CEF Cumulative Effects Framework

BRITISH COLUMBIA

Interim Assessment Protocol for Moose in British Columbia

Standards for British Columbia's Cumulative Effects Framework Values Foundation

Prepared by

Provincial Moose Technical Working Group – Ministries of Environment and Climate Change and Forest, Lands and Natural Resource Operations and Rural Development

May 1. 2018

Version 1.0

The Interim Assessment Protocol (the Protocol) provides an initial standard method for assessing the current condition of the value selected for cumulative effects assessment across the Province of British Columbia. The Protocol is designed to use a multi-scaled approach to depict data at a broader (provincial) scale and to allow for refinements in data at a finer (regional) scale.

The assessment results based on this Protocol indicate the modelled condition of the value. Results are intended to inform strategic and tactical decision making, and may also provide relevant context for operational decision making. Engaging local value experts to identify additional regional scale information – if applicable – and to support interpretation and application of results is encouraged.

The Protocol outlined in this document is subject to a) periodic review to support continuous improvement and b) regionally specific modifications, consistent with criteria for enabling regional variability. Where regional modifications are approved, they will be documented in this protocol, and become the standard for assessment in that area. If applicable, regional modifications are listed in the appendices of this document.

Citation: Provincial Moose Technical Working Group (PMTWG). 2017. Cumulative Effects Assessment Protocol for Moose in British Columbia. Version 2.0 (May 2017). Prepared by the Provincial Moose Technical Working Group – Ministries of Environment and Climate Change and Forest, Lands and Natural Resource Operations and Rural Development – for the Value Foundation Steering Committee.

Acknowledgements

This protocol is based on foundational work developed by Demarchi and Hertze (2015) and Dawson et al. (2015).

The Provincial Moose Technical Working Group (PMTWG) (Tony Button, Gerald Kuzyk, Mark McGirr, and Steve Wilson) of the Cumulative Effects Framework (CEF) initiative adopted a moose management assessment protocol in August 2016 (Version 1.0). The logic and parameters of the protocol were documented in a draft report *Cumulative Effects Assessment Methods for Moose in British Columbia* (August 26, 2016). The assessment approach was consistent with one developed for use in regional cumulative effects work in the Thompson-Okanagan.

Version 1.0 of the CEF assessment protocol for moose in British Columbia (B.C.) was circulated for internal review starting in October of 2016. An updated version of the documentation (February 21, 2017; Version 1.1) incorporated editorial review and feedback, and summarized limitations and issues noted from the internal engagement process. The updated document (Version 1.1) was circulated and a webinar was hosted by PMTWG on April 12, 2017 for additional internal engagement.

External engagement was initiated in March of 2017 via invitation to a webinar hosted by the PMTWG.

Updates and enhancements to this document are the direct result of feedback provided through internal and external engagement. A number of the enhancements to the protocol are related to Habitat and Risk Assessments adapted from work completed by Rick Dawson, Robin Hoffos, and Mark McGirr in *A Broad Scale Cumulative Impact Assessment Framework for the Cariboo-Chilcotin* (Dawson et al. 2015).

Executive Summary

Moose are one of five high-value resources identified for provincial assessment under British Columbia's (B.C.) Cumulative Effects Framework (CEF). Moose are a high priority species for the Province, which has legal authority for its conservation and management. The importance of this species is reflected in the objectives established for moose through legislation, regulation, and policy.

Moose are a conspicuous and iconic part of British Columbia's fauna that have environmental, economic, social and cultural importance. First Nations rely on moose for social, ceremonial, and sustenance purposes. Moose also provide recreational opportunities to resident and non-resident hunters, and their harvest provides economic benefits through the sale of hunting licenses and associated expenditures.

Moose are a wide-ranging species, and they depend upon multiple, well-connected and functioning habitat with properly functioning ecosystem processes. As such, moose are susceptible to cumulative impacts on their habitat and their populations from extensive land use activities and disturbances. As a species that can tolerate, and may even benefit from, some human activities on the landscape, moose-human interactions are common and complex.

The purpose of this document is to provide a standardised provincial method (protocol) for evaluating cumulative effects on moose across the province of B.C.; while also allowing a degree of flexibility within regions of the province. The protocol is intended to provide a transparent and repeatable provincial standard for assessing moose that can be periodically updated. The protocol consists of two assessment components: 1) habitat, and 2) population. Results from habitat and population assessment components provide a systematic and comprehensive approach to describing, rating, and estimating risk.

Assessment of the habitat component is organized around habitat capability, habitat suitability, and habitat effectiveness. Habitat suitmability is integreated directly into the population assessment.

Assessment of the population component provides an indication of whether moose in a Wildlife Management Unit (WMU) are increasing, stable, or decreasing; based on indicators representing various aspects of moose population structure and dynamics.

Results of the habitat and population assessments provide estimates of risk that focus on ecological importance, hazards, and current mitigation.

While there has been general agreement that the assessment protocol captures appropriate variables and relationships, feedback through internal and external review highlighted opportunities for improvement.

Use of this information should anticipate some changes in the substance and formatting of the assessment protocol in the future. It is expected that results from regional assessments will potentially clarify, standardize and improve the assessment protocol.

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List of Acronyms

BBN	Bayesian Belief Network
B.C.	British Columbia
BEI	Broad Ecosystem Inventory
CDC	Conservation Data Centre
CE	Cumulative Effects
CEF	Cumulative Effects Framework
CPT	Conditional Probability Table
FLNRO	Ministry of Forests, Lands and Natural Resource Operations
FRPA	*Forest and Range Practices Act*
HHS	Hunter Harvest Statistics
LEH	Limited Entry Hunting
WMU	Wildlife Management Unit
OGAA	*Oil and Gas Activities Act*
VRI	Vegetation Resource Inventory

1 Introduction

Moose (*Alces americanus*) are a conspicuous and iconic part of British Columbia's (B.C.) fauna that have environmental, economic, social and cultural importance. First Nations rely on moose for social, ceremonial, and sustenance purposes. Moose also provide recreational opportunities to resident and non-resident hunters, and their harvest provides economic benefits through the sale of hunting licenses and associated expenditures. The importance of this species is reflected in the objectives established for moose through legislation, regulation and policy.

Moose are a wide-ranging species, and they depend upon multiple, well-connected and functioning habitat with properly functioning ecosystem processes. As such, moose are susceptible to cumulative impacts on their habitat and their populations from extensive land use activities and disturbances. As a species that can tolerate, and may even benefit from, some human activities on the landscape, moose-human interactions are common and complex.

Additionally, the harvest demand for moose is high and typically exceeds the available yield. Thus, moose are a high priority species for the Province, which has legal authority for its management and conservation. Moose management strives to balance the use, rights, and traditions of First Nations, the hunting opportunities for resident hunters, and the hunting opportunities for non-resident hunters through the guide outfitting industry, with conservation requirements and objectives of the species.

Based on the numerous factors outlined above, moose have been identified as a high-value resource for provincial assessment under British Columbia's Cumulative Effects Framework (CEF). The purpose of this document is to provide methods for evaluating cumulative effects on moose across the province of B.C. This protocol is intended to provide a transparent, repeatable provincial standard for assessing moose that can be periodically updated.

1.1 Current Distribution and Status

Moose are generally abundant and distributed widely throughout most of B.C., with notable exceptions being Haida Gwaii, Vancouver Island, the Lower Mainland, and portions of the mainland coast. In B.C., moose are managed at the species level, and are currently on the provincial Yellow List and are not considered at risk (CDC 2017).

1.2 Cumulative Effects Framework and Legal Context

In B.C.'s CEF, cumulative effects are defined as "changes to environmental, social, and economic values caused by the combined effect of past, present, and potential future activities and natural processes". In addition to moose, other values currently being assessed under the CEF include: Grizzly Bear, Forest Biodiversity, Old Forest, and Aquatic Ecosystems.

Cumulative effects assessments (CEAs) are completed on identified environmental, social, and economic values using the best-available scientific knowledge, information, and understanding. This science-based assessment relies on the identification of benchmarks[1] to appraise the condition of the value. The desired outcome from this assessment is to provide information that can be used by decision makers to maintain the value objectives.

Objectives are the desired condition of a value obtained from existing legislation, policy, land use plans, and other agreements that are described in a qualitative or quantitative manner. Cumulative effects are assessed relative to the objectives for the value on a regional basis. Objectives for moose are derived from provincial legislation and regulations that outline both broad and specific direction for sustaining moose populations.

Some pieces of legislation that inform objectives for moose include:

- *Forest and Range Practices Act* (FRPA) – Ungulate Winter Range designations
- *Oil and Gas Activities Act* (OGAA) – Ungulate Winter Range designations
- *Land Act* – Land-use plan direction and objectives specific to moose
- *Wildlife Act* – hunting regulations

The Provincial Framework for Moose Management in British Columbia (FLNRO 2015) supports the goal "to ensure moose are maintained as integral components of natural ecosystems throughout their range, and maintain sustainable moose populations that meet the needs of First Nations, licenced hunters, and the guiding industry." The associated broad objectives are to:

1. Ensure opportunities for consumptive use of moose are sustainable;
2. Maintain a diversity of hunting opportunities; and
3. Follow provincial policies and procedures (e.g. provincial moose harvest management procedure) as guidance for regulatory options and management objectives.

The broad objective for this moose assessment summarizes a number of provincial broad and specific objectives for moose included in various legislation, regulations and policy, and is stated as follows:

> *"Maintain self-sustaining populations of moose throughout their current range and provide opportunities for consumptive and non-consumptive use."*

Where specific objectives exist, they may be approved for use as management review triggers in the assessment. Management review triggers identify where government is approaching or exceeding a specific legal or policy objective. Management review triggers delineate enhanced or intensive management review classes, where the review of management responses will be considered to either prevent the condition of the value from exceeding the objective, or to return the condition of the value to meeting the objective.

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[1] Benchmarks are proposed reference points that support interpretation of the condition of an indicator or component. Benchmarks are based on our scientific understanding of a system, and may or may not be defined in policy or legislation.

1.3 Overview of Assessment Protocol

The moose assessment protocol comprises components, indicators, factors, functions and processes that capture different aspects of moose ecology. Two ecological components and their associated indicators are assessed: 1) habitat, and 2) population.

Inputs and outputs (results) from assessment of these two components are used to provide measurements and ratings of ecological importance and hazard. When examined in combination with current mitigation an estimate of risk to the moose value is determined. Figure 1 provides a conceptual diagram for the moose value assessment protocol.

The habitat, population, and risk assessments are not intended to capture all potential factors, functions, and indicators but, rather, focus on ones hypothesized to have a significant effect on moose. Key factors, functions, and indicators selected for assessment include ones that are:

i. under management control, and/or
ii. associated with existing regulations, policy or guidance, and/or
iii. measurable with available data sets (or confidently quantifiable using expert opinion), and/or,
iv. believed to comprise the most parsimonious set of variables.

The systems affecting moose, as currently conceptualized, are based on expert knowledge from moose biologists and researchers throughout B.C., and a review of existing information presented as a supporting document to the protocol; *Moose Value Knowledge and Legislation Summaries*.

1.3.1 Scale of Analysis

The population assessment is designed to reflect increasing confidence in the values assigned to specific indicators and/or components as more precise input data become available. Although initial data are not required for every input to generate an estimated condition, assessment confidence increases as data quantity and quality increase.

The scale of analysis (the assessment unit) is important to consider; review feedback and discussions regarding this topic during internal engagement were extensive. If very large areas are used, the results will be the average for a very large area, which will often mask important variation within the unit.

Indicators and components can be mapped at any scale, depending on the resolution of the input variables, but are generalized to the WMU scale (. MUs are the spatial areas used to manage moose harvest and these align with the harvest data and management options inputted into the population assessment.

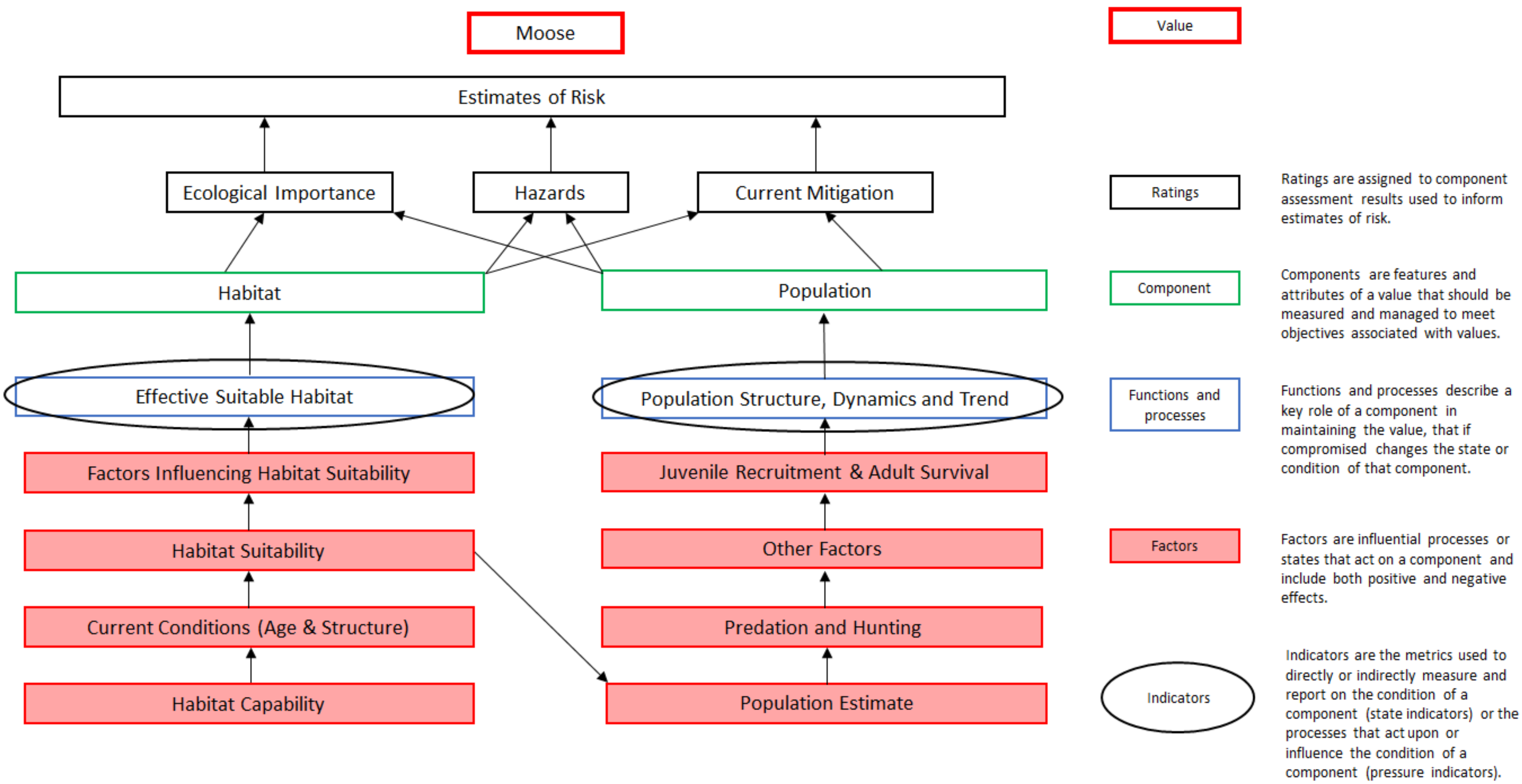

Figure 1. Conceptual diagram for the moose value assessment protocol.

Adult Female Survival Rate, Juvenile Recruitment Rate, and Population Trend should only be applied and used at a WMU level. Harvest data derived products should not be developed or used at a finer scale than the WMU. Harvest data is gathered and estimated at the WMU scale and can be applied across one or more Management Units. Population assessment indicators that use harvest related inputs must be summarized at the Management Unit or coarser scale.

Habitat is mapped and managed at a variety of scales in order that it can be scaled up and summarized at a WMU level to accommodate an integrated habitat-population model. Habitat assessment units are sub-units of Landscape Units based largely on watershed boundaries.

2 Habitat Assessment

Concepts important to understanding the selection of habitat indicators include key life requisites for moose, and associated habitat capability, suitability, and effectiveness (how the habitat is affected by human disturbance). Capability indicates the potential number of moose when habitat is in optimal condition for moose. Suitability indicates the potential number of moose in its current condition (before adjusting for non-habitat factors; e.g. predation, inter/intra species dynamics). Habitat effectiveness incorporates the effects of human access and disturbance on amount and quality of available habitat.

2.1 Key Life Requisites

Food, cover, reproduction, and mobility are all basic requirements for moose. Although these needs are all important, and may change according to season, the assessment focuses on the life requisites that are considered most limiting to the population (referred to as key life requisites).

Winter forage and shelter habitat are key life requisites used because they are important limiting habitats for moose populations. Moose will also use some of the same habitats in spring, summer and fall, but they will range much more widely in those seasons allowing them to spread out to access more forage that was not available in the winter and to more effectively avoid predation.

2.1.1 Dynamic and Static Forage

Two types of forage habitat are identified:

- **Dynamic** forage habitat is created by disturbances such as fire or harvesting which put forested sites back to an earlier, shrubby successional stage that lasts for a relatively short period of time at a specific location and then may be created in another location by further disturbance.
- **Static** forage habitat does not move around the landscape and includes habitats such as wetlands, riparian areas and self-sustaining deciduous forests.

These two types of moose forage habitat have different management implications because of their different degrees of permanence on the landscape. Maps and assessment information that separate the two types therefore provide useful information for resource managers.

Forest cover for hiding, thermal protection, and snow interception (shelter) are important components of moose winter habitat. The requirements and relative importance of these three functions of cover vary across the province, between and within regions depending on factors such as snow depth and winter temperature.

2.2 Habitat Capability and Suitability

Wildlife habitat capability and suitability describe the potential quality and current state of wildlife habitat in a given area. Capable habitat includes all the area that has potential value for moose winter habitat. Suitable habitat represents the current state of the habitat and is a subset of capable habitat.

Definitions for capability and suitability from the Ministry of Environment publication *British Columbia Wildlife Habitat Rating Standards*[2] are:

*"**Capability** is defined as the ability of the habitat, under the optimal natural (seral) conditions for a species to provide its life requisites, irrespective of the current condition of the habitat.* It is an estimate of the highest potential value of a particular habitat for a particular species and is useful in providing predictive scenarios for various habitat management options. The provincial Broad Ecosystem Inventory (BEI) maps for moose capability were used for the habitat capability. The highest capability rating for each BEI polygon was used as the input.

***Suitability** is defined as the ability of the habitat in its current condition to provide the life requisites of a species*. It is an estimate of how well current habitat conditions provide the specified life requisite(s) of the species being considered. The suitability of the land is frequently less than the capability because of unfavourable seral conditions.

Reductions to suitable habitat from human access and disturbance result in effective habitat (Figure 2).

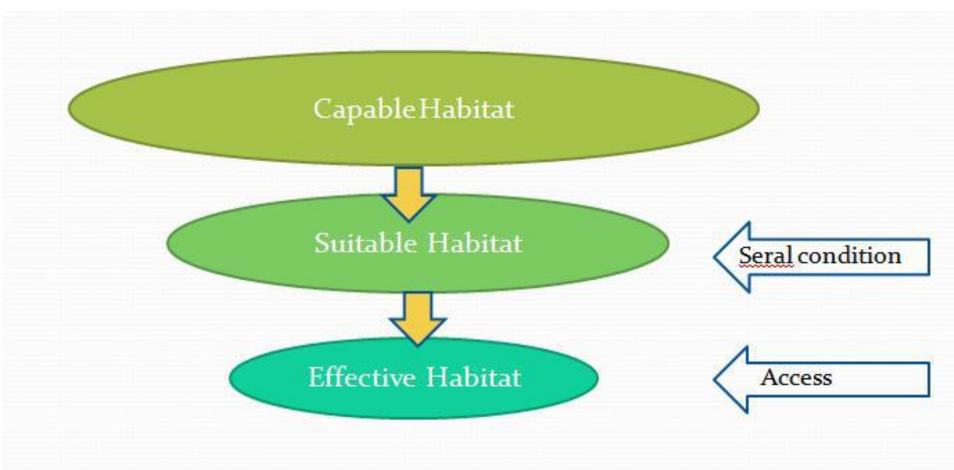

Figure 2. The relationship of capable, suitable, and effective habitat.

[2] https://www.for.gov.bc.ca/hts/risc/pubs/teecolo/whrs/assets/whrs.pdf

Figure 3 is a conceptual diagram of factors, functions and processes affecting the moose habitat component, and associated indicators. The habitat indicators are summarized in Table 1 and described in the following subsections.

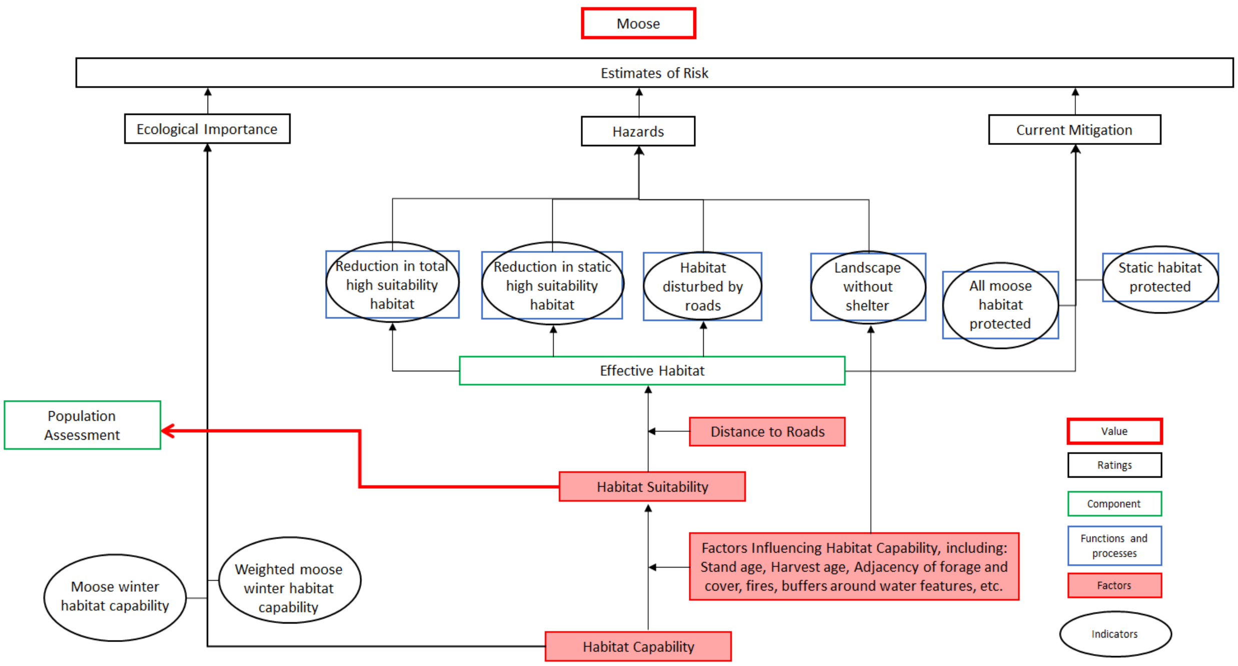

Figure 3. Overview of the key factors, functions, and processes for the moose value habitat assessment.

2.3 Habitat Indicators

Careful selection and design of habitat indicators is critical to produce meaningful assessments. Criteria used for selection of indicators included the following:

- Clear and meaningful relationship between each indicator and key habitat requirements for moose, and key attributes for coarse filter values;
- Readily measureable and understandable;
- As simple as and as few as possible while still providing a meaningful assessment; and
- Hazard indicators that relate to expected types of impacts resulting from human activities and natural disturbance.

Table 1. Summary of indicators in the moose habitat assessment.

Category	Indicators	Description of Measurement	Comments
Habitat Baseline	Moose winter habitat	Percent of the assessment unit classified as capability class 1-5. Class 1-5 includes all winter habitat from very high to very low capability.	Based on provincial Broad Ecosystem Inventory (BEI) moose winter habitat capability mapping. The weightings for the second indicator are based on the relative habitat quality estimates built into the provincial wildlife habitat capability ratings.
	Weighted habitat capability	Weighted % of the total moose winter habitat classified as low, moderate and high capability: 100/75 X ((class 1-2 area X 0.75)+(Class 3 area X 0.37)+ (class 4-5 area X 0.125)) The number is multiplied by 100/75 to standardize the maximum score to be 100.	
Habitat reduced by development	Reduction in total high suitability habitat	Percent reduction in total high suitability moose winter habitat between undeveloped and current landscape.	Indicates the reduction in total modelled high suitability moose winter habitat as a result of forest harvesting to date.
	Reduction in Static high suitability habitat	Percent reduction in static, high suitability moose winter habitat between undeveloped and current landscape.	Indicates the reduction in static modelled high suitability moose winter habitat as a result of forest harvesting to date.
Capable area lacking Adequate cover	Landscape without adequate shelter	Percent of capability 1-5 habitat that does not meet shelter criteria. Evaluated in all 10 km^2 cells in capable habitat.	
Road Disturbance	% Road disturbance of high suitability habitat	Percentage of the high suitability moose habitat in all capability classes that is within 1000m of a paved or gravel road.	This indicator assesses habitat disturbance resulting from paved and gravel roads as defined in the Digital Road Atlas. It does not include the many small roads and 'in block" roads referred to as "undefined".

2.3.1 Habitat Baseline

Current high suitability moose winter habitat area is compared with the same area in a simulated "Undeveloped Landscape" which is used as a baseline. This undeveloped landscape is created by replacing logged areas with conifer stands capable of providing moose shelter habitat (>60years old). The assessment determines the area of "Total High Suitability Moose Winter Habitat" in the undeveloped landscape and compares it with the current landscape to indicate change in available habitat.

Using this undeveloped landscape as a reference point for the analysis is a simple approach to assessing landscape change which does not incorporate the potential landscape composition effects of natural disturbance. However, after examination of the options, this approach was selected because it provides a way of documenting how much habitat change has happened up to the present and because it does so spatially.

For moose, this spatially explicit analysis recognized the need to have current forest cover adjacent or close to important feeding areas. It also allowed habitat suitability (current patterns of winter habitat) to be assessed in relation to habitat capability. In addition, this assessment provides a baseline for evaluation of moose forage areas created by forest harvesting and wildfire.

An alternative method would compare non-spatial habitat proportions in the current landscape to habitat proportions in a simulated naturally disturbed landscape. While this approach would better reflect natural disturbance effects, it would lack the important spatial specificity related to adjacency of cover and forage.

The use of a simple reference landscape allows for meaningful, spatially explicit assessments. The possible errors resulting from the use of this method due to the omission of natural disturbance are acknowledged. Therefore the raw numbers for habitat reduction indicators are an approximate measure of divergence between a consistent reference landscape and current conditions. This comparison is intended to provide a meaningful indication of relative habitat conditions across the province.

2.3.2 Landscape Shelter Indicator

Each moose winter home range requires both forage and adequate shelter to provide effective habitat. A potential home range area with lots of forage habitat will only function as fully effective habitat if it also has adequate shelter. Landscapes with a very high level of disturbance can sometimes have much forage habitat but not enough shelter. The landscape shelter indicator assesses the adequacy of cover for moose over all potential home range units in the assessment unit. As well as estimating the proportion of potential home ranges with adequate cover, it is also an index of the distribution of the amount and distribution of cover required for moose to travel across the unit.

This indicator is different than the other indicators in that it is assessed across all capable habitat rather than just over the best habitat. It essentially measures if, or the extent to which, moose winter habitat values across the whole assessment unit have been compromised by very high levels of disturbance even if this disturbance has provided large areas of forage habitat.

The landscape shelter indicator is designed to estimate the proportion of the capable habitat area within each assessment unit that has an adequate amount and suitable distribution of thermal/snow interception cover to provide useful habitat for moose in winter.

2.3.3 Static Habitat

As large-bodied browsers, moose require abundant, shrubby vegetation, which is found most commonly in riparian and wetland areas, as well as in young, regenerating forests (Shackleton 2013).

Two types of forage habitat are identified:

1) "Dynamic" early seral forage habitat is created by disturbances such as fire or forest harvesting which put forested sites back to an earlier, shrubby successional stage that lasts for a relatively short period of time at a specific location and then may be created in another location by further disturbance.

2) "Static" forage habitat does not move around the landscape and includes habitats such as wetlands, riparian areas and self-sustaining deciduous forests. Static habitat is also considered important for life requisites such as calving.

Static habitat was defined as areas classified as wetlands or >50% riparian habitat using land cover data. Seral forest-related inputs were based on Vegetation Resources Inventory (VRI) data.

2.3.4 Roads

The effectiveness of moose habitat is reduced by having well-used roads located within one kilometre of important habitat. The assessment methods recognize this by calculating the proportion of "disturbed" moose habitat within the high suitability areas.

Disturbed Moose Winter Habitat (ha) = High Suitability Moose Winter Habitat that is within 1 kilometre of a gravel or paved road or the footprint of a major development such as a mine.

2.3.5 High Suitability Winter Habitat

The assessment first defines potential habitat for winter feeding and winter thermal/snow interception cover. It then applies a proximity constraint between the potential feed and cover habitats types to ensure that the habitat can be effectively used. The result is "Effective Winter Feeding Habitat" and "Effective Winter Shelter Habitat". The sum of these two is defined as the "Effective High Suitability Moose Winter Habitat". This approach is designed to define the high suitability habitat, but does not identify all habitat used by moose throughout the winter. Moose can make significant use of sub-optimal habitat for various reasons such as reducing predation risk.

Since high suitability habitat is defined the same way in every assessment unit, this approach allows for valid and consistent broad scale assessment and comparisons between assessment units. However, care must be taken when using maps of habitat for planning at scales finer than the habitat assessment unit since GIS data is rarely perfect. In addition, not all details of habitat across the province and within regions are incorporated yet.

2.4 Integration With Population

Results of the habitat assessment are integrated into the population assessment via providing a population estimate based on the abundance and quality of moose habitat. In addition, habitat data related to early seral and road density are integrated into factors related to predation, and the indicator related to vulnerability to hunting in the population assessment.

3 Population Assessment

Of all the wild ungulates in B.C., moose are among the most productive because: (i) adults can breed every year, (ii) twin calves are not uncommon, and (iii) calf survival can be high where predation is modest. The combination of these factors makes moose particularly responsive to management actions geared to increasing moose production. It is important to note that although a species may be capable of a rapid population increase, environmental (e.g. predation) and human-caused factors can override the species' intrinsic tendency toward high rates of survival and reproduction, thereby causing a population decline.

Identifying the factors that limit or regulate moose numbers is complex. A population at any given time and place reflects the composite effect of all limiting and regulating influences; rarely is it possible to measure the effect of any single factor or to rank that factor's importance relative to other factors (Connolly 1981). Despite these challenges, successful moose management requires that those factors that limit moose populations be understood if they are to be manipulated with the goal of managing moose (Van Ballenberghe and Ballard 1998).

Although population dynamics can be very complex, at its simplest level population size is simply the mathematical result of births (natality) and deaths (mortality). If births exceed deaths the population will increase. If deaths exceed births, it will decrease. If births equal deaths, the population will be stable.

Natality refers to the addition of new animals to a population via the birth. Moose mortality occurs via a number of pathways that alone, or in combination with others, can lead to a population decline. Important causes of moose mortality in B.C. include: hunter harvest (legal and illegal), predation by large carnivores (i.e., wolves, bears, cougars), and accidents (e.g., rail kill, roadkill, drowning).

The population assessment comprises factors, functions and processes, and indicators that capture different aspects of moose population dynamics and structure. Figure 4 provides an overview of the key indicators, factors, functions, and processes for the moose value population assessment.

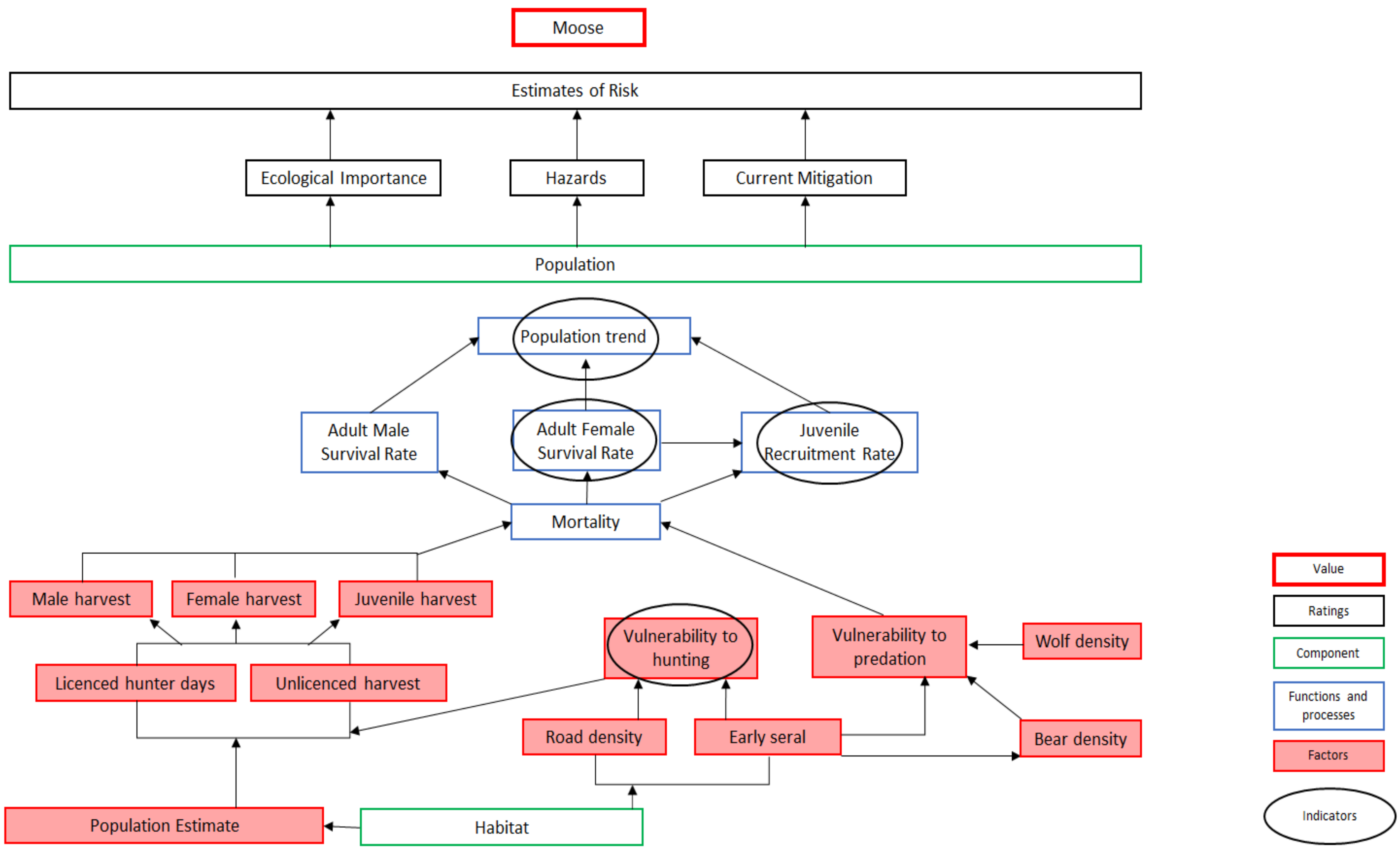

Figure 4. Overview of the key indicators, factors, functions and processes for the moose value population assessment.

The primary indicator of the population assessment is population trend, which provides an indication of whether moose in a given WMU are increasing, stable, or decreasing. Moose population trend and related indicators are structured in a Bayesian Belief Network (BBN)[3] model that provides a testable, causal approach to evaluate the relationships among indicators and their effects on population trend. The assessment explicitly presents interrelationships among indicators and inputs. The assessment process generates useful testable hypotheses, but does not explicitly test their validity.

Indicators, inputs, and latent factors included in the population assessment model are summarized in Table 2, and described in the following sub-sections.

Table 2. Summary of indicators, inputs, and latent factors included in the moose population assessment.

Name	Measurements
Primary Indicator	
Population Trend	Negative, Stable, Positive
Secondary Indicators	
Hunting Vulnerability	Low, Moderate, High (based on % early seral and road density)
Adult Female Survival Rate	<85%, 85-95%, >95%
Juvenile Recruitment Rate	Less than 30%, 30-40%, >40%
Inputs	
Licenced Hunter Days	Low (<500 days), Moderate (500-5000), High (>5000 days)
Unlicenced Hunter Days	Low (<100 days), Moderate (100-500), High (>500 days)
Road Density	<1 per km^2, 1-2 per km^2, >2 per km^2
Wolf Density	Less than 2 per 1000 km^2, 2-6 per 1000 km^2, >6 per 1000 km^2
Population Estimate	<1500, 1500-4000, >4000
Other Juvenile Mortality	Low, Moderate, High
Other Adult Male Mortality	Low, Moderate, High
Other Adult Female Mortality	Low, Moderate, High
% Early Seral	<5%, 5-10%, >10%
Latent Factors	
Adult Male Harvest	<50, 50-100, >100
Adult Female Harvest	0, <10, >10
Juvenile Harvest	0, <5, >5
Adult Male Survival Rate	<50%, 50-65%, >65%
Predation (Wolves, Bears, and other)	Low, Moderate, High

[3] The population assessment was developed as a Bayesian Belief Network (BBN) using Netica 3.24 (Norsys Software Corp., Vancouver, BC).

3.1 Indicators

State indicators are metrics used to directly measure and report on the condition of a component, while pressure indicators measure and report on processes that act upon or influence the condition of a component. The primary state indicator of the habitat component is Population Trend. Secondary state indicators are: Hunting Vulnerability, Adult Female Survival Rate, and Juvenile Recruitment Rate.

3.1.1 Population Trend

Adult survival rates are frequently available for only the female component of the population. Researchers rarely radio-collar males, because their contribution to population trajectories is minor compared to females and calves and thus the utility in monitoring males is lower. Because population growth rates depend on female reproductive success, the equation to calculate *lambda* (population growth rate) is restricted only to the female component of the population. The output for population trend is either stable (lambda value of 0.98-1.02), declining (lambda value of <0.98), or increasing (lambda value of >1.02).

3.1.2 Vulnerability to Hunting

A proposed hypothesis to explain the decline of moose observed in some regions of B.C. is that moose become more vulnerable to hunting and predators when road density and the abundance of early seral habitat <20 years old increases (Kuzyk and Heard 2014). Roads can facilitate travel for hunters and predators, and early seral habitat can reduce cover that visually screens moose from hunters and predators.

Hunting vulnerability is a derived variable that is scaled from 0 to 1 and is used to estimate hunter success and the number of animals removed from a WMU.

3.1.3 Adult Female Survival Rate

Adult female survival rate is a standard metric of reproductive performance in moose populations (Hatter and Bergerud 1991). It estimates the proportion of a population of adult females at time *t* that are expected to be alive at time *t + 1* (where time is generally measured in years). The principal drivers of adult female survival rate are assumed to be: the size of the population available to hunted, the number of females removed from the population by hunting and wolf density.

There are other factors (e.g., accidents, health, other predators) that affect this rate that are not considered in the model but will contribute to unexplained variance.

3.1.4 Juvenile Recruitment Rate

Juvenile recruitment rate is another standard metric of reproductive performance in moose populations (Hatter and Bergerud 1991) and is generally measured by the number of juveniles observed in early winter (typically December to January) per 100 cows surveyed. It estimates the proportion of young moose that are "recruited" into the breeding population.

The principal drivers of juvenile recruitment rate are assumed to be: the size of the population available to hunted, the number of juveniles removed from the population by hunting and wolf density. There are other factors (e.g., accidents and health) that affect this rate but are not considered in the model but will contribute to unexplained variance. Other sources of predation, specifically bears (Kuzyk et al. 2016), are included in this version of the population model.

3.2 Inputs

All test input data were assembled with input values assigned by WMU and then processed through the Netica model as a case file.

3.2.1 Estimated Population (Habitat Input)

The estimated population is an input produced from the habitat assessment that feeds directly into the population assessment. An estimate of potential moose density is based on the abundance and quality of moose habitat. Maximum moose density is limited by the capability of the habitat within a WMU.

Population estimates produced by the habitat assessment have the potential to be adjusted based on current research results, and known population densities from regions (i.e., stratified random block (SRB) surveys).

3.2.2 Road Density

Roads provide primary access for hunters and predators and they are one of the assumed correlates of hunter success and, therefore, may create a population pressures on moose (Rempel et al. 1997). However, licenced hunting should not be a population pressure on par with predation as licenced hunting is regulated.

Road length was summed within the area of capable moose habitat by WMU and then divided by the area of capable moose habitat in each WMU to derive road density estimates (km of road per km^2). Road density is stratified into three states to calculate hunting vulnerability: <1, 1-2, and >2 km of road per km^2

3.2.3 Early Seral

In this context the Percent Early Seral input is seen as a negative variable when it is combined with the Road Density input to produce the Hunting Vulnerability indicator.

Early seral habitat reduces visual screening that hunters may use to their advantage (Kuzyk and Heard 2014). This input informs the vulnerability to hunting (sightability) index. WMUs with different percentages of early seral habitat (<5%, 5-10%, and >10%), along with road density, are assigned coefficients to estimate hunting vulnerability.

3.2.4 Licenced and Unlicenced Hunter Days

Hunter days by resident and non-resident hunters (Licenced Hunters) is the primary indicator of hunter effort used in B.C. Resident hunters are sampled annually via a voluntary, randomly assigned questionnaire; and guide-outfitters are required to report all hunting activity by their clients. These data are often referred to as the Hunter Harvest Statistics (HHS) database.

Unlicenced hunting is a right of First Nations hunters and data are not routinely reported, but may be available for some areas if provided by communities.

Licenced hunter days were averaged for each WMU from FLRNO big game harvest statistics for 2010-2015. Days were summed for resident and non-resident hunters. These data are derived from questionnaires returned by a sample of resident hunters and from guide-outfitter reporting. No data were available to inform unlicenced hunter days.

Hunter days are stratified into three broad categories of effort and are assigned coefficients of low (0.25), moderate (0.5) and high (1). The categories are scaled differently for licenced and unlicenced hunters based on their estimated proportional representation in the hunter population.

3.2.5 Wolf Density

Wolves are the primary predator of moose and they can regulate moose population growth (Ballenberghe and Ballard 1993). Wolf density was derived from the *Management Plan for the Grey Wolf in British Columbia* (FLNRO 2014). Density estimates by WMU were assigned from the Ecosection-based management plan map at the centre of each WMU polygon.

Wolf density is used to estimate survival and recruitment rates (along with the number of animals removed and the size of the hunted population). It is acknowledged that relatively poor survey history of wolves exists over much of the province. In combination with how quickly wolf populations can change over time makes wolf density a difficult metric to estimate with any degree of accuracy.

3.3 Latent Factors

Latent factors are not directly quantified but are calculated from combinations of inputs and indicators. Latent factors included in the CE population assessment for the moose value are: Adult male harvest, Adult female harvest, Juveniles harvest, Adult male survival rate, and predation.

3.3.1 Adult Male, Female, and Juvenile Harvest

Licenced hunting removes predominantly adult males. Adult females constitute approximately 2% of the harvest and calves approximately 0.1%. The number of animals removed can be estimated by a function of the effort (as measured by hunter days), as well as the number of animals available to hunt. Equations for all demographic components of the population are the same except for scaling factors applied to unlicenced hunting.

3.3.2 Adult Male Survival Rate

Adult male survival rate is not required to estimate indicators and/or components, but because most hunting is focused on males it is included in the model for completeness and validation purposes. Adult male survival rate is calculated in a manner analogous to adult females.

3.3.3 Predation

Predation from wolves and bears are accounted for in the population assessment as a latent factor. This factor is determined indirectly via estimated predator density and expert knowledge on predator populations in a given WMU, as well as the hypothesized influence of current conditions (habitat) on predator densities. Wolves and bears are the primary predators of focus in the assessment.

3.4 Other Considerations

3.4.1 Health

There are growing concerns about moose health as an indicator (including nutrition-related concerns related to habitat) and related implications on survival and reproduction (Kuzyk et al. 2016). The singular and cumulative roles that disease (organisms such as liver flukes and ticks can stress individual animals which can then contribute to premature death) might play in causing or contributing to moose mortality are probably important, but are largely unknown. There continues to be ongoing research to isolate factors and to hypothesize causal effects and possible management responses. Therefore, health effects cannot be included in the BBN model of the population assessment in a manner that is meaningful at this time.

3.4.2 Climate Change

Requests to see climate change as an indicator in the assessment protocol were raised in the engagement sessions. Current work by the Climate Change (CC) and Integrated Planning Branch of FLNRO provides a draft approach of how climate change could be considered for the moose value (Daust and Price 2017). Their work describes an approach for incorporating the effects of climate change into BC's cumulative effects framework through adding pressure indicators within the CEF assessment protocols, using climate vulnerability assessments in current condition analyses and using climate scenario modeling in future condition analysis. The document presents a general discussion of the impact of climate change on each priority CEF value, including moose. As work is completed on the CC assessment protocols, they could be considered in future iterations of the moose assessment protocol.

4 Risk Assessment

Outputs from the assessment of the habitat and population components provide ratings for estimates of risk related to:

- Ecological Importance,
- Hazards, and
- Current Mitigation.

4.1 Ecological Importance

Ecological Importance evaluates the ecological importance of each assessment unit. This rating can also be thought of as the level of ecological consequence if the value is impacted. Ecological importance is equivalent to the consequence of impact used in traditional risk analysis. Higher importance ratings reflect a greater consequence of any impacts. Factors evaluated and rated for ecological importance in the habitat assessment include: moose winter habitat, and weighted habitat capability. Future iterations of the protocol will likely identify additional factors of ecological importance for moose to include in the risk assessment.

4.2 Hazards

Hazard ratings assess the degree to which inherent sensitivity and development impacts have reduced available habitat or reduced the effectiveness of the habitat. They provide a measure of the probability of impact and/or the degree of impact. Hazard ratings are key as they flag current environmental conditions.

In the habitat assessment, hazard ratings are developed to measure changes in the amount of high suitability habitat (i.e., both dynamic and static types) and change in just the static high suitability habitat as a result of development.

The ecological importance and current mitigation component information can help provide a deeper understanding of the management significance of any hazards. For example, two areas may have identical high hazard ratings, but one has high ecological importance while other has low ecological importance. Management Units with high hazard, high ecological importance, and high population trend concern (declining trend) would warrant greater consideration.

4.3 Current Mitigation

Current mitigation indicators assess the level of risk reduction currently provided by legally designated no forest harvest and modified forest harvest areas. Two of the measures associated with current mitigation condisered in the protocol include:

- Percent of habitat protected (The percentage of the high suitability moose habitat in all capability classes that is overlapped by no forest harvest land use designations). Protected areas included in the analysis are Parks, protected areas, goal 2 protected areas, Permanent OGMAs, and riparian reserves (no forestry harvest designations).
- Percent of static habitat protected (The percentage of the static high suitability habitat that is overlapped by no forest harvest land use designations).

In future iterations of the protocol, there will likely be additional mitigation measures to include in the risk assessment.

4.4 Risk Ratings

The level of associated risk is based on a 5-scale rating system of Very Low, Low, Moderate, High, and Very High. The ratings are necessarily qualitative, but based on quantitative information from the literature and/or expert opinion. The ratings are meant to flag potential issues requiring management attention. As such, they are not designed to make decisions but rather to identify areas and issues where additional consideration is required.

The following points summarize considerations to be made in developing ratings:

- Available knowledge concerning habitat relationships;
- Established or commonly used threshold values;

- Natural benchmarks based on the estimated attributes of naturally disturbed landscapes;
- Expert judgment related to habitat relationships, system sensitivity and ecological processes;
- Range and frequency distribution in provincial or regional data;
- Level of precision and/or certainty of the input assessment data; and
- Expert assumptions about the "shape" of the relationship between the ranges of indicator values to risk, e.g. linear vs. bell shaped vs. other shape.

Advantages of this type of rating approach include transparency, uniformity of output and ease of modification based on expert input. Due to the standardization of outputs, users can quickly comprehend the results of a variety of assessments. Outputs can be checked and validated using a variety of actions including: comparison with local animal abundance and distribution data, comparison with other peer reviewed models, and checks for reasonableness by topic experts, especially those familiar with moose habitat relationships in B.C. Experts with local knowledge can validate assessment results by comparing results with their expectation for areas for which they have intimate knowledge. They can also compare assessment results across the province and within regions with expectations of patterns of results.

Associated with the ratings are benchmarks. Benchmarks are proposed reference points that support interpretation of the condition of an indicator or component. Benchmarks are based on our scientific understanding of a system, and may or may not be defined in policy or legislation. Appropriate benchmarks are determined for ecological importance, hazard, and current mitigation.

4.5 Composite Ratings

The ratings provided for ecological importance, hazard, and current mitigation are each composite ratings derived from multiple indicators. The steps in calculating the ratings are:

- Apply the classification ranges to determine the rating for each indicator.
- Apply indicator weightings.
- Average the individual indicator ratings that make up each component. Round composite ratings to the nearest whole number.

4.6 Management Ratings

The range of values measured for each indicator is classified into three levels for management consideration to facilitate interpretation of assessment results. These indicator ratings are then considered as composite ratings for ecological importance, hazards, and current mitigation. Table 3 provides a general interpretation from the ratings.

Table 3. Management Ratings.

Management Rating		
Very Low/Low	**Moderate**	**High/Very High**
Little or no further consideration required.	Consideration required. For hazard component or indicators: May require additional information and/or management actions designed to maintain current status.	Very careful consideration required. For hazard component or indicators: Likely requires additional information to clarify situation. May required management actions to reduce environmental impacts.

Development of management ratings associated with the range of values for each indicator is a challenging but important step in the assessment approach.

5 Assumptions and Limitations

While there has been general agreement that the assessment protocol model captures appropriate variables and relationships, feedback through internal and external review highlighted opportunities for improvement.

5.1 Habitat Assessment

The following is a summary of assumptions and limitations related to the habitat assessment component:

- Reliability of several aspects of the habitat assessment is limited by the accuracy, currency and polygon size limitations of forest inventory data and by the quality of the data in the digital road atlas.
- Ratings for the landscape shelter indicator have not been peer reviewed.
- The relationship between various levels of stand mortality and its effectiveness for moose security and thermal cover is not known with any precision. Thermal and security cover values in high mortality pine stands would be reduced in relation to totally green stands, but would be significantly higher than in clearcut areas.
- The "reduced habitat" hazard indicator uses a very simple reference condition which does not explicitly reflect historic natural disturbance processes. However this indicator has been retained because it provides a valuable, spatially explicit assessment of current habitat. Due to the nature of the reference condition, the indicator does not completely reflect the difference between the current landscape and a naturally disturbed landscape condition. However, since the same methodology is applied the relative differences in indicator values can be rated to meaningfully estimate relative habitat change across the province, and between and within regions.
- Current classification of digital road data is very coarse and classifies all roads into only three classes: paved, gravel, and undefined. The undefined class includes many roads to and through cut blocks that are relatively large and well-travelled which would ideally be included as roads that that reduce habitat effectiveness for moose. Because of the coarseness of the road classification, these roads had to be excluded

from the moose analyses when ideally they would have been included. Future, more refined road classifications may allow for a more refined treatment of roads with variable disturbance distances depending on road classifications that would reflect industrial and hunter traffic.

5.2 Population Assessment

Although the population assessment output aligned in general with expectations provincially (e.g., relative population differences and general trends), the following limitations were raised:

- Stratification of factors into states, coefficients and equations are based largely on expert opinion and have not yet been tested with available data. The expert opinion provided was through workshops with Thompson-Okanagan staff and does not represent province-wide knowledge. Additionally, while the initial assessment was completed, results were not reviewed with experts to assess correlations with regional expectations other than in the Thompson-Okanagan.
- Trends were sensitive to the population estimates, which are based on assumed densities, by habitat suitability class. If higher population estimates are used, estimated trends improve significantly in many areas.
- Related to the above, regional data could provide better population estimates based on survey data and fine-scale habitat suitability mapping, rather than on the BEI coverage currently used.
- Lack of data for unlicenced hunting is an outstanding issue and in the model it is not separated from the licenced harvest.
- There is a reliance on overly coarse stratification of some categories applied in the assessment (e.g., 3 classes for population size).
- Gaps remain in the specific demographic parameters of all age and sex classes of moose in the province. For example, while survival of adults, especially bulls, may be more confidently known, there is a lack of information on moose calf survival rates and behaviour from 6–12 months of age (Van Ballenberghe and Ballard 1998).
- Related to the recommendations of McNay et al. (2013), the influence of nutritional constraints and the effects of habitat on the nutritional condition of moose (especially cows) have been noted as knowledge gaps (Kuzyk and Heard 2014).

5.3 Risk Assessment

Validation of the risk assessment results by value experts and data such as census and radio-telemetry data is important to ongoing credibility and usefulness of the assessment protocol. Transparency and credibility are also enhanced by clear discussions of the strengths and limitations of the assessment for moose. It is important to remember that the main purpose of the arisk ssessment is to flag potential management concerns, which should then be more fully explored rather than to make definitive judgments.

6 Considerations and Next Steps

This protocol provides a standardised provincial method of assessment for evaluating cumulative effects on moose across the province of B.C.; while also allowing a degree of flexibility within regions of the province. Use of this information should anticipate some changes in the substance and formatting of the assessment protocol in the future. It is expected that results from regional assessments will potentially clarify, standardize and improve the assessment protocol

Factors, functions, and processes included in the habitat and population assessments are approximations based on best available data, expert opinion, and a thorough literature review. The relationships are testable where data exist to calibrate and refine the assessment inputs. Improving assessment calibration based on analysis of existing data is a logical next step. Concurrent with model calibration will be development of current condition maps. This may require further decisions regarding baseline mapping for habitat capability, suitability, and effectiveness.

6.1 What can the broad scale assessment results be used for?

Some possible uses include:

- Flagging specific issues and geographic areas requiring more management attention, more detailed analysis and assessment, or additional inventories and/or research.
- Input into environmental impact assessments.
- Providing a common source of information to all stakeholders to stimulate and focus discussion.
- Prioritizing which geographic areas may benefit from additional information and/or evaluation prior to development decisions.
- Input to proponents to help them better assess their business case and better design projects to meet environmental concerns.
- Input to decision-makers to support authorization decisions and inform mitigation and monitoring requirements.
- To provide context information to professionals developing or approving Forest Stewardship Plans and Site Plans, under FRPA

6.2 Site Level Considerations

This section is included to give decision-makers additional guidance and information at a finer scale of detail than the broad scale assessment provides. This type of information can lead to more informed discussions of the risk and more effective proposals for potential mitigation.

Moose feeding habitat is sensitive to the following types of changes in habitat:

- Reduction in shrub productivity in winter feeding areas;
- Loss of shrub habitat or adjacent forested thermal cover due to land use changes;
- Forest harvesting of the thermal cover near to the productive shrub habitats;
- Development of roads within 1000 m of moose winter habitat areas;
- Increased vehicle use of roads within 1000 m moose winter habitat areas; and
- Snow ploughing of roads within 1000 m of moose winter habitat areas.

Important site level habitat characteristics
Mapped information resulting from this assessment protocol could be used to roughly identify the relative site level importance and sensitivity to development of specific locations in the landscape as shown below.

Highest Importance ↓	○ Areas with concentrations of static winter feeding habitat and adjacent shelter habitat especially where they overlap with high and moderate winter capability habitat. ○ Concentrations of high suitability moose winter habitat overlapping high and moderate winter capability. ○ Any other areas mapped as high winter capability. ○ Any large concentrations of moose winter habitat in other capability areas. ○ Areas mapped as moderate capability that are not overlapped with areas of modelled moose winter habitat. ○ Areas mapped as low capability that are not overlapped with areas of moose winter habitat.
Lowest Importance	○ Areas with nil capability.

Figure 5. Static winter feeding habitat and adjacent shelter habitat in southeast Omineca Region. Photo credit: Tania Tripp.

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