Mountain Pine Beetle -Habitat Supply Modelling Project

Modelling Approach & Species Accounts for Selected Wildlife Species

Draft Final Report

1 of 2

Draft for Review - not for wider distribution

March, 2008

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Acknowledgements

We thank Don Morgan and Jennifer Burleigh, both of MoFR, for technical advice and financial support to undertake this project. Members of the project team (Art Tautz, Dave Clark, Chris Ritchie, Matt Austin, Pauline Hubregtse, Hannah Horn, Pierre Iachetti) have provided input into this analysis including suggestions for selection criteria. Reviews of an earlier version of this report by the above team members have improved it.

Preface

This report is the first of three products that are intended as a design and initial test of a habitat supply modelling and simulation approach to projecting habitats and distributions of 13 selected focal species in relation to the consequences of the current large-scale MPB outbreak in British Columbia.

The series of deliverables for this project are:

1. **Report #1 - Modelling Approach & Species Accounts for Selected Wildlife Species** (this report)
   - review and selection of a species distribution model approach suitable for general application across a variety of species affected by MPB disturbances (originally Working Report #2 for this project);
   - identification of wildlife species that are anticipated to be either adversely affected by the MPB outbreak and the associated forest management response; or serve as contrasts to these (originally WR #1)
   - species accounts for the selected species, including published species accounts, extracted information about their current range extents, distribution and habitat requirements at the stand and landscape scales, and primary factors and relationships needed for subsequent modeling.
2. **Report #2 –Modelling of Habitat Supply in Response to MPB-induced Disturbance**
   - a general, conceptual description of ecological changes resulting from MPB and related forestry and management activities, including potential shifts in forest pattern, structure and composition as they relate to wildlife species distributions;
   - design and description of a habitat supply modelling framework using a two phased approach for the identified species using the information synthesized through the previous objectives;
3. **Mapping Products**
   - Current probabilities of occurrence for selected species in the Nature Conservancy of Canada's Central Interior Ecoregion Conservation Assessment study area (http://science.natureconservancy.ca/centralinterior/central.php).
   - Associated meta-data describing key assumptions, data attributes and environmental correlates defining species' habitat and occurrence.

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Introduction

British Columbia is experiencing the largest forest insect infestation ever recorded in Canada (Bunnell et al. 2004). By 2007, the mountain pine beetle (*Dendroctonus ponderosae*; MPB) killed an estimated 620 million cubic metres of timber on 14.6 million ha of forest largely dominated by lodgepole pine (*Pinus contorta*). The beetle has occurred in such high numbers that it has also led to significant mortality in a variety of non-typical forest types, such as young plantations (British Columbia Mountain Pine Beetle Action Plan 2006). While population growth and rate of spread exceeded projections made during the initial years of the outbreak (Eng et al. 2006), the spread of the outbreak is subsiding province wide, with expansion only occurring on the peripheries of the infestation (e.g., the Peace, Kootenays and southern Interior).

Even though large-scale insect outbreaks are a natural phenomenon, epidemics of this magnitude can have widespread and significant effects on wildlife; challenging paradigms for management of wildlife habitat and forcing broad-scale changes in policy intended to guide resource development. Chan-McLeod and Bunnell (2004) estimated 195 vertebrate species that may be affected by the MPB outbreak and/or the associated management intended to control or mitigate the MPB effects. MPB-induced mortality and the resultant timber salvaging activities cause change in forest overstory and understory composition and structure (Eng et al. 2005) and therefore the ecological and physical characteristics of habitat available to wildlife. Along with the expected losses of habitat for foraging and reproduction, other potential effects upon wildlife populations may include (Morgan *pers. comm*.): (1) degradation of remaining habitat below the quality needed to sustain reproduction, (2) altered community structure through shifts in ranges of other species, causing potential food-web shifts and altered predator prey interactions; and (3) changes in dispersal opportunity and success resulting in altered gene flows and potential failures to reoccupy parts of species ranges.

Our overall goals in this study are to investigate the nature of these potential effects on wildlife using simulation modeling of changes in habitat attributes. This investigation would apply knowledge of the key ecological interactions that have accumulated through recent research studies undertaken throughout BC. Estimation of likely occupancy of habitats by wildlife species as forests are altered by the MPB-induced mortality plus forest management responses to the outbreak, could lead to more informed decisions by those attempting to mitigate impacts of the MPB epidemic. The first 3 of 6 steps in the overall study are described in this report.

Chapter 1 – Review of Approaches for Projecting Species Distributions

Our specific objective in this chapter is to review potential modeling approaches and platforms and select ones for use in modelling the effects of habitat change caused by the MPB and associated management responses.

Study Area

Our study area for this project is the Nature Conservancy of Canada's Central Interior Ecoregion (see http://science.natureconservancy.ca/centralinterior/central.php). The current mountain pine beetle outbreak has significantly affected the interior of the province ranging northward from the BC – United States border to the northern end of the Mackenzie Timber Supply Area (TSA) and as far east as Slave Lake, Alberta. In total, 20 TSAs are impacted to varying degrees by the MPB epidemic. Due to the broad geographic extent, an extreme range of climate, biogeoclimatic, and topographic conditions can be found. Topographic conditions vary from the rugged mountains of the Kootenays to the flat plateau landscapes of the central interior. Forest structure and composition also vary greatly across the study area. For example, the composition of lodgepole pine in some TSAs, such as Robson Valley, is as low as 12% of the total mature volume inventoried pre-outbreak, where as in other areas, such as Vanderhoof portion of the Prince George TSA, pine makes up >73% of the mature volume (BC MoFR 2007).

Methods

We reviewed technical and scientific literature to collect a list of reasonably feasible and available platforms presently used in species distribution modelling. Many descriptive dimensions have been used to characterize these model platforms. The dimensions are usually fundamental to the purpose for which models are constructed and may include, but are not limited to, the following:

- Purpose – prediction / explanation;
- Algorithm structure – mechanistic / correlative;
- Ecological complexity -- multi-trophic (multi-species) / singular
- Treatment of time – forecast (simulation) / static
- Spatial, temporal, and/or functional resolution – coarse / fine
- Type of reasoning used – empirical (inductive) / theoretical (deductive);
- Statistical foundation – frequency / probability;
- Outputs – capability (potential) / suitability
- Type of result – deterministic / stochastic

In our review of potential platforms, we sought to evaluate each characteristic as it applied to our goals. This was achieved by first expanding the expression of the modeling goal to account for each model characteristic. Second, the platforms were then evaluated for the likelihood of being able to achieve our modelling goal. All models require testing, an assessment of error, some measure of uncertainty, and documentation of assumptions. We assumed these activities would be routine to all species distribution models and therefore did not let discussion of these particular activities influence our assessment of the potential platforms other than to confirm the activity was possible.

Results and Discussion

Expanded Articulation of Modelling Goals

Purpose: The purpose of modelling the widespread effects of the MPB epidemic on wildlife was to gain a better understanding for the type and magnitude of some of the most important ecological interactions between the effects of stand- and landscape scale tree mortality induced by this forest disease insect, and the consequences for the near-term and long-term distributions (as measured by the probability of occupancy) of selected wildlife species. With that understanding, managers could then begin to assess and prioritize the mitigation issues that will require deeper investigation. The implication therefore was that *explanation* of these potential interactions was more important than being able to *predict* them. Bunnell (1998) used this characteristic of purpose to distinguish the difference between the interests of the scientific community from those of the resource management community. In resource management, being able to predict a result is most often the primary goal. In science the most common goal is to understand why a particular result occurs. Although the two goals are related and somewhat inseparable, our use of simulation modelling was clearly a research investigation to improve understanding and not an attempt to construct a management tool.

Algorithm structure: It follows from the modelling purpose that the most suitable algorithm structure would be mechanistic rather than correlative. If our purpose was prediction, correlative models could suffice. In our case however, a focus on mechanistic ecological function was required as the fundamental basis to understanding the MPB effects and the ecological interactions involved.

Ecological complexity: The level of ecological complexity sought (i.e., functional resolution) was not only influenced by the modelling goals but also by the availability of data or information, the amount of available resources (e.g., time, computer capability), and sophistication of the model platform. Because multi-species interactions were of interest, our models would necessarily tend to be more complex than not. However, given our need to treat the entire spatial range of potential MPB effects, there was the competing need to restrict model complexity. We judged the availability of model reduction routines (i.e., sensitivity analyses) to be an important component of the modeling platform.

Treatment of time: A common instruction for developing species distribution maps based on presence/absence data is to ensure datasets are collected to address project goals (Johnson and Gillingham 2005, Guisan and Zimmerman 2000). The product from such modeling methods is usually a static output representing the combination of the inputs for a given time step. Applying event simulators to depict environmental change due to disturbance, whether natural or anthropogenic, results in a model capable of forecasting future conditions (Jones et al. 2002) so long as some model inputs are responsive temporally.

Our project was focused on evaluating the impacts of the MPB epidemic and subsequent management actions, specifically the ecological changes resulting from the attack and/or post-attack management, on a selected group of wildlife. We therefore needed the ability to simulate future beetle attack and post-attack management and to forecast the ecological results of these disturbances into the future. This activity is similar to Peterson et al.'s (2003) view of scenario planning. We therefore expected part of the modelling platform to support the use of disturbance simulators as an enabling foundation for forecasting comparative scenarios of MPB attack and management.

Spatial and temporal resolution: Spatial resolution (grid or pixel size) impacts model outputs and physical model structure. Regardless of the modeling platform applied, a spatial resolution of 1 ha grid size will be applied. For some attributes this resolution may be finer than necessary and a cell size of twice, or 4 times the dimensions (i.e. 4 or 8 ha respectively) would be adequate to capture variation. There are other data sets, however, where more appropriate interpretations result from fine resolutions less than 1 ha. In the development of species models, resolution of the input data must be considered, and factors not adequately represented by 1 ha pixels must be excluded.

We expect the temporal resolution to vary through the modeled scenarios. Because the MPB epidemic is still relatively recent in some areas and still spreading into other locations, we expect the initial time steps will be approximately annual while later in the forecasts where less resolution is necessary, the time step will be expanded to decadal.

One-hectare cells over the extent of the study area will necessarily produce physically large datasets. This level of resolution creates two problems. First, though technology has advanced such that computer processing requirements generally do not limit modeling capabilities, modelers must be aware that some tools and platforms are limited by physical size of data sets, and some software may have internal limits on "problem sizes" they can manipulate. The addition of temporal resolution very much impacts on the physical properties of a model. Each time-step application requires a complete data set, with cumulative effects resulting in large physical storage and processing capabilities being required. Second, fine-scale resolution can create expectations of modeling accuracy that in many situations is unwarranted. Errors in biophysical attributes based on extrapolations of sample data may become substantial when projected at a 1-ha resolution. Although researchers are usually aware of this limitation, managers may be tempted to use model predictions at those scales in ways that go beyond the original objectives of the model (i.e. to apply them operationally).

Type of reasoning used: Application of inductive modeling depends on detailed observations to make general expressions of habitat use by a species. Use of these models is correlative because modelers evaluate habitat based on the combination of environmental factors present at locations used by animals. Deductive modeling, by contrast, is generally mechanistic. It aims at using theory and conceptual ideas to define locations that are used by wildlife based on the relationship of environmental variables present at a site and the life requisites of a species. In situations where environmental data is incomplete, or the environmental situation is changing, it is possible for inductive, or correlative, models to forgo some accuracy in favour of obtaining higher levels of precision when projected forward, because empirical conditions that gave rise to the models may not encompass conditions in the future, and correlation structures may change. In such cases, deterministic models may provide a better picture of a changing reality (Guisan and Zimmerman 2000), because they are intended to depict the functional attributes selected by a species. Because our goals were focused on research of, and explanation for, particular environmental interactions, we considered that deductive modelling approaches would suit our needs in this project.

Statistical foundation: Two general statistical foundations available for modelling are frequentism (prediction is the probability of observing a specific outcome based on frequency of data observed) and Bayesian (prediction is the probability of observing a specific hypothesis based on the data observed). The primary differences between Bayesian-based and frequency-based methods relate to how observations are used to draw conclusions about the state of nature. Most simply, the frequentist approach asks the question "How likely are these observations, given a hypothesis (an 'expectation)?", while the Bayesian approach asks the question "How likely is the hypothesis, given these observations?". Although an in-depth review of the conceptual differences between interpretations of frequentist and Bayesian probabilities is beyond the scope of this study (see Berger 1984 for a more thorough treatment), we offer some summary statements here to illustrate the key elements. The first is that frequentist methods emphasize the "hypothesis under investigation" and a probability in this context is interpreted as the likelihood that the statistical properties of a set of observations reasonably conform to the statistical properties of the underlying hypothesis being examined. Frequentist methods therefore work best when the hypotheses are based on well-understood properties of systems, and typically require an explicit probability distribution to be formulated for each hypothesis studied. Bayesian methods emphasize the strength of the relationship between observations and one or more hypotheses, and a probability is interpreted as the likelihood that a given hypothesis could have given rise to the set of observations. Second, Bayesian methods allow prior information to be explicitly represented in the calculation of the probability, where frequentist methods do not (except in the design of the properties of the hypothesis). Returning to the idea with which we opened this section, frequency-based methods are associated with types of phenomena derived from physical systems exhibiting describable statistical properties, while Bayesian probabilities are less dependent on description of the properties of systems and provide a means to represent the degree to which a statement (conclusion) is supported by the available evidence (observations).

The practical differences between these two approaches are subtle, but we draw out two ideas that relate to the goals of this study. First, Bayesian methods can offer practical guidance in situations where hypotheses may not themselves be based solely on mechanistic or statistical models (e.g., physical properties of systems). Second, Bayesian-based probabilities can be used in a relative sense (i.e. the relative evidence that alternative hypotheses are supported by the observations), while frequentist-based probabilities cannot be interpreted this way. These two properties of Bayesian-based approaches offer very important advantages when developing models in conditions of significant uncertainty, and we have used the characteristics of this approach to guide our selection of model approaches and platforms.

Outputs: Most models produce an output that is related to (or can be interpreted as representing) the suitability of a site to meet the needs of a species. Suitability is a static picture presented for a specific time step. Evaluating the capability of a site involves the assessment of the potential for providing life requisites irrespective of limitations on the supply of resources. Otherwise stated it is a depiction of habitat under optimal conditions that is independent of time or other non-site (i.e., displacement or mortality) elements. Although we could model both suitability and capability, or modelling goal was mostly focused on suitability of a site at varying time steps.

Type of result: Models can be a either deterministic or stochastic in nature (and frequently the same model can be operated in either mode). Deterministic models produce an output that generally represents the response to mean (expected) conditions of the inputs. They do not reflect variations in inputs that occur in a system in response to annual variations in input values such that the outputs have a distribution of values for defined sets of input conditions. Stochastic models do incorporate variation of both physical conditions of data sets and temporal settings. In a stochastic model there are multiple resultants that a process might lead to, but some endpoints are more probable than others. Given uncertainty associated with the MPB epidemic, we believe resultants from a stochastic model better facilitates investigations of potential ecological outcomes resulting from the MPB outbreak.

Common Model Approaches and Platforms

Platforms for modelling species distributions and/or quality of range vary widely in their application and are referenced somewhat indiscriminately in the literature. Specific approaches have often been forwarded with an emphasis on their more beneficial contributions to the characterization of wildlife range values. Although the platforms are different, the user goals and objectives and the results obtained are similar in many ways. For example, most platforms are used to evaluate and produce maps of wildlife range. There is no one platform that defines species distribution modelling, but conversely, some platforms are better at, and more appropriately implemented to, than others to reach some goals.

Element Distribution Models: Element distribution models (EDM), a generalization of Species Distribution Models, are used to map environments predicted to be suitable for occupation by a given element in a defined area (Beauvais et al. 2006). The product represents a static picture of the distribution of the elements based on presence/absence data and is a good example of inductive modelling. One strength of this approach is that elements can be flexibly defined to suit the modelling goals. However, EDMs produce an output with no temporal component to reflect that an elements relationships with its environmental changes as a result of different disturbance events (Guisan and Zimmerman 2000, Beauvais et al 2006). Thus, to reflect changing environmental conditions, the model must be based on data representative of varying temporal situations implying very long-term studies which are generally not available. Put another way, success of empirical based models is highly dependent on the underlying sampling characteristics (temporal and spatial) of the input variables. The strength of an EDM is relative to the quality (i.e., sample design) of the input data.

<u>Habitat Supply Models:</u> Habitat supply modeling (HSM) is a general description for a process that expresses factors, and the relationships that bind them, to present a depiction of what constitutes habitat, but also includes an analytical strategy to evaluate and predict the habitats supply through time (Jones et al. 2002). The ability to forecast or express elements of time is a fundamental strength of HSM. Habitat supply refers to the quantity, quality, and geographic distribution of habitat present over time (Jones et al. 2002). This differs from timber supply, which is the relatively simpler accounting of tree growth (volume) stratified by tree species and site productivity and its availability under different constraints. By comparison, the supply of habitat is relative to a particular organism, group of organisms or elements, and the range of elements that they require. Habitat supply is complicated beyond site and time considerations by other ecological interactions including seasonal factors such as a winter range, stratification of life stage such as reproductive status, behavioral interactions with humans which may lead to displacement from habitat, species interactions that commonly occur in attempting to model food resources and mortality agents, and (because animals move) spatial interactions among all these factors (Jones et al. 2002).

As a result, the basis for habitat supply modeling is an assessment of multiple environmental factors more complex than can be extracted from a single data source such as forest cover. Habitat supply models are mostly deductive but do not necessarily have to be so. For example, inductive models that form relationships to environmental factors that change with time could be able to predict habitat supply through time but are unlikely to be reliable in that application since the fundamental relationships have usually been derived under very specific spatial/temporal environmental conditions.

<u>Resource Selection Functions:</u> In a broad sense, resource selection functions (RSF) represent the most recent advancement in the application of frequentist statistical techniques to estimate wildlife range values. RSFs are defined as any function that is proportional to the probability of use of a resource or area by an organism. They are static depictions of a species preference given the environmental variables being assessed (Austin 2002, Manly et al. 2002). RSFs are inductive, empirical-based modelling approaches intended to describe (not explain) the relationship between observation of animal occurrences and any number of geographic and environmental parameters. These are useful inductive management tools when prediction is desired and the scope or context for prediction is similar to the environmental conditions under which the empirical foundation for the model occurred. Although popular today, the historic precursor to these models was the more parametric regression modelling approaches including but not limited to those based in multivariate statistics (Austin 2002).

<u>Habitat Suitability Index:</u> Habitat Suitability Index models (HSMs) are generally subjective models representing expert opinion on the relationships of multiple factors producing range/habitat conditions for wildlife (Verner et al. 1986). They are typically an equation of an additive, multiplicative or logical form with co-efficients representing the relative value of environmental factors (Johnson and Gillingham 2005). In conjunction with a GIS they are used to map habitat units classified by rank or some other general metric (Johnson and Gillingham 2005). HSIs are suited to linkages with disturbance simulators and could therefore fit as habitat supply models. However, by the nature of applying index values to

relate the importance of a resource for a species they tend to be correlative and do not necessarily provide explanation for the system they are interpreting.

Wildlife Habitat Ratings: Wildlife habitat ratings (WHR) define the relative importance of various ecological units to wildlife. The rating reflects the value of a habitat type against the best available in the province for that particular species (BC MOE 1999). To determine the habitat rating, expert biologists use experience, literature and site visits to produce index values for environmental variables. In this manner, WHRs and HSIs are not dramatically different. Both are correlative and deductive but WHRs rely on a fundamental basis of empirical data to help inform modeled relationships. The index values are summarized, generally in a linear multiplicative model structure, and scores are classified for mapping purposes (Johnson and Gillingham 2004). Because of the linkage to ecological units, terrestrial ecosystem and predictive ecosystem mapping are used for the basis on large-scale mapping projects. The broad ecosystem inventory is used as a base for small-scale mapping.

Desired Modelling Platform Attributes and Use of Available Data

Desired Modelling Platform Attributes.

The widespread, and unprecedented, changes to the provincial interior landscape resulting from the MPB epidemic have generated large levels of uncertainty in predicting the attributes of the resulting ecological landscape and concomitant needs for assessing resource management policies. The primary sources of uncertainty in this situation are due to: (1) a lack of understanding about which ecological functions mass amounts of dead pine will have in the future landscape; (2) our limited understanding of the expected changes in hydrologic processes and plant community dynamics that may result from the environmental changes brought on by the MPB epidemic; and (3) the direct and indirect effects of climate change on habitat structures, ecological relationships between species (e.g., food-web effects) and effects on demography of each species. These uncertainties resulting from climate change extend to significant uncertainty about the magnitude and frequency of mean trends in each climate variable, and the effects on natural disturbances and the rates of ecosystem recovery from disturbance. Models predicated on existing data will not accommodate the varied conditions that will be experienced through the epidemic because the data were observed in an era of relative ecological stability. Some relatively predictable inter-relationships between species may shift into different states (stability regimes) as a consequence of significant changes in food-web and/or predator/prey structures. Furthermore, the physical properties of the study area are not homogenous. A broad range of climate, biogeoclimatic, topographic, and forest conditions are present and empirical (i.e., element distribution) data have not been collected for the full range of these conditions.

This shifting and uncertain future state of the ecological landscape in the areas affected by MPB creates immense challenges for modelers. For our modelling purposes, the selected platform must be sensitive to the known resource requirements of target species, but at the same time be able to represent the relative level of uncertainty in ecological relationships used. The modeling platform must also be able to accommodate tradeoffs between scale (the geographic scale of the outbreak and of each species' habitat requirements, including effects on habitat fragmentation and demography) and resolution required to capture management responses (e.g., roads, salvage operations) and, where possible, fine-scale habitat elements (Guisan and Thullier 2005). The data we do have available (see McNay et al. 2007) can be used to inform opinions about expected ecological relationships that may occur as a consequence of the MBP outbreak. This limited available data, and limitations on its use to represent dramatically different ecological conditions, forces us to consider model platforms that will be constructed at least in part based on theoretical concepts (Jones et al. 2002). We argue that given this context, sole reliance on inductive empirical approaches will be insufficient (at least at present) for meeting the goals of managers to sustainably plan management policies to conserve species' habitats in the wake of the outbreak. A multi-scaled approach building from theory and deductive reasoning offers a more workable starting point.

The above considerations lead us to recommend multiple modeling approaches, that are implemented in a Bayesian belief network to produce spatially referenced probability statements about the suitability of a given spatial unit (e.g., cell) to support a particular element (e.g., occupancy by a species). Bayesian belief networks (BBN) are probabilistic graphical models that represent a set of variables and their independencies to calculate the probabilities of different outcome states given a set of input data. A number of software tools are available for construction of Bayesian nets (Marcot et al. 2006). One of the more commonly used ones applied in British Columbia is Netica (Norsys), and we recommend its use in this application. Due to the range of data and uncertainties associated with this project we conclude that Bayesian modeling is a solid tool for the task. Recent studies illustrate the range and types of questions that can be asked using a Bayesian framework that have similarities to those at the heart of this study (e.g., habitat characteristics in response to disturbance: McNay et al. 2006; demographic responses to habitat change: Steventon et al. 2006; demographic responses to future habitat and climate: Amstrup et al. 2007; adaptive management and policy analysis: Nyberg et al. 2006).

There are multiple avenues for developing strength into model structure in a BBN framework. Existing data can be used to calculate parameters and probabilities within the model structure while at the same time providing flexibility for expert judgment to be used where data gaps exist (Nyberg et al. 2006). Incorporating ecological knowledge into the model will result in a more robust process and greater explanatory power (Austin 2002, Guisan and Thuiller 2005). While it is impossible to infer causation from the correlation structure that results from many inductive approaches (Austin 2002), using a BBN cause-effect relationships can be explicitly mapped limiting the inference required to reveal a functional response from coefficient factors (strength, magnitude, sign). Given the variability in habitat conditions present throughout this project study area, some level of reliance on expert opinion will of necessity be required. Multiple modeling approaches can provide avenues for incorporating expert based rationale, common examples are habitat suitability indexes (HSI) , WHR and HSMs constructed using Bayesian belief networks (BBN). HSI and WHR algorithms are generally based on classified or indexed resource values, where co-efficients represent the relative value of environmental factors (Johnson and Gillingham 2005). Updates to the coefficients in the equation can be made; however, the interpretation of the weighting of each varies relative to the variance addressed by each individual factor. This process for updating an entire equation of a HSI is not as transparent as adjusting the relationship in a BBN. A BBN usually contains multiple summaries prior to making a final output. At any summary location within a network, updates can be made explicitly expressing the effects of a data set to specific factors, as compared to modifying an entire equation in a GLM. The updates in a BBN can be made with expert opinion or learning algorithms can be used to incorporate empirical data to define relationships.

Simplification and generalization of the resulting models are an important requirement, given the large spatial scale, and multiple species focus of the modeling problem. Besides its algorithmic basis in Bayesian decision theory, Netica also offers users the practical advantages of having facilities for testing sensitivities among variables in the network to aid in model simplification where correlations between input variables exists and for identifying and removing redundant variables and relationships. Finally, Netica has facilities for incorporation inside other modeling frameworks (e.g., spatially explicit simulation software) permitting the strengths of both simulation projections and Bayesian probability calculations to be brought together.

Regardless of the modelling platform that is applied, some form of model evaluation to assess the predictive power of the results are required (Guisan and Zimmerman, 2000, Jones et al 2002). This phase cannot unbiasedly be accomplished with data that was used to build a model. Rather, we believe that ensuring a significant portion of the collected data is used for model evaluations will capture its maximum value (see also Beauvais et al. 2006). There are multiple methods for sub-setting data, or bootstrapping to allow construction and evaluation from an original single source. Regardless of the method, however, the size of sub-setted data is inherently smaller than the whole for any given phase. Given the large spatial extent we are working with, smaller samples on data driven models will likely result in weaker predictive power (Hernandez et al. 2006). Given the other sources of ecological uncertainty, this loss of power may have a relatively minor effect on the accuracy of predictions relative to the gains in confidence in the underlying relationships made by applying a formally structured evaluation.

Use of Available Data

Based on three concurrent project activities: (1) scoping and design of the individual species accounts and habitat models; (2) investigation and acquisition of GIS data for implementing the models; and (3) discussions with research analysts undertaking the development of predictive models for stand attributes in stands after MPB mortality occurs (as projected by SORTIE as parameterized by stem-mapped plot data) and assessed via statistical relationships with attributes available in our data) we outline the data currently known to be available for use in this project.

The main types of inventory GIS data required by the project were as follows:

- BEC mapping to variant
- TRIM data (roads, streams, waterbodies)
- VRI data (tree species composition of each stand, age and height of dominant/codominant tree species, herb, shrub cover, non-productive codes, canopy closure, disturbance history)
- Inventory type grouping

Note that a more complete listing of the specific attributes required by the species models will be included with the final report and meta-data associated with the final species probability maps.

The main types of projected MPB data required are:

- Year of mortality
- % of pine killed at year

Finally, the main types of recovering stand dynamics data that in future could be used by the species models are:

- Projected canopy closure class at year
- Projected tree heights by species and dbh class
- Projected snag densities by size and decay class
- Projected downed wood volumes by decay class

Summary of Rationale

Bayesian modeling in ecology is not new (McCann et al. 2006) and has proven useful in other resource management issues particularly when empirical approaches (i.e., solution characterization) were intractable (Reckhow 1999; Marcot et al. 2001; Rowland et al. 2003; Peterson and Evans 2003; Poirazidis et al. 2004, McNay et al. 2006). Bayesian modeling is probabilistic and can therefore include data and other sources of information even though either may be incomplete. This characteristic was considered especially useful in our pursuit to better understand the potential ecological effects of the MPB epidemic where relationships varied in level of uncertainty. Results in Bayesian modelling are characterized by measurable uncertainty allowing for risk assessments and other forms of decision analysis. The approach is therefore consistent with at least some properties of formal decision-making (Berger 1985; Peterman and Peters 1998) and forwards a problem-solving technique to support critical decisions about the effects of the MPB on other elements. The probabilistic nature of Bayesian statistics allowed us to address the fact that most research on the distribution of our 10 wildlife species was collected during a period of endemic MPB populations; specific empirical results were not readily generalized to new ecological settings (spatially or temporally); and the response of these species to proposed management strategies has not been thoroughly investigated.

The focus of our work here was to develop a tool that would assist the management decision-making process rather than predict ecological consequences (Bunnell 1989). In addition to assisting decision-making, we consider our approach of Bayesian modelling to the problem of species distributions offers the extended benefit of having formal and explicit hypotheses that could be evaluated and tested through more traditional statistical methods, and inductive approaches as data for them becomes available.

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Chapter 2 – Selection of Wildlife Species for Modelling

For this component of the project, we wished to identify approximately 10-12 wildlife species (vertebrates) that are: (1) anticipated to be most adversely affected by the MPB outbreak and the associated forest management responses to that outbreak; (2) include a few representative examples of hunted or trapped species; and (3) at least one example of closely related species that contrast in their habitat requirements. The determination of 10-12 potential species was in part a pragmatic one given the extensive data requirements and resources available to undertake the study.

Methods

Prior to 2004, there was little information about how wildlife or their habitat was affected by epidemic levels of MPB and/or the associated management of such epidemics. While there is still a paucity of information in this regard, there is now a small and growing body of research papers that list and describe the potential effects of MPB-induced habitat alterations on some vertebrate species. We used this recent literature to compile a list of 32 affected species. We then scored each of the listed species using criteria that would reveal relative ranks of priority for including the species in further research. The criteria used were:

- Species conservation status,
- Spatial distribution,
- Habitat use,
- Key ecosystem function[1]
- Stakeholder interest, and
- Perceived MPB-based threat to the species habitat needs.

The species conservation status was determined by its rank with the Council on the Status of Endangered Wildlife in Canada (COSEWIC) and the BC Conservation Data Center (CDC). Spatial distribution was defined as a coarse resolution confirmation or rejection of the overlap between the species and the MPB outbreak area, including areas forecasted to be affected by MPB in the future. Habitat use was defined as a coarse resolution confirmation or rejection of the species' requirement for forested areas dominated by lodgepole pine. Key Ecosystem Function (KEF) is based on Bruce Marcot's (Marcot et al. 1997, Marcot and Vander Heyden. 2001) definition of the general type of relationship between a species and its environment. For our purposes the relative importance of a species was scored as high, med or low on the basis of the number of KEF categories the species was judged to be associated with. Only certain aspects of Marcot's system could be used for this analysis, for example, since we did not build a matrix for all species associated with the area of the MPB outbreak, we could not determine whether species could be judged as functional keystone species. In our analysis, we were only able to roughly categorize the number of KEF's each of the 32 species fell under and therefore determine the "Functional breadth and functional specialization of species" (Marcot and Vander Heyden 2001). Although not used here, Gillingham (2003) has done work on developing and testing relationships between groupings of vertebrate species called "lifeforms" and landscape structural attributes. The premise that Gillingham's work is based on is that lifeform groups are associated with certain structural attributes that are typical of

[1] http://www.spiritone.com:80/~brucem/kef1.htm

seral stages and if these attributes are maintained it should also be possible to maintain the species. This method was not used to help select our species because it is based on groups rather than individuals.

Stakeholder interest was defined as a coarse resolution confirmation or rejection of the species having been previously noted as a management concern by stakeholders. The perception of MPB-based threats to the species was a general criterion under which we reviewed the nature of the potential threats from a MPB epidemic. For example, Chan-McLeod and Bunnell (2004) stated that there are generally 6 forest stand structures that are important components of wildlife habitat: large trees, dead and dying trees, coarse woody debris (CWD), shrubby undergrowth, canopy cover, and deciduous trees. These components must be maintained in appropriate quantities to support viable populations of native species. We augmented the list of forest structural components to include landscape factors associated with habitat continuity (i.e., lack of fragmentation), dependence on riparian or wetland habitat, and potential for increased mortality from use of roads by humans or predators. Finally, we added a consideration for administrative effects by noting whether the species had current legislated habitat management (e.g., Ungulate Winter Ranges or Wildlife Habitat Areas) that would be detrimentally affected by the MPB. We considered whether the effect of the MPB outbreak and associated management would be a positive or negative stressor on each particular species and their habitat components. The habitat components affected by the MPB and the relative importance of these components to each species helped determine our estimate of the relative degree to which each species could be affected.

We developed a means of ranking the 32 species by (1) scoring each criterion with an overall weight; then (2) scoring each stratum under the criterion as a percentage of that weight (calculated as the reciprocal of the criterion code). When the resulting scores were summed, the species rank was revealed (Table 1). The score (weight) for each criterion is listed in Table 1. Our rationale for the weights applied is as follows. We gave species status an overall weight of 17 as we felt this factor was more important than stakeholder interest or species general distribution in BC but less important than MPB threat to habitat components or landscape features. Within this criterion, status from the Conservation Data Centre was given a greater percentage of the criterion score (13) then COSEWIC (4) to provide a more provincial perspective. Stakeholder interest was given a weight of 6 (divided equally with 3 points for NCC and 3 points for MOE). No species list was provided for Hectares BC so this stakeholder interest did not enter the scoring. Overall, the stakeholder criterion was weighted relatively low in order to shift emphasis to the species and their ecology. KEF was given a weight of 15, slightly less weight than status or dependence on pine due to the coarse resolution used in this analysis. However it was given a greater weight then stakeholder interest to keep the emphasis on the species and its ecology. Distribution was weighted comparatively low (5) as threat to the habitat components and landscape features was considered of more importance. Dependence on pine habitat was weighted high (17) because the MPB epidemic itself is focused on lodgepole pine. Threat to habitat components or landscape features was given the greatest weight due to its apparent importance to the objectives of this study. It was given an overall weight of 40 with each individual threat given a portion of this weight depending on how much and how long the component would likely be affected by the epidemic; for example dead trees, CWD and canopy was weighted greater than large trees as the use of individual large pine may be replaced by a large tree of a different species, but CWD, dead and dying trees and canopy will be greatly effected for long periods by the massive loss of pine.

Results and Discussion

Wildlife Species Negatively Impacted by MPB-Attack. In our determination of the 8 wildlife species that were considered to be most detrimentally affected by the MPB epidemic in BC, we reviewed coarse resolution information for 32 different species: 21 mammals and 11 birds (Table 1). Four species (grizzly *Ursus arctos*, caribou *Rangifer tarandus*, wolverine *Gulo gulo*, and fisher *Martes pennanti*) received the highest rankings by our method. Although these species range widely throughout the province and hence overlap with the area affected by MPB, they are also sensitive species that are expected to respond negatively to increased fragmentation brought on by management responses to the MPB epidemic. In many cases, conservation of habitat for these species is represented in legislated UWRs or WHAs and the long-term integrity of this management policy has become uncertain due to the MPB epidemic and associated management.

Caribou depend on access to terrestrial lichens as a major component of seasonal diets and these sites are often, if not exclusively, found within forests dominated by lodgepole pine. Lichen (and caribou) response to the changes brought on by MPB-killed pine stands is currently unknown (Whittaker and Wiensczyk 2007), yet 100's of thousands of hectares of habitat will be affected, much of this being legally designated UWR.

Grizzly bear is found throughout much of BC but its range is decreasing and it is now extirpated from south-central and southern regions of BC (Bunnell et al. 2004). Even though the grizzly may draw some benefits from the MPB, loss of habitat components such as CWD, increased fragmentation and increased access that accompanies mitigation measures may have detrimental effects on this species (Bunnell et al. 2004).

The wolverine is rare but occurs throughout much of BC; it is most prevalent in areas that have high habitat diversity and prey abundance. They depend largely on carrion and so require other carnivores as well as their associated prey species (Bunnell et al. 2004). Increased access and other effects of the MPB epidemic are a threat both indirectly through loss of prey as well as directly from increased access for hunting and trapping (Bunnell et al. 2004).

Like the wolverine, the Fisher is rare and occurs at low densities in central and northeast BC (Bunnell et al. 2004). They are found in forested landscapes with a preference for structural complexity and habitat components such as large trees, gaps in the canopy, understory, dead and dying trees, and CWD. As well, they appear to require a canopy closure of at least 30% for movement (Bunnell et al. 2004). Loss of these components and habitat fragmentation due to the MPB epidemic will negatively affect this species (Bunnell et al. 2004).

Spruce grouse (*Falcipennis canadensis*), marten (*Martes americana*), Lewis's woodpecker (*Melanerpes lewis*), and red squirrel (*Tamiasciurus hudsonicus*) are the other species ranked in the top 8. Pine is an important component of the spruce grouse's diet (CDC 2007b, CDC 2007c, VanderWall 1988). The spruce grouse feeds primarily on conifer needles in the winter and in the southern part of its range prefers lodgepole pine (CDC 2007c). A study in Washington found that not only was lodgepole pine preferred over engelmann spruce (*Picea engelmannii*), the birds did not survive on an exclusive diet of engelmann spruce (Hohf et al. 1987).

The marten is yellow listed but is dependent on many of the habitat components that the MPB epidemic will alter. Tree death, canopy loss, stem removal, and loss of CWD will detrimentally affect this species habitat (CDC 2007a). Marten will also be affected by fragmentation (CDC 2007a).

Lewis's woodpecker is red listed by the CDC and is ranked as Special Concern by COSEWIC. The greatest threat to this species is considered to be loss or alteration of its habitat (CDC 2007f). The MPB epidemic is considered to be a substantial threat to this species by limiting or eliminating potential nest trees. Even though the population trend is not currently understood, the drastic decline in habitat for this species leads the province to consider this species to be under substantial and imminent threat (CDC 2007f).

The red squirrel, although yellow listed, is highly dependent upon many of the habitat components that the MPB epidemic threatens, and is also an important prey item for marten and fisher. The mountain pine beetle threatens both the lodgepole pine and the white bark pine (*Pinus albicaulis*) of which the seed is an important source of dietary fat for the squirrel (Campbell 2007).

Wildlife Species Selected by Other Contrasting Criteria. To this list of 8 species top-ranked as being most detrimentally affected by MPB-induced stand mortality, we added five species: Mule deer (*Odocoileus hemionus*), Canada lynx (*Lynx canadensis*), Elk (*Cervus canadensis*), Moose (*Alces alces*), and Sharp-tailed grouse (*Tympanuchus phasianellus columbianus)*. With the exception of Sharp-tailed grouse, all of these species are at least partly dependent upon pine as component in their habitats, these species are expected to exhibit either a neutral or positive distributional response to the changes in habitat composition as a consequence of MPB- mortality to stands within their present range (Table 1). As such they provide some testable contrasts to the expected more significant alterations to the geographic distributions of occupiable habitats for the other 8 species. Because these species play an important ecological role in predator-prey food webs within B.C. and most are also economically significant (game species: mule deer, elk, moose) or furbearers (Canada lynx), there is therefore potential to use the results of this study to help inform future management options for these species. Sharp-tailed grouse provides an ecological contrast to Spruce grouse, as it is not a pine forest-dependent species, and could in future act as a species whose range may change as a consequence of other ecological drivers, such as climate change.

We considered modeling Snowshoe hare (*Lepus americanus*) because of this species' role as critical prey for several of the predator species we are modeling (especially Canada lynx). However, resource constraints prevented us from developing a snowshoe hare habitat model, although we did produce an account for this species (see Chapter 3).

Table 1. List of species anticipated to be adversely affected by the MPB outbreak.

Rank	Species	Status		Stakeholder[3]			Distribution[4]	KEF[5]	Habitat pine[6]	Threat[7]									
		cdc[1]	Cosewic[2]	winlose	nc	Habc				lgtrees	deadtrees	cwd	shrubs	canopy	deciduous	continuity	roads	wetlands	uwrwha[8]
	Scores[9]	13	4	3	3	0	5	15	17	3	6	6	2	6	3	3	4	3	4
1	Fisher	1	100000	1	1	0	7	3	2	1	1	1	1	1	1	1	1	100000	100000
2	Grizzly	2	3	1	1	0	9	3	2	100000	2	1	1	2	100000	1	1	2	1
3	Caribou	2	2	1	1	0	5	1	1	1	100000	100000	1	1	100000	1	1	100000	1
4	Wolverine	2	3	1	1	0	7	3	2	2	2	1	2	2	2	1	1	100000	100000
5	Spruce grouse	3	100000	1	100000	0	9	2	1	2	100000	2	1	1	100000	100000	100000	100000	100000
6	Marten	3	100000	1	1	0	9	2	2	2	100000	2	100000	1	2	1	100000	100000	100000
7	Lewis's Woodpecker	1	3	100000	100000	0	1	2	2	2	1	2	1	1	2	100000	100000	100000	100000
8	Red squirrel	3	100000	1	100000	0	9	2	2	2	1	2	100000	2	100000	2	100000	100000	100000
9	Badger	1	1	100000	1	0	1	2	2	100000	100000	100000	100000	100000	100000	1	1	100000	100000
10	Ermine	3	100000	1	100000	0	9	2	2	2	2	2	100000	100000	100000	2	100000	100000	100000
11	Mule deer	3	100000	100000	1	0	8	2	2	2	100000	100000	2	1	100000	100000	100000	100000	1
12	Clark's nutcracker	3	100000	100000	1	0	3	1	1	2	100000	100000	100000	2	100000	100000	100000	100000	100000
13	Canada lynx	3	100000	100000	1	0	5	2	1	100000	100000	2	100000	100000	100000	100000	100000	100000	100000
14	Ruffed grouse	3	100000	1	100000	0	9	2	2	100000	100000	2	2	100000	100000	100000	100000	100000	100000
15	Barrow's goldeneye	3	100000	100000	1	0	9	2	2	100000	100000	100000	100000	100000	100000	100000	100000	1	100000
16	Lesser scaup	3	100000	100000	1	0	9	2	2	100000	100000	100000	100000	100000	100000	100000	100000	1	100000
17	Red fox	3	100000	1	100000	0	9	2	2	100000	100000	2	100000	100000	100000	100000	100000	100000	100000
18	Long-tailed weasel	3	100000	1	100000	0	5	2	2	2	2	2	100000	100000	100000	2	100000	2	100000
19	Northern goshawk	3	100000	100000	1	0	9	2	2	2	100000	100000	100000	100000	100000	100000	100000	100000	100000
20	Great blue heron	2	3	100000	1	0	2	2	2	2	100000	100000	100000	100000	100000	2	100000	1	100000
21	Bighorn sheep	2	100000	100000	1	0	1	2	2	100000	100000	100000	100000	100000	100000	2	2	100000	1
22	Bobcat	3	100000	1	100000	0	5	2	2	2	100000	2	100000	2	100000	2	100000	100000	100000
23	Least weasel	3	100000	1	100000	0	7	2	2	2	100000	2	100000	100000	100000	2	100000	100000	100000
24	White-tailed deer	3	100000	100000	100000	0	3	2	2	2	100000	100000	2	1	100000	100000	100000	100000	1
25	Elk	3	100000	100000	100000	0	3	2	2	2	100000	100000	2	1	100000	100000	100000	100000	1
26	Perigrine falcon	1	2	100000	100000	0	1	2	2	100000	100000	100000	100000	100000	100000	100000	100000	100000	100000
27	Mtn goat	3	100000	100000	1	0	6	2	2	100000	100000	100000	100000	100000	100000	100000	2	100000	1
28	Sandhill crane	2	100000	100000	1	0	1	2	2	100000	100000	100000	100000	100000	100000	100000	100000	1	100000
29	Moose	3	100000	100000	100000	0	8	2	2	100000	100000	100000	100000	100000	100000	100000	100000	2	1

30	Thinhorn sheep	3	100000	100000	1	0	1	2	2	100000	100000	100000	100000	100000	100000	100000	100000	100000	1
31	sharp-tailed grouse - columbianus	2	100000	100000	100000	0	2	2	2	100000	100000	100000	2	100000	100000	1	100000	2	100000
32	Townsend's big-eared bat	2	100000	100000	100000	0	2	1	2	100000	100000	100000	100000	100000	100000	100000	100000	2	100000

Note: The codes 1, 2, 3 and 10,000 are defined under the footnotes explaining each criterion: 10,000 replaces a 0 for calculation purposes.
1 red=1, blue=2, yellow=3
2 endangered=1, threatened=2, special concern=3, not at risk=10000
3 species of concern listed by that stakeholder =1, not listed=10,000
4 Distribution is represented by a number between 1 and 10, the higher the number the wider its distribution through the province.
5 represents number of KEF categories: high=3, med=2, low=1
6.dependant on pine=1, less dependant=2
7 highly dependant on component=1, lower dependence on component=2, component not needed=10,000
8 classified as requiring UWR or WHA=1, not classified as requiring UWR or WHA.
9 weight of each criterion.

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B.C. Conservation Data Centre. 2007f . Conservation Status Report: *Melanerpes lewis* . B.C. Ministry of Environment. Available: http://srmapps.gov.bc.ca/apps/eswp/ (accessed Dec 19, 2007).

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Chapter 3 - Species Accounts for Selected Species

Below we present a summary of general 'account' information for the selected species, extracted from published reports. The background literature search was not intended to be exhaustive for each species, although it was intended to be sufficient to determine the key habitat factors required by each species for the purposes of habitat supply modeling. A list of other references consulted is included in the Literature Cited for this chapter.

We present each species account under the following sub-headings:

- List of published species accounts available (with an emphasis on B.C.)
- Geographic distribution in B.C.
- General ecology and life history
- Range use
- Potential limiting factors and threats (if known for British Columbia)

Note that federal and provincial species status designations for listed species are defined in Appendix A.

Although these accounts are general, we do place a particular focus on the ecological relationships for each species that are pertinent to modeling the availability and use of habitat in response to MPB-induced mortality in forests (at the stand and landscape-scales) and management responses to that mortality.

Fisher

Scientific name:	*Martes pennanti* (Erxleben 1777)
Species code:	M-MAPE
BC status:	Blue-listed
COSEWIC status:	no status assessment available (March, 2008)

Published species accounts

BCMWLAP (British Columbia Ministry of Water, Land and Air Protection). 2004. Accounts and Measures for Managing Identified Wildlife. Version 2004. Biodiversity Branch, Identified Wildlife Management Strategy, Victoria, B.C.

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Weir, R.D. 2003. Status of fisher in British Columbia. Wildlife Bull. No. B-105, British Columbia Min. of Water, Land, and Air Protection, Victoria, BC 38pp.

Distribution

<u>Provincial range:</u> Fishers occur throughout BC but are only rarely found on the coast (BCMWLAP 2004). They are thought to occur mainly in Boreal Plains, Sub-Boreal Interior, Central Interior, and Taiga Plains ecoprovinces but may be found in some parts of the Coast and Mountains, Southern Interior Mountains, and Northern Boreal Mountains ecoprovinces. They have apparently disappeared from the Cascade

(Coast and Mountain ecoprovince), Okanogan Mountain ranges (Southern Interior ecoprovince), and Columbia and Rocky Mountain ranges (Southern Interior Mountain ecoprovince) south of Kinbasket reservoir (BCMWLAP 2004).

Elevation range: This species is generally found in low- to mid-elevations up to 2500m (BCMWLAP 2004). Powell and Zielinski (1994) found that most fisher occurrences were below 1000m. They are thought to be restricted to low elevations during times of heavy snow(Banci 1989).

Provincial context: In 2004, the provincial population was estimated to range from 1403 to 3715 individuals based on an extrapolated estimate from a study in the Williston region of BC (Harestad 2004).

General ecology and life history

Reproduction: Female fishers reach sexual maturity at ≤2 years of age and will produce 1 litter per year (BCMWLAP 2004). Fishers have delayed implantation with the fertilized egg laying dormant for approximately 10 months before implantation occurs. Parturition generally occurs between February and April (Douglas and Strickland 1987). Fishers give birth to 1 to 3 kits in natal dens and offspring may not disperse to establish new ranges until 2 years of age (BCMWLAP 2004).

Movements and home range: Fishers are usually solitary and will only interact during mating and territorial disputes. Disputes among fishers can prove fatal as they are very aggressive (BCMWLAP 2004). Fishers of the same sex rarely have overlapping home ranges while those of opposite sex usually overlap (BCMWLAP 2004). Females have home ranges that vary in size from 4 to 32 km^2 with an average of 15 km^2 and males from 19-79 km^2 with an average of 38 km^2. It is also thought that fisher have poor dispersal capabilities (BCMWLAP 2004, Kyle et al. 2001). However, individuals have been known to travel great distances around the landscape. Weir and Harestad (1997) found that translocated fishers covered more than 700 km^2 and topographic features such as major rivers were not barriers to movement. This contradiction between dispersal and movement distances may be due to a combination of factors such as disturbance, inter- and intra-species competition, mortality agents, or suitable habitat (BCMWLAP 2004).

Feeding habits: Fishers are generalists and eat anything they can catch and kill ranging from deer (mostly carrion), medium and small mammals, birds, fish and snakes. In some areas they may specialize on snowshoe hare (*Lepus americanus*) or porcupines (*Erethizon dorsatum*) (Powell 1993). They may also feed on vegetation (BCMWLAP 2004). The primary prey of fishers is associated with abundant understory and coarse woody debris (CWD) and therefore summer foraging is strongly associated with abundance and quality of CWD. Foraging during winter months occurs mostly above the snow layer and therefore snow conditions impact feeding and distribution (BCMWLAP 2004). Fishers are able to switch prey according to prey availability (BCMWLAP 2004).

Range use

Life requisites

General: Fishers use a variety of forest structural stages but favor mature and older forest with old-forest elements such as CWD and large wildlife trees. Other forest attributes that characterize fisher range is a productive understory and canopy closure of 30% or more. In BC, these forest attributes are often found in riparian and dense wetland areas in the SBS, SWB, and BWBS biogeoclimatic zones. Connectivity among areas of habitable range is also important to the fisher (BCMWLAP 2004) and is therefore a landscape feature that is likely to influence occurrence and distribution of the species (BCMWLAP 2004).

Forage: Fishers forage in a variety of forest structural stages. They also forage in non-forested and tall shrub areas in the summer if enough security cover is available (BCMWLAP 2004). For efficient foraging, the fisher requires the combination of adequate prey and high quality security cover. "Adequate" prey is determined by both the amount of prey and its vulnerability (Buskirk and Powell 1994). The prey's vulnerability is influenced by the amount of escape cover such as snow cover and the complexity of vegetative structure (Buskirk and Powell 1994). In Powell (1993), he discusses foraging by fisher in two hierarchical activities: locating patches of habitat with prey and searching for prey items within these patches. Fishers are believed to know and seek out the locations within their home range that provide sufficient amounts of different types of prey (Powell 1994a); for example fishers will hunt specifically for snowshoe hare in dense lowland conifers and porcupine in open upland habitat (Powell 1994b). Fisher will use different strategies to hunt for the different types of prey.

<u>Cover from thermal extremes:</u> The type of thermal cover sought by the fisher is determined by the ambient temperature (Weir et al. 2003). Taylor and Buskirk (1994) studied the thermal qualities of the different type of rest sites used by fisher: branch, cavity and CWD sites. In winter, CWD sites offered the warmest microenvironments when temperatures were less than -5°C, and snowpacks were >15cm deep. Weir et al. (2003) found that fishers in BC used subnivean CWD sites exclusively when temperatures were <-15oC. The use of branch and cavity structures are most likely used through most of the rest of the year as they provide adequate thermal cover for most other temperatures and wind speeds (BCMWLAP 2004).

<u>Natal sites:</u> Fishers seem to need specific structural attributes in which to raise their young (BCMWLAP 2004). Cavities in deciduous trees are most often used for natal and maternal dens (Powell 1993); it is believed these types of den are more easily defended and also provide sufficient thermal cover (Leonard 1980). In BC, maternal and natal dens were located an average of 15m above the ground in large diameter (average=105.4cm in diameter) deciduous trees such as black cottonwood or balsam poplar (*Populus balsamifera balsamifera*) (BCMWLAP 2004). It is thought that in order for the cottonwood to be of sufficient size for the fisher to den, the bole diameter must be > 54cm at >5m above the ground (BCMWLAP 2004).

<u>Security:</u> Security habitat, for resting and seeking refuge from predators is most often associated with mature or old forest (BCMWLAP 2004). The availability of suitable dens and resting sites is one of the factors that determine the quality of range for fisher (BCMWLAP 2004). Weir et al. (2003) found that fisher used 4 different types of rest sites: CWD, cavities (in trees or in the ground), and tree branches. Branch sites usually involved abnormal growths but sometimes consisted of large limbs of black cottonwood (*Populus balsamifera trichocarpa*) or spruce (*Picea* spp.) trees. Tree cavities were usually located in the decayed heartwood of black cottonwood, aspen (*Populus tremuloides*), or Douglas fir (*Pseudotsuga menziesii*) trees. Ground cavities consisted of loose, large diameter, rock piles or pre-excavated burrows. The most commonly used rest site was tree branches followed by tree cavities, and CWD (Weir et al. 2003).

Interaction with agents of disturbance/competition

<u>Disturbance:</u> no specific information available for large-scale disturbances such as MPB.

<u>Competitors:</u> Fisher and marten can compete for similar food resources such as voles and mice. Other potential competitors for food are the coyote, lynx, wolverine and weasels (Weir 2003). It is thought that fisher can out-compete marten in areas of low snowfall, but marten may outcompete fisher in areas with greater snowfall such as the Engelmann Spruce-Subalpine Fir biogeoclimatic zone (Weir 2003).

Mortality factors

The fisher has few natural predators most likely because they are agile and fast. Although fisher have many internal and external parasites, these are unlikely to be a significant source of mortality (Weir 2003). However, human-caused mortality is thought to have the potential to negatively influence fisher populations and is the major source of mortality (Weir 2003).

Potential limiting factors and threats

Fisher populations are considered inherently unstable and therefore their ability to recolonize areas within which they have become locally extinct is important for population persistence (Powell 1993, Powell 1994b). Fragmentation of their range with barriers or large area of unsuitable characteristics, therefore, may have detrimental effects on their ability to successfully disperse among disconnected ranges. Habitat alteration from forestry, hydroelectric development and other land clearing activities has detrimentally altered the fisher's range and has likely had a considerable effect on their populations. Fishers were known to use late-successional riparian areas subsequently flooded during hydro-electric developments such as that in the Williston area (BCMWLAP 2004). As well, land clearing for agriculture and development in areas such as that in the Nechako, Bulkley and Fraser River valleys has had a detrimental effect on fisher populations in these areas by removing the structural attributes necessary for their survival (BCMWLAP 2004). Forest harvesting and widespread mortality of forests resulting from the mountain pine beetle (MPB) epidemic has probably had the most effect on fisher populations in BC. Loss of canopy in MPB-killed forests is detrimental and the associated salvage of timber in these areas is likely to contribute to the decrease in available habitat both short and long term (BCMWLAP 2004).

Increased human access to fisher range via roads and trail systems can also affect their populations by increasing risk of mortality from hunting and trapping. Trapping is known to increase mortality rates and therefore impact reproductive potential through reduced chance of finding mates (BCMWLAP 2004).

Grizzly Bear

Scientific name:	*Ursus arctos* (Linnaeus 1758)
Species code:	M-URAR
BC status:	Blue-listed
COSEWIC status:	SC (May 2002)

Published species accounts

BCMWLAP (British Columbia Ministry of Water, Land and Air Protection). 2004. Accounts and Measures for Managing Identified Wildlife. Version 2004. Biodiversity Branch, Identified Wildlife Management Strategy, Victoria, B.C.

Cannings, S.G., L.R. Ramsay, D.F. Fraser, and M.A. Fraker. 1999. Rare amphibians, reptiles, and mammals of British Columbia. Wildlife Branch and Resour. Inv. Branch, B.C. Ministry of Environment, Lands and Parks, Victoria, BC. 198pp.

Conservation Data Centre. 2008d. Species Summary: *Ursus arctos*. B.C. Ministry of Environment. Available: http://srmapps.gov.bc.ca/apps/eswp/

British Columbia Ministry of Environment, Ecosystems Branch. Species Account for Grizzly Bear. URL: http://www.env.gov.bc.ca/wildlife/whr/provincialex.html (cited asBC MoE SA-GB in text below).

Distribution

Provincial range: BGC available (CDC 2008d). Grizzly bears are found throughout BC except on Vancouver Island (although animals have been sited occasionally) and the Queen Charlotte Islands, and are extirpated from some areas of south and south-central BC (BCMWLAP 2004). Grizzly bears are found in all ecoprovinces in BC except the Northeast Pacific (Cannings et al. 1999).

Elevation range: Grizzly bears are found at all elevations from sea-level to alpine.

Provincial context: The population of grizzlies in the province was estimated at 16,887 bears in 2004 (Hamilton et al. 2004). BC's population accounts for roughly half the number of grizzlies found in all of

Canada (BC MoE SA-GB). For the most part, the population is considered stable, although there is thought to be some areas of local decline. It is felt that they are threatened in 8% of their BC range and extirpated from roughly 10% of their BC range (BCMWLAP 2004).

General ecology and life history

Reproduction: In south-eastern BC grizzly bears were found to begin breeding when they were approximately 6 years old and produced young approximately every 2.7 years (McLellan 1989). Like fisher, grizzly bears have delayed implantation so breeding occurs between April and June but the cubs are born during hibernation between January and March (BC MoE SA-GB); the average litter size was reported by (McLellan 1989) to be 2.3. The young tend to stay with the mother for at least 2 years (BCMWLAP 2004).

Movements and home range: Grizzly bears are generally solitary with the exception of females with cubs, sibling groups or during mating. They have large annual and seasonal home ranges; one study in the Flathead Valley averaged 446 km^2 for males and 200 km^2 for females (McLellan 1981). Mother and daughters often overlap and males will tend to overlap with several females (Bunnell and McCann 1993). The size of the home range is in proportion to food quantity, quality and distribution (BCMWLAP 2004). For example, the home range of a grizzly on the coast that includes salmon streams was smaller (male avg min=137 km^2; females=52 km^2) then drier interior mountains and plateaus (male avg min=804 km^2; female=222 km^2) (Ciarniello et al. 2001; McLellan 1981; Russell et al. 1979; Wielgus 1986). Grizzlies display strong site fidelity and will return to the same sites throughout their lives (BCMWLAP 2004).

Feeding habits: Grizzly bears are omnivores and are opportunistic foragers (BCMWLAP 2004). They tend to have flexible eating habits and usually use the same seasonal areas and food sources throughout their lives (BCMWLAP 2004). The Grizzly makes use of the most digestible food in the various seasons such as early spring vegetation, ungulates in early spring and often salmon in the fall (BCMWLAP 2004). The greatest regional difference in feeding pattern happens between the coastal and interior bears. On the coast (Hamilton 1987; MacHutchon et al. 1993), bears begin the year feeding on young vegetation (i.e., skunk cabbage (*Lysichiton americanus*) and sedges) in estuaries and wetland sites and as the snows melts, work their way up avalanche chutes feeding on the emerging vegetation. Having completed this seasonal migration in pursuit of fresh vegetation, bears then return back down onto the lower slopes and floodplains. Here, they feed on berries, shifting to salmon as they become available. Throughout the seasons they are also opportunistic, feeding on other sources available such as insects, grubs and mollusc in the intertidal. In the interior (Ciarniello et al. 2001; McLellan and Hovey 1995), the bears begin the year feeding on roots (i.e., *Hedysarum* spp., spring beauty (*Claytonia lacneolata*), avalanche lily (*Erythronium grandiflorum*)), carrion and ungulates weakened by the winter. They then feed on the emerging green vegetation such as grasses and sedges as well as calving ungulates and continue to feed on emerging vegetation (i.e., cow parsnip [*Heracleum* spp.]), fruit and small mammals throughout the summer. Berries at high elevations are the most important fall food for the interior bears although, like the coast, remain opportunistic throughout the year feeding on such things as fish, insects and roots as they are available.

Range use

Life Requisites

General: Grizzly bear habitat is closely associated with the seasons. As the food requisites change so does the habitat. Specific seasonal habitat attributes are listed in BCMoE SA-GB.

Forage: Feeding habitat changes as the diet changes throughout the seasons. In spring, vegetation is found in forest openings (i.e., meadows, wetlands and seepages) riparian areas, south and west facing vegetated avalanche chutes, alpine meadows, cutblocks and floodplains (BCMoE SA-GB). Grizzlies usually stalk winter-weakened ungulates in ungulate winter ranges. During the summer north aspect wet areas that provide the favoured vegetation and berries at low and high elevations are used. Berry production is most abundant at high elevations and at lower elevations in natural openings and forests with canopy closures of 20-50% as well as openings created by disturbances such as fire and 10-20 year-old clearcuts (BCMoE SA-GB). In the fall, depending on the region, either salmon spawning streams or areas of high berry production become important. Coarse woody debris as a source of insects and larvae are important throughout the year (BCMoE SA-GB).

Cover from thermal extremes: To escape the heat of summer, bears will seek out shade under rock overhangs, in shrub areas or in forested areas with CWD. They will also use water such as ponds, streams and wetlands to cool down (BCMoE SA-GB). In the winter, bear dens are located in areas where the hillside and snow can provide insulation (BCMoE SA-GB).

Denning: Habitat used for hibernating tends to be on slopes that are dry and stable and remain frozen throughout the winter (Bunnell and McCann 1993). They usually den from mid-October to May, however, adult males tend to be active longer and emerge earlier than females (Wielgus 1986). Dens can occur on any aspect but are usually in alpine and sub-alpine habitat where the snow and hillside provide insulation. Habitat characteristics needed for dens include, stumps, large trees, steep slopes or cutbanks and well drained substrate (BCMoE SA-GB). Vroom et al. (1977) found the mean slope of dug out dens in the Banff area was 33^{o}.

Security: Security habitat for grizzlies is needed to avoid both intra- and inter-specific (primarily with humans) contact (BCMoE SA-GB). To avoid other bears, grizzlies require forested habitat for security that is adjacent to early successional habitat for foraging (Jonkel 1987). To avoid aggressive males, females with cubs will use isolated rugged habitat and forest with diverse understory that is older than pole-sapling (Pearson 1975). To avoid humans, grizzlies require an adequate amount of high quality forest cover next to roads or these areas will be avoided (McLellan and Shackleton 1988).

Interaction with agents of disturbance/competition

Disturbance factors: The increase in backcountry recreation has raised concerns because grizzly bears are vulnerable to disturbance at their den sites (Podruzny et al 2002). This disturbance may lead to elevated energy use as a result of increased movement in the den, abandonment of the den, potential loss of cubs and displacement from the den (Podruzny et al 2002).

Competitors: For part of its diet the grizzly bear competes for food with other carnivores such as wolves, black bears, and cougars.

Mortality factors

Human caused deaths are the major source of mortality for grizzly bear (Cannings et al. 1999). McLellan et al. (2000) when looking at data of 388 grizzly bears from studies in the Rocky and Columbia mountains of Alberta, BC, Montana, Idaho and Washington found that 77-85% were killed by people. Where hunting was allowed, legal harvest accounted for 39-44% of deaths. They found that males had higher mortality due to hunting than females but females had higher mortality rates from natural causes. Natural mortality however, seems to be relatively minor; there appears to be no known diseases or parasites that would impact natural populations (BCMWLAP 2004). Within the first 4 weeks of life, malnutrition appears to play a role in cub mortality indicating that the pregnant females nutritional state entering the den is important (BCMWLAP 2004). As well, predation or cannibalism appears to play a role in population regulation but the extent is not known (BCMWLAP 2004).

Potential limiting factors and threats

Inter/intra specific competition, predation, and hunting can all influence grizzly populations and distribution. Grizzly distribution is especially influenced by intra-specific interactions and human disturbance (BCMoE SA-GB). Human disturbance may come in many forms, from urban and industrial development to recreation and hunting. The major limiting factor of the current population of grizzlies is thought to be human related; especially habitat loss, alienation and fragmentation (McLellan et al. 2000, Kansas 2002). Human related mortality also comes in the form of hunting, poaching, control kills (required because of too close human-bear contact i.e., poor garbage management, threatened livestock etc.) (BCMWLAP 2004). Increased road access leads to both, direct mortality from accidents, hunting and poaching as well as habitat alienation (McLellan 1990). Roads also increase human activity such as recreation which can also lead to displacement. Direct human related mortality of adult females can be a significant threat if they occur in localized populations that experience low immigration rates (BCMWLAP 2004). Isolation can also play a significant role in threatening grizzly populations; if populations in these isolated areas are low, restricted immigration can lead to a poor chance of recovery as well as potential inbreeding (BCMWLAP 2004).

Caribou

Scientific name:	*Rangifer tarandus* (Linnaeus 1758)
Species code:	M-RATA
BC status:	Red/Blue: Some local populations of northern woodland caribou in the Southern Mountain Ecological area are designated as Red-listed, while some northern populations of northern caribou are designated as Blue-listed (CDC 2008k).
COSEWIC status:	T/SC: Northern caribou in the Southern Mountains National Ecological Area are designated as Threatened and northern caribou in the Northern Mountains Ecological Area is designated as Special Concern (CDC 2008k).

Published species accounts

British Columbia Ministry of Water, Land and Air Protection. 2004. Accounts and Measures for Managing Identified Wildlife. Version 2004. Biodiversity Branch, Identified Wildlife Management Strategy, Victoria, B.C.

Conservation Data Centre. 2008. Conservation Status Report: *Rangifer tarandus* pop. 15. B.C. Ministry of Environment. Available: http://srmapps.gov.bc.ca/apps/eswp/

COSEWIC. 2002q. COSEWIC assessment and update status report on the woodland caribou *Rangifer tarandus caribou* in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa. xi + 98 pp.

Paquet, M. 2000. Caribou in British Columbia. Ecology, Conservation and Management. B.C. Ministry of Environment, Lands and Parks, Wildlife Branch. 6 pp.

Thomas, D.C., and D.R. Gray. 2002. Update COSEWIC status report on the woodland caribou *Rangifer tarandus caribou* in Canada. Committee on the Status of Endangered Wildlife in Canada, Ottawa. 1-98 pp.

Distribution

Provincial range: The northern woodland caribou occur in the western and northern mountainous parts of BC where snowfall is relatively low. In west central BC they are located in and around the Itcha, Ilgachuz, Rainbow, and Trumpeter mountains, northern Tweedsmuir Provincial Park, Entiako Provincial Park and Protected Area, Telkwa Mountains as well as the northern part of Takla Lake. In the northern part of the province they can be found from the Williston Lake area north to the Yukon border, as well as northwest to Atlin, and southeast along the east side of the Rockies to the Alberta border near Kakwa Provincial Park (CDC 2008k). The northern ecotype is found in the following ecoprovinces: Boreal Plains, Central Interior, Coast and Mountains, Northern Boreal Mountains, Sub Boreal Interior, Southern Interior Mountains, and Taiga Plains (BCMWLAP 2004).

Elevation range: Northern caribou use a variety of elevations depending on season and local population. In winter, they are found in subalpine forest or above the treeline on windswept alpine slopes from 1500m to over 2000m or in forested habitat at lower elevations; 500 to 1500m depending on local population. In the summer they may be found anywhere from 500m in coastal areas to 2500m in mountainous areas (BCMWLAP 2004).

Provincial context: The population of northern caribou is estimated at 16,235; 5,235 in the Southern Mountains National Ecological Area and 11,000 in the Northern Mountains Ecological Area (CDC 2008k).

General ecology and life history

Reproduction: The rutt for this polygynous ungulate occurs from late September to mid October. Rutting groups may number 20 or more with a dominant male mating with several cows (BCMWLAP 2004). During calving, this species exhibits a number of anti-predator strategies, including calving alone in isolated rugged locations or on islands in low elevation lakes in forested habitat (BCMWLAP 2004). Caribou have relatively low productivity compared to other ungulates. Adult females generally have only have one calf per year and most yearlings do not become pregnant (BCMWLAP 2004). Gestation is approximately 230 days. When calves are first born they make up approximately 27 to 30% of the population but within a year they only represent less than 20% of the population (BCMWLAP 2004).

Movements and home range: Home range sizes for northern caribou are highly variable depending on the local population and horizontal distances moved between summer and winter ranges. In north and north-central BC the home range size may be as large as 1100-1900 km^2 or as small as 150 km^2 (Hatler 1986, Terry and Wood 1999, Poole et al. 2000). There are also variable seasonal movements and habitat use by this ecotype. Some populations migrate long distances between summer and winter range. The relative use of high elevation versus low elevation winter range may vary not only between populations but also within populations between winters. These variations reflect differences in the topography, snow accumulation and availability of habitat at low elevations that occurs between areas and populations (BCMWLAP 2004). Similar to mountain caribou, the northern caribou can be described as having 4 seasonal time periods: (1) late fall (e.g., November) movements from high elevation summer ranges to early winter habitat at lower elevations triggered by snowfall; (2) mid to late winter movements into low elevation forested habitat or high elevation alpine/subalpine winter ranges providing abundant terrestrial lichens (BCMWLAP 2004); (3) in late April, those caribou that choose to migrate begin moving back to calving and summer ranges along relatively snow-free low elevation routes (Cichowski 1993, Johnson et al. 2002); and (4) those that winter at high elevations move to lower elevations to take advantage of spring green-up (BCMWLAP 2004).

Feeding habits: The primary forage of northern caribou is terrestrial lichens; in the winter their preferred forage is *Cladina* but they will also feed on genera such as *Cladonia*, *Cetraria*, and *Stereocaulon* (BCMWLAP 2004). They may also feed on some arboreal lichens in winter, especially when conditions make access to terrestrial lichens difficult (BCMWLAP 2004). In the spring, they also feed on forbs and graminoids. Summer diets consist of a variety of forbs, graminoids, lichens, fungi and leaves of some shrubs (BCMWLAP 2004).

Range use

Life Requisites

Breeding: Both calving sites and rut locations are important and vulnerable habitat elements. Each are difficult to classify as a specific habitat type. Calving sites can vary between years and do not appear to be chosen according to habitat type but rather by the extent of isolation from other caribou, ungulates and predators. Rutting locations, although more predictable from year to year, can only be located by having knowledge of specific local populations (BCMWLAP 2004). The most critical component of northern caribou range is access to high undisturbed calving range (BCMWLAP 2004).

<u>Forage and security:</u> Foraging and security habitat for northern caribou often are in the same locations, and commonly consist of older forest in large contiguous patches. These large old growth areas generally have fewer alternate prey species (Bergerud 1992). These forests also provide better visibility for predator avoidance as well as being a good source of terrestrial lichens such as *Cladina*, *Cladonia*, and *Cetraria*. The large crowns of the older trees provides good snow interception and the contiguous nature of these larger patches decreases the energy needed by caribou to move between foraging sites (BCMWLAP 2004). Old stands of lodgepole pine (*Pinus contorta*) or lodgepole pine and white spruce (*Picea glauca*) at low elevations are widely used. Alpine habitats are also used by northern caribou in both summer and winter. Such alpine areas provide forage as well as open vistas that allow detection of predators (BCMWLAP 2004).

<u>Mineral licks:</u> Mineral licks are also considered a vulnerable habitat element. These licks are used consistently year to year and can only be located by having knowledge of local populations (BCMWLAP 2004).

Interaction with agents of disturbance/competition

<u>Disturbance factors:</u> Caribou are most sensitive to disturbance during calving and the rut (Webster 1997). Caribou are known to be affected by disturbance factors such as petroleum exploration activities and may become displaced as a consequence (Bradshaw et al. 1997). Snowmobile activity in traditional winter ranges causes increased stress on the caribou and invokes avoidance behaviours. Hard packed snowmobile trails also provide predators with easy access to caribou wintering areas (Webster 1997). The significance of disturbance to caribou by aircraft is uncertain; however, caribou have shown increased sensitivity to aircraft during the rut (Calef et al. 1976, Webster 1997). All terrain vehicle (ATV) use also has the potential to disturb caribou. In particular, ATVuse in the alpine during calving may displace the caribou into less preferred habitat (Webster 1997) where they may be at increased risk of mortality. Human presence and road traffic also has the potential to increase stress levels (Webster 1997).

<u>Competitors:</u> Elk, deer and moose may compete with caribou for some forage. However, the main threat these other ungulates pose to caribou is by being significant prey for predators (BCMWLAP 2004), thereby increasing the mortality risk to caribou.

Mortality factors

Predation is often the leading cause of mortality. In a recent study on woodland caribou, Wittmer et al. 2005 states that the major proximate cause of population decline appears to be predation on adult caribou. In the northern subpopulations wolves and bears were the predominant predators and in the southern subpopulations, bear, wolverine and cougar were predominant. Recent studies are indicating that an increase in populations of alternative prey is leading to increased predator pressure on the caribou (Wittmer et al. 2005). In multiple predator/prey systems caribou tend to be the most vulnerable species (BCMWLAP 2004). This increase in alternative prey may have been influenced by habitat alterations that have led to more early seral habitats preferred by other ungulate species (Kinley and Apps 2000). Other causes of mortality in caribou are hunting, poaching accident and malnutrition (BCMWLAP 2004, Wittmer et al. 2005).

Potential limiting factors and threats

The CDC (2008k) lists the major threats to northern caribou as: predation, access, industrial development, and natural disturbances. Predation is thought to be the greatest threat (CDC 2008k); it is suggested that in areas where wolf populations are sustained by alternate prey species, caribou populations can be eliminated (Seip 1992). Increased access leads to disturbance from such things as recreation, hunting and poaching as well as increasing predator efficiency (CDC 2008k). Industrial development can threaten winter food supply as well as lead to an increase in early seral stages which supports alternate prey; it will also increase habitat fragmentation and access (CDC 2008k). Natural disturbances such as fire and the current mountain pine beetle epidemic may also threaten northern caribou herds. Williston and Cichowski (2004) note that the mountain pine beetle outbreak may greatly affect terrestrial lichen abundance upon which these caribou depend for forage.

Wolverine

Scientific name: *Gulo gulo luscus* (Linnaeus 1758)
Species code: M-GUGU-LU
BC status: Blue-listed
COSEWIC status: SC (May 2003)

Published species accounts

BCMWLAP (British Columbia Ministry of Water, Land and Air Protection). 2004. Accounts and Measures for Managing Identified Wildlife. Version 2004. Biodiversity Branch, Identified Wildlife Management Strategy, Victoria, B.C.

Cannings, S.G., L.R. Ramsay, D.F. Fraser, and M.A. Fraker. 1999. Rare amphibians, reptiles, and mammals of British Columbia. Wildlife Branch and Resource Inventory Branch, B.C. Ministry of Environment, Lands and Parks, Victoria, BC. 198 pp.

Conservation Data Centre. 2008. Species Summary: *Gulo gulo luscus*. B.C. Ministry of Environment. Available: http://srmapps.gov.bc.ca/apps/eswp/

Distribution

<u>Provincial range:</u> Historically, wolverines were found throughout BC at low densities except on the Queen Charlotte Islands. They may now be extirpated on Vancouver Island, the lower Fraser Valley, Okanogan Basin and the Thompson River (BCMWLAP 2004). Wolverines could be found in all ecoprovinces except Northeast Pacific (Cannings et al. 1999).

<u>Elevation range:</u> Wolverine may be found from the valley bottoms up into the alpine. The upper limit is most likely determined by prey distribution (BCMWLAP 2004). Adult females are found at higher elevations then other sex and age-classes; this is followed by sub adult females and adult males with subadult males typically found at the lowest elevations (Lofroth 2001; BCMWLAP 2004).

<u>Provincial context:</u> In BC the present population estimate for wolverines is 3,530 (Lofroth and Krebs 2007). Predicted mean densities varied with habitat quality but ranged from 0.3/1000 km^2 to 6.2/1000 km^2 (Lofroth and Krebs 2007). The highest densities were predicted to be in the Interior Mountains of BC and moderate densities in the Interior plateau and boreal forest with low densities predicted on the mainland coast and drier interior plateaus. Wolverines are thought to be rare on Vancouver Island, outer mainland coast and dry interior forest. Besides the Queen Charlotte Islands, wolverine are not found on interior grasslands or in areas of high urban development (Lofroth and Krebs 2007).

General ecology and life history

<u>Reproduction:</u> Wolverines exhibit delayed implantation. Breeding occurs between April and September but implantation occurs in January. One to five cubs are born between late February and mid-April and will stay with the mother for the first winter, dispersing in the spring (BCMWLAP 2004). Reproduction is found to be closely associated with food abundance (Lofroth et al. 2007).

Movements and home range: Home ranges of males are often 3 times as large as females; for example in the Omineca males home range was 1366 km^2 and females was 405 km^2 and in the Columbia Mountains males was 1005 km^2 and females was 311 km^2 (Krebs and Lewis 2000). Home ranges are kept between years but males will overlap home ranges with females and males, but females do not overlap with other females (Krebs and Lewis 2000). Wolverines will display slightly nomadic behaviour when they first disperse away from their mothers; males will disperse between 30-100 km and females a shorter distance (BCMWLAP 2004). Daily movements by wolverine are most likely influenced by the distribution and availability of food. In highly modified landscapes, human activity can lead to displacement and alterations to the movement paths of wolverines (BCMWLAP 2004).

Feeding habits: Wolverine feed on a variety of food depending on the season and its location in BC (Lofroth et al. 2007). Moose (*Alces alces*), caribou and hoary marmots (*Marmota caligata*) are common prey, however, in the Columbia mountains the most common and abundant prey are mountain goats (*Oreamnos americanus*) and porcupine (*Erithizon dorsatum*) (Lofroth et al. 2007). In the Omineca mountains, the most common and abundant prey are the snowshoe hare (*Lepus americanus*) and the beaver (*Castor canadensis*) (Lofroth et al. 2007). In the winter, the prey of reproductive females was most often caribou, hoary marmots and porcupines – a different selection than made by other sex and age classes (Lofroth et al. 2007).

Range use

Life Requisites

General: The predominant structural stage used by the wolverine is mature and old forest. However, due to the varied diet of wolverines, a wide variety of structural stage may be used in their day to day movements (BCMWLAP 2004), although Lofroth (2001) found that there is relatively little use of mid-successional forest and late successional forest is used at least 50% of the time. Lofroth (2001) also reports that use of different structural stages varies with sex and season; females use early and late successional forest and males are generally found most often in late successional forest. Females use early successional structural stages usually at high elevations while rearing their young. Wolverines also frequent alpine habitat (BCMWLAP 2004). Wolverines seem to prefer traveling by following riparian corridors and using low elevation passes between valleys (BCMWLAP 2004). Wolverines will avoid clearcuts and watersheds with extensive clearcuts (<25 years old) (BCMWLAP 2004).

Habitat associations for male wolverines are strongly associated with food (Krebs et al. 2007). In winter, Krebs et al. (2007) found that there were positive associations between male wolverines and moose winter range, valley bottom forests and avalanche terrain. They also found a negative association between helicopter skiing areas and male and female wolverine habitat use. Habitat use by female wolverines was also found to be negatively associated with other winter recreation such as backcountry skiing. Winter habitat use by female wolverines was positively associated with moose winter range in rugged landscapes (Krebs et al. 2007).

Forage: In a study by Krebs et al. (2007) male habitat use was positively associated with food in both summer and winter in the Omineca and Columbia mountains. Female habitat use is more complex; however, there seems to be a shift from high sub alpine and alpine in the summer to low-elevation forests in the winter. Both male and female wolverines use avalanche paths consistently in both summer and winter. Avalanche kill of large mammals such as moose and mountain goat likely provide abundant prey for wolverines in winter and in the summer and late winter, hoary marmots provide key prey especially for reproductive females (Krebs et al. 2007).

Security: Wolverines tend to use habitat at a landscape scale. The main stand level features that wolverine seem to use are natal and maternal dens (BCMWLAP 2004). Placement of these dens in the landscape is important in order to provide security cover for the kits and proximity to food. Dens are usually associated with high elevation (i.e. ESSF/ESSFp) forest openings that are less than 100 m across and are often composed of snow tunnels that lead to piles of CWD or to rocky colluviums (Krebs and Lewis 2000; Lofroth 2001).

Interaction with agents of disturbance/competition

Disturbance factors: Wolverines are considered sensitive to disturbance from roads and recreational activities such as snowmobiles, backcountry skiers and helicopter skiers (BCMWLAP 2004).

Competitors: Wolverines compete with other predators for food although they also rely on these same predators to provide them with carrion[2].

Mortality factors

Although parasites are present in wolverines, their populations are not known to be affected by chronic disease or parasite disorders[1]. The greatest source of mortality to wolverine is thought to be trapping and hunting. The greatest source of natural mortality is predation by wolves and starvation[1].

Potential limiting factors and threats

The key demographic characteristics of wolverines mentioned above (low densities, large home ranges and have relatively low reproductive rates) suggest this species has a low resiliency to population perturbation (Banci and Proulx 1999). Human related activity such as roads and recreation has a negative association with wolverine habitat use and distribution (Krebs et al. 2007). Krebs et al. (2007) found that female wolverines were positively associated with roadless areas and negatively associated with logged areas in summer. From their study, they conclude that both male and female wolverines respond negatively to human activity in their home range. It is thought that habitat loss, over-harvest, and the presence of major transportation corridors and other human related disturbance factors decrease dispersal success between metapopulations (Kyle and Strobeck 2001). Habitat loss and alienation such as large scale conversion of mature and old growth to early structural stages and logging of high elevation forests are thought to be major contributing factors to population declines and may also influence rearing success (BCMWLAP 2004).

Harvest of wolverines can also contribute to population decline (BCMWLAP 2004). Overharvest in the past contributed to the decline of wolverine across North America (BCMWLAP 2004). Human alterations that have contributed to a changing prey base are also a potential contributor to population decrease over the past 100 years. BCMWLAP (2004) states that the additive mortality from trapping is thought to be the primary population threat and that increased access due to forest development increases this threat.

Spruce Grouse

Scientific name: *Falcipennis canadensis* (Linnaeus 1758)
Species code: B-SPGR
BC status: Yellow-listed
COSEWIC status: no status assessment available (March, 2008)

Published species accounts

Conservation Data Centre. 2008. Species Summary: *Falcipennis canadensis*. B.C. Ministry of Environment. Available: http://srmapps.gov.bc.ca/apps/eswp/ (accessed Jan 16, 2008).

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[2] http://www.elp.gov.bc.ca/fw/docs/wolverine.pdf

Distribution

Provincial Range: Spruce grouse are found throughout BC in all ecoprovinces except for some coastal regions[3] (parts of Coast and Mountain ecoprovince and the Georgia Depression) and Northeast Pacific ecoprovince.

Elevation range: Spruce grouse can be found from sea level to greater than 3600m[1].

Provincial context: Populations usually occur at low densities (CDC 2008f). Boag et al. (1979) found that populations in southwestern Alberta ranged from 5 to 30 birds per km^2. Populations in other areas fluctuated between 1 and 11 birds per km^2 (CDC 2008f). Keppie (in CDC 2008f) reported up to 50 birds per km^2 in eastern Canada. No population densities were found for BC.

Published species accounts

Conservation Data Centre. 2008. Species Summary: *Falcipennis canadensis*. B.C. Ministry of Environment. Available: http://srmapps.gov.bc.ca/apps/eswp/ (accessed Jan 16, 2008).

General ecology and life history

Reproduction: Spruce grouse are polygynous. They generally lay their eggs in May but it is thought that this date is related to green-up and <50% snow cover (CDC 2008f). It may take 10-12 days for a female to lay a clutch of 5 or 6 eggs. Subsequent incubation lasts for approximately 21 to 24 days (CDC 2008f). Clutch sizes are variable across the range of this species. Spruce grouse nest on the ground in a depression lined with conifer needles and feathers with overhead cover[4]. Females generally begin breeding as yearlings. Males generally breed later, with many not breeding until they are adults at 3 years old (CDC 2008f).

Movements and home range: Spruce grouse are generally solitary. However, small loose flocks may sometimes form during winter and females with broods may form loose flocks during the late summer[3]. Breeding territories are aggressively maintained and some birds will maintain territories all year round[3]. Males will often have the same territory for life and females are territorial during breeding and nesting (CDC 2008f). Home range size varied: 6 to 155 ha for nesting females; 3 to 20 ha for moulting males; 6 to 160 ha in the fall and 3 to 113 ha in the winter for either sex (CDC 2008f). A 21 year long study in Alberta indicated that densities may vary between 5 to 30 birds per km^2 (CDC 2008f). Generally migrations of 0 to 11 km occur between breeding and winter territories with females migrating greater distances and more frequently than males[3]. In Alberta, overall survival rates averaged 68% and that female survival was lower than male survival (CDC 2008f).

Feeding habits: In the summer spruce grouse have a varied diet of berries, ground vegetation and insects; however, in the winter they feed exclusively on short-needled conifer needles. Spruce and pine are generally favoured (CDC 2008f). One study in Washington found that spruce grouse preferred lodgepole pine and could not survive on a diet exclusively of Engelmann spruce (Holf et al. 1987). A study in Michigan found that grouse chose specific jack pines for feeding that provided higher crude protein, lower crude fat and higher ash content than trees that were not selected (Gurchinoff and Robinson 1972).

Range use

Life Requisites

General: Spruce grouse are residents of taiga and conifer forests. They are often found in early successional stands of 7-14m high lodgepole pine (*Pinus contorta*) and jack pine (*Pinus banksiana*) that have

[3] http://www.gct.org.uk/gsg/grousesp/SPRUCE.HTM

a well developed intermediate layer[4]. Historically, they are associated with a fire generated patchwork of forest in various stages of regeneration[5]. The species composition in forests used by this species varies across its range but some features are the same throughout. These features are: an understory of berries such as *Vaccinium* spp and good cover in the form of either low branches (0-4m from the ground) or high tree density that provides sufficient escape cover. When grouse occupy lodgepole pine or jack pine forests, these trees must be successional and less than 12m in height so as not to be at the stage they self prune. If the occupied forest is older pine subdominant spruce must be present (CDC 2008f). In the winter this grouse is mainly arboreal. In the summer they will feed and nest on the ground and as well as forage in the trees (CDC 2008f).

<u>Security:</u> Spruce grouse will often remain quietly in their food tree all day (Cannings 2005). Nest sites are usually well concealed either under low branches, bush or other vegetation (CDC 2008f).

Interaction with agents of disturbance/competition

<u>Disturbance factors:</u> no specific information available for large-scale disturbances such as MPB.

<u>Competitors:</u> no specific information available for competitors in BC.

Mortality factors

Predation is thought to be the primary source of mortality in spruce grouse (Boag and Schroeder 1992). Spruce grouse are preyed upon by a number of predators including raptors, foxes, coyotes, weasels as well as red squirrel (clutch predator). Spruce grouse are vulnerable to hunters as they are not wary of humans (NatureServe 2007).

Potential limiting factors and threats

The leading threat to the spruce grouse is loss, degradation, and fragmentation of habitat by forest practices and fire suppression in pine dominated habitat (NatureServe 2007). This grouse may undergo declines as available habitat matures, is logged or is otherwise removed (i.e. pine beetle kill) (NatureServe 2007).

Sharp-tailed Grouse

Scientific name:	*Tympanuchus phasianellus columbianus*
Species code:	B-STGR-CO
BC status:	Blue-listed
COSEWIC status:	no status assessment available (March, 2008)

Published species accounts

BCMWLAP (British Columbia Ministry of Water, Land and Air Protection). 2004. Accounts and Measures for Managing Identified Wildlife. Version 2004. Biodiversity Branch, Identified Wildlife Management Strategy, Victoria, B.C.

Conservation Data Centre. 2008. Species Summary: *Tympanuchus phasianellus columbianus*. B.C. Ministry of Environment. Available: http://srmapps.gov.bc.ca/apps/eswp/

Conservation Data Centre. 2008 . Conservation Status Report: *Tympanuchus phasianellus columbianus* . B.C. Ministry of Environment. Available: http://srmapps.gov.bc.ca/apps/eswp/

[4] http://ilmbwww.gov.bc.ca/risc/pubs/tebiodiv/gamebirds/gameml11-02.htm#2.1

[5] http://www.birds.cornell.edu/AllAboutBirds/BirdGuide/Spruce_Grouse.html

Fraser, D.F., W.L. Harper, S.G. Cannings, and J.M. Cooper. 1999. Rare birds of British Columbia.Wildlife. Branch and Resource Inventory Branch, B.C. Ministry of Environment, Lands and Parks, Victoria, BC. 244pp.

Leupin, E.E. 2003. Status of the Sharp-tailed Grouse (*Tympanuchus phasianellus*) in British Columbia. B.C. Ministry Sustainable Resource Management, Conservation Data Centre, and B.C. Ministry Water, Land and Air Protection, Biodiversity Branch, Victoria, BC. Wildl. Bull. No. B-104. 25pp.

Ritcey, R. 1995. Status of the Sharp-tailed Grouse (columbianus subspecies) in British Columbia. B.C. Ministry of Environ., Lands and Parks, Victoria, BC. Wildl. Working Rep. WR-70. 52pp.

Distribution

Provincial range: The sharp-tailed grouse (*columbianus* subspecies) is found from the central interior and into southern BC in the following ecoprovinces: Sothern Interior, Southern Interior Mountain, Central Interior, Sub-Boreal Interior (Fraser et al. 1999). This subspecies is thought to be extirpated from the Okanogan, virtually extirpated from the grasslands of the southern Rocky Mountain Trench, marginally and locally distributed in the Thompson Uplands, Thompson Basin, and Nechako Lowlands, and have a greatly contracted range in the Bulkley Basin. It is considered widespread in the Chilcotin Plateau, Cariboo Basin and Fraser River Basin (Fraser et al. 1999).

Elevation range: The sharp-tailed grouse can be found from 275m to 1190 m in elevation during the breeding season (BCMWLAP 2004).

Provincial context: In 2001, there was an estimated 10,000 breeding sharp-tailed grouse in BC. The highest numbers occur in the central interior estimated at between 4000 to 8200 birds. The southern interior has an estimated 600-1200 birds (BCMWLAP 2004). Populations in the Cariboo Basin and the Chilcotin Plateau where forest regrowth is limiting habitat counts at leks decreased from an average in 1993 of 18 birds per lek to 10 birds per lek in 2000 (CDC 2008l).

General ecology and life history

Reproduction: Leks are specific areas where breeding males congregate to attract females; nearly all breeding occurs in these areas. Females will select, when available, the male positioned closest to the centre of the lek (Ritcey 1995). Females lay approximately 12 eggs per year and will first lay when they are 11 months of age. Even though only 1 brood occurs per year, if the nest is destroyed, they may attempt to re-nest up to three times in that year. There is large variability in survival of the young; therefore, there are distinct year to year fluctuations in fall population numbers (BCMWLAP 2004).

Movements and home range: Sharp-tailed grouse are thought to have relatively limited home-ranges that are used year-round. In BC, Van Rossum (1992) found that they had year-round home ranges of 4.9 km^2. These birds are non-migratory but are capable of sustained flight (BCMWLAP 2004). A study in the US found that sharp-tailed grouse made movements of up to 148 km (Robel et al. 1972).

Feeding habits: Sharp-tailed grouse vary their diet depending on the season feeding on forbs, grasses and insects in the spring. Insects become important in the summer; and insects as well as leafy plants and berries are utilized in the fall. Grouse switch leaves and twigs of deciduous trees as winter approaches. Buds and catkins of deciduous trees and shrubs are their primary food in winter and, to a lesser extent, fruits and berries. Different forage is important to populations on grasslands versus clear-cuts. Snowberry (*Symphoricarpus alba*), rose (*Rosa* spp), dandelion (*Taraxacum officinale*), water birch (*Betula occidentalis*), trembling aspen (*Populus tremuloides*), saskatoon (*Amelanchier alnifolia*), and choke cherry (*Prunus virginiana*) in grasslands and in clearcuts; kinnikinnick (*Arctostaphyllos uva-ursi*), common juniper (*Juniper communis*), prickly rose (*Rosa acicularis*), scrub birch (*Betula glandulosa*), and to a lesser degree, water birch and aspen (BCMWLAP 2004).

Range use

Life Requisites

General: During breeding, the Sharp-tailed grouse requires open habitats to allow room for a mating ground (breeding lek). The openness allows easier detection of predators, and allows easier detection of the lek by other grouse. However, a successful lek is also secluded and is often located on elevated ground or ridge tops (BCMWLAP 2004). During nesting, this species requires adequate cover for concealment and nests are spread over a wide area to decrease the predator's chances of concentrating their efforts. A minimum of 25cm high residual grass cover seems necessary for nesting sites in grasslands; rough fescue (*Festuca campestris*) is dominant at many sites in BC (BCMWLAP 2004). In the summer during brooding, some populations seemed to prefer grass/forb habitats while others used shrub habitats. The Identified Wildlife Species Account for Sharp-tailed grouse provides a table of broad ecosystem units and structural stage needed for each season (BCWLAP 2004).

Forage: In the summer, areas that provide a large quantity of ground dwelling insects are important for chicks (BCMWLAP 2004). In the fall, berries become an important component of their diet as well as greens such as clover, dandelions and yarrow that grow abundantly on disturbed sites such as landings and roadsides. In dry situations and during the first snowfalls of winter, lodgepole pine stands with developed or developing canopies provide heavy crops of kinnikinnik and berries in the understory (BCMWLAP 2004). In the winter, important feeding habitat with berries, catkins and twigs is found in riparian areas with plentiful deciduous shrub and tree species. Clear-cut populations often use shrub carrs and low growing scrub birch in winter (Ritcey 1990).

Cover from thermal extremes: In the winter, the Sharp-tailed grouse often snow roosts to conserve energy; these roosts are usually located near deciduous riparian and shrub cover (Evans and Moen 1975).

Security: Residual grass cover of a minimum height of 25 to 30 cm is needed for cover for nesting sites (BCMWLAP 2004).

Interaction with agents of disturbance/competition

Disturbance factors: Leks are traditional sites and may be used year after year. However, even though males may tolerate disturbance to a certain degree, females avoid disturbed sites (Baydack and Hein 1987). Disturbance may come from livestock or pets or excessive human activity (BCMWLAP 2004).

Competitors: no specific information available on competitors in BC.

Mortality factors

Predation is thought to be the highest source of mortality for the sharp-tailed grouse (Ritcey 1995). Northern goshawk (*Accipiter gentilis*), golden eagle (*Aquila chrysaetos*) and great horned owl (*Bubo virginianus*) are some of the predators of the sharp-tailed grouse in Washington (Ritcey 1995). Near Kamloops, northern harriers (*Circus cyaneus*), coyotes (*Canis latrans*), northern goshawk and short-eared owls (*Asio flammeus*) were all observed preying on sharp-tailed grouse (Ritcey 1995). Hunting and accidents are also sources of mortality for grouse (Ritcey 1995).

Potential limiting factors and threats

The northern range of this species and its clearcut habitat is not considered threatened; however, in the southern range of the sharp-tailed grouse, grassland and riparian habitat has been lost due to urbanization and agriculture (Fraser et al. 1999). Isolated populations of sharp-tailed grouse that are depressed by fragmentation and habitat alteration can be threatened by illegal hunting. As well, in habitats that provide poor cover or where predator populations are high, predation can depress populations (BCMWLAP 2004). Some silvicultural and agricultural practices can contribute to population depression. The major habitat threats to this species include the subdivision of ranchlands, heavy livestock grazing, fire suppression, and water management (BCMWLAP 2004).

Marten

Scientific name: *Martes americana* (Turton 1806)
Species code: M-MAAM
BC status: Yellow-listed
COSEWIC status: NL (not listedMarch, 2008)

Published species accounts

Conservation Data Centre. 2008. Species Summary: *Martes americana*. B.C. Ministry of Environment. Available: http://srmapps.gov.bc.ca/apps/eswp/.

Distribution

Provincial range: Marten are found throughout BC generally coinciding with boreal and montane coniferous forest (Eder and Pattie 2001). In BC, the marten are found in most forested biogeoclimatic zones and are found in every ecoprovince except Northeast Pacific (Lofroth 1993).

Elevation range: Marten may be found at most elevations including alpine (Eder and Pattie 2001).

Provincial context: Marten population numbers are considered fairly stable[6] although may be cyclic in nature (Eder and Pattie 2001). Densities of marten may vary considerably among seasons and years largely driven by changes in food supply[7]. In the fall, densities of 1 to 2 per km^2 have been recorded (CDC 2008g). Although there is variation depending on the area population densities of marten across North America range from 0.4 to 2.4 animals per km^2, the highest densities occurring in the fall[8].

General ecology and life history

Reproduction: The marten breeds in the summer but has delayed implantation and bears 1 to 5 young the following spring. Natality and food supply appear to be correlated. When food is scarce, fewer young are born. Females become sexually mature at 1 to years of age and males at a year (CDC 2008g).

Movements and home range: Marten are generally solitary creatures with home ranges that vary in size but average less than 10 km^2. This may increase if food becomes scarce. Female home ranges are usually smaller than males and males will often overlap with several females (CDC 2008g). In the early fall, densities may be 1-2 marten per km^2. Young can disperse more than 40 km (CDC 2008g).

Feeding habits: Marten feed mainly on small mammals, birds, insects or carrion but may also feed on vegetation such as berries and other seasonal vegetation (CDC 2008g). They may use various foraging techniques such as tracking, ambushing, excavation of burrows and hunting subnivean prey. They also use hunting perches (CDC 2008g). In summer, they may also feed in the alpine on pikas and marmots (Eder and Pattie 2001).

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[6] http://www.ccmf.org/ci/rprt2005/English/pg31-47_1-2-3.htm

[7] http://ilmbwww.gov.bc.ca/risc/pubs/tebiodiv/marten/maweml20-07.htm

[8] http://www.elp.gov.bc.ca/fw/docs/marten.pdf

Range use

Life Requisites

General: Marten are usually found in coniferous upland and lowland forests with an abundance of CWD but may also be found in either dense deciduous or mixed forest (CDC 2008g, Eder and Pattie 2001). They may also use rocky alpine areas (CDC 2008g). They are not known to occupy recent clear-cuts or burns (Eder and Pattie 2001). Lofroth (1993) found that marten generally avoid young seral stages, xeric habitat types and wetlands. However, if specific habitat needs are met, marten with larger home ranges and lower population densities may use areas with younger seral conditions (Lofroth 1993). Lofroth (1993) also found that, at the stand scale, habitat was selected for the abundance of structural features such as CWD, deciduous canopy closure, high and low shrub closure, as well as abundance and size of trees and snags. Habitat selection is most pronounced during winter when foraging opportunities become limited, thermoregulatory costs are at their peak and movement is restricted (Lofroth 1993).

Forage: The marten is often used as an indicator species due to its dependence on mature conifer forests for food (Eder and Pattie 2001). They forage in forests that have plenty of CWD as well as branches and leaves that provide cover for their prey.

Cover from thermal extremes: The marten may find thermal cover in a hole in a tree or a subnivean burrow or rock pile (CDC 2008g).

Security: The marten may find security cover in a hole in a live or dead tree or stump, an abandoned squirrel's nest, conifer crown, rock pile, burrow or snow cavity. In the winter, they most commonly use subnivean sites often associated with CWD. Natal and maternal dens are often located in hollow trees or rock piles (CDC 2008g).

Interaction with agents of disturbance/competition

Disturbance factors: no specific information available for large-scale disturbances such as MPB.

Competitors: Marten and fisher can compete for similar food resources such as voles and mice (Weir 2003). It is thought that fisher can out-compete marten in areas of low snowfall, but marten may out-compete fisher in areas with greater snowfall such as the Engelmann Spruce-Subalpine Fir biogeoclimatic zone (Weir 2003). Species that prey on marten also compete for the same food resources such as coyote, fisher and raptors[9].

Mortality factors

No diseases or parasites, although present, are thought to influence marten population levels[8]. However, due to their high metabolic rates and low fat reserves they are susceptible to energetic stresses increasing their vulnerability to the effects of parasites and disease as well as starvation. This also increases their vulnerability to predation. Marten that do not have secure home ranges or dispersing juveniles are most susceptible to these mortality factors. Predators of marten include larger raptors, fisher, lynx, bobcat, coyote, wolves, and in extreme conditions, other marten[8]. Marten is also one of the primary furbearers trapped in BC[8].

Potential limiting factors and threats

The main threats to marten are silvicultural practices that lead to loss of habitat structure and over trapping[10]. Food supply is also a major determinant of population levels[8].

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[9] http://www.elp.gov.bc.ca/fw/docs/marten.pdf

[10] http://www.ccmf.org/ci/rprt2005/English/pg31-47_1-2-3.htm

Lewis's Woodpecker

Scientific name: *Melanerpes lewis* (Gray 1849)
Species code: B-LEWO
BC status: Red-listed
COSEWIC status: SC (Nov 2001)

Published species accounts

BCMWLAP (British Columbia Ministry of Water, Land and Air Protection). 2004. Accounts and Measures for Managing Identified Wildlife. Version 2004. Biodiversity Branch, Identified Wildlife Management Strategy, Victoria, B.C.

Conservation Data Centre. 2008. Species Summary: *Melanerpes lewis*. B.C. Ministry of Environment. Available: http://srmapps.gov.bc.ca/apps/eswp/

Conservation Data Centre. 2008 . Conservation Status Report: *Melanerpes lewis* . B.C. Ministry of Environment. Available: http://srmapps.gov.bc.ca/apps/eswp/

Cooper, J., C. Siddle, and G. Davidson. 1998. Status of the Lewis' woodpecker (Malanerpes lewis) in British Columbia. Wildlife Working Report No WR-91, Ministry of Environment, Lands and Parks, Wildlife Branch, Victoria, BC. 24pp.

Fraser, D.F., W.L. Harper, S.G. Cannings, and J.M. Cooper. 1999. Rare birds of British Columbia. Wildlife Branch and Resource Inventory Branch, B.C. Ministry of Environment, Lands and Parks, Victoria, BC. 244pp.

Distribution

Provincial range: The Lewis's woodpecker is found throughout the southern interior of BC and has been seen in east-central BC. It is thought to be extirpated from around Golden and Revelstoke and formerly was an abundant breeder in the lower mainland and southeast Vancouver Island. It is currently found in the following ecoprovinces: Central Interior, Southern Interior Mountains and Southern Interior (BCMWLAP 2004).

Elevation range: The Lewis's woodpecker has been detected nesting at elevations from 250 to 1160m (BCMWLAP 2004).

Provincial context: It is thought that there are fewer than 1000 individuals left in BC. Current breeding season estimates are 20 breeding pairs in the Cariboo-Chilcotin, 75 in the Thompson-Nicola, 100 in the East Kootenay Trench, and 180 pairs from Boundary-Grand Forks to the south Okanagan (CDC 2008i).

General ecology and life history

Reproduction: One clutch of 2 to 8 eggs is raised annually with a potential for approximately 1 to 5 young successfully fledging (Campbell et al. 1990, Cooper et al. 1998). It is not known at what age breeding begins (Cooper et al. 1998). Incubation lasts approximately 14 days and nestling 4 to 5 weeks (Cooper et al. 1998). It is thought that this species forms long-term bonds, but will find new mates if their current mate is lost (Cooper et al. 1998). In some regions of BC, this species is known to breed in loose colonies; the highest densities occur in the southern Okanagan in riparian black cottonwood groves (Cannings et al. 1987, Cooper et al. 1998).

Movements and home range: In BC, most Lewis's woodpeckers are migratory, returning in spring as early as mid-April but usually in the first 2 weeks of May. In the late summer, this woodpecker forms large flocks; most migrate in late August and early September with few remaining after the end of September (BCMWLAP 2004). This species has been noted to meander irregularly in different parts of the province; for example it has been observed in the Queen Charlotte Islands as well as at Takla Lake in the central interior (Campbell et al. 1990).

There is little known about the Lewis's woodpecker's home range. Adults are known to defend the area around their nest trees and caches but have been observed foraging more than 1 km from their nest site (BCMWLAP 2004).

Feeding habits: The diet of the Lewis's woodpecker varies seasonally, and includes insects, nuts such as acorns, seeds, berries, and fruits (domestic and wild) (BCMWLAP 2004). Insects eaten by this woodpecker are primarily free living (not wood boring) and include ants, crickets, grasshoppers, butterflies, bees, wasps and beetles (Cannings et al. 1987). During the breeding season, fruits and free flying insects appear to be the most important food item (Cannings et al. 1987). Lewis's woodpecker will hawk insects from the air as well as glean them from trees, bushes and the ground. They have also been observed caching beetles in the bark of ponderosa pine for later consumption (BCMWLAP 2004). In the winter, Lewis's woodpeckers collect and store nuts (BCMWLAP 2004).

Range use

Life Requisites

General: Suitable habitat for the Lewis's woodpecker is often found in stands of mature ponderosa pine, Douglas fir, and black cottonwood. Many of these stand types are declining through timber harvest, urban development, procurement of firewood (BCMWLAP 2004) and mountain pine beetle mortality. Breeding habitat is usually comprised of deciduous groves such as mature cottonwood stands, open ponderosa forests, recent burns, sagebrush/pine/bunchgrass grasslands, agricultural and urban areas (Campbell et al. 1990, Cooper et al. 1998).

Nesting: The attributes defining good breeding habitat are an open canopy of <25% canopy closure, presence of dead or dying trees with greater than 30cm dbh and understory vegetation (BCMWLAP 2004). The most common nest trees reported out of 215 observed were ponderosa pine (47%) and black cottonwood (33%) (Campbell et al. 1990).

Forage: Foraging habitat during the breeding season include open forests and valley bottoms, burns, logged areas, agricultural sites, deciduous groves that are close to streams and lakes and rural and urban areas. Hawking perches to search for insects are usually broken topped or large limbed living or dead trees (BCMWLAP 2004). In the winter, foraging is usually restricted to mature cottonwood groves, residential areas and orchards (Cannings et al. 1987).

Interaction with agents of disturbance/competition

Disturbance factors: Lewis's woodpecker seems to habituate well to routine human activity and have been known to nest near parks and beaches and in orchards (Cooper et al. 1998). However, they are more susceptible to disturbance than other woodpeckers. It was noted during one study in open ponderosas pine that birds would not resume their normal activities till the observers retreated at least 100m from the nest (Cooper et al. 1998). Although this woodpecker will generally ignore humans greater than 15m from the tree nest abandonment can occur if the nest cavity is disturbed (Cooper et al. 1998).

Competitors: Starlings are a competitor for Lewis's woodpecker, although Lewis's woodpecker is more successful at competing with this species then other woodpeckers (BCMWLAP 2004). In most places in BC they appear to coexist, however, Sorenson (1986) found that there was a correlation between starling population increase and Lewis's woodpecker decline; he attributed this to resource availability – if resources are scarce and starling numbers are high relative to the woodpecker, the energetic costs of competition on Lewis's woodpeckers become significant.

Mortality factors

Most mortality of Lewis's woodpecker is thought to be from avian predators such as American kestrels (*Falco sparverius*), merlins (*Falco columbarius*), Cooper's hawks (*Accipiter cooperi*), prairie falcon (*Falco mexicanus*) and red-tailed hawks (*Buteo jamaicensis*). Other potential predators of woodpecker nests are weasels, mice and black bear (Cooper et al. 1998). Shooting of individuals is not thought to be extensive, however, in the past farmers have shot them to protect their fruit crops. Collision with cars as well as exposure to pesticides and chemicals are also a mortality factor for this species although not thought to be significant (Cooper et al. 1998).

Potential limiting factors and threats

It is thought that loss and alteration of habitats is the greatest single threat to this species (Fraser et al. 1999). Losses of nest trees may have the greatest negative impact on this species as they are not quickly nor easily replaced. Such losses may occur through the removal of dead and dying trees for various human uses or from such natural causes such as the mountain pine beetle outbreak (Fraser et al. 1999, CDC 2008i). It is thought that the loss of nest trees in southwest coastal areas of BC may have contributed to the decline and extirpation in this area. Removal of Garry oak likely contributed to declines on Vancouver Island (BCMWLAP 2004). Fire suppression is also thought to contribute to population decline by altering the habitat into dense stands that are not suitable for the Lewis's woodpecker (Cooper et al. 1998).

Red Squirrel

Scientific name:	*Tamiasciurus hudsonicus* (Erxleben 1777)
Species code:	M-TAHU
BC status:	Yellow-listed
COSEWIC status:	no assessment available (March, 2008)

Published species accounts

Conservation Data Centre. 2008. Species Summary: *Tamiasciurus hudsonicus*. B.C. Ministry of Environment. Available: http://srmapps.gov.bc.ca/apps/eswp/

Distribution

Provincial range: The red squirrel occurs through most of BC except for the south west corner of the mainland in the Coast and Mountain ecoprovince and the Georgia Depression and the Queen Charlotte Islands (Eder and Pattie 2001).

Elevation range: wide-spread at all elevations with suitable habitat.

Provincial context: In parts of the States population densities can range from 1 every 3.2 ha to 1 every 0.2ha. In a comparison of studies Wheatley et al. (2002) found squirrel densities in BC in pine forests was 1.1 per hectare and in mixed conifer forests densities ranged from 0.5 to 2 squirrels per hectare.

General ecology and life history

Reproduction: The red squirrel breeds in the spring and has a gestation period of 31 to 35 days producing 4 to 5 young (Lair 1985, Lair 1986). Females may start breeding when they are less than a year and may produce 2 litters per year (Lair 1986). In some areas of BC, the red squirrel has lower reproduction when food is limited (Sullivan 1990).

Movements and home range: Home range size may vary in size from ½ to 2 ½ ha (Banfield 1974) with densities ranging from 1 per 0.2 ha to 1 per 3.2ha (Layne 1954). In one study in Minnesota young dispersed a median distance 100m; of the 8 squirrels studied, 4 remained in their natal range and 4 dispersed (Sun 1997). In BC, Haughland and Larsen (2004) found that most juveniles remained on or adjacent to their natal territory. The red squirrel is more territorial than most squirrels (CDC 2008j) and this behaviour may limit populations at high densities (Klenner and Krebs 1991, Klenner 1991).

Feeding habits: The red squirrel has a diet of seeds, conifer cones, nuts, fruits, and the occasional invertebrate and small vertebrate (CDC 2008j). However, their staple food is conifer seed and they defend territories in order to maintain exclusive rights to this resource (Kemp and Keith 1970). This species does not hibernate so caches large amounts of food for consumption later (CDC 2008j, Eder and Pattie 2001).

Range use

Life Requisites

General: This squirrel prefers coniferous and mixed forest but may also be found in deciduous forest, hedgerows and second growth. It prefers to nest in tree cavities but will also use leaf nests, ground burrows, CWD, or witch's broom for denning (CDC 2008j). The red squirrel is considered forest-dependent: Herbers and Klenner 2007) found that the density of red squirrel dropped 40% in stands with 50% basal-area tree removal, 2 to 4 years after logging.

Forage: The red squirrel requires mature conifer forest for its cones and seeds. In central BC, Sullivan and Moses (1986) found that red squirrels were much more abundant (2 and 5 times more abundant) in unthinned stands of 20 year old lodgepole pine than in thinned stands and most abundant in mature stands. They suggested that the 20 year old stands were acting as a sink for excess juveniles.

Cover from thermal extremes: The red squirrel stays active in the winter except when temperatures drop below -25^{o} after which it will rest in its nest (Eder and Pattie 2001). One or more red squirrels will use nest cavities to shelter from severe weather. The red squirrel will also tunnel in to deep snow to find food or shelter[11].

Interaction with agents of disturbance/competition

Disturbance factors: Red squirrel does not seem to be affected by human disturbance (Banks et al. 1999).

Competitors: In the fall, grizzly bears can seek out red squirrel middens and consume their stores[12]. Other squirrels will also compete for food resources.

Mortality factors

The red squirrel has many predators. In a review of various studies Sullivan (1995) lists the following predators: northern goshawk (*Accipiter gentilis*, red-tailed hawk (*Buteo jamaicensis*), red fox (*Vulpes vulpes*), bald eagle (*Halieaatus leucocephalus*), marten, lynx (*Lynx canadensis*), and ermine (*Mustela erminea*). Red squirrels may be trapped as furbearers in BC.

Potential limiting factors and threats

Klenner and Krebs (1991) reviewed many studies that indicated red squirrel population density varied with cone crops[13]. Sullivan (1990) found that red squirrel population density increased if food was supplemented indicating that the availability of food was limiting population density.

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11 http://www.fs.fed.us/database/feis/animals/mammal/tahu/all.html

12 http://imnh.isu.edu/digitalatlas/bio/mammal/Rod/squir/resq/reds.htm

13 http://www.fs.fed.us/database/feis/animals/mammal/tahu/all.html

Canada Lynx

Scientific name:	*Lynx canadensis* (Kerr 1792)
Species code:	M-LYCA
BC status:	Yellow-listed
COSEWIC status:	NAR (May 2001)

Distribution

Provincial range: The lynx is found throughout the province except for coastal regions (parts of Coast and Mountain ecoprovince, Georgia Depression, and Northeast Pacific) but is most common in the more isolated northern portions of BC (Eder and Pattie 2001).

Elevation range: The lynx is found from valley bottom to alpine CDC 2008a, NatureServe 2008a). McKelvey et al. (1999) found that lynx were most often found at elevations between 250-750 m, however, USFW (2001) found the lynx ranged from 51m to 1109 m with an average of 365 m.

Provincial context: The population in BC is thought to be stable and is estimated to range from 20-80,000 (CDC 2008a; Northwest Wildlife 2008).

Published species accounts

Conservation Data Centre. 2008. Species Summary: *Lynx canadensis*. B.C. Ministry of Environment. Available: http://srmapps.gov.bc.ca/apps/eswp/

General ecology and life history

Reproduction: The lynx breed in late winter/early spring and has a gestation period of 62 to 74 days (CDC 2008a). Females may begin breeding as yearlings but will have a lower pregnancy rate then adults (Brainerd 1985). Adult females produce a litter of 3 to 4 kits every year or 2. The young will stay with the mother until the next mating season or may stay longer (CDC 2008a). Breeding will be suppressed if prey is scarce and prey scarcity can also result in extremely high mortality of young (Brand and Keith 1979).

Movements and home range: The lynx is usually a solitary animal with a population density averaging between 2 to 9 per 100 km^2 but may be up to 20 depending on prey abundance (CDC 2008a). Home range size is also influenced by prey abundance. As prey becomes scarcer, home range size increases and individuals may become nomadic (Ward and Krebs 1985). The male's home range averages between 15-30 km^2 but can increase to hundreds of km^2. The males' home range is larger than the females (CDC 2008a). Some individuals have been recorded having dispersal movements of several hundred kilometres (CDC 2008a).

Feeding habits: The lynx preys on small mammals and birds, but depends primarily on snowshoe hare (*Lepus americanus*). Although the lynx has many competitors for this prey species, it is by far the most efficient predator at catching showshoe hares (Eder and Pattie 2001).

Range use

Life Requisites

General: The lynx is usually found in coniferous or mixed forest with thick undergrowth in boreal and montane regions. They can also be found in other habitats such as rocky areas, open forest or tundra when searching for prey (CDC 2008a). Winter habitat is usually associated with snowshoe hare habitat (CDC 2008a). The snowshoe hare is mostly found in dense forest and the associated debris such as grasses, twigs, leaves, and bark (Eder and Pattie 2001). In some parts of the lynx's range, this habitat consists of early successional lodge-pole pine with trees >6ft in height (US Forest Service et al. 1993).

Forage: Feeding habitat for the lynx is often associated with snowshoe hare habitat such as 15 to 35 year old lodgepole pine.

Cover from thermal extremes: CWD and thick understory are important thermal cover for lynx.

Security: The lynx often makes its den or find security in thick brush, a hollow tree or under a stump, cave or under rocks (CDC 2008a, Eder and Pattie 2001). Denning sites usually occur in mature or old growth such as greater than 200 year old spruce and fir patches with a high density of CWD (CDC 2008a, Koehler 1990). The lynx can climb trees to avoid predators (Eder and Pattie 2001).

Interaction with agents of disturbance/competition

Disturbance factors: Roads may lead to fragmentation as well as increase access for hunters, trappers and recreation, both summer and winter. As lynx tend to avoid humans, forestry, agriculture, industry, development and roads all have the potential to disturb lynx populations. Any disturbance factor that effects the snowshoe hare population will, as a consequence, effect the lynx population.

Competitors: The lynx has many competitors for their prey species: wolves, coyotes, red fox, cougar, bobcat, fisher, marten, wolverine, mink, skunk, owls, eagles and hawks (Eder and Pattie 2001).

Mortality factors

The most common natural cause of mortality is thought to be starvation[13]. Lynx are also prey to wolverines, cougars, wolves, coyotes as well as other lynx. Lynx may host a number of parasites, and are subject to several different diseases. However, no outbreaks are thought to have effected populations. Where lynx are close to human development and access, human related mortality such as trapping is thought to be the highest mortality factor[14].

Potential limiting factors and threats

The major limiting factor for the lynx is the availability of its primary prey, the snowshoe hare (CDC 2008a). Habitat fragmentation may also threaten lynx populations as this species tends to avoid human contact. Forestry activities, agriculture and roads all have the potential to threaten this species or its primary prey, the snowshoe hare (Eder and Pattie 2001, NatureServe 2008a). Roads may also increase access to hunters and trappers. Increased winter recreation (i.e., snowmobiles and recreational development) may also displace this species or increase accidental mortality (NatureServe 2008a).

Snowshoe Hare

Scientific name:	*Lepus americanus* (Erxleben 1777)
Species code:	M-LEAM
BC status:	Yellow-listed
COSEWIC status:	no assessment available (March, 2008)

Published species accounts

Conservation Data Centre. 2008. Species Summary: *Lepus americanus*. B.C. Ministry of Environment. Available: http://srmapps.gov.bc.ca/apps/eswp/

[14] http://www.elp.gov.bc.ca/fw/docs/lynx.pdf

Distribution

Provincial range: The snowshoe hare is found throughout BC except the islands and some of the northern coast (Eder and Pattie 2001). The snowshoe hare is found in all ecoprovinces except for some parts of Coast and Mountain ecoprovince, Georgia Depression, and Northeast Pacific (Eder and Pattie 2001).

Elevation range: The snowshoe hare is found in most elevations in BC as they can be found almost anywhere in BC where there is forest or dense shrub (Eder and Pattie 2001).

Provincial context: Populations fluctuate over a 10 to 11 year cycle. Densities may vary from 1 hare to a few hundred per square kilometre (CDC 2008n).

General ecology and life history

Reproduction: The breeding season of the snowshoe hare goes from February to mid-August with a gestation period of 36-37 days. Litters of 1 to 6 are born from May to August with a total of 1 to 4 litters per year. They become sexually mature the spring following their birth and usually only live 2 years but may live up to 5 (CDC 2008n).

Movements and home range: Home range size of the snowshoe hare is usually small, ranging from approximately 3 to 20 hectares with males having larger home range than females (CDC 2008n). Home range varies with the location and season (CDC 2008n).

Feeding habits: The snowshoe hare is an herbivore feeding on succulent vegetation in summer and in winter on twigs, buds, the bark of small trees, as well as dung (CDC 2008n). Favoured conifers include jackpine, white pine, larch and cedar[15].

Range use

Life Requisites

General: The snowshoe hare prefers dense coniferous or mixed forests with abundant understory. The understory is extremely important to this species. They may also be found in coniferous swamps, second growth adjacent to mature forests, alder fens or conifer bogs. They nest in ground depressions or a hollow log (CDC 2008n). It is found throughout much of the boreal forest but habitat within the boreal forest varies greatly[14].

Security: During the daytime, the snowshoe hare will rest in dense cover. Underground burrows are generally avoided (CDC 2008n).

Interaction with agents of disturbance/competition

Disturbance factors: no specific information available for large-scale disturbances such as MPB.

Competitors: no specific information available for competitors in BC.

Mortality factors

The snowshoe hare is affected by a wide variety of infectious diseases ranging from viral, bacterial to parasitic. It also has a wide variety of predators both avian and mammalian. The most common predators are the lynx, fox, coyote, mink, great-horned owl and northern goshawk[14]. Disease and predation are usually the cause of death, but the impact this has on the hare populations is often mediated by weather and nutritional stresses[14].

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[15] http://www.britishcolumbia.com/Wildlife/wildlife/landmammals/cw/cw_snowshoehare.html

Potential limiting factors and threats

A study in Wisconsin suggests that the probability of a population going extinct is related to the degree habitats become fragmented. This study found that patch size and hare numbers were important and that fall population of less than 10 hares in a patch of prime habitat less than or equal to 5 ha is unlikely to persist without ingress (Keith et al. 1993).

Mule Deer

Scientific name: *Odocoileus hemionus hemionus* (Rafinesque 1817)
Species code: M-ODHE
BC status: Yellow-listed
COSEWIC status: no assessment available (March, 2008)

Published species accounts

Blood, D.A. 2000. Mule and Black-tailed Deer in British Columbia, Ecology, Conservation and Management. B.C. Ministry of Environment, Lands and Parks, Wildlife Branch. 6pp.

Conservation Data Centre. 2008. Species Summary: *Odocoileus hemionus*. B.C. Ministry of Environment. Available: http://srmapps.gov.bc.ca/apps/eswp/

British Columbia Ministry of Environment. Species account for mule deer: URL: http://www.env.gov.bc.ca/wildlife/whr/provincialex.html (cited as BCMoE SA-MD in following text)

Distribution

Provincial range: Mule deer are found throughout BC. There are 2 subspecies; the black-tailed deer (*columbianus* Columbian and *sitkensis* Sitka) and the mule deer (*hemionus*). The Columbia Mountains separates the 2 subspecies although some interbreeding occurs along the edges of their range (Blood 2000a). The mule deer subspecies is found in all ecoprovinces except the Coast and Mountain and Northeast Pacific ecoprovince.

Elevation range: Mule deer are found at all elevational ranges from sea-level to alpine (BCMoE SA-MD).

Provincial context: The population of the coastal subspecies is estimated at 150,000 to 250,000. The interior subspecies is estimated at approximately 165,000 and in the northern ranges the population is estimated at 20,000 to 25,000 (Blood 2000a).

General ecology and life history

Reproduction: Breeding occurs in the fall, usually late November to mid-December and 1 to 2 fawns are born in May and June (CDC 2008h). Males may breed as yearlings, but due to dominance, the older males do most of the breeding (Blood 2000a). Females also begin breeding as yearlings (Blood 2000a).

Movements and home range: Mule deer are generally solitary or may travel in small groups, but are rarely found in large groups. Clans of females related by maternal decent will travel together sometimes with an unrelated male (Blood 2000a). Home range size differs depending on sex, habitat (such as availability of food, water and cover) and individuals (BCMoE SA-MD) but may vary from 30 to greater than 240 ha (CDC 2008h). Mule deer demonstrate a high fidelity for their seasonal home ranges (CDC 2008h). Many of the interior mule deer are migratory, moving from subalpine in the summer to lower montane winter range when snow depth increases (Wallmo and Regelin 1981) although some individuals will remain residents at lower elevations all year (Blood 2000a). Snow becomes too deep for deer movement and forage when depths are greater than 30cm (Blood 2000a).

Feeding habits: Mule deer are mainly browsers, but will also forage on grasses and forbs. They are able to digest a wide variety of plant material and will vary their diet seasonally depending on forage digestibility and protein content as well as the nutritional needs of the animal (BCMoE SA-MD). In the spring and summer they prefer grasses (i.e., *Agropyron spp., Poa spp. Koeleria spp*), shrub leaves as well as herbs such as clover (*Trifolium spp*.), and fireweed (*Epilobium spp*.). They may also feed on dandelion (*Taraxacum officinale*), lupine (*Lupinus spp*.), alfalfa (*Medicago sativa*), vetch (*Vicia* spp.), peavine (*Lathyrus*), horsetail (*Equisetum* spp.), showy daisy (*Erigeron speciosus*), yarrow (*Achillea millefolium*), mariposa lily (*Calochortus spp*.), common harebell (*Campanula rotundifolia*), gentian (*Gentianella* spp), and rock cress (*Arabis spp*.) (BCMoE SA-MD). In winter they feed on grasses and herbs as well as Douglas fir tree foliage and shrubs such as big sagebrush, pasture sage, bitterbrush, rabbitbrush, snowbrush, rose, saskatoon, and serviceberry (Blood 2000a).

Range use

Life Requisites

General: Mule deer in the interior are generally found in open coniferous forests and in early structural stages where they can find plenty of forage and cover (BCMoE SA-MD). In the interior, winter range usually consists of shrubland in the dry forest zone and in broken terrain on steep south and west facing slopes. They will often not migrate from their high elevation summer range until December when they descend to lower elevations to areas with shallower snow (Blood 2000a).

Forage: In the interior, spring forage is usually found on moderate to steep mid elevation south to west facing slopes where early green up occurs; usually close to their winter ranges (BCMoE SA-MD). In the spring they also use low elevation grasslands, open mixed forests, clear cuts and riparian areas (BCMoE SA-MD). In the summer they tend to use higher elevations such as shrubby alpine, alpine tundra, subalpine parkland and subalpine wet meadows.

Cover from thermal extremes: Mule deer require winter range that has snow depths of less than 30cm as snow becomes too deep for deer movement and forage when depths are greater than this (Blood 2000a).

Interaction with agents of disturbance/competition

Disturbance factors: no specific information available for large-scale disturbances such as MPB.

Competitors: Mule deer occupy the same ranges and can compete for forage with Rocky Mountain elk, white-tailed deer and domestic cattle (Blood 2000a).

Mortality factors

In general, the main causes of death are predation, starvation and hunting (Blood 2000a). Mule deer are prey to predators such as cougars, wolves and bears as well as bobcats and coyotes. Another form of mortality for mule deer is accidents (Blood 2000a).

Potential limiting factors and threats

One of the limiting factors for deer is snow and the chance of fawn survival decreases with occurrences of heavy snowfall (BCMoE SA-MD).

Rocky Mountain Elk

Scientific name:	*Cervus canadensis nelsoni* (Linnaeus 1758)
Species code:	M-CECA
BC status:	Yellow-listed
COSEWIC status:	no assessment available (March, 2008)

Published species accounts

Blood, D. 2000. Elk in British Columbia: ecology, conservation and management. B.C. Ministry of Environment, Lands and Parks, Wildlife Branch. 6pp.

Conservation Data Centre. 2008. Species Summary: *Cervus canadensis*. B.C. Ministry of Environment. Available: http://srmapps.gov.bc.ca/apps/eswp/

British Columbia Ministry of Environment. Species account: URL: http://www.env.gov.bc.ca/wildlife/whr/provincialex.html (cited as BCMoE SA-RME in following text).

Distribution

Provincial range: Rocky Mountain Elk are found in all ecoprovinces in BC except for the Coast and Mountains, Georgia Depression, Central Interior, Taiga Plains, and Northeast Pacific (BCMoE SA-RME).

Elevation range: Elk may be found at all elevations from sea level up to and including alpine (BCMoE SA-RME).

Provincial context: Historically, elk were widespread in the province but in the mid to late 1800's these numbers decreased rapidly. Since the mid 1970's however, numbers have been increasing with current estimates of 15,000 to 40,000 elk in BC; 18,000 in northern BC, 20,000 in the Kootenay region, 1350 in the Thompson Okanagan region and a few other scattered herds throughout other areas of BC (Blood 200b).

General ecology and life history

Reproduction: The rut begins in mid-September when the bull elk seeks out the female groups and establishes harems which they aggressively guard (Blood 2000b). Females are usually bred in mid to late September with those that are not bred coming into oestrus again in October and sometimes a third in November. The cows seek out secluded areas in dense cover in late May and early June to give birth to a single calf; twins are rare. The cow and her calf usually rejoin the matriarchal group after 2 to 3 weeks (Blood 2000b). Females generally breed and produce a calf for the first time around 2 years old and will continue annually through life, however, pregnancy rates are lower on poor range. Bulls can breed as yearlings but generally don't until they are 4 or 5 years old due the dominant males winning the females (Blood 200b).

Movements, home range and social hierchy: Elk are social but have dominance hierarchies; cows, calves and yearlings can be found in herds of 20 or more. Bulls tend to hang out in smaller groups that remain separate from cows except during the rut. Rocky Mountain elk tend to be migratory but a wide variety of migration distances exist. Bulls usually migrate first from their winter range; cows will wait until the calves are old enough to follow (Blood 2000b).

Feeding habits: The feeding habits of elk are largely dependant on available forage and can be widely variable, however, grasses are preferred. Browse is also consumed throughout the year. BCMoE SA-RME lists 20 trees and shrubs, 17 graminoids, 22 forbs and 3 species of horsetails, mosses and lichens that are considered key forage for Rocky Mountain elk. Elk will feed on early seral vegetation that occurs after disturbance such as fire, clearing, forest harvesting and agriculture (BCMoE SA-RME). Elk usually forage within 200m of cover. In winter, snow condition and depth is the factor that most influences diet. Snow depths of 46 to 71 cm can lead elk to switch from grazing to browsing (Skovlin 1982).

Range use

Life Requisites

General: Elk use a variety of habitats and may be found in varied ages of coniferous forests, deciduous stands as well as non-forested habitats such as wetlands, vegetated slides and rock outcrops (Nyberg and

Janz 1990). They prefer moist areas such as wetlands, seepage sites, meadows, estuaries and riparian sites adjacent to streams and alluvial floodplains of major rivers. Abundant preferred forage grows in the rich moist soils of these areas.

<u>Forage:</u> In spring, elk depend on the early green up vegetation adjacent to their winter range. In summer, they generally move to high elevation basins, ridgetops and avalanche chutes often north facing with slopes 27-58% within 400m of a water source (Marcum 1975). During the late summer, drainage bottoms are often preferred due to the cooling winds, riparian forage species, water and travel potential (Skovlin 1982). In the winter, elk are usually found on south and southeast facing slopes with slopes of less than 18% and low snow accumulation (Mackie 1970; Skovlin 1982). Winter habitat consists of grasslands, open Douglas fir, ponderosa pine, and lodgepole pine forests (Jamieson and Hebert 1993; Halko and Hebert 1997).

<u>Cover from thermal extremes:</u> In the summer, the coolest habitat is in upper north facing older stands that have pruned lower branches, allowing wind circulation (BCMoE SA-RME). In the winter, thermal cover is found in older coniferous stands with a minimum height of 10-12m, a closed canopy with at least 70% cover and sufficient understory to break the wind (BCMoE SA-RME). As forest cover influences the density, depth and surface hardness of snow, a canopy of at least 60% closure is needed to provide favorable snow conditions that limit elk movement the least (Bunnell et al. 1985; Nyberg and Janz 1990).

<u>Calving areas:</u> Calving often occurs in spring transitional ranges that are found in moderately dense forests with small openings, nearby escape cover and open water. They are generally found on gentle slopes (20-30%) with ground cover such as shrubs, CWD broken terrain and good forage areas and thermal cover (BCMoE SA-RME).

<u>Security:</u> Security cover for elk is generally thick forest that is structurally complex and canopy closure of 75-100% (Marcum 1975). The minimum vegetation cover needed for security is described as being able to hide 90% of a standing adult elk from a distance of 61m; this quality may be found in coniferous stands that are greater than 3m tall and 100m wide (Black et al 1979; McNamee et al. 1981).

Interaction with agents of disturbance/competition

<u>Disturbance factors:</u> no specific information available for large-scale disturbances such as MPB.

<u>Competitors:</u> Elk range with Mule and White-tailed deer and less frequently with moose, caribou and bighorn sheep. However, due to differences in diet, none of these species usually offer serious competition. However, in some areas, domestic cattle can seriously compete for food resources (Blood 2000b).

Mortality factors

Mortality factors for elk include predation, hunting, malnutrition and accidents. Predators include grizzly bear, black bear, wolf, cougar, and coyote (CDC 2008m). Male elk do not feed during the rut, therefore they enter winter in poor condition and typically have a higher death rate then females during the winter. Malnutrition is one of the main mortality factors for adult elk (Blood 2000b).

Potential limiting factors and threats

The primary limiting factors of elk populations is the quality and quantity of wintering habitat, predation and winter severity (Bircher et al. 2001). Some populations may also be limited by competition for forage with domestic livestock, mountain sheep, deer or other animal that is sharing critical habitat. Other factors that may periodically limit elk populations are road and rail kills, hunting mortality or poaching (Bircher et al. 2001).

Moose

Scientific name: *Alces alces* (Clinton 1822)
Species code: M-ALAM
BC status: Yellow-listed
COSEWIC status: no assessment available (March, 2008)

Published species accounts

Blood, D.A. 2000. Moose in British Columbia, Ecology, Conservation and Management. B.C. Ministry of Environment, Lands and Parks, Wildlife Branch. 6pp.

Conservation Data Centre. 2008. Species Summary: *Alces americanus*. B.C. Ministry of Environment. Available: http://srmapps.gov.bc.ca/apps/eswp/

British Columbia Ministry of Environment. Species account: URL: http://www.env.gov.bc.ca/wildlife/whr/provincialex.html (cited as BCMoE SA-M in following text).

Distribution

Provincial range: Moose can be found throughout BC except on the coastal islands including Vancouver Island and the Queen Charlottes, as well as the coastal fjords therefore are in every ecoprovince except the Georgia Depression and the Northeast Pacific. They can be found in all biogeoclimatic zones with the exception of the CDF, Bunchgrass and Ponderosa Pine (BCMoE SA-M).

Elevation range: Moose can be found from sea-level to alpine but are seldom found in areas above 1300m in the winter (BCMoE SA-M).

Provincial context: The population of moose in BC is estimated at 240,000 (BCMoE SA-M). Moose are most abundant in central and northern BC (Blood 2000c). In BC, typical population densities in winter range from 0.3 moose per km^2 to 1.5 per km^2 (Blood 2000c).

General ecology and life history

Reproduction: The moose breed between September and late October and bear 1 to 2 calves in late May or early June. They can first breed at 1.5 years but peak productivity for females is not reached until 4 years of age. Due to intra-sexual competition, males often don't begin breeding until 5 or 6 years of age (CDC 2008e).

Movements and home range: Not all moose are migratory and the size of their home ranges varies widely. Non-migratory moose may have a home range anywhere from 6 to 27 km^2 in the winter to 2 to 35 km^2 in the summer (Petticrew and Munro 1979, Stevens and Lofts 1988). In the southern interior, seasonal ranges may vary from 2.2 km^2 (males) to 6.2 km^2 (females) in the summer, to 10 km^2 (males) to 7.4 km^2 (females) in the fall and 5.8 km^2 (males) to 6 km^2 (females) in the winter (Stevens and Lofts 1988). Densities of moose can also vary greatly.

Feeding habits: Moose are browsers but will occasionally graze during the summer (Franzman 1978). Although feeding habits can vary greatly, they are generally characterized by heavy use of woody browse from early successional sites such as is found during the early stages after disturbance (Franzman 1978). In the winter, they will feed on mainly low quality woody browse but will feed on non-woody vegetation if it is available (BCMoE SA-M). During the spring and summer, they feed more selectively then in winter but feed primarily on leaves of woody plants. In BC preferred browse includes willows, red osier dogwood, saskatoon, aspen (*Populus tremuloides*), high bush cranberry (*Viburnum edule*), bog birch (*Betula glandulosa*), lodgepole pine (*Pinus contorta*), paper birch (*Betula papyrifera*) and mountain ash

(*Sorbus sitchensis*) (BCMoE SA-M). Species specific browse may occur preferentially depending on its height and accessibility.

Range use

Life Requisites

General: Moose are generally found in semi-open forest with abundant browse as well as floodplains of major rivers, riparian areas of streams and lakes, wetlands, regenerating burns and cutblocks and early successional avalanche chutes with abundant shrubs (BCMoE SA-M). In BC they also seem to prefer successional stages dominated by deciduous trees and shrubs. Forage and climate are considered the 2 most important variables determining moose distribution (BCMoE SA-M). Winter range is usually restricted to elevations lower than 900m and is critical to moose survival; the lack of winter range can be a limiting factor in moose populations (BCMoE SA-M). Moose have the ability to adapt to varied vegetation but are greatly dependant on key shrub species in winter such as: willows, falsebox (*Pachistima myrsinites*), balsam (*Abies spp*.), serviceberry (*Amelanchier alnifolia*), paper birch, and mountain ash (*Sorbus spp*.) (Singleton 1976). They may also feed on red-osier dogwood (*Cornus stolonifera*), red cedar regeneration, *Vaccinium spp*., alder, cottonwood (*Populus balsamifera ssp. trichocarpa*), paper birch, and aspen (Peek 1974; Petticrew and Munro 1979). Winter range may include forested areas adjacent to either natural openings or recently disturbed sites such as clearcuts or fires. The structural stage is important as it is related to the amount of available shrubs and winter browse. Clearcuts 10-20 years old often have these characteristics (BCMoE SA-M). Areas of high value winter habitat can be described as having > 30%-50% shrub cover, mature tree density of <200 stems/ha and gentle slopes of <7% (Romito et al. 1996; VanDyke 1995). Preferred winter habitat is riparian habitat on the floodplains of major rivers, riparian shrub thickets on tributaries, or low elevation regenerating burns on warm aspects (BCMoE SA-M).

Forage: Ideal spring habitat for moose is considered to be south facing, deciduous leading stands which provide relatively open conditions and abundant preferred forage (BCMoE SA-M). In the spring they feed on aquatic vegetation and forage primarily in areas that have early green-up. In the summer, the amount of woody browse is decreased and the amount of succulent vegetation such as aquatic macrophytes increases. Much of the summer is spent around wetlands such as shallow ponds and small lakes where aquatic vegetation is accessible. Not all wetlands provide similar life requisites for moose, and the capability of a wetland to produce aquatic macrophytes and preferred browse depends on substrate, pH, soil temperatures and flow rates (Fraser et al. 1984). Adair et al. (1991) state that small lakes 1-5ha in size with organic bottoms, slow streams and beaver ponds are most likely to produce this habitat. Willow and horsetail (*Equisitum spp*.) are considered the most important terrestrial species consumed by moose in the summer (Peek 1974; Singleton 1976). Other terrestrial browse used by moose in the summer is: swamp birch (*Betula glandulosa*), include red-osier dogwood, highbush cranberry, trembling aspen, saskatoonberry, and twinberry (BCMoE SA-M). In central BC, the area of highest summer use is thought to be the ESSF biogeoclimatic zone, in particular, areas with low slopes, seepages and standing water, and other upper elevation sites described as climax timberline communities of birch and willow combined with heath and forbs interspersed with sub-alpine forest (LeResche et al. 1974; Modaferri 1992). Peek (1974) states that the use of any particular browse is contingent on season of use, population density as well as, abundance and distribution of the browse species. Winter habitat is described in the sections below.

Cover from thermal extremes: In summer, moose will often immerse in water to stay cool but shaded forest is considered more important; structure and species does not seem as important as a canopy closure of at least 60% (BCMoE SA-M). In winter, as snow depth increases, thermal cover becomes more important. It is suggested that the most effective habitat for snow interception is low elevation, south exposure with a minimum of 65% canopy closure (Nyberg 1990) although too much canopy closure restricts light to the understory. During periods of heavy snow accumulation most foraging occurs within

80m of cover (Hamilton et al. 1980). During periods of high wind chill, shelter is important; this may be topographic or small coniferous stands that are low enough density to allow solar radiation to penetrate (Forbes and Théberge 1993).

Security: Security habitat is most vital during calving and usually consists of islands and gravel bars on floodplains or areas of dense growth of shrubs or mature white spruce-poplar stands with a minimum of dense understory. Cows and calves require landscape features adjacent to water for escape from predators. They also may use dense stands of deciduous or tall shrubs with a canopy cover of at least 50% (BCMoE SA-M). In the summer and fall, moose may also use coniferous and mixed forest, shrubs in riparian habitat and thickets of willow on plateaus. Winter security cover is often in dense coniferous forest adjacent to foraging habitat (BCMoE SA-M).

Interaction with agents of disturbance/competition

Disturbance factors: no specific information available for large-scale disturbances such as MPB. There is potential for loss of cover in high-quality wetland complexes.

Competitors: Deer will compete with moose for browse. In addition, in times of food shortage elk will also compete for food resources (McMillan 1953). However, moose are adapted to a niche where there is minimal competition from other ungulates (Blood 2000c).

Mortality factors

The main natural causes of death in moose are from predation and starvation (Blood 2000c). During severe winters with deep snow cover moose are in poor condition and the most common cause of death is starvation or wolf kill. Black bears are a significant predator on newborn calves and grizzly bears will also predate on moose from spring to fall. In some areas, cougars may also predate on moose. Although not common, moose may also succumb to heavy tick infestations when they are weakened by malnutrition. Moose are also killed by humans through hunting, poaching and accidents with vehicles and trains (Blood 2000c).

Potential limiting factors and threats

Predation is a major regulating factor for moose populations (Gasaway et al. 1992; Ballard 1992). Other limiting factors of moose populations may be food availability, snow accumulation, and hunter access (Dussault et al. 2005). A study in Ontario indicated that if hunter access increased in conjunction with landscape disturbance, moose density decreased; density increased if disturbance occurred without hunter access (Rempel et al. 1997).

Winter range is usually restricted to elevations lower than 900m and is critical to moose survival. Lack of adequate winter range can be a limiting factor in moose populations (BCMoE SA-M).

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Appendix A – Species Status Categories

Table A-1. Federal COSEWIC species status categories.
Source: URL: http://www.cosewic.gc.ca/eng/sct0/assessment_process_e.cfm#tbl5.

Status Category	Description
Extinct (X)	A wildlife species that no longer exists.
Extirpated (XT)	A wildlife species no longer existing in the wild in Canada, but occurring elsewhere.
Endangered (E)	A wildlife species facing imminent extirpation or extinction.
Threatened (T)	A wildlife species likely to become endangered if limiting factors are not reversed.
Special Concern (SC)	A wildlife species that may become a threatened or an endangered species because of a combination of biological characteristics and identified threats.
Data Deficient (DD)	A category that applies when the available information is insufficient (a) to resolve a wildlife species' eligibility for assessment or (b) to permit an assessment of the wildlife species' risk of extinction.
Not At Risk (NAR)	A wildlife species that has been evaluated and found to be not at risk of extinction given the current circumstances.

Table A-2. Provincial (BC) species status categories.
Source: URL: http://www.env.gov.bc.ca/atrisk/red-blue.htm

List	Description
Red List:	Includes any ecological community, and indigenous species and subspecies that is extirpated, endangered, or threatened in British Columbia. Extirpated elements no longer exist in the wild in British Columbia, but do occur elsewhere. Endangered elements are facing imminent extirpation or extinction. Threatened elements are likely to become endangered if limiting factors are not reversed. Red-listed species and sub-species have- or are candidates for- official extirpated, endangered or threatened Status in BC. Not all Red-listed taxa will necessarily become formally designated. Placing taxa on these lists flags them as being at risk and requiring investigation.
Blue List	Includes any ecological community, and indigenous species and subspecies considered to be of special concern (formerly vulnerable) in British Columbia. Elements are of special concern because of characteristics that make them particularly sensitive to human activities or natural events. Blue-listed elements are at risk, but are not extirpated, endangered or threatened.
Yellow List	Any indigenous species or subspecies (taxa) which is not at risk in British Columbia. The Conservation Data Centre tracks some Yellow listed taxa that are vulnerable during times of seasonal concentration (e.g., breeding colonies).