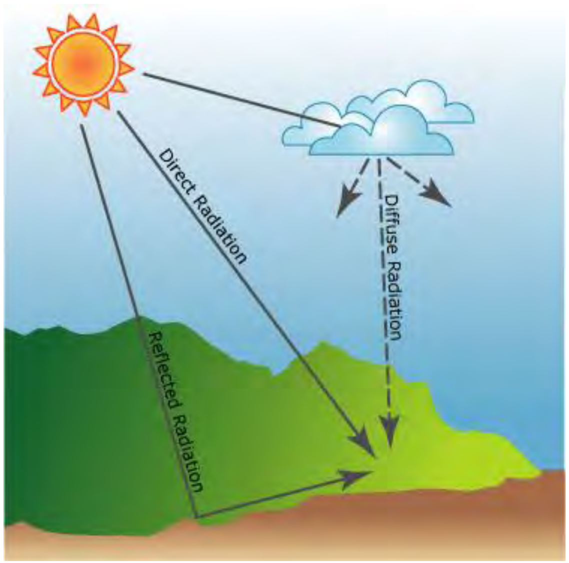


Figure 1: Incoming solar radiation gets intercepted as direct, diffuse, or reflected components (image from "Modeling Solar Radiation" http://resources.arcgis.com/en/help/main/10.1 /index.html#//**009z 000000t9000000). The combination of direct, reflected and diffuse radiation is the "Global Radiation" output value from the solar radiation model.**

The parameters run for each set of 4 included (refer to appended Table B for full list of parameters and runs):

- 100 is a value of 100 for the sky size with a 4 day interval
- 200 is a value of 200 for the sky size with a 4 day interval
- 214 is a value of 200 for the sky size with a 14 day interval

SRM Notes:

- Indicate Bands of Latitude - "Imagine the province divided into bands of latitude. One band spanning 1 degree of latitude. For example, the band surrounding the 50th parallel extends from 49 30'N to 50 30N. The solar models are more accurate if the area does not span more than one band of latitude. Therefore, if an area spans more than one band of latitude, the area is divided into bands of latitude.
- Buffer each band or area - "Solar insolation reaching the landscape is dependent upon nearby mountains and ridges. Therefore, each band or area is buffered by 2 km so that topographic features up to 2 km away will be used in calculating solar insolation. This will prevent erroneous results at the edges of the user-selected area."
- Sky size: The default for this parameter is 200 cells to represent the sky size. The ESRI model states that using a larger sky size increases the accuracy, but it also slows down the processing time. Based on the raster grid of 25 m^2, 200 X 200 cells would be 5000 m^2, which seemed far too large for the purpose of this model. To test the influence of this parameter on the output solar values, the SRM was run with a 100 cell sky size and a 200 cell size for

comparison (appended Table B). Due to little variation between the two input values, it was decided to use the default parameter setting for sky size in the final run "baseline".

- The rasters represent the amount of solar radiation for the entire period in days. The interval is used to recalculate the track of the sun over the landscape. The day interval is used to recalculate the sky map. So every 4 days the sun track is recalculated as the earth moves through it orbit. But the solar radiation is calculated for each day.
- For small day intervals (less than 4 days) a larger sky map should be used. The default parameter is 14 days for the day interval and 200 for the sky size. Some solar models have used a 4 day interval, but according to the ESRI Area Solar Radiation Tool, anything less than 4 causes overlap. Therefore, 4 days would be the minimum you could use without causing overlap. Based on the logic outlined in the on-line documentation for this tool, a 4 day interval seems to be overkill. Based on our examination of multiple runs of the model, there was not much difference in the solar values when the sky size parameter was 100 X 100 vs. 200 X 200 or the 4 day sampling vs 14 day sampling. The difference between the two outputs (4 day versus 14 day interval) was minimal, less than 0.4%. Therefore, we determined that unless there was a very sound reason for using a 4 day interval we should stay with the SRM default of 14 days.
- When test runs were applied to examine the influence of the diffuse proportion, it did not change the result very much at all.
- Applying different values to the default parameters indicated that the model was quite sensitive to transmittivity.
- The final run used 200 x 200 and 14 days and change the hour interval to 0.5, the diffuse proportion to 0.6 and the transmittivity to 0.4
- A conversion was done on the solar radiation rasters and exported as a file geodatabase (fgdb) for review. The original rasters are un-converted (i.e., they are in WH/m^2 and are the total values for the period from Dec 1 to Feb 28). Converting output to kJ/m2/day requires creating new rasters and double the size of the output, therefore, the units assigned by the ESRI model were maintained (WH/m^2). To calculate the daily average, divide by the total number of days used in the model; Dec = 31, + Jan = 31, + Feb = 28 (90 days).

Once the solar model parameters were determined, the model was run on a 1 degree of latitude band of the province that runs across the northern end of Vancouver Island extending to the east. This band was run (processed) first as it was the "largest" of the bands needed to cover Vancouver Island and the mainland coast.

The SR Model processing time is about 24 hours to process a letter block at 25 metre resolution. This time is based on running the model on the largest and most powerful GTS server available within MoE (the process is much more CPU intensive than I/O intensive). An estimate was that the processing time was 2 or 3 times as long by using the 25 m DEM compared to the 50 m DEM.

Once the solar model was run with the selected parameters (appended Table B), results were reviewed using the “Classify” tool in ArcGIS to display the results as a 4-scale output with designated ungulate winter ranges (UWRs) displayed as an overlay. Results were viewed by natural breaks, manual, and equal intervals within the Strathcona TSA.

The first stage of the review was to confirm that the solar output made sense across a given landscape (i.e., that southern slopes and high elevation mountain tops were indicated as having the highest solar values). The next step in the review process was to look at solar values within designated UWRs; specifically deer winter ranges. The deer winter ranges were used as the baseline for predicting similar high solar values in other areas (outside of winter ranges). This assessment, of where high solar values should occur, was based on known conditions for those sites (field verified as favourable solar values based on site conditions and use by deer).

Based on the review of solar values within deer winter ranges, it was determined that the best method to apply in the classification process for capturing solar code classes, was the manual 4-class approach. A series of adjustments were applied until a realistic representation of solar values within well-known deer winter ranges was reflected in the class breaks (i.e., the majority of solar values within a known deer winter range were within Class 1 and 2; High and Moderate solar values in the winter).

It was assumed that this process is applicable to the latitude that captures the South Mainland Coast of BC. Other letter blocks of the coastal solar/snowpack output would need to go through a similar review process to adjust solar values for latitudes to the north or south of the project area.

The output for solar values were classified into one of four categories as “SR_Code” based on the amount of solar radiation a site receives, with 1 = High amount of direct solar radiation during the winter months (December through February), and 4 = little to no solar energy reaches the 25 m cell (Table 7).

Table 7. Direct Solar Radiation Model Classes (Solar Code) used in the South Coast WHR project.

Solar Class	Description	Total Direct Solar Radiation Range* (WH/m^2)	Daily Value Range (WH/m^2/day)	For the months of Dec/Jan/Feb (91 days) for the south coast of BC (other latitudes must be adjusted and tested accordingly)
1	**High**	106,197-141,596	1,167 to 1,556	
2	**Moderate**	70,798-106,106	778 to 1,166	
3	**Low**	35,399-70,707	389 to 777	
4	**Very Low to Nil**	36.4-35,308	0.4 to 388	

* Total direct solar radiation for the winter period specified in the model (Dec-Feb; 91 days)
Note: WH/m^2/day X 3.6 should give kJ/m^2/day for comparison with other solar model project results.

Snowpack-Solar Processing Setup

Four separate raster layers were created for the coastal BC snowpack/solar model (v1. March 2014):

1. BEC,
2. DEM,
3. Slope, and
4. Solar Radiation.

The rasters were then added together using a weighted sum so each of the 4 values could be separated from the sum. The following steps were then applied:

- Convert the weight sum raster to integer and create a raster attribute table.
- Separate out the classified values and added a BEC label column using the values from the original BEC.
- A previous script was then modified so that it would work on the raster VAT table.
- A full letter block took between 4 to 6 hours to run.

Another script was developed to process the DEM, Slope, BEC, and solar radiation rasters into a snowpack raster. Below is a summary of the snowpack processing setup that was conducted by George Eade.

1. Use the tool "Copy ASC Rasters" to copy the letter block DEM and Percent Slope ASC raster files from the image warehouse to the DEM_SLOPE.gdb file geodatabase on the T drive. This also set the projection to BC Albers.
2. Create the solar radiation rasters for each letter block. Copy the SolarRad and DEM_Slope file geodatabases and the SolarRadProcessing MXD to the T drive. Turn on the Spatial Analyst extentions. Use the model "Create SolarRad for Snowpack" to create the solar radiation grid for a letter block. Start the model from an ArcCatalog session. Start multiple ArcCatalog sessions and run the model from each one. If you want to "stack" processing, enable background processing before starting a model. You MUST enter the LATITUDE for the model, it does not calculate the correct default.
3. Reclassify the DEM, Slope, and SR rasters use the ReclassProcessing.MXD. Turn on the Spatial Analyst extension. Use the tool "Reclassify LetterBlock". You can use the symbology from the 3 existing layers in the MXD to symbolize the newly reclassified layers if you want to view them.
4. Grid the BEC for each letter block. Use the extent from the letter block DEM as the processing extent. Use the tool "Grid BEC". This saves the BEC in the ClassifiedRasters.gdb. You can do this in the reclassify MXD.
5. Use the SnowPackProcessing.MXD to process the classified rasters into a snowpack raster. Turn on the Spatial Analyst extension.

6. Add the SnowPack_ToolBox to the ArcMap session, if it is not already added. Use the Create SnowPack Raster to create the weighted sum raster and then the snowpack raster.
7. Run the tool Calculate SnowPack values. You can enter a list of letter block values separated by blanks. The tool will add the required attributes and calculate the snowpack values. Any attribute combinations that snowpack values could not be created for are put in a CSV file called BadAttributeCombinations.csv.

   Note: Each raster was classified as per the snowpack model logic provided by the lead project biologist (Tania Tripp) ("Snowpack_Solar_Model_Ungulates_CoastalBC_v10_20140407.xlsx"). The coastal snowpack logic defaults to elevation information over BEC for "nonsense" BEC/Elevation combos that exist (most likely from the DEM intersect with broad BEC 1:250 000 classification for a lot of the northern coastal areas). Therefore, if the model indicates a pixel in an elevation of >900 m (even if it shouldn't occur in that BEC), it was assigned it a Very Deep snowpack zone ID.

8. Convert the updated raster to polygon using COMB_SNOW_CODE, do not simplify polygons.

9. Add an ADJ_SNOW_ID (short) to the polygon feature class and populate with the first digit of the COMB_SNOW_CODE. Then use the SelectCombinedSnowCodesToAdjust expression to select the polygons where the ADJ_SNOW_ID needs to be adjusted. Adjust the ADJ_SNOW_ID for the selected polygons to be ADJ_SNOW_ID - 1.[1]

Solar and Snowpack Model Output (Resultant Spatial Data)

In the March 2014 BC Coastal Snowpack-Solar model final output (in raster format), the following values were assigned to each 25 m raster cell of each mapsheet: BEC Code, Elevation Code, Slope Code, Initial Snowpack Code, Solar Code, Combined Snowpack/Slope/Solar Code, and Adjusted Snowpack Code.

The combined code represented the initial snowpack (based on BEC and elevation), Slope, and Solar Codes. For example, "322" indicates a Deep snowpack on a very steep slope (>100%) with a Moderate value for direct solar radiation in the winter (Solar Code of "2") (see appended Table B) for a more detailed example of the snowpack model logic.

The result of combining these attributes is the "Adjusted Snowpack Code" assigned to each cell. The logic of how these values were assigned was provided by Tania Tripp in consultation with Kim Brunt,

[1] During the integration of the above model into the ungulate models, it was determined that the unadjusted values for the initial Snowpack Code and the initial Solar Code were preferred over a combined (adjusted) value. The logic for how to adjust snowpack where favourable or unfavourable solar conditions were predicted in the Solar model were applied using an Attribute Value Effect (AVE) table in the Resource Ratings Model (RRM) tool in Excel.

and then applied by GIS Analyst George Eade. Snowpack codes were only adjusted for favourable solar conditions (Class 1 and 2 – High and Moderate solar values during the winter) within the Moderate to Very Deep snowpack zones. No adjustments were made for flat valley bottoms, or the Shallow Snowpack zone, and no negative adjustments were applied to poor solar site conditions. However, the initial codes for solar radiation and snowpack depth were maintained for each data cell to allow for flexibility in application of the product to future projects.

A summary of the most common BEC, Snowpack, Slope, and Solar Combinations for the Coastal Snowpack-Solar Model is provided in Table 8.

Table 8: Example of Results of the BC Coastal Snowpack-Solar Model (most common occurrence across all coastal letterblocks were selected for the below examples).

Count	BEC	BEC_CODE	ELE_CODE	INIT_SNOW CODE	SLOPE CODE	SR_CODE	Combined Code	ADJ_SNOW CODE
2,319,706	CWHvh1	12	1	1	3	3	133	1
1,815,750	CWHxm1	8	1	1	3	3	133	1
1,181,696	CWHvm1	7	1	1	3	3	133	1
930,001	MHmm1	2	14	4	1	4	414	4
862,239	CWHxm2	9	1	1	3	3	133	1
582,409	MHmm1	2	14	4	1	2	412	4
405,603	CDFmm	10	1	1	3	3	133	1
370,720	MHmm1	2	14	4	3	2	432	4
364,310	CMAunp	4	14	4	1	4	414	4
340,636	CWHxm2	9	3	1	3	3	133	1
306,603	CWHvm1	7	5	2	1	4	214	2
305,261	MHmm1	2	14	4	1	1	411	3
303,821	MHmm1	2	14	4	3	3	433	4
296,276	CWHvm1	7	1	1	3	4	134	1
275,665	MHmm1	2	14	4	1	3	413	4
250,467	CWHvm2	1	12	3	1	4	314	3
247,362	MHmm1	2	14	4	2	4	424	4
227,515	CWHxm2	9	5	2	3	3	233	2
222,729	CWHdm	6	1	1	3	3	133	1
221,965	CWHvm1	7	5	2	1	2	212	2
219,237	MHmm1	2	14	4	3	4	434	4
210,933	CMAunp	4	14	4	1	1	411	3
194,944	CWHvm1	7	1	1	1	4	114	1
194,279	CWHxm2	9	2	1	3	3	133	1
194,014	CMAunp	4	14	4	1	2	412	4

Count	BEC	BEC_CODE	ELE_CODE	INIT_SNOW CODE	SLOPE CODE	SR_CODE	Combined Code	ADJ_SNOW CODE
190,599	CWHxm2	9	4	2	3	3	233	2
186,509	CWHvm2	1	12	3	1	2	312	3
185,850	CWHvm2	1	9	3	1	4	314	3
174,587	CWHvm1	7	5	2	3	3	233	2
169,244	CWHxm1	8	2	1	3	3	133	1
163,159	CWHvm1	7	9	3	1	4	314	3
162,204	CWHvm1	7	6	2	1	4	214	2
159,191	CWHvm1	7	7	2	1	4	214	2
28,006,703	**Total Count**							

Note: The count refers to the total number of 25m raster grid cells that were assigned this combination of values across all of the BC Coastal Snowpack-Solar Model.

Reference Documents:

The following is a list of some of the documents referred to during the development of the solar and snowpack models:

Banner, A., W.H. MacKenzie, S. Haeussler, S. Thomson, J. Pojar, and R.L. Trowbridge. 1993. A Field Guide to Site Identification and Interpretation for the Prince Rupert Forest Region. Land Management Handbook #26. Ministry of Forests, Research Branch.

Brunt, K.B. 1991. Testing models of the suitability of Roosevelt Elk seasonal ranges. M.Sc. thesis, University of Victoria, Victoria, BC. 157 pp.

ESRI ArcGIS 10.1 http://resources.arcgis.com/en/help/main/10.1/index.html#//009z000000t9000000

Green, R.N. and K. Klinka. 1994. A Field Guide to Site Identification and Interpretation for the Vancouver Forest Region. Land Management Handbook #28. Ministry of Forests, Research Branch, Victoria.

Keating, K.A., P.J.P. Gogan, J.M. Vore, and L.R. Irby. 2007. A Simple Solar Radiation Index for Wildlife Habitat Studies. Journal of Wildlife Management. 71(4): 1344-1348.

Ministry of Environment, Lands and Parks. 2000. Topographic Ungulate Winter Range (TUWR) Mapping: Step 1 and Step 2 (figures and various related documents as provided by MoE and MFLNRO in 2014). http://www.env.gov.bc.ca/wildlife/whr/whrmap/versions.html

Mowat, G., K.G. Poole, R.G.D'Eon, and J. Wierzchowski. 2002. West Kootenay Ungulate Winter Range Pilot Mapping Exercise IFPA Project #718794. Prepared for Arrow Forest Licence Group, Innovative Forestry Practices Agreement (IFPA) c/o Slocan Forest Products Ltd. – Slocan Division.

Nyberg, J. B. and D. W. Janz, technical Eds. 1990. Deer and Elk Habitats in Coastal Forests of Southern British Columbia. Ministry of Forests, Special Report Series 5, Research Branch, Victoria, B.C.

Safford, K. 2004. Modelling critical winter habitat of four ungulate species in the Robson Valley, British Columbia. Extension Note in the BC Journal of Ecosystems and Management. 4(2): 1-13 http://www.forres.org/jem/2004/vol4/no2/art9.pdf

Simpson, K. and Simpson, K. Draft 2008. Deer Winter Range Management within the Fraser tSA. Prepared for the Fraser TSA Cooperative Association. Prepared by Keystone Wildlife Research Ltd. http://www.env.gov.bc.ca/wildlife/wsi/reports/3672_WSI_3672_RPT2.PDF

Table A: Solar Radiation Model Parameters, Test Runs, and Baseline applied in final Solar Radiation Model for Coastal BC.

Parameter	Explanation	Data Type	First Run	Second Run	Third Run	Fourth Run	Baseline (BL)
in_surface_raster	Input elevation surface raster.	Raster Layer	25m grid cell DEM	25m DEM	25m DEM	25m DEM	25m DEM
latitude **(Optional)**	The latitude for the site area. The units are decimal degrees, with positive values for the northern hemisphere and negative for the southern. For input surface rasters containing a spatial reference, the mean latitude is automatically calculated; otherwise, latitude will default to 45 degrees.	Double	1 degree of latitude	1 degree of latitude	1 degree of latitude	1 degree of latitude	1 degree of latitude
sky_size **(Optional)**	The resolution or sky size for the viewshed, sky map, and sun map grids. The units are cells. The default creates a raster of 200 x 200 cells.	Long	100 X 100	200 X 200	200 X 200	200 X 200	200 X 200
time_configuration **(Optional)**	Specifies the time configuration (period) used for calculating solar radiation. The Time class objects are used to specify the time configuration. The different types of time configurations available are **TimeWithinDay**, **TimeMultiDays**, **TimeSpecialDays**, and **TimeWholeYear**.	Time configuratio n	December 1 to February 28	December 1 to February 28	December 1 to February 28	December 1 to February 28	December 1 to February 28
day_interval **(Optional)**	The time interval through the year (units: days) used for calculation of sky sectors for the sun map. The default value is 14 (biweekly).	Long	4 (every 4th day)	14	14	**4**	14
hour_interval **(Optional)**	Time interval through the day (units: hours) used for calculation of sky sectors for sun maps. The default value is 0.5.	Double	1.0 (every hour)	**0.5**	**0.5**	**1**	**1**

Parameter	Explanation	Data Type	First Run	Second Run	Third Run	Fourth Run	Baseline (BL)
each_interval **(Optional)**	Specifies whether to calculate a single total insolation value for all locations or multiple values for the specified hour and day interval. **NOINTERVAL** —A single total radiation value will be calculated for the entire time configuration. This is default. **INTERVAL** —Multiple radiation values will be calculated for each time interval over the entire time configuration. The number of outputs will depend on the hour or day interval. For example, for a whole year with monthly intervals, the result will contain 12 output radiation values for each location.	Boolean	NOINTERVAL	NOINTERVAL	NOINTERVAL	NOINTERVAL	NOINTERVAL
z_factor **(Optional)**	The number of ground x,y units in one surface z unit. The z-factor adjusts the units of measure for the z units when they are different from the x,y units of the input surface. The z-values of the input surface are multiplied by the z-factor when calculating the final output surface. If the x,y units and z units are in the same units of measure, the z-factor is 1. This is the default. If the x,y units and z units are in different units of measure, the z-factor must be set to the appropriate factor, or the results will be incorrect. For example, if your z units are feet and your x,y units are meters, you would use a z-factor of 0.3048 to convert your z units from feet to meters (1 foot = 0.3048 meter).	Double	1 (x, y and z units are all in meters)	1 (x, y and z units are all in meters)	1 (x, y and z units are all in meters)	1 (x, y and z units are all in meters)	1 (x, y and z units are all in meters)
slope_aspect_input_type **(Optional)**	How slope and aspect information are derived for analysis. FROM_DEM — The slope and aspect grids are calculated from the input surface raster. This is the default. FLAT_SURFACE — Constant values of zero are used for slope and aspect.	String	FROM_DEM	FROM_DEM	FROM_DEM	FROM_DEM	FROM_DEM

Parameter	Explanation	Data Type	First Run	Second Run	Third Run	Fourth Run	Baseline (BL)
calculation_directions **(Optional)**	The number of azimuth directions used when calculating the viewshed. Valid values must be multiples of 8 (8, 16, 24, 32, and so on). The default value is 32 directions, which is adequate for complex topography.	Long	16	16	16	16	16
zenith_divisions **(Optional)**	The number of divisions used to create sky sectors in the sky map. The default is eight divisions (relative to zenith). Values must be greater than zero and less than half the sky size value.	Long	8	8	8	8	8
azimuth_divisions **(Optional)**	The number of divisions used to create sky sectors in the sky map. The default is eight divisions (relative to north). Valid values must be multiples of 8. Values must be greater than zero and less than 160.	Long	8	8	8	8	8
diffuse_model_type **(Optional)**	Type of diffuse radiation model. **UNIFORM_SKY** — Uniform diffuse model. The incoming diffuse radiation is the same from all sky directions. This is the default. **STANDARD_OVERCAST_SKY** — Standard overcast diffuse model. The incoming diffuse radiation flux varies with zenith angle.	String	STANDARD_OVERCAST_SKY	STANDARD_OVERCAST_SKY	STANDARD_OVERCAST_SKY	UNIFORM_SKY	UNIFORM_SKY
diffuse_proportion **(Optional)**	The proportion of global normal radiation flux that is diffuse. Values range from 0 to 1. This value should be set according to atmospheric conditions. The default value is 0.3 for generally clear sky conditions.	Double	0.5 (partial cloud conditions)	**0.6**	**0.5**	**0.3**	**0.3**
transmittivity **(Optional)**	The fraction of radiation that passes through the atmosphere (averaged over all wavelengths). Values range from 0 (no transmission) to 1 (all transmission). The default is 0.5 for a generally clear sky.	Double	0.5	**0.4**	**0.4**	**0.5**	**0.5**

out_direct_radiation_ raster **(Optional)**	The output raster representing the direct incoming solar radiation for each location. The output has units of watt hours per square meter (WH/m^2).	Raster Dataset	WH/m2	**kJ/m2/day**	**kJ/m2/day**	**0 - 108101 in WH/m2**	**0 - 108454 in WH/m2**
Parameter	**Explanation**	**Data Type**	**First Run**	**Second Run**	**Third Run**	**Fourth Run**	**Baseline (BL)**
out_diffuse_radiation_ raster **(Optional)**	The output raster representing the diffuse incoming solar radiation for each location. The output has units of watt hours per square meter (WH/m^2).	Raster Dataset	WH/m2	Don't need this output	Don't need this output	Don't need this output	Don't need this output
out_direct_duration_ raster **(Optional)**	The output raster representing the duration of direct incoming solar radiation. The output has units of hours.	Raster Dataset	Hours	Don't need this output	Don't need this output	Don't need this output	Don't need this output
out_global_radiation_ raster	The output raster representing the global radiation or total amount of incoming solar insolation (direct + diffuse) calculated for each location of the input surface.	Raster	WH/m2	**kJ/m2/day**	**kJ/m2/day**	**4332.52 - 128172 in WH/m2**	**4314.73 - 128447 in WH/m2**

Table B: Example of Logic Applied to BC Coastal Snowpack-Solar Model (note that in this version of combining attributes in the model, only steep and very steep sites on warm aspect slopes with solar that confirm no topographic shading (Solar Codes of 1 and 2), located in the Moderate to Very Deep snowpack zones, were adjusted by one snowpack class to indicate favourable / ideal conditions for deer winter range).

BGC	Elevation (m)*	Initial Snowpack Zone (BGC_Elevation)	Initial Snowpack Zone ID (BGC_Elevation)	Slope (%)	Slope (degrees)	Slope Code	Solar Code[1]	Combined Snowpack Code (BGC_Elevation/Slope/Solar)	Combined Snowpack - Solar Code	Adjusted Snowpack Zone Name	Adjusted Snowpack Code	Description
CWHvm1	0-250	Shallow	1	35-100	19-45	1	1	1/1/1	3	Shallow	1	Shallow throughout
CWHvm1	0-250	Shallow	1	35-100	19-45	1	2	1/1/2	4	Shallow	1	Shallow throughout
CWHvm1	0-250	Shallow	1	35-100	19-45	1	3	1/1/3	5	Shallow	1	Shallow throughout
CWHvm1	0-250	Shallow	1	35-100	19-45	1	4	1/1/4	6	Shallow	1	Shallow throughout
CWHvm1	0-250	Shallow	1	>100	>45	2	1	1/2/1	4	Shallow	1	Shallow throughout
CWHvm1	0-250	Shallow	1	>100	>45	2	2	1/2/2	5	Shallow	1	Shallow throughout
CWHvm1	0-250	Shallow	1	>100	>45	2	3	1/2/3	6	Shallow	1	Shallow throughout
CWHvm1	0-250	Shallow	1	>100	>45	2	4	1/2/4	7	Shallow	1	Shallow throughout
CWHvm1	0-250	Shallow	1	<35	0-19	3	1	1/3/1	5	Shallow	1	Shallow throughout
CWHvm1	0-250	Shallow	1	<35	0-19	3	2	1/3/2	6	Shallow	1	Shallow throughout
CWHvm1	0-250	Shallow	1	<35	0-19	3	3	1/3/3	7	Shallow	1	Shallow throughout
CWHvm1	0-250	Shallow	1	<35	0-19	3	4	1/3/4	8	Shallow	1	Shallow throughout
CWHvm1	251-500	Moderate	2	35-100	19-45	1	1	2/1/1	4	Shallow	1	Shallow, Steep, South[2]
CWHvm1	251-500	Moderate	2	35-100	19-45	1	2	2/1/2	5	Moderate	2	Moderate, Steep, West
CWHvm1	251-500	Moderate	2	35-100	19-45	1	3	2/1/3	6	Moderate	2	Moderate, Steep, North
CWHvm1	251-500	Moderate	2	35-100	19-45	1	4	2/1/4	7	Moderate	2	Moderate, Steep, East
CWHvm1	251-500	Moderate	2	>100	>45	2	1	2/2/1	5	Shallow	1	Shallow, Very Steep, South[2]
CWHvm1	251-500	Moderate	2	>100	>45	2	2	2/2/2	6	Moderate	2	Moderate, Very Steep, West
CWHvm1	251-500	Moderate	2	>100	>45	2	3	2/2/3	7	Moderate	2	Moderate, Very Steep, North
CWHvm1	251-500	Moderate	2	>100	>45	2	4	2/2/4	8	Moderate	2	Moderate, Very Steep, East
CWHvm1	251-500	Moderate	2	<35	0-19	3	1	2/3/1	6	Moderate	2	Moderate, Flat
CWHvm1	251-500	Moderate	2	<35	0-19	3	2	2/3/2	7	Moderate	2	Moderate, Flat
CWHvm1	251-500	Moderate	2	<35	0-19	3	3	2/3/3	8	Moderate	2	Moderate, Flat
CWHvm1	251-500	Moderate	2	<35	0-19	3	4	2/3/4	9	Moderate	2	Moderate, Flat
CWHvm1	501-650	Deep	3	35-100	19-45	1	1	3/1/1	5	Moderate	2	Moderate, Steep, South[2]
CWHvm1	501-650	Deep	3	35-100	19-45	1	2	3/1/2	6	Deep	3	Deep, Steep, West
CWHvm1	501-650	Deep	3	35-100	19-45	1	3	3/1/3	7	Deep	3	Deep, Steep, North
CWHvm1	501-650	Deep	3	35-100	19-45	1	4	3/1/4	8	Deep	3	Deep, Steep, East
CWHvm1	501-650	Deep	3	>100	>45	2	1	3/2/1	6	Moderate	2	Moderate, Very Steep, South[2]
CWHvm1	501-650	Deep	3	>100	>45	2	2	3/2/2	7	Deep	3	Deep, Very Steep, West
CWHvm1	501-650	Deep	3	>100	>45	2	3	3/2/3	8	Deep	3	Deep, Very Steep, North
CWHvm1	501-650	Deep	3	>100	>45	2	4	3/2/4	9	Deep	3	Deep, Very Steep, East
CWHvm1	501-650	Deep	3	<35	0-19	3	1	3/3/1	7	Deep	3	Deep, Flat

[1] Solar Code 1 = High; 2 = Moderate; 3 = Low; 4 = Low to Nil for direct solar radiation in the winter.

[2] Sites that contain this combination of values have been adjusted to reflect an expected decreased snowpack. *In some cases, a wider range of elevations has been assigned than what the generic elevations rules are that apply to a given BGC (see column "B" of first tab). This is to account for project specific corrections, which may vary from the provincial guidelines.

MADRONE
environmental services ltd.

APPENDIX 4

Application of Tools and Scripts for Updates and Habitat Supply for Sufficiency Analyses

Appendix 4: Application of Tools and Scripts for Updates and Output of Habitat Supply Values Provided for the South Coast Roosevelt Elk Habitat Model

Version 1.0 – September, 2015; Documentation by Anna Jeffries, Shari Willmott, and Tania Tripp (Madrone)

Table of Contents

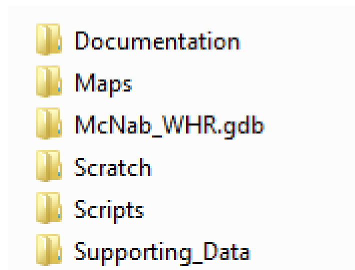
Introduction

The following sections outline the methods (steps) applied to the South Coast Roosevelt Elk WHR project area to produce habitat models for capability and suitability. This work builds off of Appendix 2: Data Development Documentation.

Initial File Format Setup

In order for the scripts to run effectively the folder structure of the project needs to be as follows:

(the scripts are case-sensitive)



"Scripts" folder – copy & house all applicable scripts here for project specific modifications

"Supporting_Data" folder – all .csv or excel outputs will be saved here

"Scratch" folder – create a "Scratch.gdb" to be housed here

"Documentation" folder – for non-spatial files – not imperative for the script to run but useful

Scripts

UniqueEcosystemList.py (tested with success)

Can be easily modified to include/exclude (– easier to exclude) specific values

Modify "required_field_list =" to suit output needs. (i.e. no site mods)

- *Script 01-ExtractPEMTEMForWHR.py*
- *Script 02-CreateSTSLookupTable.py*
- *Script 03a_AddStructuralStageFromAgePolygonsToPEMTEM.py*
- *Script 03b_AddSlopeModifiersToPEMTEM_CIKA.py*

Script 04_CreateEcosystemTablesForRRM_CIKA.py

Input(s):

Two arguments required

1) Full path to the PEM/TEM feature class (with SLOPE_MOD, LU_STS1 etc. attributes added), and
2) Full path to the Structural Stage lookup table CSV file

Notes:

- If using PythonWin, arguments are separated by spaces, not commas

Script 05_AttachRRM_StrathWHR.py

Success with Strathcona (15.0049) April 23, 2015

Input(s):

One argument required (depends on the version):

1) full path to RRM output ratings table csv file

The following needs to be updated in the script itself (lines 36-38):

scratch_gdb = whr_master_path + r'\Scratch\Scratch.gdb'

working_gdb = whr_master_path + r'\Operational_Data_Step_5_20150415.gdb'

working_fc = working_gdb + r'\WHR_Strathcona'

Output:

A feature class of the ecosystem database with attached WHR ratings

Notes:

- RRM tool generates an excel output with WHR ratings. This ratings table needs to be exported as a CSV (coma delineated) file and put in the 'Supporting_docs' folder for the script to run
- the RRM Output rating table must have proper field headings to indicate the Life Requisite and Equation # the rating applies to (MCEEL_WFD_CAPSU_E1_6C)
- Jeff Kruys – 'The field names need to exactly five "components" separated by an underscore character. It should be the species code (which doesn't have to be five letters, there could be a sixth letter for a species variation or whatever), then season and life requisite combined into one code like SFD, then CAPSU, then E1 (since we're always using the same equation now) and then 4C or 6C. So just like your example, MURAR_SFD_CAPSU_E5_6C. There needs to be only four underscores in total.'
- Depending on the equations used in the RRM tool and the fields present in the ecosystem database, the 'equation_dict' values may need to be altered (i.e remove the fields that are n/a as they will cause errors). (CIKA runs with only E1 as no other equations apply)
- Script 05 is often run more than once in a project as the RRM outputs is evaluated. Each time the script is run, a new copy of the TEM spatial data needs to be made in the geodatabase and the previous CAP/SU fields deleted. See the specific steps below for how to run script 05.

Running the RRM model in Excel:

a. The excel file must contain the RSI table(s), AVE table(s), and an empty ratings table that contains all possible combinations of BGC mapcodes, STS, etc (all components of the model). The empty ratings table will be populated with ratings from the model run, and will become the csv file that is used to make maps. For more instructions on the RRM tool see: http://www.env.gov.bc.ca/wildlife/whr/rrm_tool/
b. Run the RRM model using the RRM add-in tool (rrm.xla). Note: use the new (Jan 2015) version of the RRM tool that allows it to process >30,000 rows of data. Open Add-Ins, click RRM Tool and select "Calculate RSIs" from drop-down menu. The Calculate RSI window will allow editing of the RSI equation and destination of output results. Check that the information is correct (workbook, RSI equation, Destination workbook and worksheet). Once the model begins (by clicking "OK"), it can take 30-60+ min to run, depending on the number of records being calculated.
The new version of the RRM tool can be downloaded here:
http://www.env.gov.bc.ca/wildlife/whr/rrm_tool/rrminstall.htm

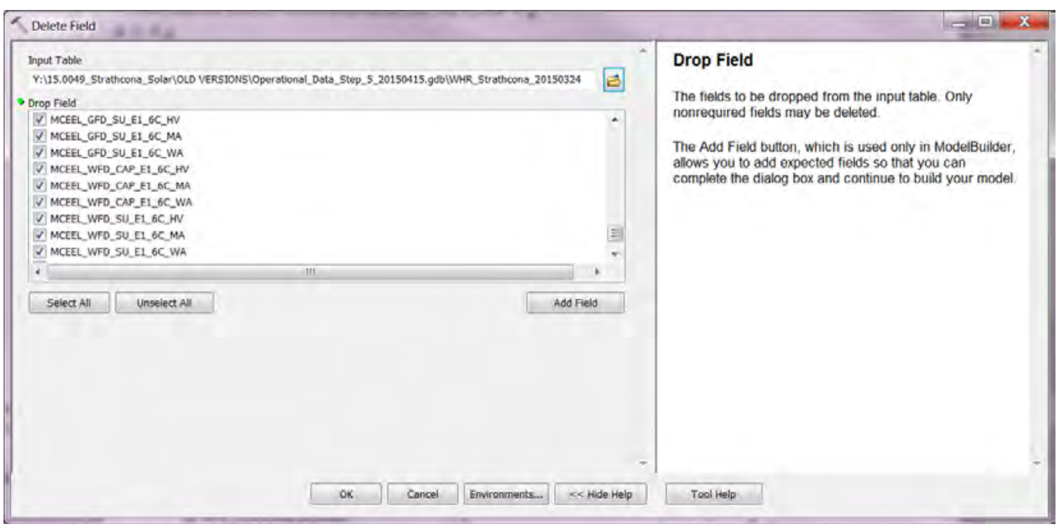
c. The final RSI column will be populated in the csv (empty ratings table). The rating must be converted to classes to be displayed in ArcMap. Use the "Convert to Rating" tool in the RRM add-in, after selecting the column of RSI values. Select the appropriate rating scheme (e.g. four-class or six-class). *Note: when there is no data (blank RSI value), the "Convert to Rating" tool will assign class 6. This is wrong. All rows with no rating data must be deleted to avoid being symbolized on the map as class 6 instead of "no data".

d. Name the new rating column so that it can be read by the Python script. The name must follow the following format:
"MCEEL_LIW_CAPSU_E1_6C" (no spaces) where
   - MCEEL is the species name
   - LIW is the life requisite
   - CAPSU tells the script to calculate capability and suitability
   - E1 is the equation used by the script
   - 6C tells the script that the six-class rating scheme is being used.

e. Save the final csv tab as a .csv file (save changes in .xls version first). Make sure to select "comma delimited" version of csv file.

In ArcCatalog

1. Open the geodatabase where the TEM spatial data is stored for the project (i.e. Operational_data_step_5.gdb)
2. Make a copy of the TEM/WHR feature class and rename it with the current date (i.e. WHR_Strathcona_20150324)
3. Open the 'Delete Fields' tool in the Data Management toolset, Fields toolbox. Delete the CAP/SU fields generated from the previous iteration of script 05. (If this is the first time script 05 has been run for the project then skip to step 5.)



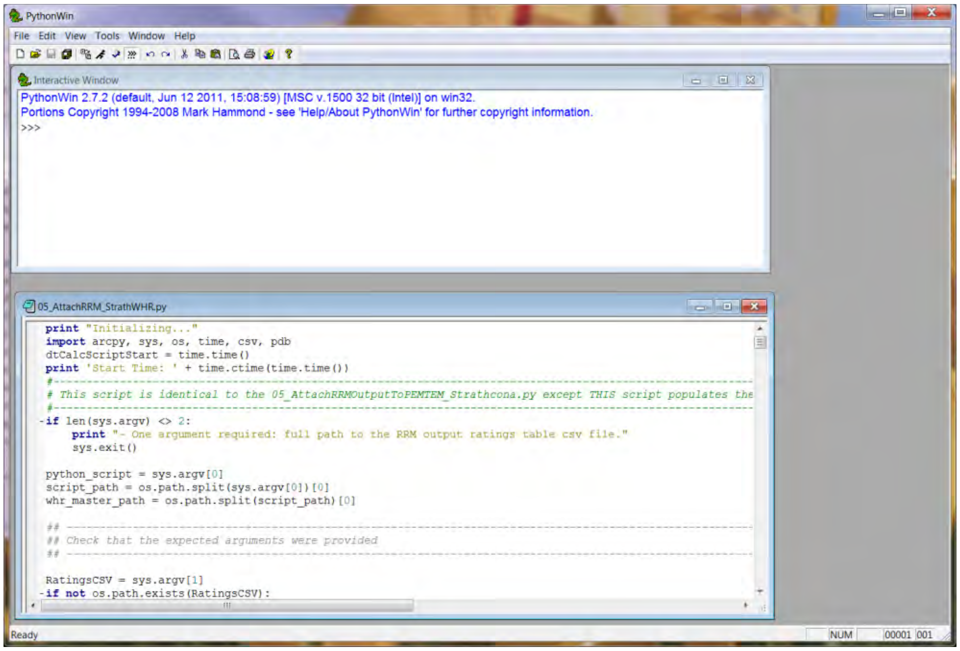
Once the "Delete Fields' function has finished, confirm that all the CAP/SU fields have been deleted from the attribute table by previewing it in Arc Catalog. There should be no fields with Life Requisite and Equation # the rating applies to (MCEEL_WFD_CAPSU_E1_6C)

*Note: the geodatabase cannot be in use in ArcMap for the delete field tool to run. Also, the tool appears to have bugs and may require two or more tries to create a copy of the feature class before it will successfully delete fields.

Troubleshooting includes deleting fields in batches (deleting a few fields at first to test whether the delete tool is functioning).

In Windows Explorer

1. Navigate to script location
2. Right click on required script and choose 'Edit with Pythonwin' – this will open the script in the following window

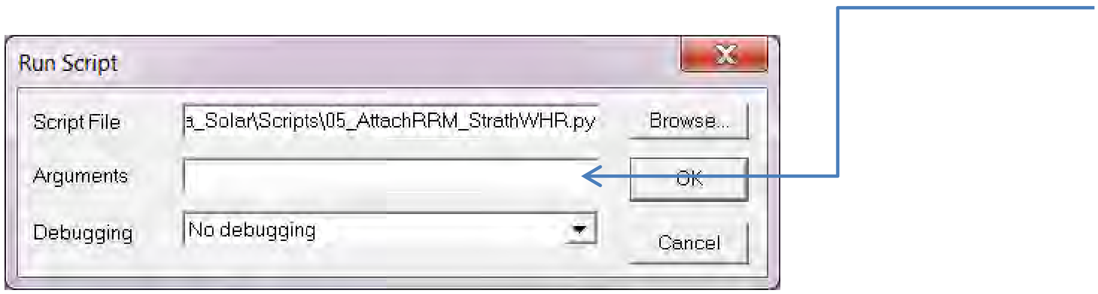


3. Click in the script itself (lower window) and find the lines where the working feature class is called. Change the name of the feature class to match the name used in step 2 above.

   scratch_gdb = whr_master_path + r'\Scratch\Scratch.gdb'
   working_gdb = whr_master_path + r'\Test_Final_WHR.gdb'
   working_fc = working_gdb + r'\WHR_Strathcona_20150710'
   Note: make this match the name of the copy made in the previous steps in ArcCatalog
4. Click on the running man in the top toolbar of the python window. This will open the Run Script window where the arguments need to be entered for the script to operate. Copy and paste the full path to the RRM output csv file and hit enter. This must contain the full file name and extension , e.g.

   Y:\15.0049_Strathcona_Solar\Supporting_Data\Strathcona_RRM_All_Results_2Jun2015.csv

5. Make sure that Arc Catalog and ArcMap are closed or the script will not run properly.



Step 5 should be after the graphic above. The graphic goes with step 4

<u>In ArcCatalog</u>

1. Look at the script output in ArcCatalog to confirm that WHR fields were generated.
2. Add the TEM/WHR feature class to ArcMap and symbolize with layer files for the life requisite and class.

Script 06_CreateAreaSummaryTable.py (tested with success)

<u>RAN IN PYTHON WIN AND COMMAND PROMPT</u>

Input(s):

Three arguments are required:

1) full path to the RRM output ratings table csv file
2) full path to the TEM/WHR polygon feature class, and
3) full path to Study Area boundary polygon feature class

Repoint working_gdb & out_csv as needed

Output:

A csv listing all of the total areas by rating for each life requisite

Notes:

- The csv file must contain a Hectares field. This is used as a maker as well as for the final calculations. Should be 'double' format for best results.
- It is best to use a dissolved output of the TEM/PEM database as the study area. This avoids any small variations in the total areas matching up.
- No spaces in the source paths
- If using PythonWin, arguments are separated by spaces, not commas
- The Feature Class cannot be in a Dataset, it must be in the root of the gdb
- If you are calculating several areas within one project dossier (ex. UWR within Strathcona) you'll need to rename the output after creation. The script will over write with the file each run through.

Troubleshooting:

- 'a field was specified that does not exist' – make sure the field headings in the FC match those listed in the script. (ex. ADJ_SNOW_CODE is now INIT_SNOW_CODE etc.)
- 'could not get scheme lock' – close any instances of the files and run again