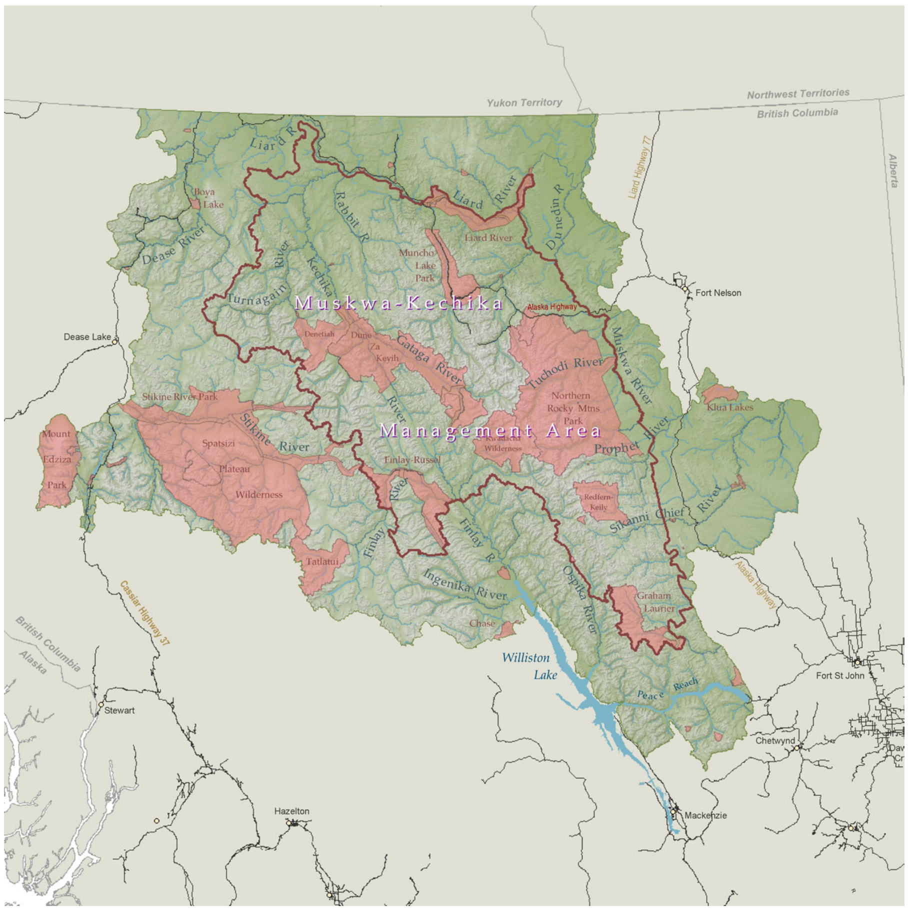
CONSERVATION AREA DESIGN
for the
MUSKWA - KECHIKA MANAGEMENT AREA
(MKMA)



Volume 1: Final Report

Kim Heinemeyer, Rick Tingey, Kristine Ciruna, Tom Lind, Jacob Pollock, Bart Butterfield, Julian Griggs, Pierre Iachetti, Collin Bode, Tom Olenicki, Eric Parkinson, Chuck Rumsey and Dennis Sizemore

July 31, 2004

Nature Conservancy of Canada
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LIST OF ACRONYMS

AMA: Access Management Agreement
BCR: Bird Conservation Region
BEC: Biogeoclimatic Ecosystem Classification
BEI: Broad Ecosystem Inventory
BLM: Boundary Length Modifier
BPPT: Besa Prophet Pre-Tenure Plan
BTM: Baseline Thematic Mapping
CAD: Conservation Area Design
CERI: Craighead Environmental Research Institute
COSEWIC: Committee On the Status of Endangered Wildlife In Canada
CSCA: Connectivity-Secondary Core Area
DEM: Digital Elevation Model
DFO: Department of Fisheries & Oceans Canada
EDU: Ecological Drainage Unit
ELU: Ecological Landscape Unit
FIP: Forest Inventory Project
FISS: Fisheries Information Summary System
FRPA: Forest and Range Practices Act
GIS: Geographic Information System
GPS: Global Positioning System
IAMC: Integrated Agency Management Committee
ITG: Inventory Type Group from FIP
LRMP: Land and Resource Management Plans
MELP: British Columbia Ministry of Environment, Lands and Parks (now BC Ministry of Water, Land and Air Protection)
MKAB: Muskwa-Kechika Advisory Board
MKMA: Muskwa-Kechika Management Area
MOF: British Columbia Ministry of Forests
MSRM: British Columbia Ministry of Sustainable Resource Management
MWLAP: British Columbia Ministry of Water, Land and Air Protection
NTS: National Topographic Series
PCA: Primary Core Area
PEM: Predictive Ecosystem Mapping
PU: Planning Unit
PVA: Population Viability Analysis
RBI: Relative Biodiversity Index
RIC: British Columbia Resources Inventory Committee
SMZ: Special Management Zones
TIEK: Traditional and Indigenous Ecological Knowledge
TEM: Terrestrial Ecosystem Mapping
TRIM: Terrain Resource Information Management
UNBC: University of Northern British Columbia
VRI: Vegetation Resources Inventory

EXECUTIVE SUMMARY

INTRODUCTION AND BACKGROUND

The Muskwa-Kechika Management Area

The Muskwa-Kechika Management Area (MKMA) is an area of 63,000 km^2 (6.3 million hectares) lying in north-eastern British Columbia. This area of the Northern Rockies is one of North America's last remaining large wilderness areas south of the 60^{th} parallel. The MKMA was established through three Land and Resource Management Plans (LRMPs) for the Fort St. John and Fort Nelson areas in 1997 and Mackenzie LRMP in 2001. The management intent for the area, as articulated in the Muskwa-Kechika Management Area Act is,

> *to maintain in perpetuity the wilderness quality, and the diversity and abundance of wildlife and the ecosystems on which it depends while allowing resource development and use in parts of the Muskwa-Kechika Management Area designated for those purposes including recreation, hunting, trapping, timber harvesting, mineral exploration and mining, oil and gas exploration and development.*

The MKMA is comprised of a mosaic of protected areas totaling approximately 1.7 million hectares (ha) or 27% of the area. Special management zones and special wildland zones, where various forms of resource development are permitted, total approximately 4.6 million ha, or 73% of the area. Access to the area is managed under a special permitting arrangement. The Muskwa-Kechika lies within the traditional territory of the Kaska Dena First Nation, Tsay Kay Dena, and Treaty 8 Nations, including the Halfway River, Prophet River, and Fort Nelson First Nations.

Project Rationale and Objectives

One of the key challenges for the MK Advisory Board was articulating a vision for the future of the MKMA that would guide the pace, scope and intensity of resource development in such a way that wilderness and wildlife values could be maintained. To inform these discussions, in 2001, the MK Advisory Board initiated a Conservation Area Design scoping project to explore the potential for a regional assessment of conservation values across the MKMA. Following this scoping study, the usefulness of a CAD was confirmed and a contract request for proposals released, which included the following deliverables:

- a key conservation biology Toolkit to assist in on-going planning and management issues, and a framework for developing direct links between regional and landscape-level objectives;
- a tool to provide strategic information to ongoing government planning processes, for example, pre-tenure planning for oil and gas development; and,
- a dynamic modeling element that can examine changes to the landscape over time, whether through natural or human developments.

In October 2002, a team led by Nature Conservancy Canada together with Round River Conservation Studies and Dovetail Consulting Inc. was awarded the contract. The MK CAD project was launched in January 2003 and was completed in August of 2004.

Regional-Scale Conservation Planning

Measuring success at maintaining long term ecological functions and biodiversity in any region has proven difficult and elusive, but in recent years the following four goals have become central to most regional conservation strategies and conservation area designs endorsed and/or developed by government agencies and conservation organizations:

1.1. Represent, in a system of protected areas, all native ecosystem types and seral stages across their natural range of variation.
1.2. Maintain viable populations of all native species in natural patterns of abundance and distribution.
1.3. Maintain ecological and evolutionary processes, such as disturbance regimes, hydrological processes, nutrient cycles, and biotic interactions.
1.4. Design and manage the system to be resilient to short-term and long-term environmental change and to maintain the evolutionary potential of lineages.

The MK CAD Project Team has made use of three types of information to provide the foundation of the design: focal species analyses, coarse-filter ecosystem analyses, and fine-filter special elements analysis. A critical addition to this suite of analysis is the explicit consideration of connectivity across landscapes for the maintenance of demographic and genetic exchange between wildlife populations. Supplementing this information is a human use analysis which maps linear, point, and area features associated with human developments in order to provide an index of landscape condition. These surrogates allow for the preferential selection of less disturbed areas for conservation purposes.

It is also important to note that as a coarse-scale regional assessment, the MK CAD is not intended to offer detailed guidance for site-level or operational management of either protected areas or the landscape matrix. Such guidance is better provided through project planning and design. The MK CAD, like other regional conservation assessments, takes a macroscopic view of the region, and is useful for 1) highlighting areas of regional biological significance; 2) portraying the spatial pattern of high conservation value sites on a broad scale; 3) illuminating the landscape context of these sites; 4) assessing the conservation needs of wide-ranging (i.e., "regional-scale" and "coarse-scale") species; and 5) identifying priorities for further, more detailed, research at finer spatial resolution. The MK CAD analyses and results incorporate precautionary levels of goal-setting, but we also highly recommend that all the landscapes of the Muskwa-Kechika be managed for conservation of biodiversity, regardless of CAD designations.

Study Area Description

The Project Team has used the British Columbia ecosection classification system to delineate a study area that incorporates all ecosections that intersect the MKMA. The northern study area boundary is delimited by the BC-Yukon boundary, as some ecosections that intersect the MKMA continue into the Yukon, where data were not available to the Team within the constraints of the project. This 16.2 million hectare study area provides the opportunity for regional analyses that will link the MKMA to surrounding, ecologically-similar areas.

According to the BC ecoregional classification system, the study area overlaps with portions of three separate ecoprovinces. The Northern Boreal Mountains ecoprovince makes up the majority of the study area, but the very western edge of the Taiga Plains ecoprovince includes the eastern slopes of the MKMA's front ranges, while the SubBoreal Interior ecoprovince overlaps with the southeastern boundary of the study area. The study area is dominated by three biogeoclimatic zones: the Spruce-Willow-Birch Zone occurs throughout the high valleys and middle slopes of mountain ranges, Alpine Tundra Zone occurs throughout the upper slopes of most mountains, while the Boreal White and Black Spruce Zone occurs throughout the valley bottoms, foothills and extensive plains. In the southern extent of the study area, the Engelmann Spruce - Subalpine Fir Zone of the SubBoreal Interior Ecoprovince occurs on the middle slopes of valleys, with the Sub-Boreal Spruce Zone dominating the lower slopes.

Average annual temperature is -1 degree Celsius with mean summer temperatures of about 10° Celsius and mean winter temperatures of about -16° Celsius. Mean annual precipitation ranges from 350 to 1,000 mm (or 15 to 40 in). The rugged, high mountains of the Muskwa Ranges trap moisture coming from the Pacific and produce a "rain shadow" effect with notably drier climates along the east-front ranges. Summertime surface heating leads to convective showers which, together with winter frontal systems, result in precipitation amounts that are evenly distributed throughout the year. Outbreaks of Arctic air are frequent during the winter and spring.

CAD ANALYTICAL COMPONENTS

Analytical Framework

The MK CAD is composed of 7 independent analytical components which provide a suite of surrogates for the ecological values and conditions of the study area. These surrogates include models to predict diversity across freshwater and terrestrial ecosystems, models of habitat suitability for freshwater and terrestrial focal species, the collection of occurrences and habitat identification for species of special concern (fine-filter analysis), models reflecting the extent and relative intensity of human uses, and models predicting landscape permeability and connectivity. These components are developed as spatial vector models at 1:20,000 or as grid-based models with 50m cells; all are subsequently summarized into a common analytical framework for integrating into the final Conservation Area Design. Regional distribution and resulting representation of ecological values within the MK CAD is assured through the stratification of analyses by the seven major river systems of the study area. The fundamental unit of analysis for the MK CAD is a 500-ha hexagon Planning Unit (PU).

Human Use Analysis

The human use analysis serves to provide the MK CAD team a regional picture of relative levels of human use and development across the study area. This analysis is not an attempt to quantify direct impacts at any given site, or to measure the ecological significance of any existing or future impact. Rather, we use the human use analysis to guide the selection of ecological sites that have minimal existing human uses in the hopes of minimizing conflicts between development and conservation objectives wherever possible. We used existing government data sources to compile information about the distribution and types of human uses across the landscape. We categorized human use "footprints" as either "linear", "point" or "area" features. Linear features (e.g., roads, trails, cut-lines, etc.) and point features (e.g., buildings, transmission towers, dumps, etc.) were identified using 1:20,000 TRIM data. We used NTS 1:250,000 data to identify area developments, which include agriculture conversions, clear-cut logging and areas tenured for grazing. For each feature, a weighting was applied to reflect relative levels of human use and potential impacts. We calculated the weighted density of each type of feature (linear, point, area) per square kilometre and converted this to z-scores (0-1) within each feature type. The z-scores across different feature types were summed to provide a metric of relative human development and use across the study area. High human use scores within the study area are concentrated in areas of human settlement and natural resource development and the pattern of combined human uses across the study area mirrors the distribution of linear features. This is not surprising: high density road networks are often associated with a diversity of resource development activities..

Terrestrial Ecosystem Analysis

A terrestrial ecosystem classification strives to identify or capture the range of variation in terrestrial system diversity across multiple spatial scales. In the absence of consistent, fine-scale terrestrial habitat classifications across the study area, we predicted the occurrence and distribution of ecological communities through the development of an ecological land unit (ELU) model. The important drivers of ecological variation that should be captured by a terrestrial ecosystem classification include climate, topography, insolation, soil moisture, soil type, vegetation type and vegetation structure. Five environmental variables were used as surrogates for these drivers in the ELU modeling: BEC, land-cover type, vegetation age, slope, and aspect. The variables were combined in a factorial approach to classify potentially unique ecological communities across the landscape.

Based on these variables, we identified nearly 2,000 potentially unique terrestrial types. From this classification, we identified an inclusive suite of 159 umbrella ELU types and a small number of special feature ELU for CAD site-selection representation goals. Data availability and spatial resolution are expected to severely limit the ability of the ELU to predict fine-scale ecological community diversity, and the predictions of the modeling have not been validated or ground-truthed. Within these limitations, the ELU classification provides a compromise in resolution and ecological interpretation for regional-scale analyses and planning.

Freshwater Ecosystem Analysis

Freshwater ecosystem diversity provides a coarse-filter environmental context for aquatic species and communities, and a classification that identifies and maps the diversity and distribution of these systems is a critical tool for comprehensive conservation and resource management planning. The MK CAD freshwater ecosystem analysis included classification of freshwater systems and an additional classification of lake systems. Seventeen abiotic variables were used to delineate freshwater ecosystem types. These variables provide surrogates the major abiotic drivers of freshwater systems, and include: drainage area, underlying biogeoclimatic zone and geology, stream gradient, accumulative precipitation yield, air temperature, dominant lake / wetland features, glacial connectivity, channel morphology, valley flat width, K factor, ecosection, maximum stream order and magnitude, hydrologic zone, and Melton’s R. Six abiotic variables were used to capture the major abiotic drivers of lakes: surface area, shoreline complexity, drainage network position, hydrologic connectivity, biogeoclimatic zone, and underlying geology. Stikine, Upper Liard, Lower Liard, Upper Peace, and Lower Peace drainages collectively consist of 5,679 freshwater systems that were classified into 49 freshwater system types. There are a total of 26,764 lakes within the study area that were classified into 140 types.

Terrestrial Focal Special analysis

We selected the following suite of 7 terrestrial focal species whose habitats characterize the landscape diversity of the MK CAD study area: grizzly bear, gray wolf, mountain goat, northern caribou, moose, Rocky mountain elk, and Stone’s sheep. Species were selected based on their umbrella characteristics, sensitivity to potential development impacts in the study area and availability of ecological information and data suitable for modeling habitat suitability.

Within focal species habitat suitability models, we used ecosection and BEC zones to capture regional and landscape variations in habitat characteristics, VRI and FIP to characterize site-level vegetation, and 50 m digital elevation model to classify slope and aspect. The models do not incorporate influences of human developments (e.g., roads, housing) except where changes in seral stages due to resource development are captured in the vegetation data (e.g., logging cut-blocks may be captured as early seral stage forest). Existing human uses are however incorporated in the selection of species core areas. We followed the BC Resources Inventory Committee (RIC) recommendation in several aspects, developing feeding and thermal/security submodels for growing season and winter season for each ungulate focal species. For grizzly bear, we developed 3 submodels for the growing season, approximately capturing changes in vegetation phenology. We developed a winter model and a growing season model for wolves. The models were developed using a three-part modeling framework. Part I incorporates regional-scale differences across ecosection and BEC types, Part II rates site-specific vegetation based on FIP and VRI and topographic characteristics based 50m DEM; and Part III provides spatially-explicit rules that potentially adjust scoring based on spatial considerations (e.g., juxtaposition of feeding and thermal/security habitats). Additionally Part III provides rules for combining within-season life requisite submodels to create a single model for each season.

All models underwent peer review and internal review; validation using GPS telemetry data and/or winter aerial survey observations was completed for woodland caribou, Stone's sheep, moose, mountain goat and grizzly bear. Results of our models were also compared to other, spatially-limited habitat suitability models developed in the region. Final model scores were standardized 1-100 and 10 equal interval classes are identified, with an additional "nil" class to allow easier interpretation of scores. Habitat scores from the 50 m grid cells were summed across the 500-ha Planning Units. Based on these, we used MARXAN software to select species-specific core areas using a greedy heuristic algorithm. This process incorporates each seasonal species model and existing human uses across the landscape to identify areas with high value habitats for each species.

Aquatic Focal Species

Similar to terrestrial focal species, aquatic focal species are selected to serve as umbrellas for aquatic biodiversity. We selected 2 species that have distinctly different ecological requirements: bull trout and Arctic grayling. The purpose of aquatic focal species modeling is to identify which watersheds in the MK CAD study area are likely to support populations of either of these species. The sequence of modeling steps included identifying pertinent data, mapping observed occurrences, identifying watersheds that are adjacent to observed occurrences, quantifying the physical characteristics of watersheds where a species has typically not been observed, and finally, extending these conclusions to unsampled watersheds.

Bull trout are believed to be absent from 13% of the study area. However, when they are present, they make up 21% of the species occurrences and form an important component of the fish fauna. Sixty-eight percent of the watershed area, but only 45% of the number of watersheds, can be geographically connected to actual observations of bull trout. There are data to suggest that Arctic grayling are absent from 2% of the area of the study area. Arctic grayling form an important component of the fish fauna make up 12% of the species occurrences in this region. Sixty-five percent of the watershed area, but only 39% of the number of watersheds, can be geographically connected to actual observations of arctic grayling.

Using a Principle Components Analysis (PCA), 29 watershed characteristics were compressed down into 3 principle components. These components were used to rank watersheds along axes that capture differences in elevation, size and gradient among watersheds. Each watershed was assigned a value for each of the first 3 PCA components. For each PC, watersheds were first ranked with respect to that component and then divided into 12 bins with equal numbers of watersheds. The relative proportion of watersheds where a species was observed across the range of each PCA habitat descriptor was calculated and used as a score to indicate the relative suitability of watersheds with respect to the habitat variation captured by each PCA. The overall habitat suitability of a watershed was calculated as the mean of the 3 component scores.

The models predict that higher elevation, higher gradient and larger watersheds provide more suitable bull trout habitat. Grayling are much more frequently observed in the warmer, lower-elevation watersheds. Neither bull trout nor grayling are extreme habitat specialists suggesting that a high proportion of the watersheds in this area appear to be capable of supporting populations of one or both of these species. The distributions of the two species are complimentary in that grayling are common in low elevation, warmer watersheds where bull trout are rare or absent.

Fine-Filter Analyses

The fine-filter or special elements approach to conservation planning works in conjunction with the coarse-filter ecosystem analyses and focal species approach. A fine filter helps planners and managers to identify species and plant communities that may not be captured by the umbrella approaches of the CAD, or that are sensitive and/or rare enough that specific identification of examples and occurrences is important and necessary.

An initial list of species considered as special elements was generated by the BC Conservation Data Centre (CDC) and derived from Forest District lists of rare and endangered species. Subsequently, a database was created with information on species and communities obtained from BC CDC, BC Ministry of Forests, Committee On the Status of Endangered Wildlife In Canada (COSEWIC), Partners In Flight, and NatureServe databases; additionally, through a review of BC land use planning documents, ftp sites, and pertinent research. Special element targets were selected in part using expert input.

The special elements database consists of 138 plant and animal targets, with spatial data obtained for 123 of them:

- 1 invertebrate (Lepidoptera)
- 83 plants (58 dicotyledons, 3 filicopsida, 21 monocotyledons, 1 ophioglossopsida)
- 54 vertebrates (12 birds, 9 mammal, 33 fish).

The data on the occurrences of these species are quite limited within the study area.

Also targeted were 17 special features, with spatial data obtained for 12 of them. Special feature selections targeted habitat types for features which may be limited within the region or known to support the identified fine-filter special elements or other rare biodiversity values:

- critical waterfowl habitat
- swamps and marshes ≥10 ha
- swamps and marshes <10 ha
- marsh adjacent to lakes
- marsh adjacent to streams or rivers
- forested riparian
- nonforested riparian
- waterfalls
- hot springs and mineral springs
- grasslands
- lakes with known occurrences of lake trout
- 4 terrestrial ecological land unit types (see Section 4 for description)
- caves and karst features (insufficient data)
- canyons (insufficient data)
- mineral licks (insufficient data)
- Important Bird Areas (insufficient data)
- lakes with early open water in spring (insufficient data)

Target-setting on special element and features was based upon the availability of data.

Permeability and Connectivity Analyses

Explicit consideration of connectivity is required when considering large study areas that will likely support multiple core conservation areas. We represented regional connectivity through three modeling analyses that predict potential movement paths or movement corridors across the extent of the MK CAD study area. We used a least-cost path (LCP) modeling approach for all analyses, such that potential movement paths or corridors were modeled as most cost-effective route connecting two points. The cost of movement was modeled as a combination of relative energetic, risk and behavioural variables, and included measures of total distance, topographic considerations, generalized habitat values, and the avoidance of human development features. Modeling included a regional permeability analysis, the identification of potential Connectivity Areas between Primary Core Areas (see below) and an additional analysis to identify potential linkage areas between Sheep Core Areas. Each modeling approach used a similar LCP approach, with a suite of start/end nodes which were connected across the landscape through least-cost paths. From these paths, individual corridors were identified based on the highest cost "accepted" along the LCP.

The regional permeability analysis included 116 nodes were uniformly distributed across the study area and connected by LCPs, creating 6,670 associated corridors. We combined all corridors to create a permeability value surface for the study area, with cell values representing the number of overlapping corridors. To provide an index of this ecological value, we attributed all 500-ha Planning Units with a Permeability Score, which is simply the average permeability index score of the Planning Unit.

The LCP topography parameters used in the permeability analysis and Primary Core Connectivity Area analysis likely generalize to most species (e.g., high cost of moving up steep slopes), with the notable exception of alpine specialists such as Stone's sheep and mountain goats. Steep slopes are key in defining high value habitat for these species, particularly security habitat. We did additional LCP modeling to predict areas that may provide suitable connectivity areas for these habitat specialists. In the modified LCP model, steep topography represents low cost areas, rather than high cost areas, and we used our sheep habitat suitability model to influence the cost of movement. We used this sheep-based LCP model to identify Sheep Connectivity Areas from every Sheep Core ≥5000 hectares to its three least-cost neighbors. Again, these neighbors could be the closest neighbors (in distance), but in many cases were not. This analysis identified approximately 3.2 million hectares of potential linkage areas for sheep and goats across the region. Planning Units with >50% area classified as corridor were attributed as potential Sheep Connectivity Areas.

Least-cost path analyses have been used in a diversity of efforts to identify species or regional linkages, but the approach should be considered exploratory, as it has received little validation or ground-truthing due to our poor understanding of animal movement and absence of data documenting the selection or use of movement routes or corridors. The predictions provided by our suite of analyses have not been validated or ground-truthed.

CONSERVATION AREA DESIGN

The Conservation Area Design integrates the CAD analytical components to describe the study area according to the following classes:

1) ***Primary Core Areas*** -- areas necessary to represent a minimum of 30% of key conservation targets, including focal species habitat values, terrestrial and aquatic ecosystem diversity and selected fine-filters; and 60% core area for each terrestrial focal species.

2) ***Connectivity-Secondary Core Areas*** -- areas identified to provide linkages between Primary Core Areas and increase overall representation of conservation targets. These areas increase representation of conservation targets to a minimum of 60% for the key conservation targets used for Primary Core Area selection, and 30% minimum representation for all other mapped conservation targets.

3) ***Supplementary Sites*** – Sites with coarse-filter or fine-filter values not captured in Primary Core Areas and Connectivity-Secondary Core Areas due to their small size and isolation, but needed to meet representation goals for rare targets.

Primary Core Area Selection

The selection of core conservation areas forms a cornerstone of CAD classification. Core area selection attempts to meet minimum representation goals for all species and ecosystem targets through the selection of a suite of conservation areas or sites. We used systematic site-selection analyses to assist us in identify core areas; this helps assure that we are identifying areas with high ecological values, and meeting our representation goals with spatial efficiency. A greedy heuristic algorithm was used to identify clusters of sites or Planning Units that meet established representation goals for our conservation targets within each of seven major River Systems, while minimizing cost. Cost is measured by the overall area and length of edge of the selected sites, combined with the human use in the areas. We used 500 ha hexagon-shaped Planning Units (PUs) to minimize area-related bias, and to reduce the edge-area ratio by approximating a circle. Every PU was attributed with the conservation target values contained within it.

The site selection procedures for Primary Core Areas were driven by the goals set for representation of the ecological values of the study area, as described by the focal species, ecological systems and fine-filters. Primary Core Area representation goals were set at 30% for most conservation targets, with a 60% goal for terrestrial focal species core habitats. We removed small, isolated selected sites <5000 ha, and reclassified any gaps internal to selected sites. The identified Primary Core Areas cover approximately 6.2 million hectares and 38.4% of the study area. There are 101 individual Primary Core Areas, ranging in size from 5000 hectares to 1,127,000 hectares. The analysis identified four large Primary Core Areas greater than 500,000 hectares.

Connectivity-Secondary Core Areas and Supplementary Sites

Primary Core Connectivity Areas were combined with additional representation goals to identify Connectivity-Secondary Core Areas. As described above, Primary Core Connectivity Areas identified potential linkage areas between every Primary Core Areas to 3 neighbouring (least-cost) Primary Core Areas. We accounted for the total representation of conservation targets within both the Primary Core Areas and the Primary Core Connectivity Areas, and set representation goals of 60% for key conservation targets (those included in Primary Core Areas selection) and 30% representation goals for the remaining mapped fine-filter targets. We "locked in" the Primary Core Areas and their Connectivity Areas, and used a greedy heuristic algorithm to meet these representation goals.

Connectivity-Secondary Core Areas included all the Primary Core Area Connectivity Areas, as well as any sites adjacent to Primary Core Areas or Connectivity Areas that identified through the greedy heuristic selections to meet our representation goal. Additionally, any sites identified through the greedy heuristic selections that were isolated, but >5000 ha were classified as Connectivity-Secondary Core Areas. Any sites that were isolated and <5000 ha were identified as potential Supplementary Sites, and examined for representation of rare conservation targets. We retained Supplementary Sites that contributed >1% representation of a coarse-filter or fine-filter target within the River System strata.

The resulting Connectivity-Secondary Core Areas cover 5.8 million hectares or 36.4% of our study area, providing both connectivity and representation values to the MK CAD. In addition, we identified 88 Supplementary Sites, ranging in size from 195 hectares to 2500 hectares and covering a total of <65,000 ha.

Conservation Area Design: Results and Discussion

The final identification of CAD classes includes Primary Core Areas, Connectivity-Secondary Core Areas, and Supplementary Sites, and identifies approximately 75% of the study area as either important to meet representation goals or maintain connectivity. Within this 75% of area, representation of conservation targets is quite high, with most targets achieving >75% representation. The efficiency of the solution is notable, given the diverse set of target types, from terrestrial focal species through aquatic freshwater classifications. The MK CAD meets representation goals set on seasonal habitats and core habitats for 7 terrestrial focal species, habitat for 2 aquatic focal species, 159 terrestrial umbrella ecological land unit types, 46 freshwater classes, 140 lake classes, 12 special features and 80 CDC special elements. When stratified by the seven major River Systems, this equates to meeting representation goals for well over 1,000 conservation targets. In addition, connectivity between all Primary Core Areas has been identified, with a minimum of three Connectivity Areas from each Core to adjacent Cores.

The MK CAD identifies 2.7 m ha of Primary Core Area within the MKMA, with represents 42.3% of the MKMA area (Table 10.3). Additionally, there is 2.1 m ha (33.1% of MKMA) of Connectivity-Secondary Core Area and 30 Supplementary Sites covering 16,751 ha in the MKMA. While the analyses identify substantial ecological values within the MKMA, they also indicate that there are substantial conservation or ecological values in the areas surrounding the MKMA (56% of the Primary Core Area falls outside the MKMA). From a regional perspective, the large amount of Primary Core Area found outside of the MKMA indicates the importance of these surrounding landscapes to the maintenance of robust natural systems within the Management Area.

We emphasize the preliminary nature of the CAD products, including analyses and results. The underlying models have yet to be validated, tested or checked for sensitivity to estimated parameters. Additionally, most models are built upon data that also has underlying weaknesses and spatial resolution limitations. Nonetheless, the MK CAD represents a suite of modeling and analytical results that form a strong integrated result, as well as useful stand-alone products that provide insights into specific targeted values across the region. We have engaged extensive peer-reviews for most analyses, and have made concerted efforts to ensure that the models, and the data upon which they are based, represent the best available information sources at the time of the analyses.

GIS TOOLKIT

The MK CAD GIS Toolkit is designed to allow managers, planners, project proponents and other stakeholders convenient access to the CAD analyses in a spatially-explicit and dynamic platform. The GIS Toolkit has three main functional components,

1. Data Access Tool
2. Data Summary and Reporting Tool
3. Scenario Tool

The GIS Toolkit has been designed to allow non-technical personnel access to otherwise sophisticated GIS functions. Particularly useful is the ability to query and summarize the information for user-defined areas, and to put that information within a user or CAD defined larger context (e.g., watershed group, landscape unit, pre-tenure plan area). The Toolkit provides a sophisticated set of development scenario analysis tools which the user can employ to gain insights into the potential regional ecological or environmental effects a particular development or a series of developments may have. The CAD development scenario tool can be used to compare how different potential developments may require modification of Primary Core Areas, Connectivity Area-Secondary Core Areas, and the intervening matrix to maintain biodiversity goals within the study area. It should be noted that the re-analysis undertaken by the development scenario tool of the Toolkit will lack the robustness of the original CAD analysis, and to that extent, the tool serves only as a convenient and relatively immediate means for exploring and comparing data and options. The insights gained through these explorations may then trigger the need for more thorough and comprehensive scientific analysis of preferred options.

The CAD GIS Toolkit is implemented via an ArcGIS-based project which has been modified to ensure that users with minimal computer experience are not overwhelmed by the complexity of the full ArcGIS interface. Our custom analysis tools go beyond the basic GIS functions and allow non-GIS users to perform planning analyses using conservation science and our CAD data. However, the GIS Toolkit retains the full functionality of ArcGIS so that the GIS professionals will not be hampered if they choose to use the Toolkit in concert with more sophisticated GIS functions.

IMPLEMENTATION

While the specific contexts for planning and management in the MKMA continue to evolve, there are several apparent examples of CAD utility for regional managers and stakeholders. The CAD provides a consistent and transparent reference for proponents and agencies across the MKMA and allows planners, managers and regulators to set local areas in regional context. For example, as a reference tool, the CAD can be used to scope values for *Forest Stewardship Plan* development and review, manage strategic access coordination, facilitate review and refinement of park management plans and permitting, and to create the necessary context for overview assessments for Oil and Gas development. Additionally, we would expect the CAD to have particular utility for tracking of changes to the region over time and facilitating monitoring by the Integrated Agency Management Committee (IAMC) and others.

Updates to the CAD should be designed to accommodate on-going consolidation of information regarding landscape scale changes to the MKMA, including the development of new roads and infrastructure, new cut blocks, burn areas etc. We suggest that input from all agencies be collated and reviewed quarterly by the Integrated Agency Management Committee (IAMC) with follow-up CAD updates by MSRM technical staff on an annual or semi-annual basis. These updates would maintain the relevance of the existing CAD data library and would continue to inform scenario development analyses. On a more extended timeframe, refinements to underlying data and field validation efforts should be made part of an ongoing update cycle for each of the CAD analytical components (e.g. focal species models, ELU's). These updates could then trigger a larger re-analysis of the entire CAD. We recommend that re-analysis of the entire CAD occur at a minimum, on a five year cycle.

Even though the MK CAD was developed with detailed input from BC government agencies, we recognize that for the full potential of the CAD to be realized, an introduction to third parties is necessary. We would recommend that such an introduction begin with presentations to First Nations, and other stakeholder groups (e.g., industry associations). This introduction should be followed by the development of a use strategy that creates an interface with other existing management tools, with possible refinements being undertaken to facilitate application by a broader range of users.

While all CAD elements will be stored centrally by the province and remotely accessed by both existing and custom software tools, consideration should also be given on how best to allow third-party access to the analysis and tools. Access could be arranged through license and partnership agreements and/or the distribution of pre-packaged data sets to important MKMA stakeholders such as First Nations.

RECOMMENDATIONS AND NEXT STEPS

The planning team strongly recommends that follow-up be undertaken to continue to improve the robustness of the CAD. This work should include field studies to validate CAD models, as well as the targeted collection of Traditional Indigenous Ecological Knowledge (TIEK) from First Nations to assist in refinement of habitat models and further identification of special elements and features. In order to advance implementation of the CAD, we suggest the design of 1-2 focused pilot studies where development is anticipated within the MKMA (e.g. forestry, oil and gas). Such pilots would facilitate field validation, create opportunities for experimentation with implementation by 3rd parties, and advance discussions around future management models in MKMA. Finally, we recommend that further implementation support be directed toward integration of CAD products with evolving adaptive management, cumulative effects and monitoring approaches.

1 INTRODUCTION AND BACKGROUND

1.1 The Muskwa-Kechika Management Area

The Muskwa-Kechika Management Area (MKMA) is an area of 63,000 km^2 (6.3 million hectares) lying in northeastern British Columbia (Figure 1.1). The MKMA begins at the margins of boreal plains and muskeg to the east and encompasses the foothills and peaks of the Rockies. The area is recognized as being of national and international ecological significance given that it constitutes one of North America's last remaining large wilderness areas south of the 60^{th} parallel where extensive predator-prey systems remain largely undisturbed by human industrial development pressures. Wildlife populations are unparalleled in B.C. and the area boasts mature and old growth forests, spectacular geological formations, lakes, rivers and streams, waterfalls and hot springs, sub-alpine and alpine areas, and wetlands.

1.1.1 Establishment of the MKMA

The MKMA was established in 1997, following the completion of two Land and Resource Management Plans (LRMPs) for the Fort St. John and Fort Nelson areas. In 2001, an additional 19,000 km^2 were added to the MKMA upon completion of the Mackenzie LRMP. Based on the consensus forged at these planning tables, the MKMA was established as a unique mix of protected areas and special management areas where wilderness and wildlife values would be maintained in perpetuity while allowing resource development to occur in some areas and where such development could be undertaken without compromising the overall values that make the MKMA so important.

In 1998, the British Columbia Government also passed the MK Management Area Act (Bill 37-1998) clarifying the legislative foundation for the area, and establishing an Advisory Board, made up of First Nations, industry representatives, conservation interests, local community leaders, guide outfitters, trappers, and recreational users to offer advice and guidance on management of the MKMA. In addition, an MKMA Trust Fund was established providing between $1-$3.4 million per year for research, planning and management, and outreach activities to support the MKMA.[1] The vision statement for the Advisory Board states:

> *"We, the Advisory Board, in partnership with the provincial government, will be stewards of the Muskwa-Kechika Management Area (MKMA).*
> *We will provide direction and leadership in balancing industrial and other human activity with the sensitive management and protection of a vast and unique natural environment.*
> *We will ensure that the fisheries, wildlife and wilderness values of the MKMA will be maintained for countless generations.*
> *In working toward this vision, the Advisory Board will promote and encourage effective and innovative resource management methods, based on the highest quality of research. Through research and funding activities, we seek world class management, monitoring, and mitigation to minimize the human footprint.*
> *Through educational and promotional activities, the Advisory Board will raise awareness about the MKMA's globally significant environmental values, aboriginal and non-native inhabitants, and their cultural histories."*

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[1] Initially under the MK Management Area Act, funding available under the MK Trust Fund was set at $2 million annually, with a further $400,000 available as matching funds from the BC Government. A further $1 million in annual funding was added in 2001 when the MKMA was enlarged following the Mackenzie LRMP. Funding was later reduced to $1 million in committed funding, with an additional $1 million in matching funds.

1.1.2 Planning and Management Context

The management intent for the area, as articulated in the *Muskwa-Kechika Management Area Act* is,

> *"to maintain in perpetuity the wilderness quality, and the diversity and abundance of wildlife and the ecosystems on which it depends while allowing resource development and use in parts of the Muskwa-Kechika Management Area designated for those purposes including recreation, hunting, trapping, timber harvesting, mineral exploration and mining, oil and gas exploration and development."*

The MKMA is comprised of a mosaic of protected areas totaling approximately 1.7 million hectares (ha) or about 27% of the area. Special management zones (SMZs) and special wildland zones, where various forms of resource development are permitted, total approximately 4.6 million hectares. Access to the area is managed under a special permitting arrangement.

Based on the outcomes of the LRMPs, a *Management Plan* for the MKMA was developed in 1997. In addition, under the *MK Management Area Act,* a suite of local strategic plans are required prior to resource development in these special management and wildland zones to guide industrial and non-industrial activities in all areas:

- Oil and gas pre-tenure plans (prior to oil and gas exploration and development);
- Landscape unit objectives (prior to forestry activities);
- Recreation management plan(s);
- Park management plans; and,
- Wildlife management plans.

Most of these local strategic plans were completed by the Spring of 2004.

The *MK Management Area Act* also states that "the long-term maintenance of wilderness characteristics, wildlife and its habitat is critical to the social and cultural well-being of first nations and other people in the area," and that "the integration of management activities especially related to the planning, development and management of road accesses within the Muskwa-Kechika Management Area is central to achieving this intent and the long-term objective is to return lands to their natural state as development activities are completed."

1.1.3 Human Communities and Demographics

The MKMA lies in a remote area and contains no large population centres. However, the MKMA is situated adjacent to the towns of Fort St. John, Fort Nelson; to the south lies Mackenzie, and to the northeast, Watson Lake. Thesmall community of Toad River lies within the MKMA boundaries along the Alaska Highway. The population of the MKMA is estimated to be less than 5,000.

1.1.4 Cultural and Heritage Values

The MKMA has tremendous cultural and heritage significance. Traditionally, and for hundreds of years, the land has been used by First Nations for hunting, gathering and fishing. There are a number of archaeological sites in the area, an historic fur trading route with related trapper cabin sites, the remains of a Hudson's Bay Trading Post, an historic commercial fishery site, a native village abandoned after World War Two, native pack trails, and an old wagon trail.

Part of the Muskwa-Kechika is within the traditional territory of the Kaska Dena First Nation. The Kaska Dena call the area Dena Kéyih (pronounced den-ah key-ah), which means "people's land" in their traditional language. The MKMA is also part of the traditional territories for the Tsay Kay Dena and Treaty 8 Nations, including the Halfway River, Prophet River, and Fort Nelson First Nations.

1.1.5 Economic Development and Future Trends

Currently, economic activity in the MKMA includes subsistence hunting, trapping and gathering by First Nations, some commercial trapping, hunting, outdoor tourism and recreational activities (including hiking, jet-boating, fishing, etc), and guide outfitting.

The MKMA also includes areas which are estimated to contain up to 6 trillion cubic feet (TCF) of gas reserves, in formations extending from the current Western Canada Basin gas fields to the east into the foothills of the Rockies (National Energy Board 2004). Oil and gas activity in the northeast of BC has increased considerably in recent years and together with forestry provides the primary economic driver for the communities of Fort St. John and Fort Nelson. With the completion of pre-tenure plans in 2004 (BC Ministry of Sustainable Resources 2003), it is anticipated that further exploration and development of gas in the MKMA will occur in the coming years. Seismic exploration has already been undertaken in several areas, and some oil and gas development has occurred in the Sikanni area.

The central and western areas of the MKMA are also high in metallic and non-metallic resources. Exploration projects have been established and there is small-scale mining of sand and gravel. Portions of the MKMA also have high timber values, particularly in the Northeast and in the southern area near Mackenzie.

The remoteness of the MKMA has limited industrial development of these natural resources to date. However, with the completion of local strategic plans, and as economic conditions allow with changing commodity prices for metals, gas and timber, economic development is now poised to begin in earnest in the area.

1.2 Project Rational and Objectives

With the establishment of the MKMA and the formation of the Advisory Board, British Columbia created one of the most innovative management models in North America. The MKMA represented an effort to balance the remarkable wilderness and wildlife values of the area with opportunities for resource development, conducted in a manner that respected and accommodated those values, as well as traditional uses by First Nations, other commercial users, and outdoor recreation.

1.2.1 The Challenge: A Vision for the MKMA

One of the key challenges for the MK Advisory Board was articulating a vision for the future of the MKMA that would guide the pace, scope and intensity of resource development in such a way that wilderness and wildlife values could be maintained. This challenge lies at the heart of the management intent for the area, as articulated in the *MK Management Area Act*. The immediate problem faced by all sectors with an interest in the MKMA was to determine what kinds of activities could occur where and under what conditions. The local strategic plans became the principal vehicles through which this challenge was to be addressed.

However, the MK Advisory Board also recognized that the management regime for the MKMA did not provide an overarching framework to address cumulative effects, nor to manage the pace and intensity of development in any particular area. As a result, the combined impact of resource development in Special Management Zones (SMZs) could threaten the overall integrity of the MKMA as a whole and potentially place wilderness and wildlife values at risk.

Since 1998, the MK Advisory Board, working in close collaboration with local resource management agencies, has initiated a suite of research and management projects supported by the MK Trust Fund to fill specific information and knowledge gaps, identify resource values and provide a more complete basis for planning and management decisions in the MKMA.

Considerable progress has been made in several areas over the years, although much remains to be learned.

1.2.2 CAD Scoping Study 2001-2002

In 2001, the MK Advisory Board initiated a scoping project to explore the potential for a regional assessment of conservation values across the MKMA as a whole. Specifically, the Board was interested in an approach that could delineate and prioritize environmentally important areas based on current scientific knowledge, the tenets of conservation biology, and the precautionary principle.

Round River Conservation Studies was contracted during the 2001/2002 fiscal year to explore the potential utility of a Conservation Area Design (CAD) for the MKMA. Although work on this project was in part redirected toward information gathering and assessment to assist with pre-tenure planning, the results of the scoping project clearly demonstrated that a CAD would provide an invaluable tool for understanding the scope and distribution of conservation values across the MKMA, and for linking local level decision-making with strategic planning decisions at the landscape scale.

1.2.3 Project Objectives: CAD for the MKMA

In August 2002, a *Request for Proposals* was issued on behalf of the MK Advisory Board by MSRM for the development of a Conservation Area Design for the MKMA (RFP M-K 2202-2003-02). The description of the project in the RFP states that

> *"the long term challenge faced by the MKMA is to develop a working framework that can link the landscape level objectives and zoning with the on-going environmental processes and development activities to ensure that the wildlife and wilderness conservation goals are met. Land use zoning has already been completed for the MKMA… Under these Land and Resource Management Plans, protected areas have already been established and no additional protected areas designations are planned. However, management strategies may dictate limited resource development within identified areas in the Special Management Zones necessary to fulfill the goals of the MKMA Act… An important step towards achieving the overarching goal of the MKMA is the development of a comprehensive Conservation Area Design (CAD) that delineates and prioritizes environmentally important areas based on current scientific knowledge, the tenets of conservation biology, and the precautionary principle. The purpose of the CAD is to delineate and describe a network of core areas and ecological corridors within the MKMA ecosystem that could enhance the long-term viability of key resident species and major ecosystem processes."*

The deliverables for the MKMA CAD were described as follows:

- a key conservation biology Toolkit to assist in on-going planning and management issues, and a framework for developing direct links between regional and landscape-level objectives;
- a tool to provide strategic information to ongoing government planning processes, for example, pre-tenure planning for oil and gas development; and,
- a dynamic modeling element that can examine changes to the landscape over time, whether through natural or human developments.

In October 2002, a team led by Nature Conservancy Canada together with Round River Conservation Studies and Dovetail Consulting Inc. was awarded the contract. The MK CAD project was launched in January 2003 and was completed in July 2004.

1.3 Regional -Scale Conservation Planning: Background and Approach

1.3.1 Rationale for Regional-Scale Planning

Across British Columbia, managers and scientists are increasingly using landscape-scale analyses to gain insights into the dynamics and conservation of the Province's vast landscapes. This follows a world-wide trend of recognizing the need to think about, and manage for, the maintenance of functioning ecosystem processes and populations across appropriately large regions (Soulé and Terborgh 1999; Howard, Davenport et al. 2000; Hawkins and Selman 2002; Jepson, Momberg et al. 2002; Pfab 2002; Wisdom, Wales et al. 2002). Planning for the maintenance of landscape functions and species across broad regions is particularly important in regions such as northern British Columbia, where ecosystem richness and productivity are maintained through large-scale disturbance regimes (e.g., fire; Bunnell 1995; Segerstrom 1997) and other natural processes (e.g., hydrologic systems; Pringle 2001). Additionally, in systems with relatively low productivity (e.g., boreal forests), some species, particularly large mammal species (e.g., grizzly bear, caribou, and wolf), have evolved life-history strategies that require extensive landscapes to meet seasonal and annual life requisites for food and breeding. Additionally, maintaining ecologically effective populations of these species also may be key to the maintenance of community dynamics and complexity over the long term (Berger, Stacey et al. 2001; Soulé, Estes et al. 2003).

While the need for biodiversity conservation and planning has long been recognized, few areas are actually managed *primarily* for this purpose. Moreover, the location, size and juxtaposition of these existing biodiversity reserves are often based on political factors rather than consideration of the needs for conservation. For example, most protected areas in Canada and the United States are located in alpine or sub-alpine zones and are usually too small and isolated to maintain viable populations of certain species, particularly wide-ranging animals such as carnivores. This becomes particularly true when human use or populations increase in the surrounding landscapes, creating conflict between people and wildlife (Newmark 1996; Woodroffe and Ginsberg 1998; Brashares, Arcese et al. 2001; Parks and Harcourt 2002; Brashares 2003). Increasing human use and population translate into an increasing need for larger and better connected protected area systems. Within British Columbia's own protected area system, 75% of the parks are less than 1000 hectares in size with the majority in alpine or sub-alpine zones resulting in the lower elevation, more productive ecosystems, being grossly under-represented (Lewis and Westmacott 1996; Sanjayan and Soulé 1997).

Gaps in ecosystem representation are by no means a purely U.S. or Canadian phenomenon. Lack of protection for the full suite of biodiversity is increasingly recognized in many countries and regions, as is the small size of many protected areas. For instance, investigations in Indonesia have shown many ecological communities to be under-represented and under-protected (Jepson, Momberg et al. 2002). Furthermore, re-assessment of the reserve system in southeast Mexico has revealed major ecosystem types also to be under-represented, and important connectivity considerations to be lacking (Galindo-Leal, Fay et al. 2000). The existing protection of Africa's biodiversity has also recently received critical attention by several researchers and conservation biologists (e.g., Heydenrych, Cowling et al. 1999; Howard, Davenport et al. 2000; Brooks, Balmford et al. 2001; Fairbanks, Reyers et al. 2001).

Worldwide, conservation scientists have become increasingly engaged in assisting conservation organizations and governments striving to meet their regional conservation missions. Measuring success at maintaining long-term ecological functions and biodiversity in any region has proven difficult and elusive. Therefore, to provide more tangible measures of success scientists have proposed sets of conservation and management goals. Noss (1992) and Noss and Cooperrider

(1994) stated four goals of regional conservation to be satisfied to achieve the overarching mission of maintaining biodiversity and ecological integrity, into perpetuity. These goals are:

1. Represent, in a system of protected areas, all native ecosystem types and seral stages across their natural range of variation.
2. Maintain viable populations of all native species in natural patterns of abundance and distribution.
3. Maintain ecological and evolutionary processes, such as disturbance regimes, hydrological processes, nutrient cycles, and biotic interactions.
4. Design and manage the system to be resilient to short-term and long-term environmental change and to maintain the evolutionary potential of lineages.

These four goals are often cited and have become central to most regional conservation strategies and conservation area designs endorsed and/or developed by government agencies and conservation organizations. For example, the BC provincial government (1993) stated that the first goal of its protected area strategy is "to protect viable, representative examples of natural diversity in the province, representative of the major terrestrial, marine and freshwater ecosystems, the characteristic habitats, hydrology and landforms ... of each ecosection". Further, the provincial government recommended in its Forest Practices Code (British Columbia 1995) that an ecosystem management approach be adopted to provide adequate habitat and to sustain genetic and functional diversity in perpetuity for all native species across their historic ranges, along with the maintenance of ecological processes. The BC government has increasingly embraced regional, science-based planning as the foundation for its land management. For example, in the central and north coast regions of BC, where conflict between the timber industry and environmental concerns has stalled land use decisions, the BC government, timber industries and environmental organizations have agreed to jointly cooperate and support a regional-scale, science-based conservation area design developed by a coalition of independent scientists (www.citbc.org).

It is also important to note, that as a coarse-scale regional assessment, the MKMA CAD is not intended to offer detailed guidance for site-level or operational management of either protected areas or the landscape matrix. Such guidance is better provided through ecosystem-based management and site-level planning and design. The MKMA CAD, like other regional conservation assessments, takes a macroscopic view of the region, and is useful for 1) highlighting areas of regional biological significance; 2) portraying the spatial pattern of high-value sites on a broad scale; 3) illuminating the landscape context of these sites; 4) assessing the conservation needs of wide-ranging (i.e., "regional-scale" and "coarse-scale") species; and 5) identifying priorities for further, more detailed research on finer spatial scales. For a comprehensive assessment of conservation and management needs, regional-scale planning should be followed by progressively more detailed research and planning at landscape, watershed, and local scales.

1.3.2 Uncertainty, Stochasticity and the Precautionary Principle

Conservation biologists and natural resources managers must allow for uncertainty inherent in limited data. Additionally, since natural systems are inherently stochastic and unpredictable, considering and incorporating natural stochasticity must be an integral part of developing a conservation area design. The "precautionary principle" forwards that the uncertainty in managing natural systems should be explicitly acknowledged and managers should make every effort to err on the side of caution (Raffensperger and deFur 1999; deFur and Kaszuba 2002; Van Den

Belt and Gremmen 2002). The Preamble to the international Convention on Biological Diversity[2] provides a definition of the "biodiversity precautionary principle" as :

> *"…where there is a threat of significant reduction or loss of biological diversity, lack of full scientific certainty should not be used as a reason for postponing measures to avoid or minimize such a threat."*

Given the finality of extinction, conservation planning should incorporate wide margins of safety against the potential loss of organisms, populations or ecological processes. In particular, biodiversity conservation plans must carefully consider the consequences of further human impact and loss of natural habitat, even when no obvious role or effect on the ecosystem has been empirically described. In other words, the absence of ecological data does not equate with the absence of ecological importance. The MKMA CAD analyses and results incorporate precautionary levels of goal-setting, but we also highly recommend that all the landscapes of the Muskwa-Kechika be managed for conservation of biodiversity, regardless of CAD designations.

1.3.3 Elements of Conservation Area Design

A number of increasingly sophisticated techniques are being applied to regional conservation area designs. Many represent technological or theoretical advancements in our attempts to model and predict the fundamental dynamics and diversity of the landscapes; most attempt to optimize the amount of information gleaned from sparse data, and rely on computer-intensive and GIS-based approaches. Regardless of the techniques, many recent landscape conservation planning efforts rely upon three types of information to provide the foundation of the design: focal species analyses, coarse-filter ecosystem representation analyses and fine-filter targets (special elements), as described by Noss et al. (1999). The combination of these analyses provides complementary information sources that should increase the robustness of the design as compared to the use of a single information source. A critical addition to this suite is the explicit consideration of connectivity across landscapes for the maintenance of demographic and genetic exchange between populations, as well as the maintenance of ecosystem and landscape processes (Taylor, Fahrig et al. 1993; Dobson 1999; Hoctor, Carr et al. 2000).

1.3.3.1 Special Elements

The special elements approach typically results in the mapping of hotspots and other biologically or ecologically important areas that are recommended for protection above other areas. Hotspots usually are based on concentrations of species (usually rare or endemic taxa) and can be recognized on a variety of spatial scales, from local to global (e.g., see Myers et al. 2000). Identified hotspots of species richness or endemism, and any other priorities based on special elements are only as reliable as the underlying data and in most cases, including the majority of British Columbia and the rest of Canada, biological surveys are spotty at best. Areas that show up as "cold spots" could either be areas where species richness or endemism is truly low or they could simply be areas that were never surveyed. In some cases, modeling is used to predict the distribution of special elements, particularly rare or highly productive habitat types that likely support high levels of biodiversity (e.g., riparian habitats).

The fine-filter approach works well for plants and small-bodied animals, especially in regions where biodiversity databases (e.g., Conservation Data Centres) are reasonably complete. It is not as well suited for large-bodied or wide-ranging animals, such as grizzly bears, salmon or northern goshawks, whose needs cannot be effectively captured by occurrence data. In all cases, the fine filter is dependent on reasonably comprehensive, or at least well-distributed, biological

[2] Preamble to the Convention on Biological Diversity can be accessed at: http://www.biodiv.org/convention/articles.asp

surveys to be most useful. But, despite the fact that surveys are not comprehensive for most of Canada, to neglect areas known to support an identified special elements simply because survey data across the region in question are incomplete would be foolhardy. A precautionary approach would protect known hotspots and special element occurrences. Hence, the fine filter remains valuable (indeed necessary, if not sufficient) even in relatively poorly surveyed regions.

1.3.3.2 Ecosystem Representation

Given that species distributions are determined largely by environmental factors, such as climate and substrate, and that vegetation and other species assemblages respond to gradients of these factors across the landscape, protecting examples of all types of vegetation or physical environmental classes should capture the vast majority of species without having to consider those taxa individually (Noss and Cooperrider 1994). It has been estimated that 85-90% of all species can be protected by this coarse-filter approach (Noss 1987). Testing this optimistic assumption empirically is difficult, as doing so would require a reasonably complete inventory of all taxa, including cryptic organisms such as bacteria and small invertebrates, sampled over a broad area. In Victoria, Australia, vegetation classes represented birds, mammals, and trees fairly well, but performed poorly for reptiles and invertebrates (MacNally 2002). In regions with relatively low endemism, such as most of Canada, the coarse filter approach is predicted to perform better than in regions with high endemism, where species populations are highly localized (Noss and Cooperrider 1994).

Representation assessments typically rely on vegetation (often mapped by remote sensing, as in the U.S. Gap Analysis Program) (often mapped by remote sensing, as in the U.S. Gap Analysis Program; Scott, Davis et al. 1993), surrogate taxa (e.g., vertebrate species richness, also used in Gap Analysis), abiotic environmental classes (e.g., landforms, habitat classes defined by soils or geology), or some combination of biological and physical factors (e.g., ecological land units) as proposed coarse filters. Increasing evidence suggests that a combination of biological and abiotic data, as in ecological land units, provides a more secure basis for representation than either class alone (Kirkpatrick and Brown 1994; Kintsch and Urban 2002; Noss, Carroll et al. 2002; Groves 2003; Lombard, Cowling et al. 2003).

A similar coarse-filter analysis can be undertaken for freshwater ecosystems, providing a classification that identifies and maps the diversity and distribution of freshwater systems and a tool for comprehensive conservation and resource management planning. While freshwater communities have not been identified in most places, and there is generally a lack of adequate survey data for freshwater species, the range of variability of freshwater system types can be characterized using combinations of physical habitat and environmental regimes that potentially describe unique freshwater ecosystem and community types.

1.3.3.3 Focal Species

Although conservation planning for all biodiversity is desirable, it would be impossible (and possibly counterproductive) to determine and manage for the ecological needs of every species in a region (Franklin 1993; Poiani, Richter et al. 2000). As an alternative, researchers have suggested the identification of a suite of focal species to guide conservation planning (Lambeck 1997; Miller, Reading et al. 1998). Focal species are selected such that their protection, as a group, would concurrently protect all or at least most remaining native species. Planning for the maintenance or restoration of healthy populations of multiple focal species can provide a manageable set of objectives for identifying and prioritizing areas, and for determining the necessary size, location and configuration of conservation areas. Focal species monitoring can also be a useful tool in judging the effectiveness of the conservation plan once implemented.

Using a diverse suite of focal species should provide umbrella protection for a broader array of biodiversity than the selection of a single focal species or guild. For example, Kerr (1997) points out that using only carnivores for conservation area selection fails to protect a number of invertebrates. Similarly, an analysis of the umbrella function of grizzly bears in Idaho found that protection of grizzly bears in Idaho would protect 71% of other mammalian species, 67 % percent of birds, and 61 % of amphibians, but only 27 % of native reptiles (Noss 1996). It is now generally accepted that a suite of focal species should be selected, and these species-specific analyses combined with other approaches, such as coarse-filter representation analyses and special elements filters (Noss, Strittholt et al. 1999; Poiani, Richter et al. 2000; Margules, Pressey et al. 2002; Reyers, Fairbanks et al. 2002).

Given the central role of focal species planning to current landscape planning efforts, much thought has gone into providing guidance to focal species selection. Below, some key characteristics that are broadly used in focal species selection are discussed.

> Keystone Species are those that play a disproportionately large role (relative to numerical abundance or biomass) in ecosystem function (Mills, Soulé et al. 1993; Power, Tilman et al. 1996; Miller, Reading et al. 1999; Collen and Gibson 2001). The influences of keystone species can occur through a variety of interactions and processes including competition, mutualism, dispersal, pollination, disease and by modifying habitats and abiotic factors. The loss of keystone species can trigger changes in relative abundance and distribution (including local extinction) of many other species present in an ecosystem (Rosell and Parker 1996; Terborgh, Estes et al. 1999; Berger, Stacey et al. 2001; Soulé, Estes et al. 2003).
>
> Umbrella species are those that require significant conservation protection, such that successful maintenance of umbrella species requirements will ensure the conservation of many other native species. Umbrella species typically have large area requirements and cover large areas in their daily or seasonal movements, and/or require a diversity of habitats to meet their life requisites (Noss, Quigley et al. 1996; Lambeck 1997; Carroll, Noss et al. 2001; Caro 2003). In general, an umbrella species approach is suited to answering the questions of how much land is necessary in a conservation area network and how that land should be configured.

1.3.3.4 Connectivity

Explicit consideration of connectivity is required when considering large study areas that will likely support multiple core conservation areas. A primary consideration in the selection of the MK CAD study area boundaries was to more effectively account for regional connectivity or movement across the MKMA boundaries (see Section9). Maintenance of ecological linkages is critical to the long term viability of all species, as well as key ecological processes across the larger region. The value of connectivity is reviewed in several publications (e.g., Andreassen, Fauske et al. 1995; Collinge 1996; Beier and Noss 1998). Regional connectivity can be represented through predictions of potential generalized wildlife movements across the study area. These predictions should capture wildlife movements that tend to be determined by considerations related to topography modified by security concerns; they will not capture the movements of species such as sheep or goats which use topography for security. Modeling the potential for movements of these alpine specialists was undertaken to account for their specialized use of terrain features.

1.4 Figures

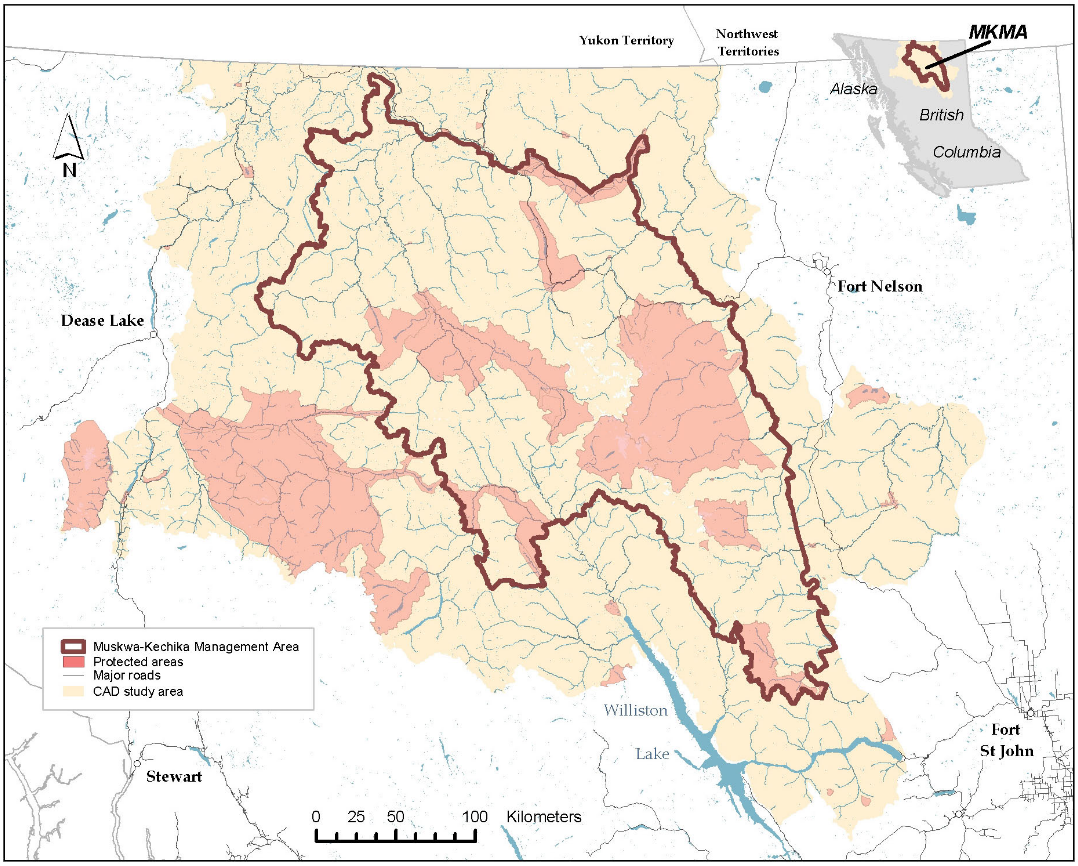


Figure 1.1 The Muskwa-Kechika Management Area.

2 STUDY AREA DESCRIPTION

2.1 Study Area Boundary

Ecoregional definitions are often used to delineate boundaries for conservation design and planning (Groves 2002). One advantage of an ecoregional approach is that it can place any landscape feature in a local, regional or global context. The MKMA spans a number of ecoregions, some of which extend into the Yukon and Northwest Territories, limiting the availability of uniform spatial data for all the ecoregions that intersect the MKMA. Given data and time limitations, the Project Team has used the British Columbia Ecoregion Classification System to delineate a study area that incorporates all ecosections that intersect the MKMA. The northern study area boundary is delimited by the BC-Yukon boundary, as some ecosections that intersect the MKMA continue into the Yukon, where data were not available to the Team within the constraints of the project. A small area of the Simpson Upland ecosection is included in the study area; this small area does not intersect the MKMA, but does encompass a very small area of BC at the border with the Yukon. This study area definition provides the opportunity for regional analyses that will link the MKMA to surrounding, ecologically-similar areas. Using this approach, the Project Team has delineated a study area (Figure 2.1) that encompasses about 16.2 million hectares (Table 2.1).

The British Columbia Ecoregion Classification System is used to stratify the province's ecosystems into discrete geographical units at five levels. At the highest levels, Ecodomains and Ecodivisions, place British Columbia in a global context. At the lowest levels, Ecoprovinces, Ecoregions and Ecosections are progressively more detailed and narrow in scope and relate segments of the province to one another. Developed by Demarchi (1988), at the British Columbia Ministry of Environment, Lands and Parks, Wildlife Branch, the classification is based on macroclimatic processes and landforms. The classification describes areas of similar climate, physiography, oceanography, hydrology, vegetation and wildlife potential. Within each terrestrial ecoregion, climatic zones occur where specific soils, plant and animal communities and aquatic systems develop because of the interaction of climate with the land surface and surficial materials (DeMarchi 1996).

2.2 Physical and Ecological Profile of the Study Area

2.2.1 Location

South of the BC-Yukon border and north of BC's central interior, between expansive boreal and taiga plains to the east and coastal mountain ranges to the west, the larger study area for the MK CAD is anchored by the Northern Rocky Mountains and their intersection with the Muskwa Plateau (Figure 2.1). The Muskwa Ranges form the headwaters of the Prophet, Muskwa, Toad, and Sikanni Chief Rivers, which flow into the Laird River and eventually to the MacKenzie River and the Arctic. Farther west, the Kechika River drains into the Northern Rocky Mountain Trench, dividing the Muskwa Ranges from the Cassiar and Kechika Ranges. The westerly boundary encompasses the headwaters of the Stikine River taking form in the Southern Boreal Plateau. To the south, are the mountains of the Northern Omineca, while on the southeastern slopes of the study area, the Muskwa Range and foothills transition to the Misinchinka Range and foothills of the Peace Valley.

2.2.2 Ecoregions and Ecosections

According to the BC Ecoregional Classification System (Demarchi 1988), the enlarged study area for the MK CAD overlaps with portions of three separate ecoprovinces. The Northern Boreal Mountains ecoprovince makes up the majority of the study area, but the very western edge of the Taiga Plains ecoprovince includes the eastern slopes of the MKMA's front ranges, while the SubBoreal Interior ecoprovince overlaps with the very southeastern boundary of the MKMA. Within these provinces, the study area overlaps with a total of 5 ecoregions and 11 ecosections, each of which are described below[3].

2.2.2.1 Northern Boreal Mountains Ecoprovince

- **The Hyland Highland Ecoregion** is represented by only one Ecosection.
    - The **Hyland Highland Ecosection** is an area of rolling upland that extends from northern British Columbia into the Yukon and Northwest Territories. This Ecosection provides a low barrier between the Interior Plains to the east and the valleys of the Canadian Cordillera to the west.

- **The Liard Basin Ecoregion** is an extensive area of lowland to rolling upland that extends from northern British Columbia into the Yukon and Northwest Territories. In British Columbia this Ecoregion is represented by only one Ecosection.
    - **The Liard Plain Ecosection** is a broad, rolling inter-mountain plain with a cold, sub-Arctic climate.

- **The Northern Canadian Rocky Mountains Ecoregion** is an area of high, rugged mountains, several of which have large glaciers and rounded isolated foothills separated by wide valleys. This Ecoregion contains three Ecosections.
    - **The Eastern Muskwa Ranges Ecosection** is the area with the highest, most rugged mountains in the Ecoprovince. It has more snowfall than the foothills to the east.
    - **The Muskwa Foothills Ecosection** is an area of subdued mountains which are isolated by wide valleys. This area is in the rain shadow of the Rocky Mountains to the west; it is also more commonly under the influence of cold Arctic air in the winter.
    - **The Western Muskwa Ranges Ecosection** is an area of deep, narrow valleys and rugged mountains. It has a cold, wet climate.

- **The Boreal Mountains and Plateaus Ecoregion** is a large area with a complex of lowlands, rolling and high plateaus and rugged mountains. It has a dry sub-arctic climate. In British Columbia this Ecoregion contains six Ecosections, three of which define much of the western portion of the MK CAD study area.
    - **The Cassiar Ranges Ecosection** is the area with the highest and most rugged mountains in the Ecoregion. It has a broad band of mountains extending from the southeast corner of the Ecoregion to the northeast corner.

[3] Descriptions taken directly from the government of BC's 'Ecoregions of British Columbia Home page http://srmwww.gov.bc.ca/ecology/ecoregions/index.html

- **The Kechika Mountains Ecosection** is an area with high mountains, but low, wide valleys in the rain shadow of the Cassiar Ranges to the west.
- **The Southern Boreal Plateau Ecosection** consists of several deeply incised plateaus. Extensive rolling alpine and willow/birch habitat occurs. This Ecosection is located in the south-central part of the Ecoregion and defines the western extension of the MK CAD study area.

2.2.2.2 *Taiga Plains Ecoprovince*

- **The Muskwa Plateau Ecoregion** lies to the east of the northern Canadian Rocky Mountains. This Ecoregion is represented by only one Ecosection.
  - **The Muskwa Plateau Ecosection** is a dissected upland area that rises above the Fort Nelson Lowland to the east. This large ecosection defines much of the eastern portion of the MK CAD study area.

2.2.2.3 *Sub-Boreal Interior Ecoprovince*

- **The Central Canadian Rocky Mountains Ecoregion** consists of steep-sided, but round-topped mountains and foothills that are lower than ranges of the Rockies to either the south or the north. It contains four Ecosections, of which 2 define the most southern portions of the study area.
  - **The Misinchinka Ranges Ecosection** is a rugged mountain area, with deep narrow valleys. Moist Pacific air often stalls over these mountains, bringing high precipitation, both summer and winter.
  - **The Peace Foothills Ecosection** is a blocky mountain area on the east side of the Rocky Mountains. Strong rain shadows exist, as this ecosection is positioned east of the rugged mountains of the Misinchinka Ranges.

2.2.3 Biogeoclimatic Zonation

Vegetation in the study area is dominated by three biogeoclimatic zones common to the Northern Boreal Mountains Ecoprovince: the Spruce-Willow-Birch Zone occurs throughout the high valleys and middle slopes of the mountains, Alpine Tundra Zone occurs throughout the upper slopes of most mountains and at high elevations, while the Boreal White and Black Spruce Zone occurs throughout the valley bottoms and extensive plains (Pojar, Klinka et al. 1987; Meidinger and Pojar 1991; see Map 2.1). This latter zone also dominates the Rocky Mountain foothills of the Taiga Plains Ecoprovince in the far eastern portion of the study area. In the southern extent of the study area that overlaps with the SubBoreal Interior Ecoprovince, the Engelmann Spruce - Subalpine Fir Zone occurs on the middle slopes of valleys, along with the Sub-Boreal Spruce Zone occurring in the lower slopes.

2.2.4 Climate

Over the larger study area, climatic trends and conditions vary to some degree, but for the majority of the region within the Northern Boreal Mountains Ecoprovince, average annual temperatures hover around -1 degree Celsius with mean summer temperatures of about 10° Celsius and mean winter temperatures of about -16° Celsius (Canadian Council on Ecological Areas, 2004). Mean annual precipitation ranges from 350 to 1,000 mm (or 15 to 40 in). The rugged, high mountains of the Muskwa Ranges trap moisture coming from the Pacific and produce a "rain shadow" effect with notable drier climates along the east-front ranges. Permafrost of low ice content is sporadically distributed throughout the region, and occurs more often on northern slopes. Summertime surface heating leads to convective showers which, together with winter frontal systems, result in precipitation amounts that are evenly distributed throughout the year. Outbreaks of Arctic air are frequent during the winter and spring. The rugged relief leads to a complex pattern of surface heating and cold air drainage in the valleys (Environment Canada 2004).

2.3 Land Use Designations

2.3.1 MKMA

Often the entire 6.3 million hectare MKMA is referred to as a 'protected area.' In reality, the management area constitutes a variety of land use designations with varying conservation restrictions. The management area consists of a network of protected areas, surrounded by legislated special management zones, where industrial activities can occur, and wildland zones, where mining and wilderness tourism can take place but logging is not permitted. This zoning is prescribed by the MKMA Act and Management Plan. The Plan designated 4 broad categories of land use which are described in Table 2.2 and shown in Figure 2.2.

2.3.2 Land Designations Outside of the MKMA

As part of the Ministry of Water, Land and Air Protection's Environmental Stewardship Division, the BC Parks and Protected Areas Branch is responsible for the designation, management and conservation of the province's system of ecological reserves, provincial parks and recreation areas. Their mission is to protect representative and special natural places within the Province's Protected Areas System for conservation, outdoor recreation, education and scientific study. The larger CAD study area sweeps in 23 other BC provincial parks, either in whole or part, which accounts for an additional 1.3 million hectares of protected area in the study area. This leaves about 8.6 million hectares of the study area outside of the MKMA unprotected. However, most of this area is attributed to the reserves and parks of the Southern Boreal Plateau, in which one finds the headwaters of the Stikine River protected by the Spatsizi Plateau Wilderness and a series of other protected areas (see Table 2.3).

2.4 Analytical Stratification of the Study Area

2.4.1 River Systems

A fundamental goal of regional conservation strategies is to maintain well-distributed populations and occurrences of conservation targets that are serving as surrogates for ecological process and integrity. To ensure that we are achieving this goal, we have spatially stratified the MK CAD study area, and have met representation goals for all identified conservation targets present within each of the strata. The spatial stratification is defined by the major river systems of the region (Figure 2.3). We used coarse-scale drainage patterns define our spatial stratification within the MK CAD study area. The BC Watershed Atlas was used as a guide and reference for hydrologic patterns in the area; this 1:50,000 scale GIS database defines the spatial locations of watershed boundaries, rivers, streams, and lakes.

In the study area, there is an obvious pattern of divergence between the major river systems, which generally flow either north, south, east or west. To create stratification regions, we identified major topographic divides separating large river systems, then headwater drainages (third order watersheds defined in the Watershed Atlas) were grouped based on these general flow direction patterns. This grouping scheme resulted in 7 large "River Systems" that formed our spatial strata across the study area (Figure 2.3). The sizes of the River Systems (RSs) range from the 721,747 ha Beatton/Halfway region, to the 3,755,490 ha Finlay/Ospika region. The average size of the River Systems is 2,308,400 ha (Table 2.4). Each RS or target strata is named after the major river systems (or portions thereof) that they encompass.

2.4.2 Planning Units

The Project Team made concerted efforts to use the finest resolution spatial data available across the extent of the study area for all individual analyses. In many cases this is 1:20,000 vector spatial data and 50 m grid data. Many of these data sources have unknown or untested spatial or interpretation error, have little to no ground-truthing and a poorly documented maintenance record. The resulting analyses, while using the best information available, have carried forward any errors in the underlying data. While we cannot account for or control for interpretation errors (e.g., attributes that are erroneously classed), we have generalized our integration analyses spatially such that any small spatial errors may be subsumed within our larger analytical units. We have selected 500 ha hexagon-shaped "Planning Units" (PUs) as our basic unit of analyses for regional integration analyses (e.g., selection of Primary Core Areas). Hexagon-shaped Planning Units are preferred as they minimize edge: area ratio of the resulting grid of selection units or Planning Units. Additionally, groups of hexagons can also conform fairly well to sinuous features, such as rivers or roads. All underlying analytical results are summarized up to these 500 ha PUs for the integration analyses, as well as for use within the GIS Toolkit (Section 11).

While generalizing to coarser-scales (e.g. up to 500 ha) may be an effective solution to spatial resolution concerns, our selection of the 500 ha PU size was based primarily on computing ability for the integration analyses, and particularly for Core Area selections. These analyses are limited in the number of Planning Units on which the site selection algorithms can operate. We have maximized the number of PUs we could feasibly include in the site selection effort, thus minimizing the size of the individual PUs. The smaller the Planning Unit size, the more efficient the site selections tend to be. Increasing the PU size can lead to variable results in site selection (Warman, Sinclair et al. 2004). This is partly because increasing the PU size forces inefficient selection of large PUs that may contain a spatially-limited amount of a conservation target. Additionally, large PU sizes cause averaging of the underlying data or ecological values, potentially "averaging out" locally high value sites. We used the smallest PU feasible for our study area and analyses to minimize these scale-based issues.

2.5 Tables

Table 2.1 Total area within ecosections of the study area boundary, as determined by including all ecosections that intersect the MKMA; only BC portions of ecosections extending into the Yukon Territory are included.

Ecosection	Area (hectares)
Liard Plain	1,310,918
Muskwa Plateau	2,550,171
Hyland Highland	493,722
Cassiar Ranges	1,777,146
Kechika Mountains	1,053,020
Eastern Muskwa Ranges	1,710,112
Muskwa Foothills	1,079,598
Western Muskwa Ranges	1,033,486
Northern Omineca Mountains	1,559,381
Simpson Upland	780
Misinchinka Ranges	656,321
Peace Foothills	666,161
Southern Boreal Plateau	2,310,501
TOTAL	16,201,317

Table 2.2 Land Use Designations in the MKMA

Designation	Total Ha	% of MKMA	Management Direction
Protected Area	1,751,442	27.4	- All uses of Protected Areas must be assessed in regard to their impact on the ecological systems and the key natural, cultural and recreational values of particular areas. -Use of Protected Areas will be encouraged, where appropriate and consistent with the principle of maintaining ecological integrity, in order to realize the spiritual, recreational, educational, cultural, tourism and health benefits that Protected Areas can provide.
Special Wildland Area	923,447	14.5	-Priority for ecological conservation while providing for opportunities for commercial and industrial activities (mineral and oil and gas development). -Timber harvesting is not allowed and is excluded from the timber harvesting land base.

			-Road development is temporary and once industrial activities are completed, roads are to be deactivated and returned to a vegetative state that approximates natural conditions.
Special Management Area	3,674,007	57.5	-Emphasis on identified non-extractive values with respect to either wildlife and wildlife habitat, fish and fish habitat, heritage and culture, scenic areas and recreation. -Opportunities for commercial and industrial activities (timber, mineral and oil and gas development) are allowable while managing to maintain the identified special values. -There most likely will be areas with restrictions where there are special values. -There may be permanent access with the remainder of roads as temporary.
Enhanced Resource Development Area	37,698	0.6	-Emphasis on timber growth and utilization with the recognition that mineral and oil and gas resource exploration and development may also benefit in this zone. -Fewer restrictions on industrial development and a permanent and more intensive access network is allowable. -May be small areas with restrictions for special values with respect to wildlife and wildlife habitat, fish and fish habitat, heritage and culture, scenic areas and recreation.

Table 2.3 Protected Areas of the CAD study Area outside of the MKMA

Protected Area Name	***Hectares***
Spatsizi Plateau Wilderness	637,665
Mount Edziza	228,992
Stikine River	227,460
Tatlatui	102,684
Gladys Lake	42,433
Klua Lakes	28,273
Boya Lake	4,684
Sikanni Canyon	4,282
Mount Edziza (RA)	3,434
Kinaskan Lake	1,801
Grayling Hotspring AOI	1,415
Smith River	1,289
Scatter River	1,141
Portage Brule Rapids AOI	1,031
Blue/Dease Rivers	941
Sikani Falls	720
Chickens Neck Mountain	497

Smith River Fort Halkett AOI	242
Tetsa River	108
Dunlevy	106
Pink Mountain	104
Buckinghorse River Way	32
Hyland River	30

Table 2.4 Major River Systems used for the MK CAD regional stratification of Analysis

River System Name	River System Number	Hectares
Stikine/Iskut	1	2,213,774
Finlay/Ospika	2	3,755,491
Beatton/Halfway	3	721,747
Muskwa/Prophet	4	2,589,286
Kechika/Gataga	5	2,670,000
Toad/Liard	6	3,213,052
Dease	7	995,449

2.6 Figures

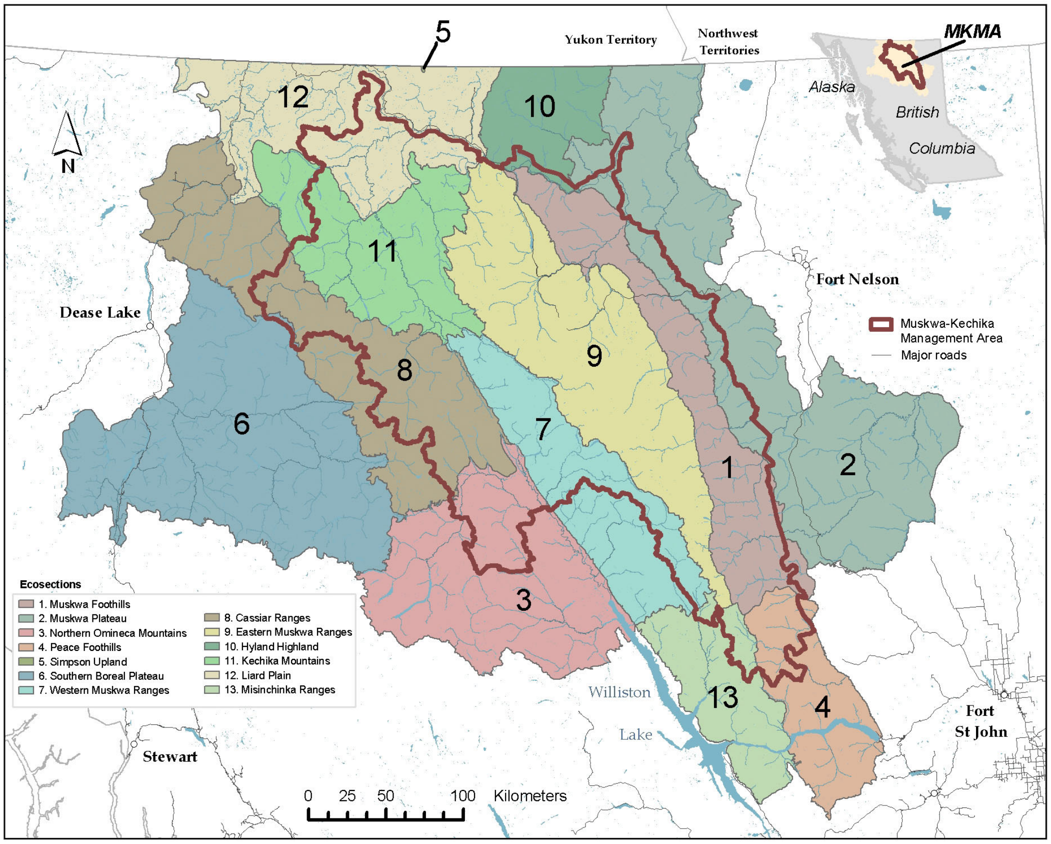


Figure 2.1 area for the Muskwa-Kechika Management Area Conservation Area Design showing ecosections that intersect the MKMA and used to define the extent of the study area.

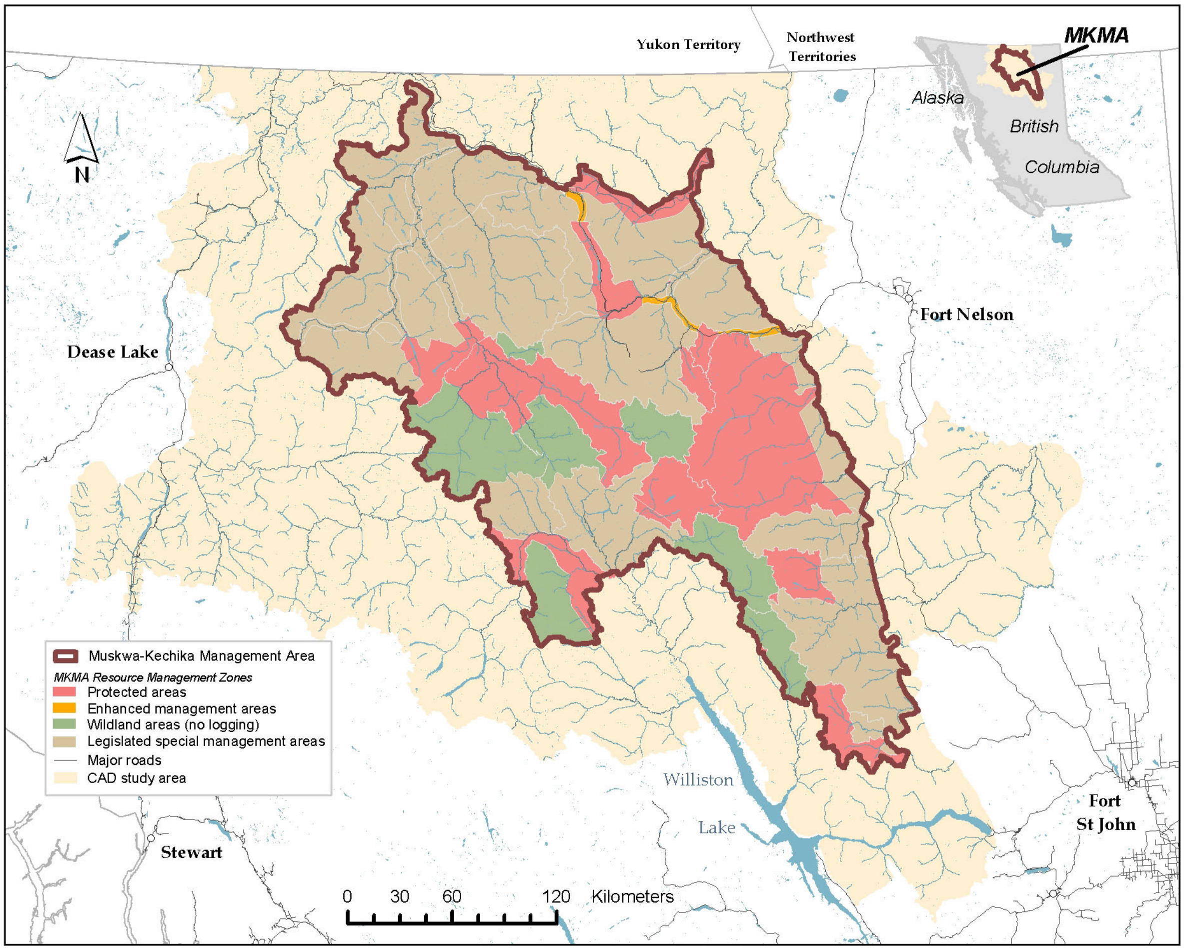


Figure 2.2 Land Use Designations for the MKMA

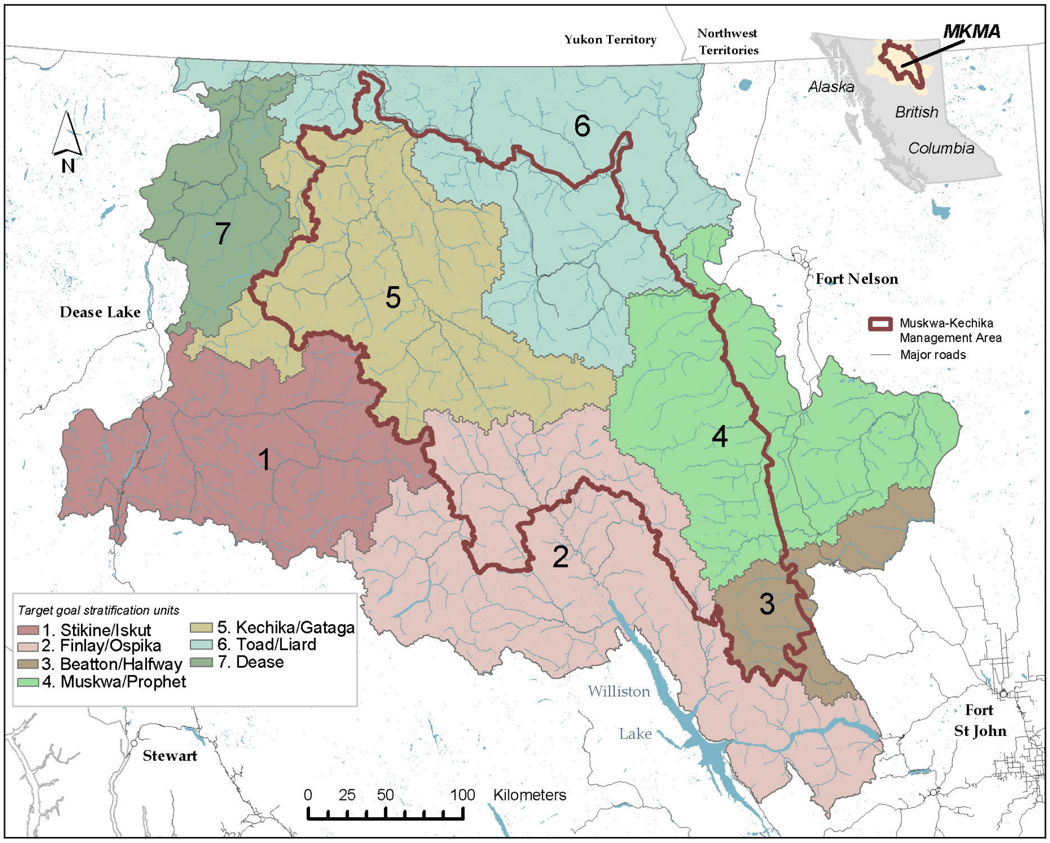


Figure 2.3 Major River Systems defining the regional stratification for the MK CAD analysis.

3 HUMAN USE ANALYSIS

3.1 Introduction and Background

An important component of any regional assessment of environmental or ecological conditions is the compilation and assessment of human uses across the region. As many human uses result in the direct or indirect modification and/or degradation of natural habitats and ecological processes, they form important barometers of current ecological conditions, as well as insights into areas where continued or increased human uses may be expected, given existing infrastructure.

The Muskwa-Kechika Management Area is presently relatively undeveloped, with few roads, limited industrial resource use and primary access being either by bush plane or non-motorized means. However, portions of NE BC, including regions within the MK CAD study area, show the footprint of a diversity of developments. These include oil and gas development along the eastern portions of the study area, logging activities in some areas of the southern and southwestern portions of the study area, and rural developments along the 2 primary highways (Alaska and Cassiar Highways).

The intent of the MK CAD approach is to provide guidance on areas that support high ecological value, both inherently due to habitat characteristics, as well as due to minimum human uses. This approach should assist managers, planners and developers by also minimizing the opportunities for immediate conflict between identified biodiversity conservation goals and existing uses of landscapes. Of course, some ecological values are spatially-limited or rare with few alternative examples across the region; in such cases, landscapes currently supporting a wide variety and intensity of human uses may be identified as important for conservation of biodiversity within our analysis.

To provide a broader context for the importance of assessing human uses across landscapes, we review some of the most important effects of human developments.

3.1.1 Habitat Loss and Fragmentation

There is consensus among biologists that anthropogenic habitat loss and degradation, including habitat fragmentation, represent the greatest threats to biodiversity worldwide (Harris 1984; Wilcove, McLellan et al. 1986; Heywood 1995; Collinge 1996; Laurance and Bierregaard 1997). Habitat fragmentation is a critical type of degradation that can cause long-term and profound changes to landscapes and populations. Still, habitat fragmentation is not entirely an anthropogenic phenomenon, as natural disturbances and geological events can act to separate ecosystems and landscapes into isolated parts. Some habitats are naturally isolated, such as oceanic islands, mountaintops, and desert springs. However, humans are currently the primary agent of habitat fragmentation world-wide and anthropogenic habitat disturbances far exceed naturally occurring phenomena in both scale and frequency.

History has shown that the end result of most human uses, beginning with natural resource extraction and infrastructure development, is a landscape of isolated habitat remnants accompanied by a severe reduction in biodiversity. While species with modest area requirements might maintain viable populations entirely within fragments, the presence of these and more resilient species does not negate the dire consequences that arise as a result of habitat fragmentation for more vulnerable species. It is typically the large carnivores and habitat specialists that are most susceptible to the effects of habitat fragmentation (Newmark 1986; Harris and Gallagher 1989; Newmark 1995; Newmark 1996; Holt, Lawton et al. 1999; Gittleman and Gompper 2001; Crooks 2002; Forman, Sperling et al. 2003). Additionally, naturally rare species are particularly susceptible to habitat degradation, and to displacement by species invading these newly accessible systems. Application of the precautionary principle suggests that conservation plans should consider the ecological needs of the species that are most sensitive to the effects of habitat loss, fragmentation and degradation.

3.1.2 Linear Developments: Keystone Impacts

A number of studies have described patterns of landscape fragmentation caused by roads and the direct and indirect impacts of roads on a wide diversity of species (Rich, Dobkin et al. 1994; Fahrig, Pedlar et al. 1995; Reed, Johnson-Barnard et al. 1996; Forman and Alexander 1998; Mace, Waller et al. 1999; James and Stuart-Smith 2000; Carr and Fahrig 2001; Papouchis, Singer et al. 2001; Dyer, O'Neill et al. 2002). Due to the systemic nature of these impacts, the density of roads is often used as an indicator of the ecological or habitat value of an area (Lyon 1983; Miller, Joyce et al. 1996; Moyle and Randall 1998; Nellemann and Cameron 1998; Stoms 2000; Wisdom, Holthausen et al. 2000; Barry, Rooney et al. 2001; Schenck 2001; Heilman, Strittholt et al. 2002; Chu, Minns et al. 2003; Rowland, Wisdom et al. 2003; Jedrzejewski, Niedzialkowska et al. 2004).

While the direct loss of habitat is an immediate effect of roads, most road impacts are long-term and their effects lagged in time (Loehle and Li 1996; Purvis, Gittleman et al. 2000; Forman, Sperling et al. 2003). Reductions in populations numbers due to habitat loss, degradation and fragmentation and/or increased direct or indirect mortality are longer term potential impacts (reviewed in Cantrell, Cosner et al. 1998; Trombulak and Frissell 2000; havlick 2002; Forman, Sperling et al. 2003). Roads may be considered "keystone disturbance", as the construction of a new road has a proliferation effect that facilitates further human uses within an ecosystem and initiates the spread of degradation across the landscape. Road access provides opportunities for accelerated resource extraction and development, as well as increased human presence for a variety of purposes, from development to recreational use to settlement. Roads also serve as an avenue for increased hunting and poaching because they allow greater access to target species (McLellan 1990; Trombulak and Frissell 2000; Wolfe, Griffith et al. 2000). For large carnivores, roads also translate into an increase in non-hunting related, but nonetheless fatal human encounters (e.g., bears killed in life or property defense). Roads also directly impact biodiversity through traffic-caused mortality which can often exceed mortality rates in hunted populations.

Some species, such as grizzly bears and woodland caribou, show a marked avoidance of roads and other human activity areas, thereby causing further fragmentation of home ranges and reduction in potential habitat (Archibald, Ellis et al. 1987; Kazworm and Manley 1990; Mattson 1990; Mac, Waller et al. 1996; Mace, Waller et al. 1999; James and Stuart-Smith 2000; Wolfe, Griffith et al. 2000; Dyer, O'Neill et al. 2001; Dyer, O'Neill et al. 2002; Gibeau, Clevenger et al. 2002). It has been found that adult female grizzly bears may avoid using otherwise high quality habitat if it is near a road, indicating that roads can potentially cause the indirect loss of such habitat to key reproductive animals in the population (Mace, Waller et al. 1999; Gibeau, Clevenger et al. 2002). Additionally, roads can potentially increase the susceptibility of prey species to predation, as these linear features may increase the mobility of the predators, particularly in the winter. For example, it was found that woodland caribou experienced higher wolf predation near roads (James and Stuart-Smith 2000).

Roads also serve as an active avenue for the spread of exotic and invasive species. The edge habitats created by roads facilitate and support species that thrive in disturbed or ecotone habitats; these species can often displace native species through competition and predation (Stohlgren, Binkley et al. 1999; James and Stuart-Smith 2000; Winter, Johnson et al. 2000), and reduce the habitat quality for a diversity of other species (Reinhart, Haroldson et al. 2001). Additionally, vehicles and people facilitate the spread of diseases through transport on spores and individuals; these diseases can have dramatic effects on the host species, as well as species that utilize the host (Hunt 2000; Tomback 2001; Gelbard and Belnap 2002). Finally, the soil erosion and sedimentation caused by roads and their construction can cause widespread and chronic degradation of streams and rivers, destroying or degrading important aquatic habitats (Findlay and Bourdages 2000).

Many similar potential impacts and concerns apply to motorized boat access. Jet boats and motorized boat transportation can represent affordable and accessible access to otherwise remote regions, potentially causing increased wildlife mortality due to legal and illegal harvest, as well as killings of predators in defense of life and property. Boat access and use of the near-shore habitats can displace wildlife, impact sensitive riparian vegetation, cause soil erosion and transport exotic species. In remote areas with navigable rivers, streams and lakes, jet-boat access may currently represent the largest existing and potential access impact. This is most likely the case in the remote waterways of the study area; unfortunately, there is not a standardized description of current jet boat access and so, we could not include it in this analysis. We recommend that such information is collected and included in future updates.

3.2 Human Use Analysis: Methodology and Results

We used existing government data sources to compile information about the distribution and types of human uses across the landscape. We categorized human use “footprints” as either “linear”, “point” or “areas” features. Linear features (transportation, cultural line, and cut-line) and point features (cultural) were identified using 1:20,000 TRIM data. We used NTS 1:250,000 data to identify area developments, which include agriculture conversions, clear-cut logging and areas tenured for grazing. In some instances, we considered a TRIM linear feature as a point use; these include airports, airstrips, mines, dumps, power substations, settling basins and tailings ponds.

For each feature, a weighting was applied to allow ranking of relative potential human use impacts. Similar weighting approaches to evaluating the relative influences of human uses across the landscape have been applied to identify areas of low human influence or “wilderness” areas (Lesslie, Mackey et al. 1988; Lesslie 1991; Kliskey 1994; Aplet, Thomson et al. 2000) based on expert opinion of relative impacts or (for wilderness), perceptions of wilderness experience. We limited our analyses to attributes of physical human infrastructure, with relative weightings respective to the assumed level of human use (no or little data are available on levels of human use or activity associated with the spatial attributes). For example, trails and cut lines were not considered as having the same relative impact as primary roads such as the Alaska Highway. The ranking of human development features is provided in Table 3.1, and ranges from 0 (no impact) to 10 (high impact). More detailed descriptions of the weightings are provided below for each of the 3 feature types.

3.2.1 Linear Features

Linear use features are primarily transportation right-of-ways, and as such have potentially high direct and indirect impacts on species. A diversity of linear developments were considered in the analysis, including paved roads, gravel roads, unimproved roads, railroads, trails, transmission lines, pipelines, and cut-lines (see Table 3.1 for complete list). In the relative weighting of these different types of linear features between 0 and 10, it is assumed that potential impacts increase with increasing ease of human access. Unfortunately, the amount of human access and purpose of access are critical variables that were not available in our analysis. Thus, the ranking is based upon linear feature type and assumptions about how this may translate into human access and use. Additionally, all linear developments were assumed to have some potential impact, due to the fragmentation effects, edge effects and potential to change predator movements.

The paved roads, which are limited to the Alaska Highway and the Cassiar Highway, were ranked as the highest intensity linear human use in the study area (a 10 out of 10). These routes provide easy access to vehicles of all types for high speed travel, and funnel large numbers of people within their corridors. Direct mortality along the road route may be a significant impact to some species, and the road corridor, paved surface, and high speed traffic may represent a significant barrier to movement for a diversity of species. Additionally, human use along portions of the bordering landscapes is likely high due to the ease of access.

Gravel roads are limited within the study area, but appear to provide the next highest quality human access routes; these gravel roads include portions of the Highway systems and connect some urban clusters. We ranked these roads as 8 (out of 10) due to the potential funneling of human use along these routes (e.g., segments of the Highway systems are classified as gravel roads). These roads likely limit the speed of travel, though significant mortality may still occur and these likely provide access for human use of the bordering habitats.

The vast majority of the roads within the study area were classified in TRIM as unimproved roads; these even include roads associated with towns such as Ft. Nelson. Based on the available data, it is impossible to meaningfully subdivide the road classification further. We assumed that unimproved roads reduced travel speed and volume of use, and thus ranked these roads 3 (out of 10). Still, these roads are likely the primary access routes for a number of human uses of natural landscapes; this impact is likely not accounted for appropriately within this model, which is limited primarily to impacts associated directly with the human development feature.

We ranked seismic lines and closed trails as the lowest linear impact weighting (0.5). Some of these linear features undoubtedly represent significant modifications of the local landscape. Unfortunately, we do not have the information available to identify, for example, cut lines that are thin, hand-cut paths from cut-lines made with heavy equipment. All cut lines represent potential access routes for human use, particularly in the winter on snowmobile. Yet, the low human population in the region and the opinion of many local experts is that the vast majority of the cut lines are rarely, if ever, used. Additionally, increasing restrictions on the type of cut lines developed has resulted in the predominance of hand-cut lines in the more recent seismic activity, with the wider cut-lines being older and likely over-grown in most areas. Given these anecdotal information sources, we chose to rate cut-lines as relatively low impacts on the landscape. Still, the high density of cut-lines in some regions results in their predominance as the primary impact in these regions.

The remaining suite of linear developments was ranked relative to these extreme and intermediate rankings. For example, railroad lines were assumed to be similar to unimproved roads in that they provide relatively easy access, but are likely limited in the volume of use that they receive. Open trails and transmissions lines received a ranking of 1, as these are maintained as open routes that are periodically cleared or kept clear due to use, and receive the type of human use, such as hunting, that can have a direct impact on animals. Based on comments from MSRM staff, we rated pipelines as higher potential impacts, because these are associated with relatively wide corridors of cut vegetation and potentially areas of exposed pipe that may form direct movement barriers.

We modified the classification of unimproved roads and trails within the MKMA using the Access Management Agreement (AMA), which provides approved road closures within the MKMA based on LRMP guidance. Closed trails received a weighting equal to that of cut-lines, or narrow linear features with minimal human use.

3.2.2 Point Features

There is a diversity of development features classified as "points" of human use in the study area. These include buildings, oil wells, gas well, mines, settling ponds, transmission towers, dumps, gravel pits, etc. We accounted for differences in potential direct and indirect impacts to habitats and wildlife through a relative weighting from 0 (no impact) – 10 (high impact), based on expert opinion and local knowledge. Ratings for all point impacts included in the analysis (i.e., weighting >0) are in Table 3.1.

Buildings are assumed to have the highest point impact, due to the high level of human use that can be associated with most buildings, and the intolerance to native regrowth of vegetation and wildlife damage or proximity. Urban areas represent high density extremes of these point impacts, while hunting lodges represent low density, but still significant, human use centers. Oil wells, gas wells, mines and piers or docks were considered intermediate point impacts, due to potentially high levels of human uses at certain times. We did not have information on whether wells and mines were currently active; thus many of the identified points may be well beyond having any level of human use. The exception to this is the identification of "abandoned mine" points, which received a low impact weighting under the assumption that there was little human use currently associated with the site. Dumps received a weighting of 5, due to the high mortality associated with wildlife species attracted to these sites. Point locations that represent physical disturbance (e.g., settling pond, gravel pit) without associated on-going high levels of human activity received lower impact scores.

3.2.3 Area Features

Area impacts include land uses that are dispersed across identified areas, as captured within available data. We used NTS 1:250,000 data to identify three types of area-based human uses: agriculture, logging and rangeland grazing. Similar to other types of human uses, these received a relative weighting from 0 to 10 to distinguish the intensity of the impact per unit area (ha).

Agriculture received the highest impact weighting (8), under the assumption that commercial scale agriculture provides little value to most native biota. Clear-cut logging received a low to intermediate score of 3; logging dramatically changes the age structure and potentially the species complex of the area. Still, regeneration of clear-cut patches is allowed to occur (though natural succession may be altered), and human use of the clear-cut patch is likely relatively low once the harvesting and restoration activities are completed. Grazing tenures identified within the NTS data received a low impact rating of 0.5. Grazing can have severe localized impacts (e.g., riparian areas), and mismanaged grazing can have high impacts on the vegetative structure and complexity of an area. Given the nature of the study area and information from local sources, it is assumed that the grazing tenures are not being used for commercial purposes such as cattle grazing, but are primarily associated with hunting lodges and camps, thus we have assumed that the overall impacts to the relatively large tenure areas is generally low.

3.2.4 Relative Human Uses across Study Area

We calculated the weighted density of each type of feature (linear, point, area) per square kilometer as a metric of relative human development and use across the study area within the 50 m grid base model. Additionally, to attribute the 500-ha Planning Units, we calculated density of features within each PU. For both outputs resolutions (50 m grid and 500 ha hexagon), linear feature density was calculated in total kilometers per square kilometer, point feature density was calculated as the number of point features/sq. km, and area features as ha/sq. km. The weighted density for each feature type was calculated by multiplying the density by the appropriate weighting factor.

Within each feature type, we standardized (z-score) the weighted density to create a feature human use score from 0 - 1, with 1 indicating the highest relative human use density within that feature type. Within our study area, the highest value linear score equated to a total road density of 14.6 km/km^2 (4.8 km/km^2 of paved road and 9.8 km/km^2 of unimproved road). The highest area score equated to 85 ha/sq.km (85% coverage) of agriculture, and our high point density was found to 13.4 buildings/sq.km. These were all set equal to each other, as all received a standardized feature score of "1".

The highest *linear* human use scores are generally associated with areas along the Alaska Hwy, and particularly those that also have multiple unimproved roads immediately associated with it (see Map 3.1). Other areas showing high scores from linear development include the southern Rocky Mountain Trench area, which have high densities of logging roads. The highest *area* human use scores are generally associated with clear-cut logging. There are some area developments along the eastern border of the study area associated with agriculture, but, in general, there is little agriculture identified in the study area (Map 3.2). The highest *point* human use score is found associated with oil and gas development (pads and buildings) in some of the eastern portions of the study area (Map 3.3). After standardization, the scores across the 3 feature types were added.

3.2.5 Combined Human Uses

To create a single index of human use across the region, we combined the 3 standardized human use scores. The resulting, single combined human use score has a potential range of 0-3. This was attributed both at the 50 m grid and the 500 ha PU resolutions. The realized scores ranged from 0 to 1.6 for the 50 m grid model and from 0 to 1.35 for the 500 ha PU model, with the same patterns of distribution across spaces. The pattern of combined human uses across the study area mirrors the distribution of linear features (Map 3.4). This is not surprising: high density road networks are often associated with a diversity of resources development activities. High human use scores within the study area are concentrated in areas of human settlement and natural resource development. Areas of multiple and concentrated human uses can be found along the eastern portions of the study area, outside of the MKMA, with oil and gas related activities dominating the east-side resource development. These include a large number of cut lines, roads, oil pads and buildings. High intensity linear developments such as the Alaska Highway, with the presence of associated developments intermittently along its length create a narrow band of high impacts along the east and northeast; this cuts through the northeast portion of the MKMA. Similarly, the Cassiar Highway and associated development along it, in the southwest portion of the study area, creates an additional corridor of relatively high human use. Clear-cut logging, with associated road development, forms localized regions of high modification in the southwest and western portions of the study area.

3.3 Human Use Analysis: Discussion

This human use analysis serves to provide the MK CAD team a regional picture of relative levels of human use and development across the study area, and is not an attempt to quantify direct impacts at any given site, or the ecological significance of any existing or future impact. While the techniques used are rudimentary and limited, the assessment of regional patterns of human influence is difficult, and similar weighting additive approaches have been used for identifying areas with limited human influence elsewhere (Lesslie, Mackey et al. 1988; Lesslie 1991; Kliskey 1994; Aplet, Thomson et al. 2000; Church, Gerrard et al. 2000) We use the human use analyses to guide the selection of ecological sites that have minimal existing human uses. This allows us to select those areas in the landscape that have likely minimal degradation, and thus may represent the best examples of conservation targets. Additionally, the selection of sites that avoid areas with existing uses may decrease any potential conflicts with those existing activities. Because new developments often coincide with existing infrastructure, using existing human uses to guide the selection of sites should also minimize future potential conflicts between ecological values identified in the MK CAD and human use and development of those sites.

Alternatively, our use of the human development analysis does not preclude the selection of areas with existing human uses, even areas of high use. This is particularly true if a rare ecological value is located in an area of existing human uses; these sites, in particular, are identified for these rare values regardless of the level of human uses. In these instances, the identification may serve as an indication of the priority for conservation or restoration of the rare feature.

The data used for the human use analyses is limited to those data sets that identify existing infrastructures across the region: TRIM 1:20,000 and NTS 1:250,000. These data are continually being updated and maintained by the BC government and, therefore, represent the best available region-wide information. Still, many localized differences exist between what is identified in the data and what is realized on the ground. We made some limited adjustments to TRIM attributes within the MKMA to reflect recent changes to accessible roads and trails. We were unable to attempt a study area-wide update to the underlying data. Additionally, the attributes available to more fully understand the actual infrastructure or development were extremely limited, and we had to make several assumptions about feature classes, many of which are described in this report. For example, we have no information on the age or width of cutlines; these attributes would be useful to further classify cutlines. As it stands, the lack of use intensity and current status of most features severely limits any finer classification of all features used in this analysis.

Finally, as mentioned previously, there are some classes of human uses that are not included within the analyses including water access (e.g., jet boat, float plane), land use tenures, and remote infrastructures such as campgrounds. As these data become available, we would recommend they be appropriately included in future updates to the analyses. In general, the ability to update this analysis will be a critical task to ensuring the continued utility of the MK CAD components. We recommend that data warehousing on new developments be maintained and included within the Toolkit, as described in Section 11.

3.4 Tables

Table 3.1 Weighting of human development features in the study area. Human development features includes linear and point features identified with the TRIM transportation and cultural spatial data.

Development Feature	Feature Type	Relative weighting
Linear Impacts		
Closed trails (based on AMA)	Linear	0.5
Open trails	Linear	1
Unimproved roads	Linear	3
Gravel roads	Linear	8
Paved Roads	Linear	10
Cut-lines	Linear	0.5
Pipelines	Linear	2
Railroad	Linear	3
Transmission line	Linear	1
Point Impacts		
Building	Point	10
Gas or oil well	Point	5
Mine	Point	5
Abandoned mine	Point	1
Tailing pond	Point	1
Settling basin	Point	1
Pier or dock	Point	5
Electrical substation	Point	1
Gravel pit	Point	1
Airstrip, airports	Point	1
Commun./microwave station	Point	1
Tanks	Point	1
Dumps	Point	5
Area Impacts		
Agriculture	Area	8
Clear-cut logging	Area	3
Grazing tenures	Area	0.5

4 TERRESTRIAL ECOSYSTEM ANALYSES

4.1 Introduction

The objective of the coarse-filter or ecosystem analysis is to identify and protect intact examples of each ecological community type in a region (Anderson, Comer et al. 1999; Anderson 1999; Groves 2003). This generally equates to a strategy of protecting ecosystems rather than targeting individual species (Noss, Strittholt et al. 1999; Kintsch and Urban 2002; Margules, Pressey et al. 2002; Sarkar and Margules 2002; Sierra, Campos et al. 2002). The assumption is that if ecological communities or ecosystems remain intact and well-distributed, so, presumably, will populations of species that depend on these communities. A further assumption, often implicit, is that gradients in species composition parallel environmental gradients and are surrogates for biodiversity (Noss 1999). If data regarding species composition is limited, environmental gradients captured within existing environmental spatial data may have utility to predict potential community diversity.

Coarse-filter approaches have wide appeal because they tend to protect a large fraction of biodiversity and are relatively easy to carry out. Many hundreds of species of yet unknown bacteria, fungi, invertebrates, and plants reside in northern BC, particularly in the soil or forest canopy; there is little hope for a comprehensive examination of all these species. Large-scale approaches at the level of the ecological communities, ecosystems and landscapes are probably the only way to conserve these essential elements of biodiversity (Franklin 1993). A major advantage of using a coarse-filter approach is that vegetation and habitat data are widely available and are relatively easy to obtain and map, as compared with demographic and autecological information on a particular focal species or suite of focal species.

We created a terrestrial ecological system classification scheme for the MKMA which incorporates vegetation as well as abiotic environmental influences. The end result is a series of Ecological Land Units (ELUs) that describe the study area in a uniform manner, using the best available data at a scale appropriate for planning (Anderson, Comer et al. 1999; Anderson 1999; Groves 2000; Groves 2003). The "units" or "systems" are actually descriptions of both biotic and abiotic conditions on the landscape that could be important for diversity (e.g., "old-growth lodgepole pine on a steep, south-facing slope in the Spruce-Willow-Birch BEC zone"), as well as interpreting the ecological value of the site.

There have been ecological community classifications completed within some spatially-limited regions of our study area such as the Besa Prophet area (e.g., Besa Prophet area; R. A. Sims and Associates 1999). These efforts have used approaches such as terrestrial ecosystem mapping (TEM; Resources Inventory Committee (RIC) 1998) and predictive ecosystem mapping (PEM; Resources Inventory Committee (RIC) 1999); a complete list of these efforts is available at ftp://ftp.env.gov.bc.ca/dist/wis/tem/warehouse. While these offer standardized and fine-resolution classifications, they are only available within limited regions, and a uniform classification across the extent of our study area was not available. Our challenge was to create a classification across the extent of the MK CAD study area, at an appropriate scale and for which data are available. Scale or resolution is determined both by availability of data and limitations around how much data can be analyzed with current computing power--the finer the scale, the greater the total data and the more computationally intensive the exercise. Additionally, complete data sets for such a large area (16 million ha) tend to be available only at coarse scales; this is particularly true for relatively undeveloped areas such as the MKMA.

4.2 Ecological Landscape Units

The ELU classification is an exercise in balancing data availability, spatial scale, ecological importance and redundancy. Our analysis was primarily driven by data availability and ecological importance. We selected a suite of ecological attributes from multiple data sources to provide classification variables in the ELU.

4.2.1 Ecological Variables

The important drivers of ecological variation include climate, vegetation type, insolation (local or micro-climates), topography and landform, soil moisture, soil type, and vegetation structure. While data on each of these are not available within our study area, we used the best available surrogates to capture these primary environmental drivers, as described below.

Climate: Climate is one of the most important drivers of species distribution as most species cannot live outside a limited temperature and precipitation regime, and often depend on the relative timing of temperature changes and precipitation. Climate data are scarce in the study area; however, the biogeoclimatic ecosystem classification (BEC; Pojar, Klinka et al. 1987; Meidinger and Pojar 1991) is partially based on climate and represents the best surrogate for climate information available for the study area. We use BEC zone-subzone-variant as the primary classification variable for our ELUs.

Vegetation type (or land cover): Vegetation type is also one of the most important drivers of ecological diversity, and ecological communities are often named for their dominant vegetation (e.g. grasslands or spruce forest). The BC Forest Inventory Project (FIP) provides the best species-specific vegetation data (including age) for the study area although the data are biased towards tree species and timber inventories. The BC Vegetation Resources Inventory (VRI) provides data on non-tree plant life forms such as shrub, herb and bryoid, but generalizes tree information to three classes: broadleaf, conifer and mixed. The FIP and VRI data vary with regard to accuracy and consistency and some parts of the study area contain more detailed data than others.

Neither VRI or FIP have attempted to provide adequate classification of alpine areas, and over 95% of the alpine habitats within our study area were classified as “unvegetated rock and rubble”. This counters information obtained in conversation with local experts and our own field surveys. The broad ecosystem inventory data (Resources Inventory Committee (RIC) 1998) includes a potentially more accurate classification, in that much of the “unvegetated rock and rubble” is classified as vegetated. However, the BEI data are at a much more coarse-scale (BEI is at 1:250,000 compared to 1:20,000 for FIP and VRI). We chose to use a combination of FIP and VRI data to determine vegetation and land cover (along with TRIM wetland data as described below) outside of alpine areas. We used the BEI data to correct for the deficiencies in the FIP and VRI alpine vegetation classification, allowing us to define alpine areas as “vegetated” or “unvegetated”. This issue is especially important to address because vegetated alpine habitats are critical to many species in the region and because up to one-third of the study area is in the alpine zone. Because of the differences in scale and to avoid integrating a third classification scheme (VRI and FIP are similar in the units classified, the scale and the original data sources), we only used BEI to define the unvegetated alpine areas and classified the remaining area simply as vegetated. This provided only a coarse delineation of alpine diversity but dramatically improved upon the FIP and VRI alpine classification. We applied this BEI correction to all areas identified in the VRI as “alpine” and "unvegetated".

Insolation: Insolation, or the amount of solar energy available, drives productivity. It varies with aspect and shading from adjacent landforms. Generally, a cool northern aspect will be wetter and support shade tolerant vegetation. Conversely, warm aspects tend to be drier and support shade intolerant species. Shading can be particularly important in the MKMA where there are many steep slopes. A south-facing slope in a broad valley with a general east-west trend will receive large amounts of sunlight whereas a south-facing slope in a narrow valley with a north-south trend will receive less light. Detailed insolation data are not available for the study area, but aspect is readily available from Terrain Resource Information Management (TRIM) data. We used ARCGIS to convert TRIM 50m grid digital elevation models (DEM) into a warm aspect and a cool aspect class.

Topography: Landforms such as ridge tops, valley bottoms, slopes and benches create different physical environments that often support different species. While these differences are a function of other factors such as soil depth, wind exposure and water holding capacity, some of this variation can be captured by surrogate variables. Landform is not available for the study area but slope is available from the TRIM DEM. We define a flat, moderate and steep slope class to capture some of the topographic variation that drives ecological diversity.

Soil type: Soil type is undoubtedly an important driver of vegetative diversity. Different plants will thrive on different soil types and rare plant species are often restricted to rare soil types. However, soil mapping does not exist across our study area. Because of the link between soil type and vegetation, we can imperfectly and indirectly capture some of the broad soil type variation through our use of the BEC classification and vegetation data.

Soil moisture: Soil moisture can drive strong differences in vegetation, as exemplified by the differences between wetland vegetation and the vegetation present on a steep dry slope. As with soil type, we have no direct measure of soil moisture across the study area. Slope and aspect both can affect soil moisture; water will drain off of steep slopes quickly and collect in flat areas whereas south and west facing slopes tend to be drier than north and east facing slopes. We use slope and aspect derived from TRIM DEM to capture this ecological variation. We also use TRIM wetland classification to capture to very moist or wet soil classes. The TRIM identifies "marsh" and "swamp"; these two classes are approximately equivalent to non-forested wetland and forested wetland, respectively.

Vegetation structure: Vegetation structure can be important for animals and for secondary vegetation. Animals use vegetation for food as well as security cover; densely vegetated areas can be important protection for prey species, but sparsely vegetated areas can provide easier hunting for predators and easier movement for both predators and prey. Vegetation and habitat structure provide critical habitat components at multiple spatial scales. Both vegetation density and age relate to vegetation structure, are available within our land cover data and, thus, could be used as surrogates for vegetation structure. Forest canopy cover (density) creates shading, determining the types and density of understory species . Forest age, in particular, can potentially predict several characteristics of forest stands. We chose age as our surrogate for vegetation structure because it directly captures seral stage of the vegetation, as well as the structure. We used the FIP age estimates to distinguish a mature to old-growth class (>140 years), a mid-seral class (20 – 140 years), and an early-seral class (0 – 20 years).

4.2.2 Data Sources

We used five sources of data to capture the ecological variation discussed above (Tables 4.1). Several variables used the same data source. The five sources discussed below are: Biogeoclimatic Ecosystem Classification (BEC), Terrain Resource Information Management (TRIM), Forestry Inventory Program (FIP), Vegetation Resource Inventory (VRI) and Broad Ecosystem Inventory (BEI).

Biogeoclimatic Ecosystem Classification (BEC)[4]**:** For creating ELU's we used the regional level of the BEC system. At the regional level, vegetation, soils, and topography are used to infer the regional climate and to identify geographic areas that have relatively uniform climate. These geographic areas are termed biogeoclimatic (BGC) units and consist of a zone, subzone and variant. A zone is a large geographic area with a broadly homogeneous macroclimate. Variants are generally recognized for areas that are slightly drier, wetter, snowier, warmer, or colder than that considered typical for the subzone. Subzones may include significant climatic variation marked by small changes in the vegetation. Most of the study area is classified at a 1:20,000 resolution except for the very western part, which is classified at a 1:600,000 resolution. The BEC zone-subzone-variant classes that are found in the study area are listed in Table 4.2, and displayed in Map 2.1.

Zones are usually named after one or more of the dominant climax species in zonal ecosystems (the Alpine Tundra Zone is a self-explanatory exception), and a geographic (e.g., coastal, interior) or climatic modifier (e.g., boreal, montane). The names are often referred to by a two- to four-letter acronym. For example, the Boreal Black and White Spruce Zone is referred to as the BWBS Zone and the Sub-boreal Spruce Zone is referred to as the SBS Zone. Subzone names are derived from classes of relative precipitation and temperature or continentality. The first part of the subzone name describes the relative precipitation and the second part describes either the relative temperature (Interior zones) or relative continentality (Coastal zones). For example, the SBSwk stands for the Wet Cool subzone of the Sub-boreal Spruce Zone. Variant names are given number codes (e.g., SBSwk2), which in most cases reflect their geographic distribution within the subzone from south to north.

The version of the data we use is the Provincial Digital Biogeoclimatic Subzone/Variant Mapping Version 5.0 (2003/04/17) and can be found at:

http://www.for.gov.bc.ca/hre/becmaps/BECMAPS.HTM

Terrain Resource Information Management (TRIM): TRIM provides a number of 1:20,000 base data sets which are useful for many different management applications. From the data set, we use the Digital Elevation Model (DEM) and the Marsh and Swamp fields from the Planimetric data. The TRIM DEM uses 25 meter pixels. However, we resampled to 50 meter pixels in order to accommodate computational limitations emerging from the sheer volume of data at that scale for a 16 million ha study. The Planimetric data includes all man-made features such as roads, buildings, fences, etc., as well as natural features such as streams, lakes, swamps, etc. The definitions of Swamp and Marsh are as follows:

> *Swamp:* A low-lying, water-saturated area, intermittently or permanently covered with water, having shrubs and tree-like vegetation.
>
> *Marsh:* A water-saturated, poorly drained, treeless area intermittently or permanently water covered, having cattails, rushes, or grass-like vegetation.

The TRIM data is continually being updated; our download date was March 2003. More detailed information can be found at http://srmwww.gov.bc.ca/bmgs/trim/trim/trim_overview/trim_program.htm

Forest Inventory Project (FIP): The FIP is the data storage program for forest cover data in BC. There have been many forest cover inventories done in BC in the last century and the current FIP data base includes information from several of the programs. Information about the FIP data set (including brief descriptions of the data) can be found at http://srmwww.gov.bc.ca/gis/Databases/Oracle/index.html and more detailed information can be found in the document "The Preparation and Creation of FRGIS Data Files (Volume 5) September 1998 Revision.", which can be found on the web at

[4] much of this text is excerpted from the MSRM website http://www.for.gov.bc.ca/hre/becweb/index.htm

http://srmwww.gov.bc.ca/tib/standard/volume5/maindoc.htm. From the FIP data set, we use the PROJECTED_AGE field and the INVENTORY_TYPE_GROUP_NUMBER or ITG code field. The ITG codes and definitions for the species found within the study areas are in Table 4.3.

Vegetation Resource Inventory (VRI): The VRI is the latest forest cover inventory program and represents a departure from the previous forestry-based inventories. It is designed to provide ecological information for many different types of resource managers. It builds on previous inventory efforts and the data is imbedded within the FIP data base and obtained from the same source. We give a brief description of the VRI classes we use below; more detailed information can be found at http://srmwww.gov.bc.ca/tib/vri.

VRI is a hierarchical dataset. At the first level, areas (polygons) are defined as vegetated or not. "Vegetated" is defined as "total cover of trees, shrubs, herbs, and bryoids covers at least 5% of the total surface area of the polygon." The second level, for vegetated, defines areas as treed or not. "Treed" is defined as "at least 10% of the polygon area, by crown cover, consists of tree species of any size." The Alpine class is defined as "non-treed areas above the tree line." Shrubs are defined as "multi-stemmed woody perennial plants, both evergreen and deciduous (Tall = > 2 m and Low=< 2 m).

Broad Ecosystem Inventory (BEI): BEI (Resources Inventory Committee (RIC) 1998)is an ecosystem classification system (1:250,000), that, similar to BEC, uses the BGC Zone-subzone-variant system as one of its highest hierarchical levels. This allowed us to use the "Ecosystem Unit" level of the BEI classification system since it is nested within the BGC levels. We did not choose this dataset as the primary land cover dataset because many data (TRIM, VRI, BEC, FIP) are available at a much finer resolution (1:20,000) and the final resolution of any mapping effort is always reduced to the coarsest scale of accuracy. The Ecosystem units we used to differentiate between vegetated and unvegetated alpine areas in the BEI correction to the Forest cover and VRI datasets for the ELU land cover level were:

> *Rock* (RO): Typically a mixture of gentle to steep, nonalpine bedrock escarpments and outcroppings with little soil development and relatively low vegetative cover.
>
> *Glacier* (GL): Typically a field or body of snow or ice formed in higher elevations in mountainous terrain where snowfall exceeds melting: these areas of snow and ice will show evidence of past or present glacier movement.
>
> *Unvegetated* (UV): Typically non-alpine, unvegetated areas consisting of exposed soils and excluding unvegetated bedrock sites.
>
> *Alpine Unvegetated* (AU): Typically a high elevation habitat dominated by rock outcrops, talus, steep cliffs and other areas with very sparse vegetation of grass, lichens and low shrubs.

Further information about the BEI classification system and the associated mapping effort can be found at http://srmwww.gov.bc.ca/ecology/bei/index.html.

4.2.3 Classification of Ecological Variables into ELUs

The ELU classification scheme consisting of five levels of classification: BEC, land cover, age, slope and aspect (Table 4.4). We used a 50 m grid format, and classified cells by each variable. Thus each grid cell has a BEC value, a land cover value, an age, a slope and an aspect. The naming convention is *BEC-Cover-Age-Slope-Aspect*. Thus we have one ELU named *SWBmk--True_Fir--Mid_Seral--Steep--WARM*, which is a steep, warm, medium-aged Fir forest in the Spruce-Willow-Birch (mk) BEC zone. When a particular level is not appropriate, for example rock does not receive an age classification, the classification level is skipped in the name. For example the ELU *BWBSwk3--Unveg--Flat* is a flat unvegetated area in the Boreal White and Black Spruce (wk3)

BEC zone. Age and aspect are missing (a flat area has no aspect). All ELUs have a BEC and landcover classification.

4.2.3.1 BEC classes

The 24 BEC types in the study area, as defined by the BEC zone, subzone and variant (Table 4.2, Map 2.1). They delineate broad climatic patterns. In the study area, there are 5 BEC zones, these include the alpine zone, identified as Alpine Tundra (AT, 1 type) and the subalpine zones, which are the Spruce-Willow-Birch (SWB, 2 types) to the north and Engelmann Spruce-Subalpine Fir (ESSF, 10 types) in the far south of the study area. Below these are the Boreal Black and White Spruce (BWBS, 7 types) zone across most of the study area and the Sub-Boreal Spruce (SBS, 4 types) zone in the far south. By far the three most widespread BEC zones are AT (21% of study area), SWB (34% of study area) and BWBS (34% of study area).

4.2.3.2 Land cover classes

Classifying the land cover variable (Table 4.5) involved a number of steps because several datasets were used. First we classified marsh, swamp or glacier cells using TRIM 1:20,000 data. Next, we corrected for the alpine vegetation error in the FIP and VRI data by using BEI data, as explained above. We gave all areas identified as VRI "Alpine" the land cover class “unveg” if that cell was classified as unvegetated (RO, GL, UV and AV) by the BEI data. Otherwise, it was assigned the vegetation class "other". We did not attempt to convert BEI vegetation classification to the VRI or FIP classes because the classification systems are quite different and we felt that it would introduce unnecessary error.

For forested landscape, we identified forest type using the FIP ITG or “forest cover type” definitions. There are 21 ITG classes (Table 4.3) represented in the study area; the majority of forests are primarily found at low and medium elevations. For clarity, we removed ITG definition references to secondary species that do not occur in the study area, even though they form part of the FIP ITG classification in other areas. For example, ITG 19 and 23 (Table 4.3), include the secondary species hemlock and red cedar, which do not occur in the study area so we have omitted reference to them. We amalgamated the 21 ITG groups into 7 land cover types based on the primary species or species group (Table 4.5).

Nonforested vegetation was classified as “Low shrub”, “Tall shrub” or “other veg” based on the VRI level 4 vegetation classes. The VRI level 4 “bryoid” and "herb" classes were grouped into the “other veg” category because such a small area was classified as these life forms that we felt it clearly did not reflect the true extent of those vegetation classes within the study area (based on discussion with local experts and on our own field observations). The small area classified by VRI as shrub within the AT BEC zone was also placed in the "other veg" class for the same reasons.

Thus the “other veg” class includes the VRI herb and bryoid classes, the area VRI alpine class that was reclassified by the BEI adjustment and the small area of AT shrub. VRI level 1 “non-vegetated” areas within the BWBS and SBS BEC zones were assigned to the” unveg” class. The “null” class denotes areas of no landcover data.

Due to differences in the data sources, some areas in the SWB and ESSF sub-alpine areas were identified as Alpine in the VRI classification (and, thus, also as “rock and rubble”) and were reclassified as per the BEI correction. We did this to avoid discontinuities and rings of "unvegetated" areas surrounding "vegetated alpine" areas (or visa versa) which appeared as a result of reclassifying only the AT BEC zone. Additionally, due to differences in the BEC data and the FIP data, some areas in the BEC AT zone have tree cover classification. We retained these in spite of the incongruity of having an Old-growth Spruce class in the Alpine tundra because the FIP data are based on finer-scale data observation whereas the BEC classes are generalized models of climatic influences. Readjusting the BEC boundaries to accommodate the FIP/VRI observations is beyond the scope of this project. Thus, our classification and interpretation of the data here (and also in Section 6) includes areas identified as SWB alpine and AT forested; these likely indicate ecotone areas, and are inadvertently captured through our use of multiple data sources.

4.2.3.3 Age classes

Age classes were assigned to the treed areas based on FIP age classification (Table 4.6). We created an old-growth class (>140 years) to help conserve areas with complex structure, a mid-seral age class (20 - 140 years) and an early-seral class (0 - 20 years). While seral stage structural characteristics tend to develop at different ages for different species, and even for the same species in different environmental conditions, it was beyond the scope of this effort to attempt further differentiation within the ELU. No age data were available for any vegetation other than trees.

4.2.3.4 Slope and aspect classes

All vegetated and unvegetated classes were assigned slope and aspect classes with the exception of slopes <3%, which are simply characterized as flat and do not have an aspect (Table 4.6). Three slope classes were identified: flat (<3% slope), gentle-moderate (3 – 45% slope) and steep (>45% slope. Although finer division of slope could be created, there would be a strong correlation of these finer divisions within the Planning Units, which form our fundamental regional unit of analysis.

The aspect classes were defined so that they correspond to aspect divisions found in the RIC standards for TEM and PEM (Resources Inventory Committee (RIC) 1998; Resources Inventory Committee (RIC) 1999), as well as for the biophysical zones developed for pre-tenure oil and gas planning (BC Ministry of Sustainable Resources 2003). This facilitates cross-walking between these data sets if this becomes desirable. Two classes of aspects were defined: warm aspects (135° - 285°) and cool aspects (285° - 135°). Again, there would be high correlation with the possible finer divisions of aspect at the 500 ha spatial scale, so further division of aspect classes were not defined.

4.3 Umbrella ELUs

The nearly 2,000 ELU classes create a data set that is too large to incorporate into CAD site-selection analyses, given current hardware and software availability. Therefore we reduced the ELU set to a more manageable number of classes by creating an umbrella ELU set for use in the CAD analysis. We amalgamated the ELU set by reducing the information in each of the five levels and combining the slope and aspect classes.

The BEC level classification used to identify umbrella ELUs was limited to the BEC zone, reducing the number of BEC classes from 24 down to 5 (AT, SWB, ESSF, SBS, and BWBS). The land cover level was reduced down to 8 classes from the original 14 by classifying forests as conifer, broadleaf or mixed, by combining the two shrub classes into one class and by removing the glacier class. The slope and aspect classes were combined by assigning an aspect class to the moderate and steep slopes and leaving the flat class intact. Thus, we have a flat class without an aspect, and we have warm aspect slopes and cool aspect slopes.

After these simplifications, the umbrella ELU classification had 4 levels: BEC (5 classes), cover (8 classes), age (3 classes) and aspect (3 classes) for a total of 5 x 8 x 3 x 3 or 360 possible classes (Table 4.7). Some of these possible combinations do not actually occur in the study area, leaving a resultant umbrella ELU set that is an order of magnitude smaller in size than the primary ELU set (159 umbrella ELUs compared to 1,947 primary ELUs). When stratified by the River System strata (Section 2.4.1) for the site selection process (Section 10) this resulted in 728 stratified Umbrella

ELUs (see Appendix A for full classification results). If the primary ELUs were stratified by river system for inclusion in the site selection process, it would likely result in more than 8,000 stratified ELUs. A full representation analysis was run on the primary ELU set to see how well the umbrella set captured the full ELU set within the core areas (Section 10).

The naming scheme of the umbrella ELUs is similar to that of the primary ELUs, *BEC-Cover-Age-Aspect.* For example, *BWBS--Broadleaf--Early_Seral--Cool* defines a young, cool broadleaf forest in the Boreal White and Black Spruce BEC zone. If a classification level is irrelevant, it is simply omitted from the name (and of course from the classification). For example *SBS--Shrub--Cool* defines a cool shrubland in the Sub-Boreal Spruce BEC zone - there are no age data for shrubs. There are also no age data for the other, unveg marsh and swamp classes. Similarly, since marshes and swamps are flat, they are not given an aspect from the DEM data. We also did not give an aspect to the "other" and "unveg" class within the non-AT BEC zones. Because of the small area of these classes, further stratifying them by aspect would have created a number of very rare ELUs that would have potentially biased CAD site-selection analyses.

4.4 Special Feature ELUs

Some vegetation types that have a very limited distribution within the study area were considered “special features” for site selection purposes (Table 4.8). These include a Yew/Lodgepole forest, 3 forest types with a Tamarack component and a Red Alder-conifer forest type (see Table 4.3 for ITG definitions and codes). One regional vegetation expert informed us that Yew and Red Alder do not occur in the study area (Pojar, pers comm). Because they are present in the FIP data set and because they are only 12 and 3 Ha in area respectively, we included them as special elements to alert managers in case there is indeed a small disjunct population (although this appears unlikely). Because these areas are small, the inclusion does not influence the CAD design to an appreciable degree. These habitat types, if they occur, are outside their normal distribution, and the presence of these potentially rare habitat types should be confirmed through field studies.

4.5 Results and Discussion

There are 1,947 primary ELU classes based on 5 levels of classification (BEC, land cover, slope, aspect and age; see Appendix A for full classification results). They are designed to classify the ecological variability across the study area in terms of biotic and abiotic ecological factors. The BEC level captures climate variability in 24 classes. There are 14 land cover classes which capture the vegetation (or lack thereof). Slope is divided in to 3 classes, aspect into 2 and age into 3 classes. Although we were not able to use this full set in the core selection process, the full set allows one to summarize and characterize the study area. Below we present summary and characterization results for the entire study area, but the full ELU set can be effectively used to characterize any specific area. For example, it might be desirable to characterize a pre-tenure planning area or a landscape unit or a protected area. The MK CAD GIS Toolkit (Section 11) also allows non-GIS specialists to perform similar summaries using the reduced umbrella ELU set.

The study area consists mostly of three BEC zones. Alpine tundra covers about one-fifth of the study area and both Spruce-Willow- Birch and Boreal Black and White Spruce cover one-third each. Engelmann Spruce-Sub-alpine Fir covers 10% where as the Sub-boreal spruce is only 1% of the entire study area (Table 4.9). Of the different land cover types present in the study area, spruce, lodgepole pine and fir are the dominant tree species, covering 23%, 15% and 10% respectively. A total of 16% of the study area is unvegetated (Table 4.10).

In order to better understand the distribution of land cover, we can look at the breakdown of cover class by BEC zone (Table 4.11). Of the 16% unvegetated area within the study area, threequarters of it (12% of study area) occurs within the Alpine Tundra zone. Also in the AT zone, we find the incongruous AT forest classes, most of which constitute far below one percent of the region. Again, this anomaly most likely shows the discrepancies between the different data sources.

We can also compare the relative composition of a specific class, (e.g., marsh) within each of the BEC zones. Marsh is very rare in the alpine area, <0.1% of the alpine. In contrast, the Boreal Black and White Spruce zone is comprised of 1.16 % marsh. The southern sub-alpine zone (ESSF) has only 0.2% marsh while the more northerly sub-alpine zone (SWB), has almost 1% (.086%). As is to be expected, spruce and lodgepole pine dominate the low-lying Boreal and Sub-boreal zones (BWBS, SBS) and in the Spruce-Willow-Birch zone, spruce dominates (28%), followed by fir with 15% (as noted in Medinger and Pojar, 1991). The large amount of other veg in the SWB zone (31%) is again due to the BEI reclassification.

Looking at the area of the different age classes (Table 4.12), we see that there is substantial old growth (25%) and very little early successional growth (4%). It also appears that more of the study area is on cool slopes (55%) than on warm slopes (37%), and that relatively little of the study area is flat (6%). Note that some of the totals do not add up to 100% because the glacier class is excluded from this analysis.

Table 4.13 describes the distribution of types of forest in the oldest age class. Spruce and fir account for 14% of the identified old growth in study area and fir accounts for another 7%. There is also over 1000 ha of very old birch. Table 4.14 shows that most of this old age class spruce is in the SWB zone (8% of the study area), and SWB also has the highest proportion of old growth spruce (22%). While not summed in the tables, it is apparent that the sub-alpine zones contain proportionately more old growth than the other zones; the SWB and ESSF zones both contain about 40% old growth.

The ELU classification uses the best data available for the study area, and accounts for many important ecological variables. As such, it should help planners and managers working at a broad scale, but will likely perform poorly at predicting site-level diversity or community variation. The ELU methodology is similar to other efforts at classifying coarse-scale ecological diversity, such as employed by The Nature Conservancy (Anderson, Comer et al. 1999; Groves 2000; Groves 2003), and we expect that the ELU model is a reasonable approach to creating a single, uniform classification across the study area. However, the land cover classification, which is arguably one of the most important inputs of the classification, is assembled from four data sources which are in some degree incompatible with each other. Additionally, most of the sources vary widely in the intensity of their data collection effort over the study area and give different results for the same area. In particular, the lack of realistic alpine vegetation classification represents a critical limitation to understanding this important suite of habitats. Because of these data incongruities and because of the importance of land cover and vegetation data for classifying communities, we recommend that a concerted effort be marshaled to remedy the situation. Satellite imaging appears the most promising avenue at this point.

The ELU classification has not been ground-truthed or checked with other existing fine-scale classifications such as TEM or PEM. We would recommend that such efforts be undertaken as funding becomes available. Additionally, higher resolution data, including understory composition, surficial geology and soil data, landform types, local weather and climate information are additional data gaps. Overstory and shrub layer vegetation composition and structure need accurate updates and uniform coverage across the study area. As these data are gathered, the land-cover classification should evolve in tandem. Satellite data shows promise as a source of region-wide detailed vegetation data.

4.6 Tables

Table 4.1 Summary of data sources used in the ELU classification.

Ecological Driver	Variable used	Data source(s)
Climate	Biogeoclimate	Biogeoclimatic Ecosystem Classification (BEC)
Vegetation	Land cover	Forestry Inventory Planning (FIP) Vegetation Resource Inventory (VRI) Broad Ecosystem Inventory (BEI) Terrain Resource Information Management (TRIM)
Insolation	Aspect	TRIM
Topography	Slope	TRIM
Soil type	N/A	
Soil moisture	Slope	TRIM
	Aspect	TRIM
	TRIM wetlands	TRIM
Vegetation Structure	Age	Forestry Inventory Planning (FIP)

Table 4.2 BEC classes (variants are 1, 2, 3 or 4 as labelled).

BEC code	Zone	Subzone
AT	Alpine Tundra	n/a
BWBSdk1	Boreal White and Black Spruce	dry, cool
BWBSdk2		dry, cool
BWBSmw1		moist, warm
BWBSmw2		moist, warm
BWBSwk1		wet, cool
BWBSwk2		wet, cool
BWBSwk3		wet, cool
ESSFmc	Engelmann Spruce-Subalpine Fir	moist, cold
ESSFmcp		moist, cold parkland
ESSFmv2		moist, very cold
ESSFmv3		moist, very cold
ESSFmv4		moist, very cold
ESSFmvp		moist, very cold parkland
ESSFwc3		wet, cold
ESSFwcp		wet, cool parkland
ESSFwk2		wet, cool
ESSFwv		wet, very cold
SBSmk2	Sub-Boreal Spruce	moist, cool
SBSun		undifferentiated
SBSvk		very wet, cool
SBSwk2		wet, cool
SWBmk	Spruce-Willow-Birch	moist, cool
SWBmks		moist, cool scrub

Table 4.3. ITG codes and species as defined by FIP.

ITG	1st sp name	2nd sp name
10	Yew	Lodgepole pine
18	True fir > 80%	Any
19	True fir	
20	True fir	Spruce, tamarack, lodgepole pine, deciduous
21	Spruce > 80%	Any
22	Spruce	Tamarack
23	Spruce	
24	Spruce	True fir
25	Spruce	Lodgepole pine
26	Spruce	Deciduous
28	Lodgepole > 80%	Any
29	Lodgepole pine	Tamarack
30	Lodgepole pine	Spruce, true fir
31	Lodgepole pine	Deciduous
34	Tamarack	Any
35	Balsam poplar	Conifer
36	Balsam poplar	Deciduous
37	Red alder	Conifer
40	Birch	Any
41	Aspen	Conifer
42	Aspen	Deciduous

Table 4.4 ELU classification levels.

Source	Classification Level	Description	# classes
BEC	Zone-Subzone-Variant	Table 4.2	24
various	Land cover	Table 4.5	13
FIP	Age (young, mid seral, old growth)	Table 4.3	3
DEM	Slope (flat, gentle-moderate, steep)	Table 4.6	3
DEM	Aspect (cool, warm)	Table 4.6	2

Table 4.5 Land-cover classes (see Table 4.3 for ITG definitions).

Land cover class	Data Source or definition
Marsh	TRIM Marsh class
Swamp	TRIM Swamp class
Glacier	TRIM Glacier class
True Fir	FIP ITG 18, 19, 20
Lodgepole Pine	FIP ITG 28, 30
Tamarack	FIP ITG 29,34,22
Spruce	FIP ITG 21, 23, 24, 25
Mixed Conifer/Broadleaf	FIP ITG 26,31,35,41
Broadleaf	FIP ITG 42, 36
Birch	FIP ITG 40
Low Shrub	VRI Level 4
High Shrub	VRI Level 4
Other	BEI vegetated, VRI herb, bryoid
Unveg	BEI unvegetated, VRI Rock, exposed land, etc.

Table 4.6 Age, slope and aspect classes.

Age (for forest only)
early seral (<20yrs)
mid seral (20-140 yrs)
old growth(>140 yrs)
Slope (all veg types)
flat (< 3 %)
gentle- moderate (3% - 45 %)
steep (> 45%)
Aspect (all veg types)
warm (135° to 285°)
cool (285° to 135°)

Table 4.7 Umbrella ELU overview.

Source	Classification Level	# classes
BEC	Zone(AT,SWB,ESSF,SBS,BWBS)	5
Various	Land cover (conifer, mixed, broadleaf, shrub, other, unveg, marsh, swamp)	8
FIP	Age (young, mid seral, old growth)	3
DEM	Aspect (flat, cool, warm)	3

Table 4.8 Special feature ELUs.

ITGs	Forest Name	Area(ha)
37	Alder-Conifer Forest	3
10	Yew/ Lodgepole Forest	13
29	Lodgepole/Tamarack Forest	20
34	Tamarack Forest	4,272
22	Spruce/Tamarack Forest	15,389

Table 4.9 Area of BEC zones in the MK CAD study area.

BEC zone	Area (ha)	% of study area
AT	3,370,221	21%
BWBS	5,396,886	34%
ESSF	1,526,568	10%
SBS	183,914	1%
SWB	5,459,466	34%

Table 4.10 Area of land cover types in the study area.

Cove type	Area (ha)	% of study area
Alder_Conifer	3	0.00%
Birch	157,786	0.99%
Broadleaf	531,464	3.33%
Swamp	292,951	1.84%
Lodgepole_Pine	2,439,054	15.30%
Mix_Conif_Broad	1,158,419	7.27%
Marsh	116,877	0.73%
Other	3,301,841	20.72%
Shrub_low	299,208	1.88%
Shrub_tall	3,568	0.02%
Spruce	3,642,702	22.86%
Tamarack	9,902	0.06%
True_Fir	1,497,291	9.40%
Unveg	2,485,977	15.60%
Yew_Lodgepole	12	0.00%

Table 4.11 Area of BEC zone by land cover types in the study area.

BEC zone	Land cover type	Area (ha)	% of study area	% of BEC zone
AT	**Broadleaf**	55	0.00%	0.00%
AT	**Swamp**	139	0.00%	0.00%
AT	**Lodgepole_Pine**	2,127	0.01%	0.06%
AT	**Mix_Conif_Broad**	53	0.00%	0.00%
AT	**Marsh**	2,903	0.02%	0.09%
AT	**Other**	1,292,452	8.11%	38.35%
AT	**Spruce**	11,484	0.07%	0.34%
AT	**True_Fir**	83,772	0.53%	2.49%
AT	**Unveg**	1,977,237	12.41%	58.67%
BWBS	**Alder_Conifer**	3	0.000%	0.00%
BWBS	**Birch**	150,147	0.942%	2.78%
BWBS	**Broadleaf**	447,273	2.806%	8.29%
BWBS	**Swamp**	267,240	1.677%	4.95%
BWBS	**Lodgepole_Pine**	1,479,499	9.283%	27.41%
BWBS	**Mix_Conif_Broad**	940,062	5.899%	17.42%
BWBS	**Marsh**	62,846	0.394%	1.16%
BWBS	**Other**	89,425	0.561%	1.66%
BWBS	**Shrub_low**	92,014	0.577%	1.70%
BWBS	**Shrub_tall**	1,744	0.011%	0.03%
BWBS	**Spruce**	1,675,206	10.511%	31.04%
BWBS	**Tamarack**	9,665	0.061%	0.18%
BWBS	**True_Fir**	48,975	0.307%	0.91%
BWBS	**Unveg**	132,775	0.833%	2.46%
BWBS	**Yew_Lodgepole**	12	0.000%	0.00%
ESSF	**Birch**	1,212	0.008%	0.08%
ESSF	**Broadleaf**	6,577	0.041%	0.43%
ESSF	**Swamp**	2,433	0.015%	0.16%
ESSF	**Lodgepole_Pine**	237,078	1.488%	15.53%
ESSF	**Mix_Conif_Broad**	38,973	0.245%	2.55%

BEC zone	Land cover type	Area (ha)	% of study area	% of BEC zone
ESSF	**Marsh**	2,967	0.019%	0.19%
ESSF	**Other**	220,017	1.381%	14.41%
ESSF	**Shrub_low**	26,357	0.165%	1.73%
ESSF	**Shrub_tall**	829	0.005%	0.05%
ESSF	**Spruce**	384,120	2.410%	25.16%
ESSF	**True_Fir**	533,661	3.349%	34.96%
ESSF	**Unveg**	72,346	0.454%	4.74%
SBS	**Birch**	2,615	0.02%	1.42%
SBS	**Broadleaf**	7,919	0.05%	4.31%
SBS	**Swamp**	1,213	0.01%	0.66%
SBS	**Lodgepole_Pine**	53,274	0.33%	28.97%
SBS	**Mix_Conif_Broad**	32,627	0.20%	17.74%
SBS	**Marsh**	1,270	0.01%	0.69%
SBS	**Other**	3,066	0.02%	1.67%
SBS	**Shrub_low**	2,795	0.02%	1.52%
SBS	**Shrub_tall**	423	0.00%	0.23%
SBS	**Spruce**	63,209	0.40%	34.37%
SBS	**True_Fir**	10,555	0.07%	5.74%
SBS	**Unveg**	4,950	0.03%	2.69%
SWB	**Birch**	3,812	0.02%	0.07%
SWB	**Broadleaf**	69,640	0.44%	1.28%
SWB	**Swamp**	21,927	0.14%	0.40%
SWB	**Lodgepole_Pine**	667,076	4.19%	12.22%
SWB	**Mix_Conif_Broad**	146,705	0.92%	2.69%
SWB	**Marsh**	46,891	0.29%	0.86%
SWB	**Other**	1,696,882	10.65%	31.08%
SWB	**Shrub_low**	178,043	1.12%	3.26%
SWB	**Shrub_tall**	573	0.00%	0.01%
SWB	**Spruce**	1,508,683	9.47%	27.63%
SWB	**Tamarack**	237	0.00%	0.00%
SWB	**True_Fir**	820,328	5.15%	15.03%
SWB	**Unveg**	298,670	1.87%	5.47%

Table 4.12 Area of ELU age, aspect and slope classes in the study area

Variable	Area (ha)	% of study area
Age		
Early_Seral	568,052	3.56%
Mid_Seral	4,934,320	30.96%
Old_Growth	3,934,261	24.69%
Aspect		
Cool	8,704,429	54.62%
Warm	5,811,975	36.47%
Slope		
Flat	1,010,823	6.34%
Gentle_Moderate	10,671,018	66.96%
Steep	3,845,386	24.13%

Table 4.13 Area of old growth types in the study area

Old-growth type	Area (ha)	% of study area
Birch	1,101	0.01%
Broadleaf	32,172	0.20%
Lodgepole_Pine	437,698	2.75%
Mix_Conif_Broad	181,851	1.14%
Spruce	2,232,158	14.01%
Tamarack	1,709	0.01%
True_Fir	1,047,572	6.57%
Total Old Growth	3,934,261	24.69%

Table 4.14 Area of BEC zone x old growth types in the study area

BEC zone	Old-growth type	Area (ha)	% of study area	% of BEC zone
AT	Broadleaf	12	0.000%	0.00%
AT	Lodgepole pine	454	0.003%	0.01%
AT	Mix. Conif./Broad	6	0.000%	0.00%
AT	Spruce	9,443	0.059%	0.28%
AT	True fir	64,826	0.407%	1.92%
BWBS	Birch	1,047	0.007%	0.02%
BWBS	Broadleaf	26,178	0.164%	0.49%
BWBS	Lodgepole pine	187,901	1.179%	3.48%
BWBS	Mix. Conif./Broad	152,630	0.958%	2.83%
BWBS	Spruce	713,102	4.474%	13.21%
BWBS	Tamarack	1,709	0.011%	0.03%
BWBS	True fir	30,299	0.190%	0.56%
ESSF	Birch	3	0.000%	0.00%
ESSF	Broadleaf	53	0.000%	0.00%
ESSF	Lodgepole pine	45,035	0.283%	2.95%
ESSF	Mix. Conif./Broad	3,028	0.019%	0.20%
ESSF	Spruce	248,057	1.556%	16.25%
ESSF	True fir	332,938	2.089%	21.81%
SBS	Birch	41	0.000%	0.02%
SBS	Broadleaf	315	0.002%	0.17%
SBS	Lodgepole pine	11,747	0.074%	6.39%
SBS	Mix. Conif./Broad	3,601	0.023%	1.96%
SBS	Spruce	39,796	0.250%	21.64%
SBS	True fir	5,774	0.036%	3.14%
SWB	Birch	10	0.000%	0.00%
SWB	Broadleaf	5,615	0.035%	0.10%
SWB	Lodgepole pine	192,560	1.208%	3.53%
SWB	Mix. Conif./Broad	22,587	0.142%	0.41%
SWB	Spruce	1,221,761	7.666%	22.38%
SWB	True fir	613,735	3.851%	11.24%

5 FRESHWATER ECOSYSTEMS ANALYSIS

5.1 Background

Freshwater ecosystems consist of a group of strongly interacting freshwater and riparian / near-shore communities held together by shared physical habitat, environmental regimes, energy exchanges, and nutrient dynamics. Freshwater ecosystems vary in their spatial extent, have indistinct boundaries, and can be hierarchically nested within one another depending on spatial scale (e.g., headwater lakes and streams are nested within larger coastal river systems). Perhaps the most distinguishing features of freshwater ecosystems from terrestrial ecosystems are their variability in form and their dynamic nature. Freshwater ecosystems are extremely dynamic in that they often change where they exist (e.g., a migrating river channel) and when they exist (e.g., seasonal ponds) in a time frame that we can experience. Freshwater ecosystems are nearly always found connected to and dependant upon one another, and as such they form drainage networks that constitute even larger ecological systems. They exist in many different forms, depending upon their underlying climate, geology, vegetation, and other features of the watersheds in which they occur. In very general terms, however, freshwater ecosystems fall into three major groups: standing-water ecosystems (e.g., lakes and ponds); flowing-water ecosystems (e.g., rivers and streams); and freshwater-dependent ecosystems that interface with the terrestrial ecosystems (e.g., wetlands and riparian areas).

Freshwater ecosystems support an exceptional concentration of biodiversity. Species richness is greater relative to habitat extent in freshwater ecosystems than in either marine or terrestrial ecosystems. Freshwater ecosystems contain approximately 12% of all species, with almost 25% of all vertebrate species concentrated within these freshwater habitats (Stiassny 1996). The richness of freshwater species includes a wide variety of plants, fishes, mussels, crayfish, snails, reptiles, amphibians, insects, micro-organisms, birds, and mammals that live beneath the water or spend much of their time in or on the water. Many of these species depend upon the physical, chemical, and hydrologic processes and biological interactions found within freshwater ecosystems to trigger their various life cycle stages (e.g., spawning behavior of a specific fish species might need to be triggered by adequate flooding at the right time of the year, for a sufficient duration, and within the right temperature range, etc.; seed germination of a particular plant might require a different combination of variables).

Freshwater ecosystems support almost all terrestrial animal species since these species depend on freshwater ecosystems for water, food and various aspects of their life cycles. In addition, freshwater ecosystems provide environmental services such as electricity, drinking water, waste removal, crop irrigation and landscaping, transportation, manufacturing, food source, recreation, and religion and sense of place, that form the basis of our economies and social values.

5.2 Classification of freshwater ecosystems

The classification of freshwater ecosystems is a relatively new pursuit. This classification model builds off of the first ever attempted freshwater ecosystem classification done within BC for the Coast Information Teams' ecosystem spatial assessment (www.citbc.org). For classification purposes, coarse-filter freshwater ecosystems are defined as networks of streams, lakes and wetlands that are distinct in geomorphological patterns, tied together by similar environmental processes (e.g., hydrologic and nutrient regimes, access to floodplains) and gradients (e.g., temperature, chemical and habitat volume), occur in the same part of the drainage network, and form a distinguishable drainage unit on a hydrography map. Coarse-filter freshwater ecosystems are spatially nested within major river drainages and ecological drainage units, and are spatially represented as watershed units (specifically BC Watershed Atlas third order watersheds). They are defined at a spatial scale that is practical for regional planning. Coarse-filter freshwater ecosystems provide a means to generalize about large-scale patterns in networks of streams and lakes, and the ecological processes that link them together as opposed to fine-scale freshwater systems which capture a detailed and often quite complex picture of physical diversity at the stream reach and lake level.

A classification of lakes within the Muskwa-Kechika Management Area was also undertaken to capture fine-scale freshwater systems. Lakes, particularly within the region are a hotspot of biodiversity for freshwater species and communities due to both their productivity and in many cases their ability to provide over-wintering refuge for many freshwater species.

5.3 Methods

5.3.1 Freshwater Ecosystem Classification

The types and distributions of freshwater ecosystems are characterized based on abiotic factors that have been shown to influence the distribution of species and the spatial extent of freshwater community types. This method aims to capture the range of variability of freshwater system types by characterizing different combinations of physical habitat and environmental regimes that potentially result in unique freshwater ecosystem and community types. It is virtually impossible to build a freshwater ecosystem classification founded on biological data given that freshwater communities have not been identified in most places, and there is generally a lack of adequate survey data for freshwater species. Given that freshwater ecosystems are themselves important targets for conservation because they provide a coarse filter target and environmental context for species and communities, a classification approach that identifies and maps the diversity and distribution of these systems is a critical tool for comprehensive conservation and resource management planning. An additional advantage of such an approach is that data on physical and geographic features (hydrography, land use and soil types, roads and dams, topographic relief, precipitation, etc.), which influence the formation and current condition of freshwater ecosystems, is widely and consistently available.

The proposed freshwater ecosystem classification framework is based to a large extent on The Nature Conservancy's classification framework for aquatic ecosystems (Higgins, Bryer et al. 2003). The framework classifies environmental features of freshwater landscapes at two spatial scales. It loosely follows the hierarchical model of Tonn (1990) and Maxwell et al. (1995). It includes ecological drainage units that take into account regional drainage (zoogeography, climatic, and physiographic) patterns, mesoscale units (coarse-scale freshwater systems) that take into account dominant environmental and ecological processes occurring within a watershed, and fine-scale lake units that take into account dominant physical features of lakes..

Seventeen abiotic variables were used to delineate coarse-filter freshwater ecosystem types that capture the major abiotic drivers of freshwater systems: drainage area, underlying biogeoclimatic zone and geology, stream gradient, accumulative precipitation yield, air temperature, dominant lake / wetland features, glacial connectivity, channel morphology, valley flat width, K factor, ecosection, maximum stream order and magnitude, hydrologic zone, and Melton's R. Table 5.1 summarizes data sources for each of the classification variables. These variables are widely accepted in the literature as being the dominant variables shaping coarse scale freshwater systems and their associated communities and also strongly co-varying with many other important physical processes (Vannote, Minshall et al. 1980; Poff and Ward 1989; Poff and Allan 1995; Mathews 1998; Hart and Finelli 1999; Lewis and Magnuson 1999; Newall and Magnuson 1999; Brown, Josephson et al. 2000; Brown, Hannah et al. 2003).

The freshwater classification was stratified by ecological drainage units (EDUs) in order to capture broad scale freshwater zoogeographic, physiographic and climatic patterns within each ecological drainage unit (EDU). Categorical variables with more than two categories were run through a nonmetric multidimensional scaling analysis to summarize the variability of the data into two axes. An unweighted pairs group mean cluster analysis (Sorensen; flexible beta –0.25) was then run using all variables. Number of system types was determined by capturing a minimum of 50% of variability in the distance measure followed by expert adjustments based on ecological review of the systems. See Appendix B for additional information on the classification analysis.

5.3.2 Lakes Classification

Six abiotic variables were used to capture the major abiotic drivers of lakes: surface area, shoreline complexity, drainage network position, hydrologic connectivity, biogeoclimatic zone, and underlying geology. Table 5.2 summarizes data sources and variable classes for each of the classification variables. These variables are widely accepted in the literature as being the dominant variables shaping lake ecosystems and their associated communities and also strongly co-varying with many other important physical processes (Hutchinson 1957; Browne 1981; Wetzel 1983; Peters 1986; Rahel 1986; Lodge, Barko et al. 1988; Matuszek and Beggs 1988; Hinch, Collins et al. 1991; Hakanson 1996). Changing the characteristics of any of these variables for a particular lake type will likely result in a change in freshwater communities present.

Within the study area, hydrologic connectivity categories were identified. Lakes within each of these hydrologic connectivity classes were further classified according to their surface area, dominant biogeoclimatic zone they fell within, and their dominant underlying geology. Each of these lake types were then further subdivided based on their characteristics of their placement within the drainage network (stream order of their predominant outflow) and shoreline complexity.

5.4 Results and Discussion

5.4.1 Freshwater Systems

Stikine, Upper Liard, Lower Liard, Upper Peace, and Lower Peace EDUs collectively consist of 5,679 coarse-scale freshwater systems that were classified into 49 freshwater system types. Table 5.3 summarizes the classification of these freshwater ecosystems into umbrella system types within each of the EDUs. Map 5.1 spatially summarizes the abundance and distribution of these freshwater system types within each of the EDUs.

5.4.2 Lakes

There are a total of 26,764 lakes within the study area that were classified into 140 types using variable defined in Table 5.2 A list of the lake system types is provided in Appendix B. Table 5.4 summarizes the classification of these lake types by EDU. A Primary Core Area representation goal of 30% was set for each coarse-filter freshwater system and lake type stratified by Major River System strata (Section 2.4.1). Representation goals were increased to 60% for Secondary Core Areas (see Section 10.2.2).

Freshwater ecosystem types and lake types derived from this assessment have value beyond setting priorities for biodiversity conservation. Freshwater ecosystem types can be used for evaluating and monitoring ecological potential and condition, predicting impacts from disturbance, and defining desirable future conditions. In addition, they can be used to inform sampling programs for biodiversity assessment and water quality monitoring, which requires an ecological framework in addition to a spatial framework to stratify sampling locations (Higgins, Bryer et al. 2003).

We realize that this classification framework is a series of hypotheses that need to be tested and refined through additional data and expert review. We recommend that concurrently, data be gathered to refine/test the classification to bring the scientific rigor needed to further its development and use by conservation partners and agencies.

5.5 Tables

Table 5.1 Summary of data used in freshwater ecosystem classification.

Variable	Data Source(s)	Variable Class(es)
Drainage Area	BC Watershed Atlas, 1:50,000	N/A
Accumulative Precipitation Yield	PRISM Climate Source www.climatesource.com	N/A
Air Temperature	PRISM Climate Source www.climatesource.com	N/A
Biogeoclimatic Zones	BC Ministry of Forests 1:20,000	Percentage of watershed area within each biogeoclimatic zone: Sub-Boreal Spruce Zone Engelmann Spruce-Subalpine Fir Zone Boreal White and Black Spruce Zone Spruce-Willow-Birch Zone Alpine Tundra Zone
Bedrock Geology	Geology sub-classes were delineated based: sediment texture; degree of weatherability / erodability; stream substrate material; and aquifer potential. BC Ministry of Energy & Mines at 1:250,000	Percentage of watershed area within each geology sub-class: **Sediments** – Undivided; Chemical sediments; Fine clastics (shale, mudstone); Sandstones; Coarse clastics; Carbonates; Interbedded limestone/shale **Volcanics** – Undivided; Intermediate to felsic / bimodal; Mafic; Mixed sediments and volcanics **Intrusives** - Undivided; Intermediate to felsic; Mafic / Ultramafic; Alkalic **Metamorphics** – Undivided **Alluvium** – Till
Stream Gradient	BC Watershed Atlas, 1:50,000 & BC 25m DEM	Percentage of stream reaches per watershed within each stream gradient class: <2% 2-8% 8-12% 12-16% 16-20% >20%
K Factor (Water Yield)	Eaton, Church et al. (2002)	N/A
Melton's R (Basin	Calculated using BC	N/A

relief over the square root of basin area)	Watershed Atlas, 1:50,000 & BC 25m DEM	
Hydrological Zones	Eaton, Church et al. (2002)	N/A
Channel Morphology	BC Macro-reach dataset, 1:50,000	Percentage of stream reaches per watershed within each channel morphology class: Alluvial, anastomosed; get islands; 1% or less slope; towards mouth Alluvial, braided; alluvial fan; 1-2% slope; towards head; gravel Alluvial, irregular; flat slope after steep bedrock (r). Alluvial, regular or tortuous meandering; almost always less than 1% slope Lake Rock controlled; over 20% slope; steep. Underground: Interpreted underground stream segment >500 m in length Not Mapped: Interpreted stream segment > 500m in length is not visible on the 1:50K NTS map sheet or underground flow not certain Glacier; Interpreted stream segment > 500m in length is not visible through a glacier Wetland, Unchanneled; Interpreted stream segment through a wetland > 500m in length Human-made ditch defined as a macro-reach Human-made flume defined as a macro-reach Human-made canal defined as a macro-reach
Valley Flat Width	BC Macro-reach dataset, 1:50,000	N/A
Maximum Stream Magnitude and Order	BC Watershed Atlas, 1:50,000	N/A
Ecosection	Demarchi Ecoregions of BC, 1:250,000	Percentage of area watershed within each ecosection
Total number of lakes and wetlands	BC Watershed Atlas, 1:50,000	N/A
Proportion of lake and wetland area to watershed area	BC Watershed Atlas, 1:50,000	N/A
Glacial Influence (ratio of glacial extent to drainage area)	BC Watershed Atlas, 1:50,000	N/A

Table 5.2 Summary of data used in lake classification.

Variable	Data Source(s)	Variable Classes
Surface Area	BC Watershed Atlas, 1:50,000	< 10 ha 10 – 100 ha 100- 1,000 ha 1,000 – 10,000 ha 10,000 – 100,000 ha > 1,000,000 ha
Shoreline Complexity	BC Watershed Atlas, 1:50,000	Round 0.97-1.02 Elongate 1.03-2.03 Complex 2.04 - 4.0 Very Complex >4.0
Biogeoclimatic Zones	BC Ministry of Forests (2002), 1:20,000	BEC Zones in Study Area: Sub-Boreal Spruce Zone Engelmann Spruce-Subalpine Fir Zone Boreal White and Black Spruce Zone Spruce-Willow-Birch Zone Alpine Tundra Zone
Bedrock Geology	Geology sub-classes were delineated based on the following characteristics: sediment texture; degree of weatherability / erodability; stream substrate material; and aquifer potential. BC Ministry of Energy & Mines at 1:250,000	**Bedrock Geology Class - Subclass** **Sediments** – Undivided; Chemical sediments; Fine clastics (shale, mudstone); Sandstones; Coarse clastics; Carbonates; Interbedded limestone/shale **Volcanics** – Undivided; Intermediate to felsic / bimodal; Mafic; Mixed sediments and volcanics **Intrusives** - Undivided; Intermediate to felsic; Mafic / Ultramafic; Alkalic **Metamorphics** – Undivided **Alluvium** - Till
Stream Order at Outflow	BC Watershed Atlas, 1:50,000 & BC 25 m DEM	Headwaters streams (first to third order): Fourth order Fifth order Sixth order Seventh order
Hydrologic Connectivity	BC Watershed Atlas, 1:50,000	Isolated Just inflow Just outflow Inflow and outflow

Table 5.3 Summary of freshwater system types by EDU.

System	Stikine	Upper Liard	Lower Liard	Upper Peace	Lower Peace
Total number of freshwater ecosystems	1,709	957	1,059	1,205	749
Total number of freshwater system types	31	31	29	35	25

Table 5.4 Summary of lake types.

System	Stikine	Upper Liard	Lower Liard	Upper Peace	Lower Peace
Total number of lakes	5,368	10.674	3,435	6,329	355
Total number of lake types	71	90	27	64	14

6 TERRESTRIAL FOCAL SPECIES ANALYSES

6.1 Background and Approach

Planning for the maintenance or restoration of healthy populations of focal species can provide a manageable set of objectives for identifying and prioritizing areas, and for determining the necessary size, location and configuration of conservation areas. Most commonly, focal species are selected because their large home ranges or wide-ranging habits would characterize them as "umbrella species". It is assumed that meeting the conservation needs of umbrella species will simultaneously meet the needs for many other species with smaller space or habitat requirements. Focal species may also be selected because they are sensitive to existing, potential or planned impacts, or have specialized habitat requirements that require the conservation of vulnerable or limiting habitats (Caro 2000; Fleishman, Murphy et al. 2000; Bonn, Rodrigues et al. 2002). The ability of focal species, including umbrella species, to adequately represent biodiversity needs has been inadequately tested, and in some cases, called into question (Lambeck 1997; Andelman and Fagan 2000; Kintsch and Urban 2002; Lindenmayer, Manning et al. 2002). Suites of umbrella species may provide the more biodiversity surrogates for conservation planning (Lambeck 1997; Fleishman, Murphy et al. 2000; Fleishman, Blair et al. 2001; Caro 2003; Roberge and Angelstam 2004). Combining a focal species or umbrella species approach with coarse-filter and fine-filter approaches likely provides the most robust methodology for CAD development (Noss, Strittholt et al. 1999; Noss, Carroll et al. 2002). Focal species monitoring can also be a useful tool in judging the adequacy of the conservation plan once implemented.

6.1.1 Terrestrial Focal Species Selection

We selected the following suite of 7 terrestrial focal species whose habitats characterize the landscape diversity of the MK CAD study area: grizzly bear, grey wolf, mountain goat, northern caribou, moose, Rocky mountain elk, and Stone's sheep. Species were selected based on their umbrella characteristics and sensitivity to potential development impacts in the study area. Focal species were also selected based on our ability to model habitat suitability for each species, based on the existing spatial data (e.g., adequacy of attributes, resolution) and availability of information on ecological requirements of the species. Additional sensitive, rare or declining species were included as special elements in the MK CAD assessments. We also selected 2 aquatic focal species: Arctic grayling and bull trout. These 2 aquatic species have strongly divergent habitat preferences and therefore represent a broad array of stream habitats.

6.1.2 Data Sources

We used ecosection and BEC zones to capture regional and landscape variations in habitat characteristics, VRI and FIP to characterize site-level vegetation, and 50 m DEM to classify slope and aspect. Definitions of the variables used in the habitat models are provided in Tables 6.1 – 6.4. Although TEM and PEM-based habitat models have been completed in portions of the study area, neither TEM or PEM data are available across the region, and thus could not be used to create study-area wide habitat suitability models.

We gathered existing published literature, available regional reports and habitat models on each of the focal species, and used these to inform the ratings of habitat suitability for each species. Additionally, local interview (see Appendix C) information was used to provide additional insights, as well as informal conversations with regional biologists. Draft habitat suitability models were developed by the Craighead Environmental Research Institute (CERI) and are provided in Appendix D. Peer-review and internal review of the CERI draft models provided insights and recommendations for modifying the draft models, as described below. Habitat model validation was completed using animal locations provided by the University of Northern

British Columbia (Dr. Kathy Parker's research group), animal locations obtained during winter field surveys and comparisons with existing habitat suitability models available in the Besa Prophet region of the study area. These validation efforts are summarized for each species below, with further details provided in Appendix E.

6.1.3 Spatially Explicit Habitat Suitability Models

All focal species models for the MK CAD are spatially-explicit, based on data available across the extent of the study area and provide predictions of habitat suitability for each focal species based on present vegetation conditions. The ratings tables provided with the habitat models allow the extraction of habitat capability predictions, or the highest possible habitat value any habitat patch could obtain in an optimal seral stage. The models do not incorporate influences of human developments (e.g., roads, housing) except where changes in seral stages due to resource development are captured in the vegetation data have occurred (e.g., logging cut-blocks may be captured as early seral stage forest). Existing human uses are incorporated in the selection of species core areas, as described below. Importantly, as with all habitat suitability or capability models, these models predict current habitat potential for each species rather than occupancy. The CERI report (Appendix D) describes the initial modeling framework in detail. The Project Team modified these models, based on peer-review comments, internal review, and model validation analyses using field data.

6.1.4 Habitat Suitability Modeling Framework

The British Columbia Resources Inventory Committee (Resources Inventory Committee (RIC) 1999 or RIC 1999) has developed habitat modeling standards based on Predictive Ecosystem Mapping (PEM) and Terrestrial Ecosystem Mapping (TEM). To the extent possible, BC guidelines were incorporated into the original CERI models and carried through into the final models.

The RIC standards provide recommendations on the development of submodels for different life requisites and seasons for each species except gray wolf. These guidelines were followed, developing feeding and security/thermal submodels for 2 seasons, growing season and winter season for each ungulate focal species. Seasonal submodels were then combined to produce a single seasonal living model for each species for use in the MK CAD analyses. For grizzly bear, we developed living models for the growing season, with 3 submodels approximately capturing changes in vegetation phenology (e.g., early spring green-up, mid-summer and fall periods). We developed a winter living model and a growing season living model for wolves.

The habitat suitability models use a 3-part ratings system, with each Part representing a natural division of spatial resolution. Each part of the model is briefly described below, with more detailed descriptions provided in Appendix D.

6.1.5 General Model Structure

The model rating systems is broken into 3 components, each which represent a different spatial resolution of habitat quality. Part I of the 3-part model structure provides a global degradation (i.e., a negative rating), based on regional-scale differences in climate and vegetation across ecosection and BEC types (to the variant level). Part I ratings follow provincial modeling recommendations by rating ecosections and BEC types relative to the provincial benchmark, using the same 0 to -6 scale (0 for no degradation, -6 for greatest degradation). Ecosections and BEC classifications and their abbreviations used throughout the section are provided in Tables 6.1 and 6.2.

Part II of the models rates site-specific vegetation and topographic characteristics. This part deviates from RIC recommendations, since we do not have TEM or PEM site-series classifications for site-level ratings. In lieu of study area-wide TEM or PEM, attributes from VRI, FIP, BEI, and

DEM (Tables 6.3 and 6.4) were used to assess relative habitat values and assign a positive relative scoring based on site level characteristics (with 0 indicating unclassed or nil habitat which is assumed to provide negligible habitat quality for species) and 14 (indicating the highest possible habitat quality). Scoring focused on site-level characteristics assumed to have the highest predictive utility to indicate habitat value within the submodel. For example, scoring may occur at the level of age and canopy density classes within forest species groups for woodland caribou wintering habitat. In most cases, a range of 0-10 was applied to vegetative characteristics and a range of 0-4 was applied to topographic characteristics.

Part III of each model provides spatially-explicit rules that potentially adjust scoring of each life requisite submodel based on spatial considerations (e.g., juxtaposition of feeding and security/thermal habitats). Additionally Part III provides rules for combining within season life requisite submodels to create a single model for each season.

6.1.6 GIS Implementation of Models

To implement the models in a GIS, we first applied the site-level rankings of Part II and then subtracted any Part I degradations to areas receiving Part II scores. Therefore, only habitats containing characteristics judged of value at the site-level were scored at the completion of Parts I and II of each submodel. As stated above, Part III provided further modification of scoring based on spatial relations, as well as providing rules for combining submodels within each season. In some instances, Part III required the standardization of values within each submodel prior to applying rules for combining the submodels.

Following completion of Part III, we standardized (z-score) the values in each seasonal model to range from 0 – 100, with 0 indicating habitats that did not receive any score in Part II because the site-level characteristics were assumed to have negligible value for the species (thus, the site was not scored in Part I or III either) and 100 indicating the highest valued habitat. For all habitat validation efforts, we broke the range of values (of either submodels prior to standardization, or the standardized combined models, as appropriate) into 3 to 5 classes. Of these, the unscored habitat areas were placed in a "nil" class and the remaining scored habitat were based on equal-area classification such that each class approximately covers an equal proportion of the study area.

6.1.7 Model Revisions: Peer-review and Validation

Modifications to draft habitat models based on peer review, internal review, and validation using telemetry data are described below.

6.1.7.1 Peer-Review of Focal Species Models

Each draft model (Appendix D) was sent to 3 – 5 species or regional experts for comments and suggested revisions (see Appendix E). A questionnaire accompanied the models to guide review. Peer-review comments were considered relative to importance of key habitat characteristics (e.g., which slope classes are most important for sheep security habitat, which forest age classes are the most important lichen producing habitats for woodland caribou). Peer reviews were carefully assessed prior to incorporation of recommended changes and comments by multiple reviewers on the same habitat characteristics were taken as more important for revisions than isolated comments from single reviewers. Changes based on peer-review comments were combined with changes based on internal review.

6.1.7.2 Internal Review of Focal Species Models

The Project Team conducted an internal review of the CERI draft habitat models and identified a need to simplify the original approach of scoring multiple, nested VRI hierarchies. Our revisions moved higher-order scores (e.g., scoring of VRI Level 1 – 3) into appropriate site-level habitat descriptors, thus allowing us to refine the predictions of the habitat models. For example, the CERI models scored each hierarchical level within the VRI classification so that all sites identified as vegetated by VRI level 1 received, for example, a score of 2 for winter season feeding habitat for caribou. Additionally, all upland lodgepole pine forest habitat received an additional score of 2, regardless of age or canopy density characteristics. We revised this such that only appropriate habitats, as identified by site-level characteristics received value (e.g., upland lodgepole in the mature and old age classes). The simplification creates more transparent scoring that is more easily interpreted and updated as new information becomes available.

6.1.7.3 Habitat Model validation and assessment using radiotelemetry information from UNBC

We utilized GPS telemetry data from Dr. Kathy Parker's research group at the University of Northern British Columbia for sheep, caribou, grizzly bear and wolf in the Besa-Prophet (BP) region of the study area. Their research has been conducted over the last 3 or more years, and a large database of animal locations has been acquired. The research group cooperated with the CAD Project Team in both reviewing the habitat models for these 4 species, as well as working with us to identify habitat polygons used by the animals.

For our validation purposes, we supplied UNBC with a polygon coverage of our master habitat data, and they identified which polygons contained locations of each species. We were not provided the actual animal locations or the individual identification of the animal, and so pooled all location within a season. For ease of communication, we will refer to these as "animal locations" with the understanding that we are referring to the habitat encompassing the true location. Using the habitat type within each use polygon, we conducted a validation assessment using simple chi-square analyses of the distribution of pooled "locations" by habitat class compared to the expected distribution of locations based on regional availability modeled habitat classes.

We categorized the radio-telemetry data by "season" based on season definitions in RIC standards for winter and growing seasons in the Northern Boreal Plains ecoregion that includes the Besa-Prophet study area (Resources Inventory Committee (RIC) 1999). For each season, we randomly selected half of the location data for initial validation assessment and retained the other half as a secondary validation following revisions of habitat models. We used a one-group chi-square test to compare frequencies of animal location within habitat classes to expected frequencies of each equal area habitat class within the "BP validation area".

6.1.7.4 Model assessments using winter field data

An additional assessment of some of the winter models was completed using animal observations recorded during winter field surveys (see Appendix G for details). We compared models that had undergone revisions based on peer-review, internal review, and radio-telemetry validation (if available) to information on location and habitats identified for species during the February 2004 aerial surveys. Sampling of habitats occurred across the study area, with flights based out of Fort St. John, Fort Nelson, Watson Lake and Dease Lake. The most effective surveys included more open habitats, that were not treed, sparsely treed or had open tree canopies. We visually searched for focal species, recorded a GPS location of the airplane at the time animals were observed, location of the animal(s) relative to the location of the plane, and habitat descriptions for all animals seen. Animal locations were then corrected relative to locations of the airplane based on location descriptions and buffered to account for potential errors in location estimates. Locations recorded as less than 300 m from the plane were buffered by 100 m, locations 300-500 m were buffered by 300 m, and locations greater than 500 m were buffered by 500 m. We did not use locations recorded as greater than 500 m from the plane in the habitat model assessments. We used the area-weighted average habitat score to approximate the habitat suitability at the buffered animal locations.

To quantify the types of habitats surveyed, we assumed a survey strip of 300 m on each side of the flight path (as recorded by GPS), acknowledging there was a strip of unknown width directly under the plane that was likely inadequately surveyed. While we searched for and occasionally spotted animals at greater distances from the plane, the majority of the animal locations were within 300 m. Within the survey strip, we calculated the amount of predicted habitats in each of the 5 classes of winter habitat for each species sighted (Stone's sheep, moose, elk, woodland caribou, mountain goat), and used this as a measure of habitat availability. Across the study, we surveyed approximate 255,218 ha. Details of the field effort are in Appendix G.

6.1.7.5 Comparison with TEM or PEM Models

Results of our models were also compared to PEM and TEM models developed according to Provincial Standards (Resources Inventory Committee (RIC) 1999). Direct comparisons of habitat ratings between our models and models based on TEM or PEM data are difficult because of the different habitat interpretation methods and descriptors of the underlying vegetation data. Still, there may be some value in comparing our models to existing habitat suitability models completed for portions of our study area. While habitat capability models have been completed for most pre-tenure areas within the MKMA, only the Besa-Prophet pre-tenure (BPPT) area contains habitat suitability models in addition to habitat capability models. However, these are available for the winter season only.

We compared the relative rankings (lowest class and highest class) of our habitat models and the BPPT habitat suitability models for the winter season as a relative assessment of our habitat model's performance for species for which we did not have a diversity of other validation information. Models compared included mountain goat, elk and moose, as we did not have radio-telemetry data for validating these models. Due to the lack of other validation information, comparisons with other predictive models provided may provide a valuable assessment opportunity.

6.1.8 Final Habitat Models

Following the suite of reviews and validation efforts, we finalized the habitat scoring for each of the 3 – 6 submodels for each species and implemented Part III to adjust ratings for any spatial configuration rules and combined submodels to form 2 – 3 seasonal models for each species. Final model scores were standardized (z-scores) 1-100 and 10 equal interval classes were identified, with an additional "nil" class to allow easier interpretation of scores. Thus, the top 10% of the scores define "Class 10", the next lower 10% define "Class 9" habitat, and so on. The nil class is identified as all habitats that did not receive a score in the modeling process. As a final check of the distribution of UNBC radio-telemetry animal locations within our final habitat model classes, we calculated the distribution of all locations within each habitat model, as classified by 10 equal interval classes (as opposed to the original equal area classes used for the validation tests; see Appendix E).

6.1.9 Planning Unit Scoring

Habitat scores from the 50 m grid cells were summed across the 500-ha Planning Units. Thus, the Planning Unit habitat scores could potentially range from 0 for Planning Units without any suitable habitat to 200,000 for Planning Units with 100% of the highest habitat score. For reporting purposes, we classified each Planning Unit on a scale of 0 to 10 for each habitat model, with 0 indicating no habitat value, and 1 to 10 indicating percentile rank of the Planning Unit relative to those across the study area.

6.1.10 Core Habitat Area Selections

We used the raw PU scores as inputs to spatial optimization procedures to select core habitat areas for each species, as described below. We used the MARXAN application (Ball and Possingham 2000) to assist us in selecting species core habitats. The MARXAN program works as a stand-alone application that receives spatially-explicit data generated through GIS. Goals for the representation of various conservation elements (e.g., focal species seasonal habitats) are user-defined, as are costs associated with selection of Planning Units. Cost includes edge-related costs that favor solutions with clustered Planning Units that reduce total boundary or edge length, and costs associated with the level of existing human uses on the land base.

We used the MARXAN "greedy heuristic" algorithm to identify clusters of sites or Planning Units that have been identified to support high value seasonal habitats for each focal species while minimizing cost, as defined through edge-related costs and costs of including areas with existing human uses. Greedy heuristic is a step-wise iterative process by which the Planning Unit that improves the portfolio the most is sequentially added at each step. Improvement is based on the habitat values and the human uses contained within the Planning Units (PU's) and the level of representation achieved relative to the goals for each seasonal habitat and the cost of adding the PU. This continues until the established goals are met or additional PUs do not improve the solution (e.g., all goals are met). Stated simply, the greedy heuristic iteratively adds whichever PU has the most unrepresented targets (i.e., high-value seasonal habitat). Additional MARXAN greedy heuristic parameters and settings are described in detail in Section 10.2.

Goals for species core habitats were identified within each of the 6 major river systems as percentages of the total summed habitat score values available within the river system. For example, within River System 1, there was a total caribou growing habitat summed score of 612,822,794. This is the summed value of the 50 m grid cell scores (range per cell is 0-100), summed to 500-ha Planning Units and then summed across PUs within River System 1. We set a 30% target on the seasonal summed habitat values scores for each species within each River System. Thus, for woodland caribou growing season in the River System 1, we set a goal of 183,846,838, which represents 30% of the total summed scores available. PUs with higher scores have larger amounts of high value habitats (e.g., more 50 m grid cell with high value habitat, or fewer grid cells with low value habitat). Thus, Planning Units with high scores are inherently weighted because it is more "efficient" to select these high value PUs for their utility to reduce the gap between the selected set and the goal while minimizing the area cost.

6.2 Stone's Sheep Habitat Model

6.2.1 Stone's Sheep Taxonomy, Status and Distribution

Scientific Name:	*Ovis dalli stonei*
Species Code:	M-OVDS
Status:	Blue listed (Includes any indigenous species or subspecies (taxa) considered to be vulnerable in BC. Vulnerable taxa are of special concern because of characteristics that make them particularly sensitive to human activities or natural events (Ministry of Environment 1997); not at risk (Committee on the Status of Endangered Wildlife in Canada (COSEWIC) 1998)

Provincial Range: In BC, Stone sheep are found from the Yukon border to just south of the Peace Arm of Williston Reservoir (Nagorsen 1990).

6.2.2 Stone's Sheep Ecology and Habitat Requirements

The world population of Stone's sheep inhabits mountainous areas of northern British Columbia and the southern Yukon (Geist 1971; Nagorsen 1990; Bowyer, Leslie et al. 2000) Populations occur on the Yukon and Stikine plateaus, the Skeena, Cassiar and Omenica Mountains from the Pine River to the Liard River, and the Boundary Ranges of the Coast Mountains (Wildlife Branch 1978).

Habitat of all North American wild sheep is generally restricted to semi-open precipitous terrain with rocky slopes, ridges, and cliffs or rugged canyons with gently sloping saddles and alpine meadows with abundant vegetation (Geist 1971; Lawson and Johnson 1982; Seip 1983). They eat primarily grasses and sedges, but also supplement their diet with several kinds of herbs in the summer and woody plants in the winter (Banfield 1974). While habitat quality for sheep is dependent upon the availability of suitable escape terrain, specific requirements for escape terrain are not well documented for Stone's sheep. Bighorn sheep (*Ovis canadensis*) escape terrain has been much better characterised and we assume that escape terrain requirements are similar between the two species. Van Dyke *et al.* (1983), in a review of California bighorn sheep (*O. c. californiana*) escape areas, reported that steep broken cliffs with traversable terraces are most desirable; where steep cliffs are lacking, steep slopes and talus are used.

Van Dyke et al. (1983) suggested optimal bighorn foraging habitat lies within 1 km of suitable escape terrain and few bighorns forage more than 1.6 km from escape terrain. Smith *et al.* (1991) reported more restrictive distances: generally only 300 m but as much as 500 m if escape terrain is available on more than one side. Wolf predation has been suggested as a reason for limiting wild sheep to rougher terrain, but their ability to find ample forage with little competition from other ungulates (McCann 1956) and adjacency to nearby escape terrain (Lawson and Johnson 1982) have also been proposed.

Stone's sheep typically have at least 2 seasonal home ranges (summer and winter) but some individuals, especially rams, may have additional home ranges based on periods within seasons, rutting behavior, or location of salt licks (Geist 1971). Winter range typically consists of steep south facing cliffs (Wood 1995; Corbould 2001) and windblown alpine ridges (Backmeyer 1991). Within the extent of the MK CAD study area, Backmeyer (2000) suggested 3 distinct wintering strategies among Stone's sheep on the north side of Williston Reservoir: exposed alpine/subalpine, mid-elevation conifer bluffs, and low-elevation, south-aspect, shrub/grasslands with adjacent escape terrain. Summer range is often moderately sloped (40-50%) alpine grassland and talus/scree habitats (Wood 2002), gradually increasing in elevation with the greenup of vegetation.

Stone's sheep are considered specialized grazers, often selecting more nutritious parts (seed heads or leaves vs. stems) within plants (Geist 1971). Year-round diets primarily consist of grasses and sedges but may vary in winter depending on snow conditions. Stone's sheep may stop digging for food when snow depths exceed ~30cm (Seip and Bunnell 1985) or when hard, crusty, or wet snow makes digging difficult (Geist 1971). Food intake in winter may therefore become one of availability. Examining plant fragments from sheep pellets collected during winter at 3 sites within the Peace Arm drainage, Corbould (1998) reported a dominance of graminoids at a site in the BWBSmw1 BEC zone, while results from the AT zone indicated a dominance of forbs at one site and lichens at another. Seip and Bunnell (1985) found Stone's sheep to consume a high percentage of lichen (36%) only when they were restricted to windswept alpine areas during a high snowfall year, and Corbould (1998) suspected the dominance of lichens was due to unavailability of graminoids under existing snow conditions.

6.2.3 Stone's Sheep Model Ratings

Below, we briefly describe the ratings applied to habitat characteristics in Parts I and II of the habitat models for growing and winter. These summaries are based on the draft CERI ratings and any modification of those ratings (see Appendix D). The final habitat ratings tables are provided in Appendix F.

6.2.4 Stone's Sheep Model Ratings

The final model ratings tables are in Appendix F. Ratings or patterns in ratings are described in very general terms here.

6.2.4.1 Stone's Sheep Model Ratings: Part I

Ecosections and BEC zones and subzones were rated to incorporate potential regional or coarse-scale differences in habitat quality for Stone's sheep during winter and growing season. Ecosections of the study area were rated similar to RIC Standards when applicable. The Muskwa Foothills ecosection (MUF) is the provincial benchmark during both seasons and was rated "0" while the Muskwa Plateau ecosection (MUP) was rated "-4" for both seasons. Other ecosections were rated relative to these scores. The Stone's sheep Provincial benchmarks for BEC zones are SWBmk in winter and AT in summer (RIC 1999). We rated AT as "0" in the winter, also. All other BEC zones and subzones were rated relative to these benchmarks, with details provided in Appendix D, the CERI draft habitat model report.

6.2.4.2 Stone's Sheep Model Ratings: Part II

Overall, herbaceous upland and alpine habitats were rated as the most suitable feeding habitat and steep, rocky areas in alpine and upland as the most suitable security/thermal habitat for Stone's sheep in both seasons. Non-vegetated rocky areas in alpine were assumed to have some feeding value for several reasons. Wild sheep are adapted at finding small patches of vegetation within rocky areas. Although rocky cliffs contain only sparse vegetation, they shed snow easily in winter and are warmer, thus providing easier access to available forage. Additionally, as described in Section 4, the existing data do a poor job of differentiating between alpine vegetated and non-vegetated habitats, and thus, many areas classified as non-vegetated may support vegetation.

We modified the scoring approach used on other non-alpine species, to more appropriately rate the key habitat features that define security/thermal habitat for sheep. For the sheep security/thermal submodels, we weighted the slope characteristics using a 0 - 12 ratings range, with aspect receiving a 0 - 2 score range. Vegetative conditions potentially important to define escape terrain were incorporated as higher-order constraints on the distribution of scores across the landscape. For example, suitable escape terrain based on slope characteristics received lower scores if they were within forested areas than if they were with herbaceous or open low shrub habitats. We scored the foraging habitats the same as with other species, with vegetative characteristics receiving a 0-10 range of scores and topographic characteristics receiving a 0-4 range of scores. For foraging habitat, we assumed that slope was not a useful predictor of foraging habitats, as sheep use both steep slopes and relatively flat benches or saddles for foraging. Warm aspects were assumed to be important in winter for both feeding and security/thermal, and of limited importance for feeding in the growing season to capture early growing season green-up that may draw sheep to these aspects.

6.2.4.3 Stone's Sheep Model Ratings: Part III

We used spatial juxtaposition rules to adjust the scoring on feeding and security/thermal in both winter and growing seasons. First, while the scoring of security/thermal habitat should have eliminated any ratings for areas with slopes < slope class 2, we ensured this by removing any security/thermal habitats that did not meet this definition. The realized quality of feeding habitat is largely determined by its proximity to escape terrain. Therefore, we increased the score on all feeding habitats within 100 m of escape terrain and kept the score applied to feeding habitats within 500 m of security/thermal habitat. We eliminated all predicted feeding habitats that were located >500 m from security/thermal habitat. Additionally, we eliminated all escape terrain located greater than 1 km from feeding habitat.

To combine feeding and security/thermal within each season, we standardized (z-score) the scoring of each submodel so values ranged from 0- 1. We then summed the scores between the 2 life requisite models for each season; this may account for the increase in habitat quality for areas that support both foraging habitat and escape terrain. These scores were broken into 2 - 4 equal area classes for validation purposes, as summarized below. Following validation and revisions, the final seasonal models were standardized (z-score) to scores 0-100, with 0 indicating unscored or "nil" habitat and scores near 100 indicating the highest habitat qualities predicted.

6.2.5 Refinement and Validation of Stone's Sheep Habitat Suitability Model

We used telemetry locations and observations obtained during winter aerial surveys to assess the sheep habitat models.

6.2.5.1 Model assessment using telemetry information

We received a large dataset of sheep "locations" from the Dr. Kathy Parker at UNBC. This data included over 35,000 locations of sheep between January 2001 and October 2003. We did not know the identity of individual sheep, and had to pool all locations together for use in model assessments. We used these data to assess the ability of our model to predict quality sheep habitat by comparing the relative proportions of sheep locations within habitat classes to the expected distribution of locations if selection were random (i.e., based on relative amounts of the habitat classes in the region). We randomly split the location data into 2 sets, using one subset to develop recommendations for model revisions and the second to do an additional assessment of the models following revisions. From each set, we broke locations into their appropriate season.

For each season, we assessed feeding and security/thermal habitats separately. First, we attributed all locations with each submodel equal area class. Because many high quality feeding habitats were classed as "nil" security habitat, we assumed that sheep locations in high quality (class 3 or 4) feeding habitats were feeding, and removed these locations from the security/thermal validation effort. Due to the distribution of the life requisite models, only 2 equal area classes could reasonably be defined for the security/thermal habitats, with an additional "nil" class.

Validation assessment using the telemetry information showed that a large proportion of the sheep locations fell within our highest 2 feeding habitat classes, with 97% and 93% of locations falling within the highest winter feeding and growing feeding habitat classes, respectively (see Appendix E). This is a much larger percentage than expected, with these winter feeding and growing feeding classes covering 36% and 39% of the BP study area, respectively. Similarly, we found 96% and 87% of the locations within the highest habitat classes in the winter and growing seasons, respectively. These habitats covered a relatively limited portion (18%) of the study area. The evaluation using the telemetry information shows that we were able to successfully predict high quality habitats for Stone's sheep from a regional perspective. We chose not to attempt further revisions of the models. We combined the feeding and security/thermal submodels for each season, as described in Part III, and used the second half of the telemetry data to complete a secondary validation of these combined models. Again, a larger than expected proportion (95-97%) of the locations fell within the predicted high quality classes (Tables 6.5 and 6.6). Additionally, we evaluated the distribution of locations within our final 10 equal-interval classes (see Appendix E). During the growing season, 69% of the sheep locations fell within Classes 9 and 10, which covered only 19% of the area. During the winter, 79% of the locations were found within Classes 9 and 10, though only 8% of the study area was classified as these highest suitability habitats. Given the coarse-scale evaluation of habitat availability, we caution that this assessment indicates that these habitat models appear to function well to identify potential sheep habitats at a regional level, but may not distinguish habitats well at a local level.

6.2.5.2 Model assessment using winter survey observations

During winter aerial surveys, we recorded 54 sheep observations, consisting of locations of individual or groups of animals. We overlaid these observations onto our winter habitat model. There were 47 (87%) observations located within the highest 2 habitat classes (Class 3 and 4) predicted in the habitat model, with 5 (9%) located in Class 2 habitat and 2 (4%) located in Class 1 habitat (Table 6.7). There were no sheep found in areas we predicted to not support sheep winter habitat (Class 0). This distribution of habitat use is quite different than expected, as determined by the relative amounts of habitat classes actually surveyed, with more animals found in high quality classes then expected based on habitats surveyed and assuming random distribution of animals within these habitats.

6.2.6 Stone's Sheep Habitat Model Results

The Stone's sheep habitat ratings tables for winter and growing seasons are presented in Appendix F. We applied these ratings across the MK CAD study area (Maps 6.1a and 6.1b). The amounts of habitats within Classes 0 – 10 for each season are shown in Table 6.8. The growing habitat model identified approximately 700,000 ha or 4.3% of the study area as the highest Class 10 habitat. An additional 6% of the study area (955,000 ha) was identified as Class 9 growing season habitat. There is much less Class 10 winter habitat identified, with just 56,300 ha or 0.35% of the study area classified in this highest value habitat. An additional 376,000 ha or 2.3% of the study area is classified as winter habitat Class 9. Approximately 60% of the study area is classified as "nil" or without habitat value for Stone's sheep in either season.

As described above, we summed habitat scores within 500-ha Planning Units. These Planning Unit scores are used for Sheep Core Habitat selection. For reporting purposes, we classified Planning Unit Stone's sheep winter and growing season scores into 10 classes, representing the percentile rank of each Planning Unit relative to other Planning Units in the study area, based up the realized range of scores for the habitat model (Table 6.9).

6.2.7 Stone's Sheep Core Habitat Selection

Stone's sheep core habitat areas capture 30% of the total habitat value across the study area, and contain the highest value Planning Units for both winter and growing habitat (Figures 6.1 and 6.2). A total of 12.25% (1.98M ha) of the study area is identified as supporting core habitat for Stone's sheep (Map 6.1c). Of this, 63.37% (1.25M ha) is within the MKMA; these habitats are distributed throughout the more mountainous interior portions of the MKMA. Given that the MKMA covers only 39% of our study area, the large proportion of the identified core habitats that occur within the Management Area indicates that the MKMA is particularly important for the regional conservation of Stone's sheep. The habitats outside of the MKMA are found primarily along the western portions of the study area, and likely form important linkage populations to the western extreme of Stone's sheep distribution.

6.3 Grizzly Bear Habitat Model

6.3.1 Taxonomy, Status and Distribution

Scientific Name: *Ursus arctos*
Species Code: M_URAR
Status: Blue-listed (Includes any indigenous species or subspecies (taxa) considered to be vulnerable in British Columbia. Vulnerable taxa are of special concern because of characteristics that make them particularly sensitive to human activities or natural events).

Provincial Range: Grizzly bears can be found throughout British Columbia, with the following exceptions. Grizzly bears do not occur in Georgia Depression Ecoprovince, Vancouver Island, Queen Charlotte Islands, and the Coastal Douglas-fir (CDF), Bunchgrass (BG) and Ponderosa Pine (PP) biogeoclimatic zones (reference Stevens work).

6.3.2 Grizzly Bear Ecology and Habitat Relations

Grizzly bears are a highly mobile species with large spatial requirements. They occupy a variety of habitats throughout their distribution, ranging from coastal estuaries to alpine meadows. In the Khutzeymateen Valley of coastal BC, grizzly bears consistently preferred forested habitats consisting of floodplain old growth and skunk cabbage old growth and non-forested wetlands and estuaries on lower slopes and valley bottoms (MacHutchon, Himmer et al. 1993). In the U.S. Rocky Mountains, subalpine fir communities are the most important forest type used by grizzlies overall (Blanchard 1983; Craighead, Craighead et al. 1986; Craighead, Sumner et al. 1995), and within Montana they prefer heavy timber, rockslides, avalanche chutes, wet meadows, and alpine meadows in general (Mussehl and Howell 1971). However, riparian areas, mesic meadows, and grassland/ forest ecotones are also important (Mealey, Jonkel et al. 1977; Craighead, Craighead et al. 1986; Agee, Stitt et al. 1989; Craighead, Sumner et al. 1995). A high diversity of habitat is required within their home range to meet all life requisites. Specific habitat use varies seasonally, by individual, and is often influenced by food availability and landscape connectivity.

Grizzly bears are opportunistic feeders, utilizing a variety of annual foods across their distribution and within their local range. However, they are often selective in seasonal use of food items and will track phenological development of preferred forage or switch to different items in years or time of the year they are available. In the Yellowstone National Park area of Montana and Wyoming alone, food items cover a range of habitats from lower-level riparian areas to high elevation alpine. In addition to the many documented herbaceous and shrubby plant items, grizzly bears feed on spring-spawning cutthroat within riparian areas, scavenge winter kill on ungulate winter range in spring (Mattson 1997), feed on army cutworm moths in the alpine from late June through early September (French, French et al. 1994), obtain much of their seasonal energy needs by digging whitebark pine nuts in fall from red squirrel caches in the alpine during years they are available (Mattson, Kendall et al. 2001), as well as more obscure items such as earthworms (Mattson, French et al. 2002), and fungal sporocarps (Mattson, Poduzny et al. 2002). Bears in the Yellowstone National Park area have also been shown to change their distribution corresponding to the availability of elk gut piles or animal carcasses during hunting season outside the park (Haroldson, Schwartz et al. 2004).

Grizzly bears occupy all biogeoclimatic zones within British Columbia (Saxena and Bilyk 2001), utilizing a variety of food items and specific sites within them. In the one of the most intensive habitat studies adjacent to the MKMA, (Pearson 1975) documented the following grizzly bear use in all general biotic zones (valley bottom-alluvial plains, boreal forest, subalpine willow belt and above treeline) and selection for specific seasonal foods in each. Roots of sweetvetch (*Hedysarum alpinium*) on open hillsides were the most important food after den emergence. As the season progressed, some grizzlies moved down to the valley bottoms to continue feeding on sweetvetch, while others remained at higher elevations. During June and July, most grizzlies moved into upper parts of the forests and especially subalpine willow flats where willow catkins, grasses, and dry kinnikinnick fruits were the dominant foods. When soopolallie (*Shepherdia canadensis*) ripened in late July at lower elevations, most bears moved down to feed on them until mid-August. Some bears then moved to higher elevations to continue feeding on berries while others stayed on the flats to feed on sweetvetch roots. Roots and late ripening berries remained the major food source until denning.

Similar results were reported by Miller et al. (1982) for the boreal Mackenzie Mountains of the Northwest Territories. In June and July, grizzlies fed primarily in alpine habitat on horsetails and to a lesser extent on sedges, grasses and roots, with green matter comprising more than 85% of their diet. Bears fed on berries and dug for sweetvetch roots in subalpine areas at the start of August. By late August, blueberry, crowberry and soopolallie berries made up 84 % of the diet. Bears gradually moved into the subalpine to feed on sweetvetch roots and late ripening blueberries and crowberries in fall. Alpine and subalpine areas were used equally at this time and forested areas appeared to be selected against. Bears concentrated in higher elevation areas until denning.

Within boreal floodplain habitat of Nahanni National Park Reserve, scat analyses (mix of black bear and grizzly bear) indicated the most important foods were kinnikinnick and horsetail in late June and early July, with increasing use of soopolallie fruits until it became the dominant food through August (MacDougall, McCrory et al. 1997). Some feeding of sweetvetch root was also noted.

To the south of the MKMA in Kakwa Provincial Park, field analysis of 169 grizzly bear scats indicated cow-parsnip was the most frequently consumed plant by grizzly bears from mid-June through to mid-August, with grasses, sedges, and horsetail also being important (McCrory 2003). The park is characterized by Sub-Boreal forest (ESSF) covering nearly half the area with alpine tundra, rock and ice accounting for the remainder. Based on ground-truthing and 1:20,000 mapping of grizzly habitat types, McCrory (2003) rated vegetated ATp, ESSF mv2, ESSF wc3, ESSF wk2, SB Svk and ICHvk2 as having high grizzly bear potential for at least one or more bear seasons.

High grizzly habitat values from valley bottom to alpine were also identified by detailed ground surveys in Monkman Provincial Park (McCrory and Mallam 1990). Subalpine parkland meadows in the ESSF had the highest all-season values with glacier lily corms and cowparsnip appearing as the most important food components. At lower elevations, successional areas with soopolallie were rated the most significant.

Habitat surveys and analysis of point locations of 2 instrumented grizzly bears in the area of Liard River Hotsprings Provincial Park suggested grizzlies used lower elevation areas of BWSdk2 and BWBsmw2 subzones in spring and then range widely in summer and fall at higher elevations in burned-over SWBmk and AT. Lower elevation areas along the Liard boreal floodplain (BWSdk2 and BWBsmw2 subzones) were rated low to moderate potential for grizzly bears (McCrory and Mallam 1994).

In late fall/pre-denning grizzly habitat surveys in Nevis Creek and Sikanni Chief River areas of the MKMA (McCrory 2003) made the following habitat observations:

> "I observed that spring and summer habitats supporting important green vegetation foods for bears (cow-parsnip, horsetail, grasses, sedge) were common throughout the areas surveyed. Spruce-horsetail riparian habitats, an important late spring-summer habitat in the Rockies, were interspersed. The region is noted for its high ungulate biomass. Likely, ungulates are an important, but opportunistic, food source for grizzlies throughout their active cycle from spring to den-up. Fall berry-producing habitats were available throughout in wildfire sites, in some of the maturing lodgepole pine (*Pinus contorta*) forests, river breaks (kinnikinnick and soopolallie), drier slopes, and in some of the widespread plateau spruce/pine forests (mainly crowberry). Only several small root/corm grizzly feeding sites were observed but large feeding areas for root/corm foods likely exist and would be very important. At a superficial level of evaluation, both the plateau and foothills mountains, with their generally low relief, appear to have a relatively high degree of permeability/connectivity for bear travel. Major valleys lie on an east-west axis but numerous north-south tributaries with low connecting passes provide many wildlife avenues for connectivity. This appears to be a noteworthy feature of the ecosystem."

The BEC zones/subzones surveyed were the ESSFv4, BWBSmw1, and possibly SWBmk., SWBmks, and SWBun types. Based on these limited surveys and grizzly habitat surveys elsewhere in similar ecosystems, McCrory (pers. comm.) considers all zones/subzones in the M-K CAD study area, including vegetated AT, to have a high habitat value for grizzly bears for at least one of the bear seasons.

Diverse habitat use and variability within and between years makes it difficult to model grizzly bear habitat suitability (in the Parsnip River study area of east central British Columbia, grizzly bears switched use to drier pine habitats on a year when berries were abundant after avoiding dry pine habitats the previous 2 years (Ciarniello, Boyce et al. 2003). A variety of methods have been used, including the cumulative effects model (CEM) for the Yellowstone National Park area (Weaver, Escano et al. 1986) and an adapted version for the vicinity of Banff National Park (Gibeau) that encompass hundreds of potential inputs and scenarios concerning energy availability and human disturbance. However, evaluation of models from 4 authors using locations from GPS collars on grizzly bears indicated a relatively simple model based on habitat ratings performed as well or better than more complex models including the CEM (Craighead, Haroldson et al.).

6.3.3 Grizzly Bear Model Ratings

Below, we briefly describe the ratings applied to habitat characteristics in Parts I and II of the habitat models for the early, mid and late growing seasons. The final ratings tables are provided in Appendix F. We did not develop a denning or winter habitat model. The general descriptions provided in this section are based upon the draft CERI ratings and any modification of those ratings (see Appendix D for CERI models). We describe the validation of the draft models and the refinements to those models based on radio-telemetry assessments in the section that follows.

6.3.3.1 Grizzly Bear Model Ratings: Part I

There are no Provincial benchmarks established for ecosection ratings. We chose to rate ecosections based on expected relative densities of bears within broad ecological regions (Poole, Mowat et al. 1999; Herrero, Miller et al. 2000; Ciarniello, Paczkowski et al. 2001; Poole, Mowat et al. 2001; Ciarniello, Boyce et al. 2002; Ciarniello, Boyce et al. 2003; Mowat, Heard et al. 2004; Mowat, Heard et al. 2004) and possible related productivity. These efforts have identified relatively low density of bears with boreal plains habitats and relatively higher densities of bears with the more productive habitats along the west-front of the Rocky Mountains as compared to the east front of the Rockies. Following this, west-side ecosections (MIR, WMR, CAR, KEM, SBP and NOM) were not degraded, while eastside ecosections (PEF, MUF, EMR) received a -1 and ecosections dominated by boreal plateau type habitats (MUP, LIP, SIU, HYH) received a -2.

There are no Provincial benchmarks for rating BEC units for grizzly bear habitat quality. Based on the habitats supported, peer-review comments and patterns of use seen in the radio-telemetry data used for model validation, we did not degrade scores for the SWB and ESSF BEC zones or subzones. We degraded AT scores by -2, as most alpine habitat use seen in the radio-telemetry data (from UNBC) occurred within the SWB zone (81% of alpine locations), even though only 38% of the alpine fell within this zone (60% is within the AT). This degradation assists in differentiating SWB alpine habitat, which appears to be of high value through the growing season, from AT alpine habitat, which is used substantially less, based on the UNBC data in the Besa-Prophet region. We also found that grizzly locations were rarely found within the BWBS BEC zone. Across the region encompassing the UNBC study area, the BWBS accounted for approximately 28% of the area, but only contained 2% of the locations. Alternatively, SWB covered approximately 38% of the area, with approximately 88% of the locations. Alpine Tundra covered 23% of the area, with 9% of the locations. Based on this information, we degraded BWBS by -3, degraded AT by -2 and retained the 0 score for SWB. The low use of BWBS supports other research that reports low bear productivity in these habitats (see citations above). The SBS types were degraded by -1 in the middle and late parts of the growing season when vegetation greenup has occurred throughout the study area and bears may move away from lower elevations.

6.3.3.2 Grizzly Bear Model Ratings: Part II

Site-specific ratings in Part II are phenologically influenced; early season ratings are intended to reflect increased suitability of desirable early season green-up in vegetation, mid-season rating apply when the green flush has occurred throughout, and late season submodel is applicable when berries have ripened and green vegetation has cured in many areas. Radio-telemetry validation and peer-review comments were used to guide revisions of the draft CERI Part II model ratings.

During the early part of the growing season, warm-aspect, non-forested upland herbaceous or sparse shrub and alpine habitats were considered the highest quality habitats. Additionally, warm-aspect old upland forests with sparse canopy cover were ranked high, for their potential to support early season green-up.

Ratings during mid-season reflect greenup of additional areas as the growing season progresses. Ratings are still high for open upland and alpine areas, but additionally open wetland habitats increase in importance during the mid-season, particularly for herbaceous and sparse, low shrub habitats. Both young and older forests were rated intermediate importance, based on broad use of forest types by telemetred bears (UNBC data).

During the late part of the growing season, upland older forests as well as sparse, young forests were rated as important habitats that could support berry production. Additionally, non-forested low and high shrub habitats were rated as high, particularly the denser canopied habitats. Open, herbaceous upland and alpine habitats were rated relatively high, for potential berry production. Across all seasons, moderate slopes were given additional weight, based on peer-review and patterns seen in the radio-telemetry information.

6.3.3.3 Grizzly Bear Model Ratings: Part III

We developed a single model for each of the 3 growing season periods; thus we did not develop rules for combining "security/thermal" and "feeding" submodels, as was done in the other species habitat models. But, we did develop an additional habitat attribute to allow us to add value to areas identified as avalanche chutes. Avalanche paths are an important source of plant foods for grizzly bears. These are areas where topographic effects increase moisture availability and the resulting plant species during the growing season. With respect to providing food plants for bears, avalanche paths were ranked as the most important of 14 identified habitat components (Mealey et al. 1977). Mace and Waller (1997) and Mace et al. (1996) reported selection of avalanche chutes high in relation to availability during all seasons, especially spring. To identify avalanche chutes that may provide important forage plants, polygons classified as both "Subalpine avalanche Chutes" class in the Baseline Thematic Mapping (BTM) data (cite) and as "herbaceous", "shrub low", or "shrub tall" in VRI level 4 were selected. Comparison of these identified avalanche chutes and the radio-telemetry locations did not reveal high use throughout the growing season, with the highest use during the mid-season. Therefore, we added value to habitats identified in our chute class to increase the importance of these habitats during the mid-season. We did not combine the 3 growing season models, as each identifies resources used during unique time periods, similar to the "growing season" and "winter season" models of the other focal species.

6.3.4 Refinement and Validation of Grizzly Bear Habitat Suitability Model

We used telemetry locations to assess the grizzly bear habitat models.

6.3.4.1 Model assessment using telemetry information

We received a large dataset of grizzly bear "locations" from the Dr. Kathy Parker at UNBC. This data included nearly 6,000 locations of 21 bears between January 2001 and October 2003. We did not know the identity of individual grizzly bears, and had to pool all locations together for use in model assessments. We used these data to assess the ability of our model to predict quality grizzly bear habitat by comparing the relative proportions of bear locations within habitat classes to the expected distribution of locations if selection were random (i.e., based on relative amounts of the habitat classes in the region). We randomly split the location data into 2 sets, using one subset to develop recommendations for model revisions and the second to do an additional assessment of the models following revisions. From each set, we broke locations into their appropriate season.

Initial validation of 3 seasonal submodels revealed that the draft models did a fair job of predicting use (see Appendix E). During the early season, 58% of the locations fell within the two highest habitat classes, compared to 36% regional availability. During the mid-growing season, 35% of the locations fell within the 2 highest classes of the mid-season model, which covered 30% of the region. Finally, during the late growing season, 56% of the locations fell within the 37% of the region that was classified in the highest 2 habitat classes. The remaining locations were distributed within the "nil" class and lower classes of habitat. To increase the predictive ability of the models, we explored the habitats used by the radio-telemetered bears, and revised the original draft models based on these.

Across all seasons, the grizzly bear locations were found predominantly within the upland and alpine VRI habitats, with little use of the wetland zone. Consequently, we reduced the importance of the wetland zone, to increase the relative predicted quality of higher elevation, upland habitats. Additionally, the locations showed consistent and high use of alpine habitats in the SWB, particularly during the early and late periods; we adjusted scoring to better reflect this trend. Across all seasons, notable numbers of locations were found in the alpine unvegetated class; to account for the use of these habitats, we included shallow to moderately sloped, unvegetated alpine areas in our habitat model. As described previously, this habitat likely includes vegetated habitats not captured in the VRI or BEI data used to characterized alpine habitats. Finally, many telemetry locations fell within older aged forest stands (particularly those in the upland areas) during the early and the late seasons, with a broader suite of forests used during the mid-season. The locations revealed no patterns in the use of cool or warm aspect classes, but based upon other information, we chose to retain the higher scoring for warm aspects. The majority of the locations across all seasons fell in moderately sloped habitats; we increased the value of habitats in slope classes 2 and 3, relative other habitats in the study area.

Re-evaluation of the seasonal submodels with the second set of telemetry data showed a much improved ability of the models to capture the habitats used by the telemetered bears during each of the 3 growing submodels (Tables 6.10 – 6.12). During the early season, 72% of the bear locations were found in the revised highest 2 habitat classes, which covered 35.5% of the region. During the mid season, 78% of the locations fell within the highest 2 habitat classes, which covered 30% of the study area, and during the late season, 82% of the locations fell within the highest 2 classes; these classes covered 48% of the area. Locations within the final 10 equal-interval habitat classes is provided in Appendix E. There is limited amount of the highest quality habitat classes found within the BP study area, and use of these habitats is as expected or higher based on availability.

We also assessed whether the inclusion of ungulate and avalanche models into the models, as suggested by Part III of the draft CERI models, increased the models predictive ability (Appendix D). To do this, we compared the revised models success in predicting habitat use by bears compared to the ability of the models after addition of ungulate and avalanche variables into the models. The addition of ungulate and avalanche variables appeared to either not substantially affect the ability of the models to predict bear use or decrease this ability. For example, during the early and late seasons, the percent of locations within the 2 highest classes remained virtually unchanged. During the mid-season, the percent within the 2 highest classes increased from 78% to 85%, but redistributed these locations more within the 2nd highest class rather than the highest class. Based on this assessment, we removed the ungulate modifiers from Part III of the grizzly models. Few locations fell within predicted avalanche chutes, with most use during the mid-season. The literature broadly supports the importance of avalanche chutes for grizzly bears, and thus, we have retained the avalanche modifier for the mid-season model. We have chosen not to combine the 3 submodels, but to use each in the CAD analyses.

6.3.5 Grizzly Bear Habitat Model Results

The final grizzly bear habitat suitability ratings tables for early, mid and late growing seasons are presented in Appendix F. We applied these ratings across the MK CAD study area (Maps 6.2a, b and c). The amounts of habitats within Classes 0 – 10 for each season are shown in Table 6.13. The early growing season habitat model identified nearly 1.3M ha or 8% of the study area as the highest Class 10 habitat, while the mid-growing season model identified only 168 ha in the highest class. Late growing season Class 10 habitat is represented by 1.7M ha or 11% of the study area. There are large amounts of moderate quality habitats (e.g., Class 4 – 6) for each seasonal model, and very little of the study area is classified as Class 0 habitat for grizzly bears, reflecting their more generalist habitat use patterns.

As described above, we summed habitat scores within 500-ha Planning Units. These Planning Unit scores are used for grizzly bear Core Habitat selection. For reporting purposes, we classified Planning Unit scores from the grizzly bear early, mid and late growing season models into 100 classes, representing the percentile rank of each Planning Unit relative to other Planning Units in the study area, based on the realized range of scores for the habitat model (Table 6.14).

6.3.6 Grizzly Bear Core Habitat Selection

Grizzly bear core habitat areas capture 30% of the total habitat value across the study area, and contain the highest value Planning Units for early, mid and late growing season habitats (Figures 6.3 – 6.5). A total of 21.6% (3.49M ha) of the study area is identified as supporting core habitat for grizzly bear (Map 6.2d). Of this, 48.3% (1.68M ha) is within the MKMA, while the remaining is found outside the MKMA to the west, southwest and north. Within the MKMA, a large concentration of core habitats was identified along the eastern front ranges of the Rocky Mountains. Given that the MKMA covers only 39% of our study area, the large percentage of core habitat within the Management Area indicates that the MKMA is important for the regional conservation of grizzly bears, but that there are also key habitats distributed across the region outside the MKMA.

6.4 Woodland Caribou Habitat Model

6.4.1 Taxonomy, Status and Distribution

Scientific Name: *Rangifer tarandus* (northern mountain ecotype)

Species Code: M_RATA

Status: Provincially Blue-listed. Considered to be of Special Concern (formerly Vulnerable) in British Columbia. Sensitive or vulnerable to human activities or natural events. Blue-listed taxa are at risk, but are not Extirpated, Endangered or Threatened (Govt of BC). Also provincially listed as Identified Wildlife (MAY 2004): Species and plant communities at risk designated by the Deputy Minister of Water, Land and Air Protection as requiring special management attention under the *Forest and Range Practices Act*. Federally listed as Threatened (May 2002) and of Special Concern (May 2002) by the Committee On the Status of Endangered Wildlife In Canada (Provincial and COSEWIC borders differ therefore two listings for this ecotype).

Provincial Range: Woodland caribou are associated with the boreal forest region of Canada. They are distributed across the northern portion of BC and extend as far south as Tweedsmuir Provincial Park and the southern Kootenays (Nagorsen 1990). Mainland populations have been reduced since historical times and small relic herds exist at the southern periphery of the species range in the province (Stevenson and Hatler 1985).

6.4.2 Woodland Caribou Ecology and Habitat Requirements

Woodland caribou of British Columbia can be divided into three ecotypes based on distribution, behavior, and habitat requirements (Heard and Vagt 1998). Northern caribou and mountain caribou both occur in mountainous habitat but are separated by the extent of their range and preferred winter feeding habitat; northern caribou generally occur north of 55^{o} north latitude and feed primarily on terrestrial lichens in winter, while mountain caribou are generally restricted south of 55^{o} latitude and feed primarily on arboreal lichens during winter (Spalding 2000). Caribou of the boreal ecotype are few in number and form dispersed groups rather than discrete herds, with a limited year-round distribution in the lowland boreal forests of the extreme northeast portion of the province (Spalding 2000). Although the boreal ecotype may occupy a small area along the eastern boundary of the study area, we have considered all caribou within the study area to be of the northern ecotype.

Prior to 2000, few studies in the province focused on the northern ecotype (Wood and Terry 1999; Johnson, Parker et al. 2000). Additional work has been conducted since then, but much of the literature does not differentiate by ecotype. Literature used for the following sections either specified the northern ecotype or was from work conducted in or around the study area where the likelihood of the northern ecotype was greatest.

During summer, northern caribou are generally associated with high elevation, dry, alpine landscapes of little productivity or understory cover (Spalding 2000; Apps, McLellan et al. 2001). Diets at this time are more diverse than winter and in addition to terrestrial lichens they include forbs, deciduous leaves, shrubs and graminoids (R. A. Sims and Associates 1999). In both seasons, northern caribou generally use slopes <30%, with higher use of warm aspects in late winter and cool aspects in summer (Wood 1999).

Northern caribou exhibit 2 differing strategies of habitat use during winter, within alpine areas or forested habitats at lower elevations (Apps, McLellan et al. 2001; Youds, Young et al. 2002). However, differing strategies in winter are not specific to herds or even individual animals, as marked individuals have shown variability between successive years (Johnson). Selected areas within the alpine zone during winter are generally windswept ridges (Wood 1995; Wood 2002) associated with lower snow depths and availability of terrestrial lichen (Backmeyer 1991; Johnson, Parker et al. 2000) where they crater for food.

Within forested habitats during winter, northern caribou are considered old-growth obligates due to the greater abundance of terrestrial and arboreal lichens in mature forests (Youds, Young et al. 2002) and appear to select mature stands of pine and spruce (MacKinnon, DeLong et al. 1990) or closed canopy lodgepole pine (Apps, McLellan et al. 2001). Johnson (1994) reported a weak affinity for pine-lichen woodlands within a matrix of wetlands. Lichens are very slow growing, attributing to their association with mature forests. However, terrestrial lichens may be replaced by mats of feather moss in areas of high canopy closure (Sulyma and Coxson 2001), suggesting greater production of lichens in areas of mature forests with open canopies.

While feeding preference is primarily on terrestrial lichens, northern caribou will also feed on arboreal lichens. Microhistological analysis suggested forest dwelling caribou might consume terrestrial and arboreal lichens in about the same proportion (Youds, Young et al. 2002). Selection of arboreal lichens over terrestrial lichens may be due to snow conditions. Following increases in snow depth, hardness, and density, caribou in the forest fed more frequently at trees with abundant arboreal lichens (Johnson, Parker et al. 2000).

The overall variability of habitat use observed between and within northern caribou herds, especially in winter, may be the result of predator avoidance. Caribou often disperse into areas where wolves and alternative prey species such as moose, as well as other caribou are scarce (Bergerud and Page 1987) or spread out over very large areas so it is more difficult for predators to find them (Youds, Young et al. 2002). Seip and Cichowski (1996) suggested the density of caribou populations in the province was related to their ability to become spatially separated from predators.

6.4.3 Woodland Caribou Model Ratings

Below, we briefly describe the ratings applied to habitat characteristics in Parts I and II of the habitat models for growing and winter seasons. The ratings tables are available in Appendix F. For ease of creating systematic ratings, we initially created 4 winter submodels: security/thermal and feeding submodels for a "forest" strategy and security/thermal and feeding submodels for an "alpine" strategy. While these are rated distinctly, we acknowledge that individuals and herds change "strategies" within seasons and across years. In Part III, we combine the four winter submodels together to create a single winter season model. Additionally, differences between feeding habitat and security/thermal habitat for northern caribou do not appear to be as well defined as other species, possibly due to their predator avoidance strategies. As a result, there are few differences between the ratings of security/thermal and feeding submodels.

6.4.3.1 Woodland Caribou Model Ratings: Part I

Resource Inventory Committee Habitat Ratings Standards (RIC 1999) do not recognize differences in strategies of habitat utilization during winter when rating ecosections or BEC types and were therefore only used as a relative guide. Provincial standards were more closely followed for ratings during the growing season. There were few changes to draft CERI ratings in Part I, and we refer the reader to Appendix D for detailed explanations of the Part I ratings.

RIC standards for growing and winter have been established and were followed, as applicable and available. Ratings of ecosections were relative to benchmark standards and considered the amounts of required habitats for each season and strategy (e.g., AT for growing and winter alpine strategies), the severity of winter conditions (e.g., generally higher snow west of the Rocky Mountain divide) and the juxtaposition of other ecosections and habitats. In general, ecosections and BEC zones tended to be rated similarly for the growing season and winter alpine strategies, given the importance of AT for both these submodels. Differences in the ratings most often reflect winter severity, which caused us to degrade some ecosections and BEC zones during the winter season. The winter forest strategy tended to be rated quite differently than the winter alpine strategy, as it is assumed the forest strategy encompasses primarily lower-elevation forested habitats. Again, ratings during the winter forest strategy also reflect assumed winter severity patterns at regional scales.

6.4.3.2 Woodland Caribou Model Ratings: Part II

Site-specific ratings in Part II identified alpine areas as the most important habitats for caribou during the growing season and for the alpine winter strategy. The lack of a quality alpine vegetation classification severely limits our ability to appropriately suggest ratings within alpine habitats. We have rated all shallow or moderately sloped "vegetated alpine" as high value habitats for these two submodels, and also valued relatively flat "non-vegetated" alpine, acknowledging that these areas likely contain plant communities of value to caribou (e.g., lichen). Additionally, we scored north-facing alpine as potentially valuable security/thermal habitat during the growing season, as these north slopes may support residual snowpack or glaciers used for thermoregulation and to escape biting insects.

Forested areas were given limited value for the growing season and the winter alpine strategy, except for high elevation, sparse forests which may provide some feeding as well as security/thermal values. Forests potentially supporting lichens are a key resource for caribou utilizing a winter forest strategy. We classed forested habitats by both species groups and age groups. Based on literature and peer-review comments, we created 3 age classes which may capture the potential for lichen forage. The young (0-60 years) age class is assumed to have limited potential for lichen, the mature age class (60-120 years) may have substantial lichen forage (based on peer-review comments), but we found that the radio-telemetred caribou used these age classes infrequently. The location data showed high use of our oldest age class (>120 years), and these received the highest scores. In particular, upland spruce and pine habitat types were assumed to provide the highest opportunities for lichens important to winter forest strategies.

6.4.3.3 Woodland Caribou Model Ratings: Part III

Due to the similarity in ratings between security/thermal and feeding strategies within the two (alpine and forest) winter models, we did not consider spatial configuration when combining the two submodels into a single seasonal model. Additionally, we assumed that caribou are flexible in their strategies, and that the feeding strategy employed at any site is likely partially driven by the site-level foraging potential and characteristics. Thus, we combined the 4 winter submodels (feeding and security for forest and alpine strategies) by retaining the highest relative habitat value across the 4 submodels. To do this, we first standardized (z-score) within each model 0 – 1, to assure that relative scoring between submodels was equivalent.

During the growing season, we assumed that the juxtaposition of security/thermal habitat and feeding habitat influenced the quality of site-level scoring. To incorporate this, we increased the value of feeding habitat within 1 km of security/thermal by 1; similarly, security/thermal habitat value was increased by 1 when within 1 km of feeding habitat. We standardized values within each submodel, and retained the higher submodel score to create a single growing season habitat model.

6.4.4 Refinement and Validation of Woodland Caribou Habitat Suitability Model

We used telemetry locations and observations obtained during winter aerial surveys to assess the caribou habitat models.

6.4.4.1 Model assessment using telemetry information

We received a large dataset of caribou "locations" from the Dr. Kathy Parker at UNBC. This data included over 6,500 locations of 29 caribou between January 2001 and October 2003. We did not know the identity of individual caribou, and had to pool all locations together for use in model assessments. We used these data to assess the ability of our model to predict quality caribou habitat by comparing the relative proportions of caribou locations within habitat classes to the expected distribution of locations if selection were random (i.e., based on relative amounts of the habitat classes in the region). We randomly split the location data into 2 sets, using one subset to develop recommendations for model revisions and the second to do an additional assessment of the models following revisions. From each set, we broke locations into their appropriate season.

Identifying potential equal area classes for the winter alpine habitat models resulted in 2 habitat classes and an additional "nil" habitat class for feeding and for winter. The winter forest strategy models and growing season models contained 4 classes in each model and a "nil" class. To conduct the validation, we needed to classify caribou locations by winter strategy, which we did by describing all locations within alpine habitat as "alpine strategy" and all other points as "forest strategy". While this classification is very elementary, it provides a reasonable basis for division of points for validation purposes only. Splitting the data in this way resulted in the first validation data set containing 3,510 locations within the "forest strategy" and 1,671 points within the alpine strategy.

The initial validation (Appendix E for tables) revealed that 81.5% and 81.4% the locations identified as being "winter forest strategy", fell within the 2 highest habitat classes for feeding and security/thermal, respectively. Alpine feeding and security/thermal habitat validated well, with 93.7% and 93.2% of the locations within our higher habitat quality classes for feeding and security/thermal, respectively. For growing season, 76% and 74% of the fell within the 2 highest quality classes of the feeding and security/thermal submodels respectively.

In reviewing the habitats used by the telemetered caribou, a few patterns were noted and used to adjust the model ratings. Most (84%) of the winter forest strategy locations occurred within the SWB zones; based on this we reduced the degree of degradation of the SWB types (from -4 to -2) for this submodel. A notable number of locations classified either in the growing season or the alpine winter strategy fell within our class of "nonvegetated alpine", and we increased the value of this habitat type on shallow and moderate slopes for these models.

The use of both mid-aged and the oldest age class of forest was high, with 46% and 51% of the winter forest locations within the 60-120 year age class and the >120 year age classes, respectively. Consequently, we increased the value of the oldest age class forest in the model relative to mid-aged forests. Young forests were given low habitat values.

Revalidation of the caribou submodels following the above revisions increased the proportions of locations falling with our highest habitat classes (Tables 6.15 - 6.16). We assessed this using the second set of telemetry locations, and after implementing Part III of the modeling process (which creates a single model for growing and a single model for winter). Eighty-three percent of the locations obtained during the growing season fell within our two highest quality habitat classes for that season. During the winter season, 77% of the locations fell within the highest 2 habitat classes. As a final check on the models, we calculated the number of caribou telemetry locations falling with our final 10 equal-interval habitat classes (Appendix E). More than 60% of the locations within each season are found in our 2 highest habitat classes, while these habitat cover only 18% and 36% in growing and winter seasons, respectively.

6.4.4.2 Model assessment using winter survey observations

There were a total of 45 woodland caribou observations, consisting of locations of individual or groups of animals. Of these, 32 (71%) were located within the highest 2 habitat classes predicted in the habitat model, with 9 (20%) located in Class 2 habitat and 3 (9%) located in Class 1 habitat (Table 6.17). There were no caribou found in areas we predicted to not support caribou winter habitat (Class 0). This distribution of habitat use is quite different than expected, as determined by the relative amounts of habitat classes actually surveyed, with many more animals found in high quality classes than expected based on habitats surveyed and assuming random distribution of animals within these habitats.

6.4.5 Woodland Caribou Habitat Model Results

The caribou habitat ratings tables for winter and growing seasons are presented in Appendix F. We applied these ratings across the MK CAD study area (Maps 6.3a and b). The amounts of habitats within Classes 0 – 10 for each season are shown in Table 6.18. The growing habitat model identified 983,500 ha or 6.1% of the study area as the highest Class 10 habitat. An addition 11.7% of the study area (nearly 1.9M ha) was identified as Class 9 growing season habitat. There are over 1M ha or 6.6%% of the study area classified in this highest value caribou winter habitat, and an additional 4M ha or 25% of the study area is classified as winter habitat Class 9. During the growing season, approximately 13.4% of the study area (2.2M ha) is classified as “nil” or without habitat value for woodland caribou; during winter, there is approximately 8.3% of the study area assumed to have no or limited value for caribou.

As described above, we summed habitat scores within 500-ha Planning Units. These Planning Unit scores are used for woodland caribou Core Habitat selection. For reporting purposes, we classified Planning Unit winter and growing season scores into 10 classes, representing the percentile rank of each Planning Unit relative to other Planning Units in the study area, based upon the realized range of scores for the habitat model (Table 6.19).

6.4.6 Woodland Caribou Core Habitat Selection

Woodland caribou core habitat areas capture 30% of the total habitat value across the study area, and contain the highest value Planning Units for both winter and summer habitat (Figures 6.6 and 6.7). A total of 23.1% (3.73M ha) of the study area is identified as supporting core habitat for woodland caribou (Map 6.3c). Of this, 36.4% (1.36M ha) is within the MKMA. The remaining habitats are distributed through the study area, with notable concentrations to the north in the Caribou Ranges, and throughout the western portions. Within the MKMA, the east-front ranges appear particularly important for caribou. While a large proportion of caribou core habitat is within the MKMA, caribou habitats are distributed throughout the region and caribou conservation cannot be limited to within the MKMA boundaries.

6.5 Moose Habitat Model

6.5.1 Taxonomy, Status and Distribution

Scientific Name:	*Alces alces andersoni*
Species Code:	M_ALAL
Status:	Yellow-listed (any indigenous species or subspecies (taxa) which is not at risk in British Columbia).
Provincial Range:	Moose are distributed throughout the province with the exception of Queen Charlotte and Vancouver Islands and the coastal fjords.

6.5.2 Moose Ecology and Habitat Requirements

In general, moose are abundant and widespread throughout the province and across vegetation types. They are considered a forest dwelling species, favouring immature forest shrubland for food and dense, woody forests for cover (Neitfeld, Wilk et al. 1985), but often use open habitats above timberline. Moose are generalist herbivores that feed on a variety of herbaceous plants, leaves and new growth of shrubs and trees in summer and twigs of woody vegetation during winter (Renecker and Schwartz 1998; Franzmann 2000). Aspen, birch and willow constitute major portions of their diet across their range (Renecker and Schwartz 1998).

During winter, moose often utilize riparian areas (MacKinnon, DeLong et al. 1990; Backmeyer 1991; McKenzie 1993), mixed-wood forests (Backmeyer 1991), or brushy areas and forests of early successional stages (Heard, Zimmerman et al. 1999) for feeding. The most commonly consumed food during winter is willow, but twigs of aspen, serviceberry, maple, birch, and red osier dogwood are also eaten. Conifers will not sustain moose, although some types of fir and yew are eaten readily (Peterson 1955; Spencer and Hakala 1964; LeResche and Davis 1973; Cushwa and Coady 1976; Pierce and Peek 1984; Edwards 1985; Allen, Jordan et al. 1987). Snow conditions are an important factor limiting habitat use by moose in winter (Franzmann 1978), and they may move into forested habitats when snow depths approach 80cm (Eastman). Lower shrubs may become unavailable when snow depths exceeded 110 cm (Collins and Helm 1977).

In addition to moderating snow depths, forested habitats provide thermal cover during both winter and summer. A canopy closure of 70% in a mature forest was suggested to reduce wind chill effects in winter and allow escape from high temperatures in summer (Schwab and Pitt 1991), while optimal winter thermal cover has been described as conifers taller than 6 m, with a canopy closure of at least 75% (Krefting 1974; Allen, Jordan et al. 1987).

Summer diets consist of many aquatic plants, forbs, grasses, and foliage of many trees eaten in winter. Moose are often attracted to wetland edges (DeLong, MacKinnon et al. 1990) and other areas of slow moving or standing water (such as weedy lakes, marshes and slow-moving streams) where they can feed on aquatic vegetation (Jordan 1987). Alpine and subalpine meadows with gentle terrain are also important in summer for feeding and security/thermal (Stevens and Lofts 1988).

6.5.3 Moose Model Ratings

Below, we briefly describe the ratings applied to habitat characteristics in Parts I and II and spatial modification of Part III of the habitat models for the winter and growing seasons. These summaries are based upon the draft CERI ratings and any modification of those ratings (see

Appendix D). We made few changes to the proposed CERI ratings, and we refer the reader to the CERI report for a more detailed description of the ratings. The final habitat ratings tables are provided in Appendix F.

6.5.3.1 Moose Model Ratings: Part I

RIC standards for growing and winter have been established and were followed, as applicable and available. Ratings of ecosections were relative to benchmark standards and considered the amounts of required habitats for each season and strategy, the severity of winter conditions (e.g., generally higher snow west of the Rocky Mountain divide) and the juxtaposition of other ecosections and habitats. The benchmark ecosections for growing and winter are the same and are identified as MUP and MUF; these received no degradation in either season. Similarly, the BWBSmw is considered the provincial benchmark BEC subzone during the growing season and winter (RIC 1999) and all types were rated relative to it.

6.5.3.2 Moose Model Ratings: Part II

Wetland habitats were considered important year-around, with open wetlands or sparsely treed wetlands providing feeding opportunities and more densely shrubbed or treed wetlands or upland forested habitats providing security/thermal habitat. During winter, forested habitats have increased importance to escape deep snows, and can become important for foraging. In particular, young forests and particularly young deciduous forests were rated important for foraging potential. Dense, mature forests were rated high for thermal cover in both seasons.

6.5.3.3 Moose Model Ratings: Part III

Juxtaposition of feeding and security/thermal areas within seasons may determine the suitability of each habitat. To account for this, we adjusted both security/thermal and feeding scores dependent upon the distance to the alternative habitat (feeding and security/thermal, respectively). Security/thermal and feeding habitats that were >1 km from the alternative habitat were degraded by -4; if this caused the habitat value to fall below 1, the value was set at 0 (or nil). Thus, high quality feeding habitats distant from security/thermal habitats were degraded to lower quality feeding habitats; lower quality feeding habitats far from security/thermal habitat were effectively removed from the model; the same holds true for security/thermal habitat. Alternatively, feeding and security/thermal habitats within 200 m of the alternative habitat had their suitability value increased by 4 to account for probable increased value to moose due to this near juxtaposition.

6.5.4 Refinement and Validation of Moose Habitat Suitability Model

We used observations obtained during winter aerial surveys to assess the moose habitat models. Additionally, we compared the amounts of high and low quality habitats predicted by our model and the TEM-based habitat suitability model available for the Besa-Prophet region of our study area.

6.5.4.1 Model assessment using winter survey observations

There were a total of 103 moose observations, consisting of locations of individuals or groups of animals. Of these, 71 (67%) were located within the highest 2 habitat classes predicted in the habitat model, with 26 (25%) located in Class 2 habitat and 6 (8%) located in Class 1 habitat (Table 6.20). There were no moose found in areas we predicted to not support moose winter habitat (Class 0). This distribution of habitat use is quite different than expected, as determined by the relative amounts of habitat classes actually surveyed, with many more animals found in high quality classes then expected based on habitats surveyed and assuming random distribution of animals within these habitats.

6.5.4.2 Comparison to Besa Prophet area PEM winter habitat suitability model

We were unable to utilize radio-telemetry locations or other site-specific information to use to assist in validating and refining our model beyond the refinements suggested by peer-review. To provide an additional assessment of how our model is performing, we checked the relative distribution of high and low quality habitats predicted by our model and the winter habitat suitability model developed for the BP area. The BP model is based on TEM data, and thus represents modeling using finer-resolution data than we had available, and thus may provide a relevant check on our coarser-scale modeling effort. Comparisons of the relative amounts of our predicted high and low classes habitats (based on equal-area classes) within the 6 classes of the BP model show a positive correlation between the amounts of our predicted high and low value habitats within the TEM model high and low value habitats, respectively (See Figure 6.8). The higher value TEM classes (1 -3) show the highest levels of our highest classed habitat, while the lowest value TEM classes (5 and 6), show the lowest amounts of our high value habitats and the highest amounts of our low value habitats.

6.5.5 Moose Habitat Model Results

The moose habitat ratings tables for winter and growing seasons are presented in Appendix F. We applied these ratings across the MK CAD study area (Maps 6.4a and b). The amounts of habitats within Classes 0 – 10 for each season are shown in Table 6.21. The growing habitat model identified 328,500 ha or 2% of the study area as the highest Class 10 habitat. An additional 14% of the study area (2.27M ha) was identified as Class 9 growing season habitat. There is also limited Class 10 winter habitat identified, with just 452,800 ha or 2.8% of the study area classified in this highest value habitat. An additional 1.13M ha or 7% of the study area is classified as winter habitat Class 9. Approximately 10% of the study area is classified as "nil" or without habitat value for moose in either season.

As described above, we summed habitat scores within 500-ha Planning Units. These Planning Unit scores are used for moose Core Habitat selection. For reporting purposes, we classified Planning Unit winter and growing season scores into 10 classes, representing the percentile rank of each Planning Unit relative to other Planning Units in the study area, based upon the realized range of scores for the habitat model (Table 6.22).

6.5.6 Moose Core Habitat Selection

Moose core habitat areas capture 30% of the total habitat value across the study area, and contain the highest value Planning Units for both winter and summer habitat (Figure 6.9 and 6.10). A total of 22.8% (3.69M ha) of the study area is identified as supporting core habitat for moose (Map 6.4c). Of this, only 25.46% is within the MKMA with the remaining distributed through the study area. Within the MKMA, concentrations of high quality habitat are found in the valleys associated with the Rocky Mountain Trench and in the broad valley mouths along the eastern edge of the MKMA. The large proportion of core habitats for moose found outside the MKMA indicates the importance of management across the region for this species.

6.6 Mountain Goat Habitat Model

6.6.1 Taxonomy, Status and Distribution

Scientific Name:	*Oreamnos americanus*
Species Code:	M-ORAM
Status:	Not at risk (MELP, 1997; COSEWIC, 1998) Identified Wildlife Species
Provincial Range:	Mountain goats are found throughout the Cordilleran region of western Canada and occupy the mainland portion of the province, except for the

central interior (Banfield 1974; Nagorsen 1990). In BC, the mountain goat species is divided on the basis of distribution and appearance of cranial characteristics into three subspecies: those north of the Peace and Skeena Rivers are classified as *Oreamnos americanus columbianus;* those of the Crowsnest Pass in the East Kootenays fall into the *O. a. missoulae* race; and those throughout the remainder of BC are classified as *O. a. americanus.*

6.6.2 Mountain Goat Ecology and Habitat Requirements

Mountain goats are habitat specialists, most commonly associated with sparsely forested and unforested mountainous terrain within the alpine and subalpine zones. They are dietary generalists, with predator avoidance taking precedence over forage availability (Hengeveld, Wood et al. 2003). Optimal habitat contains a mix of feeding sites adjacent to or within close proximity of escape terrain. Goats rarely range far from adequate escape terrain, with reported distances ranging from 50 m (Varley 1996) to a maximum of 400 m (Province of British Columbia 1997) or 500 m (Hengeveld, Wood et al. 2003).

The steep areas they use for escape terrain in all seasons is most often comprised of cliffs, ledges, projecting pinnacles, and talus slopes. Most literature (e.g., Varley 1996; Wood 2002) reports the majority of goat occurrence on slopes >35^{o}. Blume et al. (2003) (2003) reported the use of steep slopes (21-40^{o}) in summer and more moderate slopes (21-40^{o}) in winter. Additionally, Hengeveld et al. (2003) considered surface roughness an important factor in goat habit for providing ledges for cover, travel, and reduction in avalanche risk.

Mountain goats are considered non-migratory although there may often be a vertical movement from high elevation summer areas to lower elevations during winter. Typical summer habitat consists of steep alpine rocks or cliffs and alpine grassland of more moderate slopes near escape terrain (Wood 2002) with no apparent selection for aspect. High elevation windswept ridges or forested habitat in close proximity to escape terrain is utilized in winter. During February, Backmeyer (1991) found goats at or above timberline on alpine ridges, timberline ridges, or timberline bluffs. Wood (1994) reported all goats in a March survey on steep, rocky, south or west-facing slopes. In winter surveys centered on alpine habitat, Corbould (2001) found all goats on southerly aspects of alpine areas.

Mountain goat movements to lower forested areas in winter may be to avoid deep snow at higher elevations. Goats may avoid snow depths >50 cm (Province of British Columbia 1997) and movements to forested habitat near escape terrain provides an increase in forage availability and reduction in snow depth due to snow interception by the forest canopy (Hengeveld et al. 2003). Mountain goats are considered regionally important due to their requirement of older age class forests for winter cover (Province of British Columbia 1997).

Saunders (1955) described mountain goats as "snip feeders" that rarely graze intensively at one spot. A variety of plant species are fed upon in summer, including grasses, sedges, rushes, forbs, lichens, and mosses (Wigal and Coggins 1982). Varley (1996) suggested a preference in summer for north and east-facing slopes due to increased amounts of green succulent forage. Use of herbaceous forage decreases in winter with a corresponding increase in conifers, especially Douglas fir (*Pseudotsuga menziesii*) and subalpine fir (*Abies* spp.) (Wigal and Coggins 1982; Province of British Columbia 1997). Mineral licks are seasonally important to mountain goats and they often travel as far as 24 km to visit natural and artificial salt licks during spring and summer (Wigal and Coggins 1982). They may rely heavily on them during this period to replenish sodium reserves that are flushed from the body due to the intake of potassium-rich green forage (Hebert and Cowan 1971). The full extent and use of mineral licks within the study area is not known. However, 4 of

5 valley bottom clay bank mineral licks within the lower Ospika drainage of the study area are known to be well used by goats.

Mountain goats and sheep utilize similar habitats with only subtle differences. In March surveys, Corbould (2001) reported goats and Stone's sheep at many of the same locations or on several occasions within close proximity of each other. However, for sheep and goats during winter, goats prefer cliffs more than sheep do, seldom venture as far from open slopes, and feed on subalpine fir while sheep do not (Geist 1971). Slight differences in ratings between the 2 species are intended to reflect these subtle differences.

6.6.3 Mountain Goat Model Ratings

Below, we briefly describe the ratings applied to habitat characteristics in Parts I and II of the habitat models for growing and winter. These summaries are based upon the original CERI ratings and any modification of those ratings (see Appendix D for CERI draft models). The final habitat ratings tables are provided in Appendix F.

6.6.3.1 Mountain Goat Model Ratings: Part I

Ecosections and BEC zones and subzones were rated to incorporate potential regional or coarse-scale differences in habitat quality for mountain goats during winter and growing season. Habitat suitability across the study area for mountain goats is likely primarily due to local site-level conditions (peer-review comment); while we rated ecosections with standard ratings, we did not heavily degrade any BEC unit assuming that site-level characteristics more accurately reflect habitat suitability.

Ecosections of the study area were rated similar to RIC standards when applicable. The Eastern Muskwa Ranges (EMR), Cassiar Ranges (CAR) and Southern Boreal Plateau (SBP) ecosections received a 0 for the growing season, but were degraded during the winter due to potential snow falls. The Liard Plain (LIP) and Simpson Upland (SIU) ecosections rated -5 for both seasons. Other ecosections were rated relative to these scores. Mountain goats exhibit a high affinity for AT and because it is considered the best type within many listed biogeoclimatic zones in RIC Standards (1999), therefore it was rated zero during both seasons. Within the SWB zone, mountain goats may be locally abundant where suitable terrain exists, and appear to be more numerous in the wetter regions of this zone (Pojar and Stewart 1991); we degraded all SWB subzones by -1. SBS was considered essentially not used and rated -2. The BWBS zone is also at lower elevations and generally contains less topographic relief important to mountain goats. Use within this zone is considered sporadic (DeLong et al. 1991) and it was also degraded by -2.

6.6.3.2 Mountain Goat Model Ratings: Part II

Overall, herbaceous upland and alpine habitats were rated as the most suitable feeding habitat and steep, rocky areas in alpine and upland as the most suitable security/thermal habitat for mountain goats in both seasons. Non-vegetated rocky areas in alpine were assumed to have some feeding value for several reasons. Goats are adapted at finding small patches of vegetation within rocky areas. We modified the alpine descriptors using BEI (see Section 4), and the definition of BEI alpine unvegetated type ("habitat dominated by rock outcrops, talus, steep cliffs and other areas with very sparse vegetation of grass, lichens and low shrubs" BEI CITE, pg155) likely still provides patches of suitable foraging habitat for mountain goat. Although rocky cliffs contain only sparse vegetation, they shed snow easily in winter and are warmer, thus providing easier access to available forage. Additionally, as described above, the existing data likely does a poor job of differentiating between alpine vegetated and non-vegetated habitats, and thus, many areas classified as non-vegetated may support vegetation.

We modified the scoring approach used on other non-alpine species, to more appropriately rate the key habitat features that define goat security/thermal habitat. For goat security/thermal submodels, we weighted the slope characteristics using a 0 - 12 score range, with aspect receiving a 0-2 score range. Vegetative conditions potentially important to define escape or security/thermal terrain were incorporated as higher-order constraints on the distribution of scores across the landscape. For example, suitable escape terrain based on slope characteristics received lower scores if it was within forested areas than if it was with herbaceous or open low shrub habitats. We scored the foraging habitats the same as with other species, with vegetative characteristics receiving a 0-10 range of scores and topographic variables receiving a 0-4 range of scores. For foraging habitat, we assumed that slope was not a useful predictor of foraging habitats, as goat use both steep slopes and relatively flat benches or saddles for foraging. The warm aspects were assumed to be important in winter for both feeding and security/thermal, and of limited importance for feeding in the growing season to capture early growing season green-up that may draw goats to these aspects.

6.6.3.3 Mountain Goat Model Ratings: Part III

We used spatial juxtaposition rules to adjust the scoring on feeding and security/thermal in both winter and growing seasons. First, while the scoring of security/thermal habitat should have eliminated any ratings for areas with slopes less than slope class 2, we ensured this by removing any security/thermal habitats that did not meet this definition. The realized quality of feeding habitat is largely determined by its proximity to escape terrain. Therefore, we increased the score on all feeding habitats within 100 m of escape terrain and kept the score applied to feeding habitats within 500 m of security/thermal habitat. We eliminated all predicted feeding habitats that were located >500 m from security/thermal habitat. Additionally, we eliminated all escape terrain located >1 km from feeding habitat.

To combine feeding and security/thermal within each season, we standardized (z-score) the scoring of each submodel so values ranged from 0- 1. We than summed the scores between the 2 life requisite models for each season. This accounts for the probable increase in habitat quality for areas that support both foraging habitat and escape terrain. Final seasonal models were standardized (z-score) to scores 0-100, with 0 indicating unscored or "nil" habitat and scores near 100 indicating the highest habitat qualities predicted. These scores were broken into 2 - 4 equal area classes for validation purposes, as summarized below.

6.6.4 Refinement and Validation of Mountain Goat Habitat Suitability Model

6.6.4.1 Model assessment using winter survey observations

There were only 8 observations of goats, consisting of locations of individual or groups of animals. All were located within the highest 2 habitat classes predicted in the habitat model. Of the habitats surveyed, >43% fell within these predicted habitat classes.

6.6.4.2 Comparison to Besa Prophet area PEM winter habitat suitability model

We were unable to utilize radio-telemetry locations or other site-specific information to use to assist in validating and refining our mountain goat model beyond the refinements suggested by peer-review. To provide some assessment of how our model performed, we checked the relative distribution of high and low quality habitats predicted by our goat model and the goat winter habitat suitability model developed for the Besa-Prophet (BP) area. The BP model is based on TEM data, and thus represents modeling using finer-resolution data than we had available, and thus may provide a relevant check on our coarser-scale modeling effort. Comparisons of the relative amounts of our predicted high and low classes habitats (based on equal-area classes) within the 6 classes of the BP model show a positive correlation between the amounts of our predicted high and low value habitats within the TEM model high and low value habitats, respectively (See Figure 6.11). The higher value TEM class (3) shows the highest levels of our highest classed habitat, while the lowest value TEM class (6) shows the lowest amounts of our high value habitats and the highest amounts of our low value habitats.

6.6.5 Mountain Goat Habitat Model Results

The mountain goat habitat ratings tables for winter and growing seasons are presented in Appendix D-5. We applied these ratings across the MK CAD study area (Maps 6.5a and b). The amounts of habitats within Classes 0 – 10 for each season are shown in Table 6.23. The growing habitat model identified 827,300 ha or 5.1% of the study area as the highest Class 10 habitat. An additional 8.4% of the study area (1.36M ha) was identified as Class 9 growing season habitat. There is much less Class 10 winter habitat identified, with just 29,354 ha or 0.18% of the study area classified in this highest value habitat. An additional 705,800 ha or 4.4% of the study area is classified as winter habitat Class 9 and there is a substantial amount of moderate quality habitats identified. Approximately 38% of the study area is classified as “nil” or without growing habitat value, while only 16% of the study area is classified as nil during the winter season.

As described above, we summed habitat scores within 500-ha Planning Units. These Planning Unit scores are used for mountain goat Core Habitat selection. For reporting purposes, we classified Planning Unit winter and growing season scores into 10 classes, representing the percentile rank of each Planning Unit relative to other Planning Units in the study area, based upon the realized range of scores for the habitat model (Table 6.24).

6.6.6 Mountain Goat Core Habitat Selection

A total of 13.2% (2.14M ha) of the study area is identified as supporting core habitat for mountain goats (Map 6.5c). This area captures the best predicted habitats for mountain goats (Figure 6.12 and 6.13) and 30% of the total summed habitat values for each seasonal habitat model (growing and winter) across the region. Of this, 56.8% is within the MKMA, while the remaining is found outside the MKMA to the north and east.

6.7 Rocky Mountain Elk Habitat Model

6.7.1 Taxonomy, Status and Distribution

Scientific name:	C*ervus elaphus nelsoni*
Species code:	M-CEEL
Status:	Not at risk (Ministry of Environment 1997; Committee on the Status of Endangered Wildlife in Canada (COSEWIC) 1998)
Provincial Range:	Rocky Mountain elk primarily occur in the Kootenays, the lower Peace River area and the Muskwa-Prophet River drainages on the eastern slope of the Rocky Mountains. Although Rocky Mountain elk were historically abundant and widely distributed in the Cariboo-Chilcotin and Thompson-Nicola areas, elk declined for unknown reasons and today only small, widely scattered herds remain in these areas.

6.7.2 Rocky Mountain Elk Ecology and Habitat Requirements

Rocky mountain elk are considered dietary generalists, resulting in the ability to occupy and exploit available habitat. Food habits and habitat use tend to overlap those of other ungulates. Elk are generally considered migratory animals, often moving long distances, with typical movements between subalpine summer range and lower elevation foothills of less snow in winter (Peek 1982). Elk wintering at the National Elk Refuge in Jackson WY may migrate as far as 88 km between seasons (Cole 1969). However, some populations are essentially nonmigratory and spend both seasons in the same area, such as those in the Madison River drainage of Yellowstone National Park, WY, that only exhibit local shifts (Craighead, Atwell et al. 1973).

Elk populations within the study area appear to exhibit both migratory and nonmigratory behavior. Harrison and Wilkinson (1998) reported 5 of 7 elk groups they studied in the Muskwa Foothills and Eastern Muskwa Range ecosections exhibited migratory movement while the other 2 groups did not. For the migratory groups they observed, migration appears to occur primarily along major river and creek corridors. North of the Peace Arm of Williston Reservoir, collared elk moved from lower elevations in winter to higher elevations in fall, but did not show major movements between distinct seasonal ranges to be classified as migratory (Backmeyer 2000).

Elk occupy a wide range of habitats in British Columbia, ranging across coniferous forests of most ages, mixedwood and deciduous forests, wetlands, vegetated slide areas and avalanche chutes (Saxena and Bilyk 2001). Elk are often considered an 'edge' species, where they can forage in grassy patches but seek hiding cover in adjacent patches when resting (Lyon and Ward 1982). Adequate hiding cover is often described as vegetation capable of hiding 90% of a standing adult elk from view at a distance of 61 m (Black, Sherzinger et al. 1979). Consequently, habitat interspersion, particularly during winter, is often an important element of high quality elk habitat (Harrison and Wilkinson 1998).

Habitat use within the study area appears variable, with most overall use in lower elevation open habitats such as shrub grassland and open deciduous forests. Hengeveld and Wood (2001) characterized the best elk winter range along the Peace Arm of Williston Reservoir as gentle, south facing slopes dominated by aspen and open grasslands, interspersed with small pockets of conifers and within sight of burned areas. Backmeyer (2000) suggested a strong preference for shrub/grassland and avoidance of conifers in early and late winter, and although summer locations were dispersed amongst all types, there was an increase in use of forested areas during calving, summer, and fall. However, Harrison and Wilkinson (1998) reported several elk groups using higher elevation areas, including alpine tundra in winter.

For elk as a species, grasses or shrubs constitute the major winter diet, spring reflects a transition to predominately grasses, with forbs and potentially leaves of browse species becoming important in summer (Peek 1982). However, diets of elk are highly variable and dependent on local forage availability. In an analysis of winter diets from microhistological analysis, Corbould (1998) reported winter elk diets in the Peace Arm drainage dominated by graminoids (63%) and shrubs (23%), while those from the Ospika River drainage were overall dominated by lichen (47%: 24% arboreal, 23% terrestrial). Lichen has been reported in the diets of elk in other studies (Nelson and Leege 1982), but never to the extent as those from the Ospika River drainage (Corbould 1998).

In addition to forage availability influencing elk diets, they may also be influenced by predators. Aspen has often been considered a common food item in elk diets, and elk have been attributed to limiting new aspen stems to a height of ~1 m (Houston 1982). However, use of aspen stands may be modified in the presence of high predation risk from wolves compared to low predation (White and Feller 2001).

Elk were expanding their range across northern British Columbia 20 years ago (Peek 1982) and are now at least as far north as the Liard River (Saxena and Bilyk 2001). Overall in the Peace-Liard region, elk numbers have tripled since the 1970's, probably due in part to prescribed burning (Shackleton 1999). With continued burning and recent population trends, elk populations may continue to increase and their range may expand farther north than they currently exist. Elk may not currently occupy the northern-most extent of the study area, and we accounted for this distributional limit by heavily degrading the northern ecosections. This allows high quality potential habitats based on site-level characteristics to still be acknowledged and to identify areas that may potentially allow elk expansion (given other factors are not limiting).

6.7.3 Rocky Mountain Elk Model Ratings

Below, we briefly describe the ratings applied to habitat characteristics in Parts I and II and spatial modification of Part III of the habitat models for the winter and growing seasons. These summaries are based upon the draft CERI ratings and any modification of those ratings (see Appendix D for CERI models). We made few changes to the draft ratings, and we refer the reader to the CERI report for a more detailed description of the ratings. The final habitat ratings tables are provided in Appendix F.

6.7.3.1 Rocky Mountain Elk Model Ratings: Part I

RIC standards for growing and winter have been established and were followed, as applicable and available. The MUF and MUP ecosections were rated the same as they are in RIC standards; MUF is the provincial benchmark during both seasons and therefore was not degraded, while MUP was degraded by -2 during both seasons. The Liard Plain (LIP), Simpson Upland (SIU) and Hyland Highland (HYH) ecosections were degraded by -5 or -6 because these occur at or beyond the present northern distribution of Rocky Mountain elk. Ratings of ecosections were relative to benchmark standards and considered the amounts of required habitats for each season and strategy, the severity of winter conditions (e.g., generally higher snow west of the Rocky Mountain divide) and the juxtaposition of other ecosections and habitats.

For all BEC types other than SWB, types were generally degraded less in summer due to the generalist nature of elk and their ability to utilize a range of habitats, while providing a stricter rating in winter when elk are more likely to concentrate on specific ranges. SWBmk is considered the best biogeoclimatic subzone for both seasons (RIC 1999) and we did not degrade any SWB. BWBSmw is considered the best type within some ecosections during winter and the growing season (RIC 1999). The AT zone was heavily degraded (-4 and -5 for feeding and security/thermal, respectively) in the winter and also received a -5 for security/thermal in the growing due to the lack of overstory cover. The remaining ecosections were rated relative to these; detailed descriptions of ratings are available in the CERI report (Appendix D).

6.7.3.2 Rocky Mountain Elk Model Ratings: Part II

Few changes were made to CERI ratings for Part II, and the following is extracted from the CERI report (Appendix D). Overall, non-treed uplands containing herbaceous vegetation on gentle slopes were rated as the highest quality feeding sites for elk in the summer. Areas containing young, open age classes of deciduous trees also rated highly for feeding. Similar areas were rated highly for feeding in winter, but shrubby areas were rated higher at that time for potential use of browse. Many studies indicate a preference by elk for southerly aspects in winter and spring, but avoidance of them in summer (Skovlin 1982). Therefore, warm aspects were rated higher in winter and cool aspects higher during the growing season.

We rated older and denser treed uplands the highest for security/thermal in both seasons. These areas provide security cover in both seasons and both thermal cover and increased snow interception in winter. Shrubby areas were rated fairly high based on local literature. The most frequently used slopes are 15-30% (Skovlin 1982); slope class 2 (3-45%) was given higher ratings in all instances.

Prescribed burning has occurred on many predominately south-facing slopes within the study area to improve forage availability for elk. Topographic and vegetational characteristics of these areas have been rated highly due to their attraction for elk even in the absence of burning. Over the long term and in relation to the entire study area, burn sites are transitional features due to vegetative succession and their patchy location across the area. While locally important and of high desirability for elk in the short term, they are the result of management practices and cannot be included in models covering a large area and long time span. As such, they should be considered a site-specific feature that modifies the distribution of local populations. Any attempt to include them in models would require a yearly update to account for additional burning as well as vegetative succession in previously burned areas.

6.7.3.3 Rocky Mountain Elk Model Ratings: Part III

Juxtaposition of feeding and security/thermal areas within seasons may determine the suitability of each habitat. To account for this, we adjusted both security/thermal and feeding scores dependent upon the distance to the alternative habitat (feeding and security/thermal, respectively). Security/thermal and feeding habitats that were >1 km from the alternative habitat were degraded by -4; if this caused the habitat value to fall below 1, the value was set at 0 (or nil). Thus, high quality feeding habitats distant from security/thermal habitats were degraded to lower quality feeding habitats; lower quality feeding habitats far from security/thermal habitat were effectively removed from the model; the same holds true for security/thermal habitat. Alternatively, feeding and security/thermal habitats within 200 m of the alternative habitat had their suitability value increased by 4 to account for probable increased value to elk due to this near juxtaposition.

6.7.4 Refinement and Validation of Rocky Mountain Elk Habitat Suitability Model

6.7.4.1 Model assessment using winter survey observations

There were a total of 100 elk observations, consisting of locations of individual or groups of animals. Of these, 89 were located within the highest 2 habitat classes predicted in the habitat model, with 5 located in Class 2 habitat and 6 located in Class 1 habitat (Table 6.25). There were no elk found in areas we predicted to not support elk as winter habitat (Class 0 or nil). This distribution of habitat use is quite different than expected, as determined by the relative amounts of habitat classes actually surveyed, with many more animals found in high quality classes then expected based on habitats surveyed and assuming random distribution of animals within these habitats.

6.7.4.2 Comparison to Besa Prophet Area PEM winter habitat suitability model

We were unable to utilize radio-telemetry locations or other site-specific information to use to assist in validating and refining our elk model. To provide some assessment of how the model performed, we checked the relative distribution of high and low quality habitats predicted by our elk model and the elk winter habitat suitability model developed for the Besa-Prophet Pretenure (BPPT) area. The BPPT model is based on TEM data, represents modeling using finer-resolution data than we had available, and may provide a relevant check on our coarser-scale modeling effort. Comparisons of the relative amounts of our predicted high and low classes habitats (based on equal-area classes) within the 6 classes of the BPPT model show a positive correlation between the amounts of our predicted high and low value habitats and the TEM model high and low value habitats, respectively (see Figure 6.14). The higher value TEM class (1) shows the highest levels of our highest classed habitat, while the lowest value TEM class (6), shows the lowest amounts of our high value habitats and the highest amounts of our low value habitats.

6.7.5 Rocky Mountain Elk Habitat Model Results

The Rocky Mountain elk habitat suitability ratings tables for winter and growing seasons are presented in Appendix F. We applied these ratings across the MK CAD study area (Maps 6.6a and b). The amounts of habitats within Classes 0 – 10 for each season are shown in Table 6.26. The growing habitat model identified 98,274 ha or 0.6% of the study area as the highest Class 10 habitat. An additional 9.8% of the study area (1.58M ha) was identified as Class 9 growing season habitat. There is even less Class 10 winter habitat identified, with just 39,512 ha or 0.24% of the study area classified in this highest value habitat. An additional 183,100 ha or 1.1% of the study area is classified as winter habitat Class 9. There are large amounts of moderate quality habitat, and only 11% of the study area is classified as having no value for elk (Class 0) in each season.

As described above, we summed habitat scores within 500-ha Planning Units. These Planning Unit scores are used for elk Core Habitat selection. For reporting purposes, we classified Planning Unit winter and growing season scores into 10 classes, representing the percentile rank of each Planning Unit relative to other Planning Units in the study area, based upon the realized range of scores for the habitat model (Table 6.27).

6.7.6 Rocky Mountain Elk Core Habitat Selection

A total of 22.47% (3.63M ha) of the study area is identified as supporting core habitat for elk (Map 6.6c). This area captures the best predicted habitats for elk (Figure 6.15 and 6.16), but also is forced to take a wide suite of habitat qualities, likely due to the influence of human use patterns in or near quality elk habitats. The core habitats captured 30% of the total summed habitat values for each seasonal habitat model (winter and growing) across the region. Of this, 36.3% is within the MKMA, while the remaining is found outside the MKMA to the north and east.

6.8 Gray Wolf Habitat Model

6.8.1 Taxonomy, Status and Distribution

Scientific Name:	*Canis lupus*
Species Code:	M-CALU
Status:	Apparently secure and not at risk of extinction (Govt of BC); Not At Risk (*occidentalis and nubilis ssp.;* COSEWIC 1999).
Provincial Range:	Distributed through the Province outside of urban areas

6.8.2 Gray Wolf Ecology and Habitat Requirements

Gray wolves formerly occupied almost the entire land surface of the 2 northern continents (Mech 1970). Their range of habitat included deserts, grasslands, arctic tundra, and hardwood, softwood, and mixed forests. Only the hot dense forests of southeast Asia and the neotropics, and the hot dry deserts of northern Africa and Baja California seem to have been avoided (Paradiso and Nowak 1982). Utilized habitat appears strongly tied to availability and abundance of prey (Carbyn 1974; Fuller 1989; Huggard 1993; Paquet, Wieerzchowski et al. 1996). Although they have been considered habitat generalists (Mech 1970; Fuller, Berg et al. 1992; Mladenoff, Sickley et al. 1995) due to the range of habitats they occupy, their propensity for habitat utilization based on prey suggests a designation as ecosystem generalists and trophic specialists.

As strong of an influence as it is, prey availability is not the only factor affecting habitat use by wolves. Other influences include snow conditions (Nelson and Mech 1986; Nelson and Mech 1986; Paquet, Wieerzchowski et al. 1996), protected and public lands (Woodroffe 2000), absence or low occurrence of livestock (Bangs and Fritts 1996), road density (Thiel 1985; Jensen, Fuller et al. 1986; Mech 1988; Thurber, Peterson et al. 1994), human presence (Mladenoff, Sickley et al. 1995; Paquet, Wieerzchowski et al. 1996), and topography (Paquet, Wieerzchowski et al. 1996). However, specific populations appear adapted to local conditions and are often specialized concerning den-site use, foraging habitats, physiography, and prey selection (Mladenoff, Sickley et al. 1995; Paquet, Wieerzchowski et al. 1996; Haight, Mladenoff et al. 1998; Mladenoff and Sickley 1998).

Wolves spend most of the time they are awake either eating or hunting. The large size of wolves in conjunction with their habit of traveling in packs adapts them to feed on large prey. Studies across the northern US and Canada indicate that 59% to 96% of prey items are the size of beavers or larger (Paradiso and Nowak 1982). The most frequent prey species were white-tailed deer, mule deer, moose, caribou, wild sheep, and beaver. Wolves can adjust to a wide variation in amount of food availability and will eat as much as four times their daily maintenance requirement of 1.7 kg/wolf (Mech 1970). A mean daily rate of 3.2 kg/wolf is required for successful reproduction (Mech 1977).

Snow conditions may influence hunting success and wolf movements during winter. Kill rates may increase as snow depth increases (Mech and Nelson 1986; Huggard 1993; Huggard 1993; Paquet, Wieerzchowski et al. 1996), and the interaction of snow depth and hardness may influence prey susceptibility and rates of predation (Peterson 1955; Kolenosky 1972; Carbyn 1983). Compacted snow such as on ski and snowmobile trails, plowed roads, and snow-packed roads can affect the range and efficiency of winter movements (Paquet, Wieerzchowski et al. 1996; Singleton, Gaines et al. 2002).

Wolves generally select home ranges with adequate prey and minimal human disturbance (Mladenoff, Sickley et al. 1995; Mladenoff and Sickley 1998) and utilize them in such a way that encounters with prey are maximized (Huggard 1993; Huggard 1993). Selection often depends on location, prey availability, and pack size. Home ranges are frequently smaller during summer when packs are tied to dens and home sites (Mech 1977). Winter home ranges may be large to account for seasonal movements of ungulates, but most wolf populations maintain relatively stable annual home ranges and are considered non-migratory. However, some populations are considered migratory, such as in the wolf-caribou systems of northern Canada and Alaska (Parker 1973; Stephenson and James 1982; Ballard, Ayres et al. 1997; Walton, Cluff et al. 2001).

Dens, home sites, and rendezvous sites are specific areas important to the life history of wolves. A variety of sites are used for dens, including hollow logs, spaces between roots of trees, caves or openings in rocks, abandoned beaver lodges or expanded burrows of other mammals. Most dens are near a source of water (Joslin 1967; Paradiso and Nowak 1982) and have a southerly aspect situated to be snow free at the onset of denning (Stephenson 1974). Home sites are small but important areas where reproductive activities take place. Rendezvous sites are areas where pups are left while the pack hunts, usually centered near open, grassy areas that are bordered by trees or thickets and within 50 m of a source of water (Joslin 1967; Van Ballenberghe, Erickson et al. 1975).

6.8.3 Gray Wolf Model Ratings

Below, we briefly describe the ratings applied to habitat characteristics in Parts I and II and the rules applied in Part III of the habitat models for growing and winter seasons. There are no Provincial standards for wolf modeling, and we chose to develop a single model for winter and a single model for growing seasons, based on recommendation provided by the draft CERI models (Appendix D).

Given the broad ranging nature of gray wolves in the region, attempts to define site-specific habitat qualities are likely to be poor predictors of wolf habitat quality. In Part III of the model, we use our ungulate models as proxies for predicting the relative diversity and availability of prey species; we assume that prey availability and vulnerability are key variables determining wolf habitat suitability. While our ungulate models are not developed to predict relative densities of potential prey (information to inform such a model is not available), these proxies provide the best information available across the study area relating to prey habitat suitability; we assume this suitability translates into wolf habitat suitability. In Parts I and II, we rate broad habitat characteristics that may influence wolf distribution. In particular, we build upon on modeling done by Carroll, Noss et al. (2001) and Paquet (unpubl. data) that predict wolf occurrence using slope characteristics. Based on this, we score Part II by weighting flat and shallow slopes heavily, and stratify these by major habitats types. The final habitat ratings tables are provided in Appendix F.

6.8.3.1 Gray Wolf Model Ratings: Part I

We followed much of the recommendations provided by the CERI report, and the reader should refer to that report for additional information. We assumed that wolves are widespread across the study area and were not strongly influenced by ecosection variables. Thus, we did not rate ecosections. Additionally, we assumed that wolves had limited responses to BEC types, and rated them accordingly. We did not degrade SWB, as Olenicki (Appendix D) found a preponderance of radio-telemetry locations occurred within this BEC type. We degraded BWBS and SBS by -1, and ESSF and AT by -2.

6.8.3.2 Gray Wolf Model Ratings: Part II

We weighted slope characteristics strongly in Part II (Carroll, Noss et al. 2001; Paquet, unpubl. data). Scores ranging of 0-10 were assigned to this key variable; scores ranging from 0-4 were applied to vegetative characteristics. Slope Class 1 (<3%) received the highest scores within each vegetative strata; slope classes greater than 4 did not receive ratings beyond those provided by vegetation characteristics. Following ratings proposed in the CERI report, we rated spruce forests and open habitats higher than other habitat types. Upland habitats received the highest score, followed by wetland and alpine habitats.

6.8.3.3 Gray Wolf Model Ratings: Part III

Summed values of ratings from parts 1 and 2 were combined with ungulate suitability models to produce final wolf feeding models for the growing and winter season. For each season, we rescaled output values of all 5 ungulate suitability models as 0, 1, or 2; the 2 highest rated of the 5 categories in each ungulate model received a -2 in every grid cell, the next 2 categories received a -1 and the last category a zero. We then summed grid cells across the 5 models as a layer of prey availability. Although the maximum potential summed value from the 5 models is 10, actual values rarely reach a value of 5. Summed values from ratings in parts 1 and 2 above were added to scores from ungulate models. As we do not have separate security/thermal and feeding habitat models within seasons, we did not need to develop rules for combining these. Still, given the wide habitat averaging likely done by wolves, we smoothed the output of combined Parts I and II and the prey composite by taking the average score within a 1 km moving window. These average scores for the winter and the growing seasons create our final wolf seasonal models.

6.8.4 Refinement and Validation of Gray Wolf Habitat Suitability Model

We used telemetry locations provided by UNBC Parker research to assess the wolf habitat models.

6.8.4.1 Model assessment using telemetry information

We received a large dataset of wolf “locations” from the lab of Dr. Kathy Parker at the UNBC. This data included over 8,900 locations of wolves between December 2001 and January 2004. In 2001-2002, locations were for 14 individuals representing 6 wolf packs, and in 2003-2004, there were locations from 9 individuals from 5 packs. We did not know the identity of individual wolves, and had to pool all locations together for use in model assessments. We used these data to assess the ability of our model to predict quality of wolf habitat by comparing the relative proportions of wolf locations within habitat classes to the expected distribution of locations if selection were random (i.e., based on relative amounts of the habitat classes total area in the region). We randomly split the location data into 2 sets, using one subset to develop recommendations for model revisions and reserved the second to do an additional assessment if we revised the models. From each set, we broke locations into their appropriate season.

We validated the final habitat models. First, we classified all locations based on habitat classes, defined based on equal area divisions across the BP study area. Validation assessment using the telemetry information showed that a large proportion of the wolf locations fell within our highest habitat class, with 72% and 65% of locations falling within the two highest winter and growing habitat classes, respectively (Tables 6.28-6.29). This is a much larger percentage than expected, with these winter and growing classes covering 23% and 24% of the BP study area, respectively. The evaluation using the telemetry information shows that we were able to successfully predict high quality habitats for gray wolves from a regional perspective. We chose not to attempt further revisions of the models. We did compare the telemetry locations to the final 10 equal-interval habitat classes, and found that there was little predicted high quality habitat in the BP study area. The locations primary fell within the more abundant moderate to high quality classes between Class 5 and 8 during both seasons. Given the coarse-scale evaluation of habitat availability, we caution that this assessment indicates that these habitat models appear to function well to identify potential wolf habitats at a regional level, but may not distinguish habitats well at a local level.

6.8.5 Gray Wolf Habitat Model Results

The gray wolf habitat ratings tables for winter and growing seasons are presented in Appendix F. We applied these ratings across the MK CAD study area (Maps 6.7a and b). The amounts of habitats within Classes 0 – 10 for each season are shown in Table 6.30. The growing habitat model identified limited amounts of the 2 highest habitats, in 7,200 ha, but a large amount of moderate quality habitats (Classes 4-7) that cover approximately 80% of the study area. Given the generalist habitat use of wolves, it is not surprising that only 0.43% of the study area is considered not suitable habitat for wolves.

As described above, we summed habitat scores within 500-ha Planning Units. These Planning Unit scores are used for gray wolf Core Habitat selection. For reporting purposes, we classified Planning Unit gray wolf winter and growing season scores into 100 classes, representing the percentile rank of each Planning Unit relative to other Planning Units in the study area, based upon the realized range of scores for the habitat model. The patterns of habitat distribution closely follow the underlying model, with limited amounts of the highest quality Planning Units, but large amounts of moderate quality habitats (Table 6.31).

6.8.6 Gray Wolf Core Habitat Selection

A total of 23.4% of the study area (3.78M ha) is identified as supporting core habitat for gray wolf (Map 6.7c). Of this, 43.2% is within the MKMA, while the remaining is found either in the northeast portion or along the western side of the study area. Gray wolf core habitat areas contain the highest value PUs for both winter and summer habitat (Figure 6.17 and 6.18) available across the study area.

6.9 Focal Species Discussion

Habitat suitability models have been developed for 7 terrestrial focal species that form the suite of species we are using as surrogates for biodiversity in the MK CAD study area. The habitat models have all shown utility in predicting habitats used by individuals, as documented either by radio-telemetry or aerial survey observations. We feel confident that these habitat suitability models will perform robustly within the regional context of the MK CAD analysis. The models themselves can also serve as stand-alone analyses for assisting resource managers and planners in identifying habitat suitability for these species across a variety of project scales including tenure areas, landscapes, watersheds and watershed groups.

While robust as predictors of potentially suitable habitats for each species, it is important to note that these models do not indicate actual presence of species in these habitats. Additionally, the ratings are relative, and reflect potential habitat suitability, but do not imply apparent or realized habitat limitations or indicate critically limited habitat in any season or for any species. For example, in the mid-growing season model for grizzly bear, there is little habitat rated as the highest quality. This is the result of our assessment of existing information (literature, radio-telemetry locations) which indicated that during this period, grizzly bears use a wide variety of habitats and do not show strong habitat preferences. Thus, many habitats appear to have moderate or moderate to high habitat suitability, few habitats appear to be highly preferred or highly suitable. Similar patterns can be seen in the wolf habitat models, with large amounts of moderate quality habitat, but few areas of high habitat suitability due to the generalist nature of the species. Alternatively, some species show strong habitat preferences which can be captured well with habitat suitability models. This is exemplified in the sheep and goat habitat suitability models, where scoring can bring out the specific habitats that are assumed to have high suitability for these species, given our assumptions about habitat preferences and the spatial attributes used to capture those preferences.

The models are presented and used in multiple ways in the MK CAD. As suggested above, each analysis provides valuable stand-alone products. The original models, developed at a resolution of 100 m grids, provide the basic modeling results. These models were used in the validation efforts, and provide the basis for the regional products, such as Planning Unit summaries and core area analyses. These original models were not developed for site-level predictions, and will likely perform poorly at the site or operational scale, given the spatial resolution and inherent limitations of the underlying data. Still, used with caution, they may provide guidance on where additional survey work may be needed to provide more fine-scale, site-level evaluations. The models generalized to the Planning Units, as used through the CAD analyses, is the most appropriate resolution of the habitat models, and should provide useful information on the distribution of habitat values across project areas.

The core area analysis provides an additional product that integrates seasonal habitats and existing human uses to select the "best of the best" potential habitats within each of the 7 river system strata. Given the potential importance of these core areas for each species, these analyses provide an important management tool across the region to identify key habitat areas for each species. While we would like to emphasize the importance of these core areas, we also caution that species habitats should be conserved wherever they are identified; core areas serve only as a potential additional indicator of species importance.

We undertook a concerted effort to obtain peer-review of the habitat models and to use available information to test, refine and validate the models. Peer-reviewers provided valuable information, particularly on local ecology of each species, allowing us to refine the models prior to testing. Dr. Kathy Parker and her associates at the UNBC provided an extensive data set on locations of radio-telemetered sheep, caribou, grizzly bears and wolves in the Besa-Prophet region of the study area used to test and further refine the models. We also used observations recorded during our winter aerial surveys, providing data from across the study area. For species for which we were unable to validate with telemetry information, we compared habitat suitability models developed using fine-scale TEM in the Besa-Prophet region to our model predictions. Still, we would caution that further validation, ground-truthing and revisions are recommended for future updating.

Additionally, most models would be improved with additional information, particularly environmental attributes that are important for determining that actual distribution of animals.

These attributes include improved alpine classifications, improved forage/understory vegetation attributes, snow depth and temperature information.

6.10 Tables

Table 6.1 Ecosections within the MK CAD study area, used in Part I of the models and their associated abbreviations.

Ecosection name	Acronym
Misinchinka Ranges	MIR
Peace Foothills	PEF
Muskwa Plateau	MUP
Muskwa Foothills	MUF
Eastern Muskwa Ranges	EMR
Western Muskwa Ranges	WMR
Liard Plains	LIP
Simpson Upland	SIU
Cassiar Ranges	CAR
Kechika Mountains	KEM
Southern Boreal Plateau	SBP
Northern Omineca Mountains	NOM
Hyland Highland	HYH

Table 6.2 Biogeoclimatic zones and subzones used in Part I of the models, with their associated abbreviations.

BEC zones	Acronym
Alpine Tundra	AT
Boreal White and Black Spruce	BWBS
Engelmann Spruce - Subalpine Fir	ESSF
Sub-Boreal Spruce	SBS
Spruce - Willow - Birch	SWB
Subzone first letter designation (moisture regime)[1, 2]	
very dry	x
dry	d
moist	m
wet	w
very wet	v
Subzone second letter designation (interior temperature regime)	
hot	h
warm	w
mild	m
cool	k
cold	c
very cold	v

[1] un = undifferentiated subzone
[2] Example: SWBmk = moist and cool subzone of Spruce - Willow - Birch zone

Table 6.3 VRI data definitions used in the habitat models and definitions of slope and aspect classes used in Part II of the models.

Attribute	Definition
Vegetated polygons	
VRI level 1 - Vegetated	Total cover of trees, shrubs, herbs, and bryoids covers at least 5% of the total surface area of the polygon
VRI level 2 - Treed	At least 10% of the polygon area, by crown cover, consists of tree species of any size
VRI level 3 - Wetland	Having the water table at, near, or above the soil surface that remains saturated long enough to promote wetland processes
Upland	All non-wetland ecosystems below alpine that range from very xeric to hygric soil moisture regimes
Alpine	Non-treed areas above the tree line
VRI level 4 - Shrub tall	Shrubs >20% cover with an average height $\geq$2 m
Shrub low	Shrubs >20% cover with an average height <2 m
Herb	Vascular plants without a woody stem >20% cover
Bryoid	Bryophytes and lichens comprise >50% cover
VRI level 5 - Dense	Tree, shrub, or herb cover between 61% and 100% crown closure
Open	Tree, shrub, or herb cover between 26% and 60% crown closure
Sparse	Tree cover between 10% and 25% for treed polygons, cover between 20% and 25% for shrub or herb polygons
Closed	Cover of bryoids is greater than 50%
Open	Cover of bryoids is less than or equal to 50%
Non-vegetated polygons	
VRI level 5 - BR	Bedrock
TA	Talus
BI	Blockfield - blocks of rock derived from underlying bedrock
RS	River sediment
MU	Mudflat sediment
BE	Beach
LS	Pond or lake sediment
Vegetated or Non-vegetated	
Slope class 1	<3% slope
Slope class 2	3-45% slope
Slope class 3	45-67% slope
Slope class 4	67-100% slope
Slope class 5	>100% slope
Aspect cool	Azimuth between 286 and 134°
Aspect warm	Azimuth between 135 and 285 degreed

Table 6.4 Integrated Type Group (ITG) codes and forest species codes, as defined in FIP.

ITG codes and descriptions

ITG code	Name	First spp.	Second spp.	Examples	First spp. name
18	B	B >80%	Any	B, BFd, BPl	Fir
20	BS	B	S, Fd, Pl, L or dec.	BS, BSPl, BSAt	Fir
21	S	S >80%	Any	S, SYc, SPw	Spruce
22	SFd	S	Fd, L, Pw, orPy	SFd, SL, SFdB	Spruce
24	SB	S	B	SB, SBAc, SBH	Spruce
25	SPl	S	Pl	SPl, SPlB, SPlFd	Spruce
26	SDecid	S	Decid	SAt, SAc, SAcB	Spruce
28	Pl	Pl >80%	Any	Pl, Pa, PlPa, PaPl	Lodgepole
29	PlFd	Pl	Fd, Pw, L, or Py	PlFd, PlPy, PlL	Lodgepole
30	PlS	Pl	S, B, H, Cw, or Yc	PlS, PlB, PlBS	Lodgepole
35	AcConif	Ac	Conif	AcS, AcH	Poplar
40	E	E	Any	E, EAt, ES	Birch
41	AtConif	At	Conif	AtPl, AtS, AtFd	Aspen
42	AtDecid	At	Decid	At, AtAc, AtE	Aspen

Tree names and acronyms

Common name	Acronym	Proper name
True fir	B	*Abies* spp.
Spruce	S	*Picea* spp.
Douglas Fir	Fd	*Pseudotsuga menziesii*
Whitebark pine	Pa	*Pinus albicalis*
Lodgepole pine	Pl	*Pinus contorta*
Western white pine	Pw	*Pinus monticola*
Yellow pine	Py	*Pinus ponderosa*
Larch	L	*Larix lyalli*
Yellow cedar	Yc	*Chamaecyparis nootkatensis*
Aspen	At	*Populus tremuloides*
Western red cedar	Cw	*Thuja plicata*
Birch	E	*Betula* spp.
Balsam poplar	Ac	*Populus balsamifera*
Hemlock	H	*Tsuga* spp.

Table 6.5 Validation using GPS telemetry of the sheep winter habitat suitability model.

Habitat Class	Location (Frequency)	% Location in class	% Available in class	Expected frequency of locations[1]
Nil	46	0.2	24.6	5687
1 (low)	52	0.2	18.1	4171
2 (mod)	597	2.6	19.6	4539
3 (mod-high)	4146	18.2	19.7	4561
4 (high)	18219	78.8	18.0	4152
Total	23110	100.0	100.0	23110

[1]Distribution of sheep locations significantly different from the distribution expected by proportional availability of the habitat classes (one-group chi-square = 60775, p<0.0001).

Table 6.6 Validation using GPS telemetry of the sheep growing habitat suitability model.

Habitat Class	Location (Frequency)	% Location in class	% Available in class	Expected frequency of locations[1]
Nil	98	0.8	24.6	2982
1 (low)	240	2.0	21.9	2655
2 (mod)	282	2.3	14.6	1774
3 (mod-high)	3311	27.3	21.1	2551
4 (high)	8189	67.6	17.8	2158
Total	12120	100.0	100.0	12120

[1]Distribution of sheep locations significantly different from the distribution expected by proportional availability of the habitat classes (one-group chi-square = 23322, p<0.0001).

Table 6.7 Sheep winter season model assessment using field observation data.

Habitat Class	Location[1] (Frequency)	% Location in class	% Habitat Surveyed in class	Expected Frequency[2]
Nil	0	0	30.9	17
1 (low)	2	3.7	15.6	8
2 (mod)	5	9.3	17.5	9
3 (mod-high)	21	38.9	18.2	10
4 (high)	26	48.1	17.8	10
Total	54	100	100	54

[1] A total of 54 sheep groups of 1 or more individuals were observed.
[2] The expected distribution of observations by habitat class is based on the assumption of random distribution that would conform to the proportional availability of habitat classes (i.e., the proportion of habitat classes surveyed).

Table 6.8 Total amounts and percentages of final habitat classes for Stone's sheep growing and winter seasons within the MK CAD study area.

Habitat Class	Growing Habitat (Ha)	Growing Habitat (%)	Winter Habitat (Ha)	Winter Habitat (%)
Class 0	6,569,274	40.55	6,569,119	40.55
Class 1	241,034	1.49	367,099	2.27
Class 2	1,499,118	9.25	2,217,478	13.69
Class 3	2,235,766	13.80	1,741,055	10.75
Class 4	1,011,407	6.24	1,682,800	10.39
Class 5	1,522,388	9.40	601,448	3.71
Class 6	377,109	2.33	430,468	2.66
Class 7	474,650	2.93	1,122,643	6.93
Class 8	617,012	3.81	1,036,667	6.40
Class 9	955,051	5.89	376,052	2.32
Class 10	698,320	4.31	56,302	0.35

Table 6.9 Total amount and percentages of Planning Units in different habitat classes for Stone's sheep growing and winter seasons within the MK CAD study area.

Planning Unit	Growing Habitat		Winter Habitat	
Habitat Class	Planning Unit count	Planning Unit (%)	Planning Unit count	Planning Unit (%)
Class 0	5394	16.31	5394	16.31
Class 1	6474	19.57	6281	18.99
Class 2	3709	11.21	3664	11.08
Class 3	2963	8.96	2940	8.89
Class 4	2807	8.49	2785	8.42
Class 5	2842	8.59	2900	8.77
Class 6	3132	9.47	3284	9.93
Class 7	2755	8.33	3124	9.45
Class 8	1997	6.04	1990	6.02
Class 9	895	2.71	633	1.91
Class 10	105	0.32	78	0.23

Table 6.10 Validation using GPS telemetry of the grizzly bear early growing habitat suitability model.

Habitat Class	Location (Frequency)	% Location in class	% Available in class	Expected frequency of locations[1]
Nil	21	1.1	21.2	417
1 (low)	317	16.1	22.6	444
2 (mod)	219	11.1	20.7	406
3 (mod-high)	113	5.8	19.3	380
4 (high)	1295	65.9	16.2	318
Total	1965	100.0	100.0	1965

[1]Distribution of grizzly bear locations significantly different from the distribution expected by proportional availability of the habitat classes (one-group chi-square = 3688, p<0.0001).

Table 6.11 Validation using GPS telemetry of the grizzly bear mid growing habitat suitability model.

Habitat Class	Location (Frequency)	% Location in class	% Available in class	Expected frequency of locations[1]
Nil	22	1.0	19.2	406
1 (low)	289	13.6	29.9	633
2 (mod)	160	7.6	21.4	453
3 (mod-high)	131	6.2	14.1	298
4 (high)	1514	71.6	15.4	326
Total	2116	100.0	100.0	2116

[1]Distribution of grizzly bear locations significantly different from the distribution expected by proportional availability of the habitat classes (one-group chi-square = 5164, p<0.0001).

Table 6.12 Validation using GPS telemetry of the grizzly bear late growing habitat suitability model.

Habitat Class	Location (Frequency)	% Location in class	% Available in class	Expected frequency of locations[1]
Nil	11	0.7	2.1	33
1 (low)	62	3.9	28.4	457
2 (mod)	211	13.1	22.0	355
3 (mod-high)	837	52.0	29.7	478
4 (high)	488	30.3	17.8	286
Total	1609	100.0	100.0	1609

[1]Distribution of grizzly bear locations significantly different from the distribution expected by proportional availability of the habitat classes (one-group chi-square = 826, p<0.0001).

Table 6.13 Total amounts and percentages of final habitat classes for grizzly bear growing season models within the MK CAD study area.

Grizzly Bear Habitat Class	Early Growing Habitat Ha (%)	Mid Growing Habitat Ha (%)	Late Growing Habitat Ha (%)
Class 0	43,413 (0.0%)	43,533 (0.0%)	43,412 (0.0%)
Class 1	345,140 (2.1%)	613,395 (3.8%)	286,999 (1.8%)
Class 2	1,185,835 (7.3%)	1,871,635 (11.6%)	1,135,930 (7.0%)
Class 3	2,281,645 (14.1%)	3,625,045 (22.4%)	1,573,150 (9.7%)
Class 4	2,509,013 (15.5%)	1,737,219 (10.7%)	1,336,407 (8.2%)
Class 5	1,510,854 (9.3%)	1,485,716 (9.2%)	2,310,406 (14.3%)
Class 6	1,416,489 (8.7%)	2,273,909 (14.0%)	1,283,720 (7.9%)
Class 7	1,029,176 (6.4%)	3,425,043 (21.1%)	886,886 (5.5%)
Class 8	1,752,582 (10.8%)	1,102,442 (6.8%)	3,152,836 (19.5%)
Class 9	2,843,285 (17.6%)	23,028 (0.1%)	2,462,652 (15.2%)
Class 10	1,283,700 (7.9%)	168 (0.0%)	1,728,732 (10.7%)

Table 6.14 Total amount and percentages of Planning Units in different habitat classes for grizzly bear growing season models within the MK CAD study area.

Habitat Class	Early Growing Habitat PU counts (%)	Mid Growing Habitat PU counts (%)	Late Growing Habitat PU counts (%)
Class 0	19 (0.06)	20 (0.06)	20 (0.06)
Class 1	453 (1.37)	422 (1.28	414 (1.25)
Class 2	761 (2.30)	363 (1.10)	517 (1.56)
Class 3	4105 (12.41)	1984 (6.00)	2016 (6.10)
Class 4	4906 (14.83)	5703 (17.24)	4602 (13.91)
Class 5	3389 (10.25)	3490 (10.55)	4651 (14.06)
Class 6	3775 (11.41)	3353 (10.14)	3711 (11.22)
Class 7	4473 (13.52)	4360 (13.18)	4864 (14.71)
Class 8	4943 (14.95)	5750 (17.39)	6584 (19.91)
Class 9	5083 (15.37)	6346 (19.19)	4873 (14.73)
Class 10	1166 (3.53)	1283 (3.88)	821 (2.48)

Table 6.15 Validation using GPS telemetry of the caribou growing habitat suitability model.

Habitat Class	Location (Frequency)	% Location in class	% Available in class	Expected frequency of locations[1]
Nil	0	0	10.7	70
1 (low)	28	4.3	28.3	184
2 (mod)	81	12.5	18.8	122
3 (mod-high)	138	21.2	26.2	170
4 (high)	403	62.0	16.0	104
Total	650	100.0	100.0	650

[1]Distribution of caribou locations significantly different from the distribution expected by proportional availability of the habitat classes (one-group chi-square = 1082, p<0.0001).

Table 6.16 Validation using GPS telemetry of the caribou winter habitat suitability model.

Habitat Class	Location (Frequency)	% Location in class	% Available in class	Expected frequency of locations[1]
Nil	38	0.8	6.0	304
1 (low)	129	2.5	24.6	1251
2 (mod)	995	19.6	25.4	1291
3 (mod-high)	2740	53.9	31.2	1585
4 (high)	1181	23.2	12.8	652
Total	5083	100.0	100.0	5083

[1]Distribution of caribou locations significantly different from the distribution expected by proportional availability of the habitat classes (one-group chi-square = 2577, p<0.0001).

Table 6.17 Caribou winter season model assessment using field observation data.

Habitat Class	Location[1] (Frequency)	% Location in class	% Habitat Surveyed in class	Expected Frequency[2]
Nil	0	0	9.8	4
1 (low)	3	6.7	22.4	10
2 (mod)	9	20.0	24.8	11
3 (mod-high)	8	17.8	21.1	10
4 (high)	25	55.5	21.9	10
Total	45	100	100	45

[1] A total of 45 caribou groups of 1 or more individuals were observed.
[2]The expected distribution of observations by habitat class is based on the assumption of random distribution that would conform to the proportional availability of habitat classes (i.e., the proportion of habitat classes surveyed).

Table 6.18 Total amounts and percentages of final habitat classes for caribou growing and winter season models within the MK CAD study area.

Habitat Class	Growing Habitat (Ha)	Growing Habitat (%)	Winter Habitat (Ha)	Winter Habitat (%)
Class 0	2,172,727	13.41	1,341,395	8.28
Class 1	43,683	0.27	7,126	0.04
Class 2	424,854	2.62	152,931	0.94
Class 3	967,900	5.97	321,481	1.98
Class 4	2,275,438	14.04	1,001,029	6.18
Class 5	1,645,012	10.15	1,559,176	9.62
Class 6	2,099,171	12.96	1,710,317	10.56
Class 7	2,120,782	13.09	1,971,656	12.17
Class 8	1,578,844	9.75	3,056,940	18.87
Class 9	1,889,177	11.66	4,015,463	24.79
Class 10	983,542	6.07	1,063,616	6.57

Table 6.19 Total amount and percentages of Planning Units in different habitat classes for caribou growing and winter seasons within the MK CAD study area

	Growing Habitat		Winter Habitat	
Caribou Habitat	***Planning Unit Count***	***Planning Unit (%)***	***Planning Unit count***	***Planning Unit (%)***
Class 0	194	0.59	96	0.29
Class 1	1,831	5.54	708	2.14
Class 2	1,823	5/51	677	2.05
Class 3	3,445	10.42	775	2.34
Class 4	3634	11.03	1,213	3.67
Class 5	2,570	7.77	2,530	7.65
Class 6	4635	14.02	6,264	18.93
Class 7	6,391	19.32	8,543	25.83
Class 8	5,137	15.53	7,272	21.99
Class 9	2,599	7.86	4542	13.73
Class 10	800	2.42	453	1.37

Table 6.20 Moose winter season model assessment using field observation data.

Habitat Class	Location[1] (Frequency)	% Location in class	% Habitat Surveyed in class	Expected Frequency[2]
Nil	0	0	2.9	3
1 (low)	6	6	25.3	26
2 (mod)	26	25	30.4	31
3 (mod-high)	46	45	26.4	27
4 (high)	25	24	15.1	15
Total	103	100	100	103

[1] A total of 103 moose groups of 1 or more individuals were observed.
[2]The expected distribution of observations by habitat class is based on the assumption of random distribution that would conform to the proportional availability of habitat classes (i.e., the proportion of habitat classes surveyed).

Table 6.21 Total amounts and percentages of final habitat classes for moose growing and winter season models within the MK CAD study area.

Habitat Class	Growing Habitat (Ha)	Growing Habitat (%)	Winter Habitat (Ha)	Winter Habitat (%)
Class 0	1,619,076	10.0	1,620,591	10.0
Class 1	617,033	3.81	1,371,975	8.47
Class 2	16,038	0.10	746,698	4.61
Class 3	74,209	0.46	1,024,163	6.32
Class 4	1,685,659	10.40	1,563,876	9.65
Class 5	1,080,266	6.67	2,231,716	13.78
Class 6	2,957,598	18.26	1,675,024	10.34
Class 7	3,174,754	19.60	2,286,216	14.11
Class 8	2,376,982	14.67	2,101,535	12.97
Class 9	2,271,025	14.02	1,126,483	6.95
Class 10	328,491	2.03	452,854	2.80

Table 6.22 Total amount and percentages of Planning Units in different habitat classes for moose growing and winter seasons within the MK CAD study area.

Habitat Class	Growing Habitat		Winter Habitat	
	Planning Unit Count	***Planning Unit (%)***	***Planning Unit Count***	***Planning Unit (%)***
Class 0	207	0.63	209	0.63
Class 1	1438	4.35	2019	6.10
Class 2	1128	3.41	1793	5.42
Class 3	1272	3.85	2721	8.23
Class 4	1347	4.07	2823	8.54
Class 5	1687	5.10	3058	9.25
Class 6	3097	9.36	3531	10.68
Class 7	4449	13.45	4340	13.12
Class 8	9806	29.65	5479	16.57
Class 9	7989	24.16	6352	19.21
Class 10	653	1.97	748	2.26

Table 6.23 Total amounts and percentages of final habitat classes for mountain goat growing and winter season models within the MK CAD study area.

Habitat Class	Growing Habitat (Ha)	Growing Habitat (%)	Winter Habitat (Ha)	Winter Habitat (%)
Class 0	6,189004	38.2	2,598281	16.04
Class 1	713,800	4.41	1,476,152	9.11
Class 2	1,457,900	9.00	1,422,748	8.78
Class 3	1,043,994	6.44	2,206,648	13.62
Class 4	1,834,406	11.32	3,409,734	21.05
Class 5	2,131,037	13.15	1,653,918	10.21
Class 6	162,323	1.00	314,719	1.94
Class 7	124,087	0.77	738,304	4.56
Class 8	353,162	2.18	1,645,484	10.16
Class 9	1,364,112	8.42	705,790	4.36
Class 10	827,306	5.11	29,354	0.18

Table 6.24 Total amount and percentages of Planning Units in different habitat classes for mountain goat growing and winter seasons within the MK CAD study area.

Habitat Class	Growing Habitat		Winter Habitat	
	Planning Unit Count	***Planning Unit (%)***	***Planning Unit Count***	***Planning Unit (%)***
Class 0	4782	14.46	160	0.48
Class 1	8030	24.28	3908	11.82
Class 2	2949	8.92	3983	12.04
Class 3	2370	7.17	3101	9.38
Class 4	2166	6.55	2943	8.90
Class 5	2595	7.85	4050	12.25
Class 6	3323	10.05	4670	14.12
Class 7	3058	9.25	4274	12.92
Class 8	2569	7.77	4008	12.12
Class 9	1111	3.36	1834	5.55
Class 10	120	0.36	142	0.43

Table 6.25 Rocky Mountain elk winter season model assessment using field observation data.

Habitat Class	Location[1] (Frequency)	% Location in class	% Habitat Surveyed in class	Expected Frequency[2]
Nil	0	0	3.3	3
1 (low)	6	6	23.9	24
2 (mod)	5	5	21.1	21
3 (mod-high)	24	24	25.6	26
4 (high)	65	65	26.0	26
Total	100	100	100	100

[1] A total of 100 elk groups of 1 or more individuals were observed.

[2]The expected distribution of observations by habitat class is based on the assumption of random distribution that would conform to the proportional availability of habitat classes (i.e., the proportion of habitat classes surveyed).

Table 6.26 Total amounts and percentages of final habitat classes for Rocky Mountain elk growing and winter season models within the MK CAD study area.

Habitat Class	Growing Habitat (Ha)	Growing Habitat (%)	Winter Habitat (Ha)	Winter Habitat (%)
Class 0	1,783,093	11.01	1,787,589	11.03
Class 1	935,415	5.77	2,236,490	13.80
Class 2	286,300	1.77	825,153	5.09
Class 3	379,527	2.34	1,270,275	7.84
Class 4	1,096,066	6.77	2,329,201	14.38
Class 5	1,425,960	8.80	2,526,525	15.59
Class 6	2,523,928	15.58	2,572,881	15.88
Class 7	3,017,033	18.62	1,713,467	10.58
Class 8	3,073,266	18.97	716,938	4.43
Class 9	1,582,269	9.77	183,099	1.13
Class 10	98,274	0.61	39,512	0.24

Table 6.27 Total amount and percentages of Planning Units in different habitat classes for elk growing and winter seasons within the MK CAD study area.

Habitat Class	Growing Habitat		Winter Habitat	
	Planning Unit Count	***Planning Unit (%)***	***Planning Unit Count***	***Planning Unit (%)***
Class 0	280	0.85	282	0.85
Class 1	1312	3.97	2198	6.65
Class 2	1017	3.08	2-40	6.17
Class 3	1121	3.39	2216	6.70
Class 4	1643	4.97	2403	7.27
Class 5	2809	8.49	3483	10.53
Class 6	4712	14.25	6308	19.07
Class 7	5578	16.87	6368	19.25
Class 8	7143	21.60	5475	16.55
Class 9	6603	19.96	2145	6.49
Class 10	855	2.59	155	0.47

Table 6.28 Validation using GPS telemetry of the wolf winter habitat suitability model.

Habitat Class	Location (Frequency)	% Location in class	% Available in class	Expected frequency of locations[1]
Nil	0	0	0.2	5
1 (low)	122	3.9	27.4	860
2 (mod)	255	8.1	24.6	774
3 (mod-high)	518	16.5	24.8	780
4 (high)	2246	71.5	23.0	722
Total	3141	100.0	100.0	3141

[1]Distribution of wolf locations significantly different from the distribution expected by proportional availability of the habitat classes (one-group chi-square = 4270, p<0.0001).

Table 6.29 Validation using GPS telemetry of the wolf growing habitat suitability model.

Habitat Class	Location (Frequency)	% Location in class	% Available in class	Expected frequency of locations[1]
Nil	0	0	0.2	2
1 (low)	107	7.7	25.6	356
2 (mod)	174	12.5	27.4	382
3 (mod-high)	201	14.4	23.0	321
4 (high)	910	65.4	23.8	331
Total	1392	100.0	100.0	1392

[1]Distribution of wolf locations significantly different from the distribution expected by proportional availability of the habitat classes (one-group chi-square = 2577, p<0.0001).

Table 6.30 Total amounts and percentages of final habitat classes for wolf growing and winter season models within the MK CAD study area.

Habitat Class	Growing Habitat (Ha)	Growing Habitat (%)	Winter Habitat (Ha)	Winter Habitat (%)
Class 0	4721.25	0.03	54.5	0.00
Class 1	983797.8	6.07	798099.3	4.93
Class 2	595198.3	3.67	799051.5	4.93
Class 3	2551759	15.75	2352997	14.52
Class 4	5597410	34.55	5763181	35.57
Class 5	4470378	27.59	3943785	24.34
Class 6	1410261	8.70	1635009	10.09
Class 7	431652	2.66	709649.3	4.38
Class 8	83040.75	0.51	125524.5	0.77
Class 9	2547.75	0.02	3415.5	0.02
Class 10	4721.25	0.03	54.5	0.00

Table 6.31 Total amount and percentages of Planning Units in different habitat classes for wolf growing and winter seasons within the MK CAD study area.

Habitat Class	Growing Habitat		Winter Habitat	
	Planning Unit Count	***Planning Unit (%)***	***Planning Unit Count***	***Planning Unit (%)***
Class 0	70,364	0.43	70,364	0.43
Class 1	4,721	0.03	55	0.03
Class 2	983,798	6.07	798,099	6.07
Class 3	595,198	3.67	799,052	3.67
Class 4	2,551,759	15.75	2,352,997	15.75
Class 5	5,597,410	34.55	5,763,181	34.55
Class 6	4,470,378	27.59	3,943,785	27.59
Class 7	1,410,261	8.70	1,635,009	8.7
Class 8	431,652	2.66	709,649	2.66
Class 9	83,041	0.51	125,525	0.51
Class 10	2,548	0.02	3,416	0.02

6.11 Figures

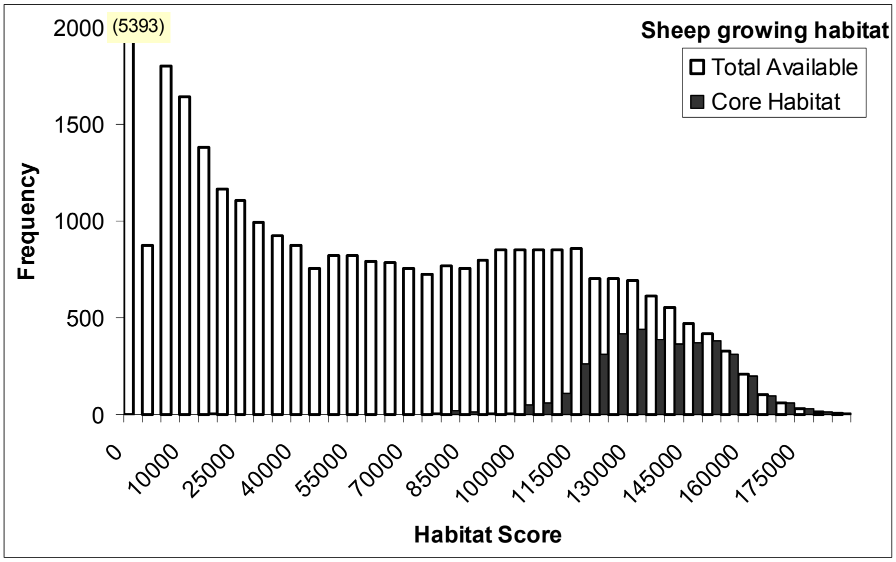


Figure 6.1 Sheep growing season habitat score distribution with sheep core habitat.

Histogram of the Planning Unit summed sheep growing season habitat suitability score (0-200,000), indicated by "Total Available" across the study area. The PU scores included within the Sheep Core Habitats are identified by "Core Habitat". Core Areas preferentially select the best available habitats for each season, while avoiding human use areas.

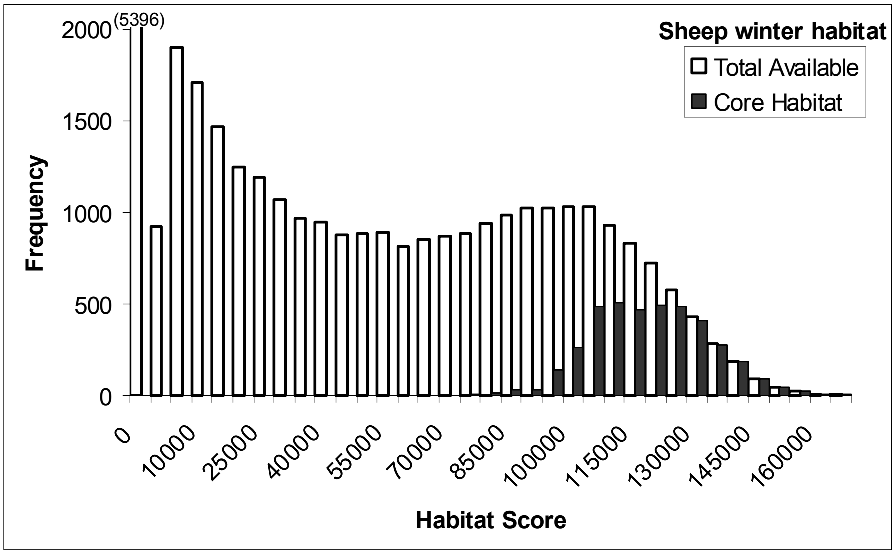


Figure 6.2 Sheep winter season habitat score distribution with sheep core habitat.

Histogram of the Planning Unit summed sheep winter season habitat suitability score (0-200,000), indicated by "Total Available" across the study area. The PU scores that were selected to be included within the Sheep Core Habitats are identified, as well, by "Core Habitat".

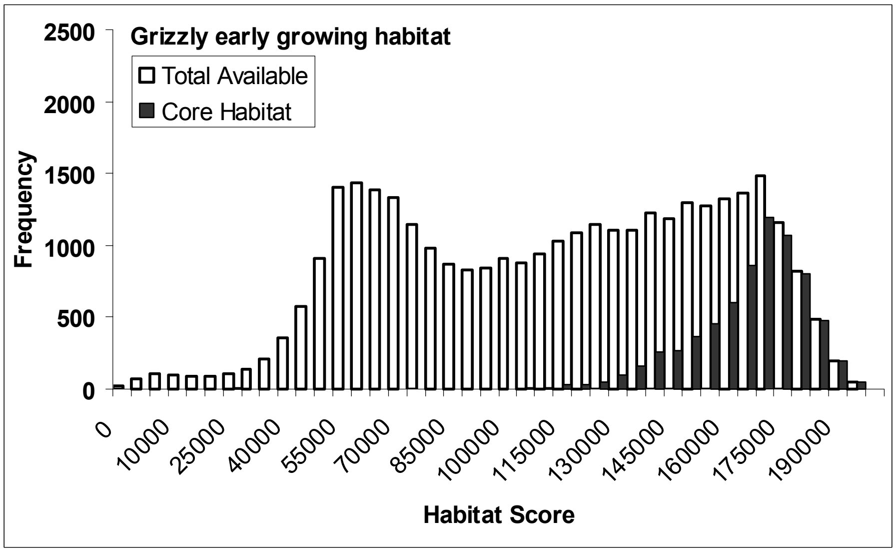


Figure 6.3 Grizzly bear early growing season habitat score distribution with grizzly bear core habitat.

Histogram of the Planning Unit summed grizzly bear early growing season habitat suitability score (0-200,000), indicated by "Total Available" across the study area. The PU scores that were selected to be included within the Grizzly Bear Core Habitats are identified by "Core Habitat".

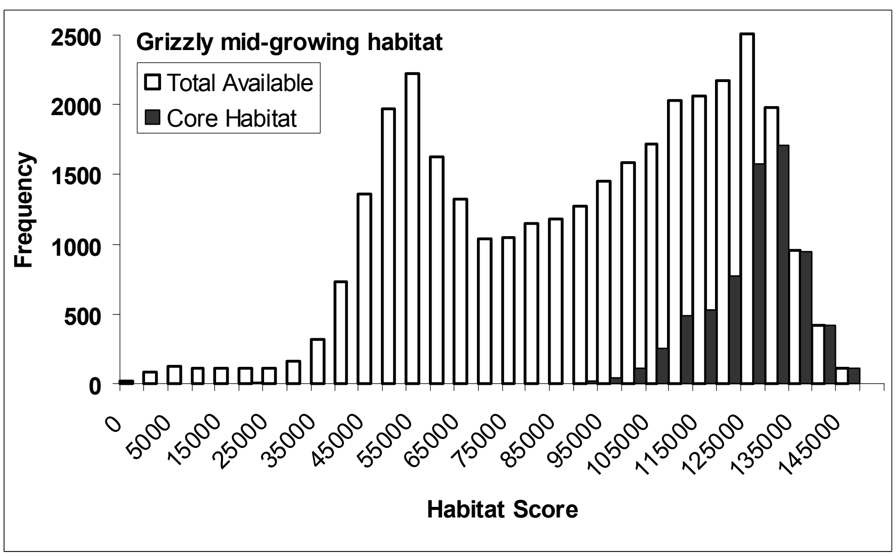


Figure 6.4 Grizzly bear mid growing season habitat score distribution with grizzly bear core habitat.

Histogram of the Planning Unit summed grizzly bear mid growing season habitat suitability score (0-200,000), indicated by "Total Available" across the study area. The PU scores that were selected to be included within the Grizzly Bear Core Habitats are identified by "Core Habitat".

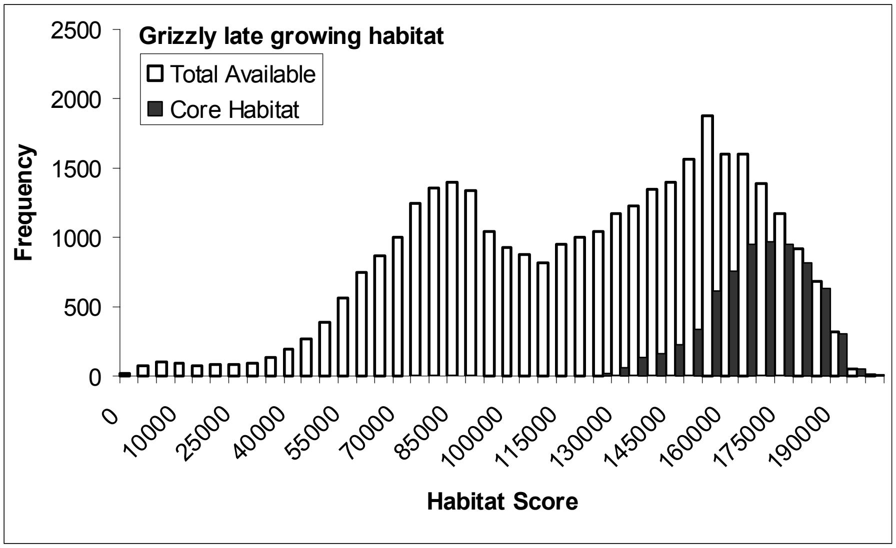


Figure 6.5 Grizzly bear late growing season habitat score distribution with grizzly bear core habitat.

Histogram of the Planning Unit summed grizzly bear late growing season habitat suitability score (0-200,000), indicated by "Total Available" across the study area. The PU scores that were selected to be included within the Grizzly Bear Core Habitats are identified by "Core Habitat".

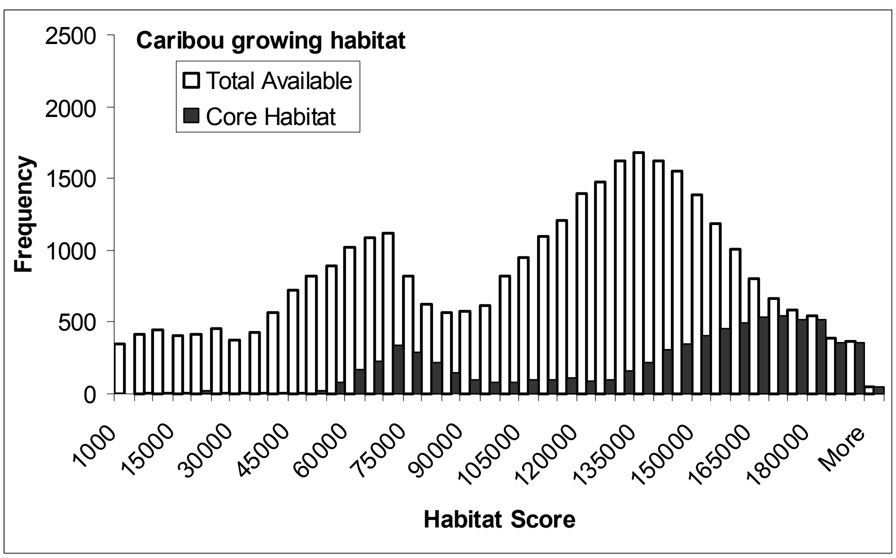


Figure 6.6 Caribou growing season habitat distribution with caribou core habitat.

Histogram of the Planning Unit summed woodland caribou growing season habitat suitability score (0-200,000), indicated by "Total Available" across the study area. The PU scores that were selected to be included within the Caribou Core Habitats are identified by "Core Habitat".

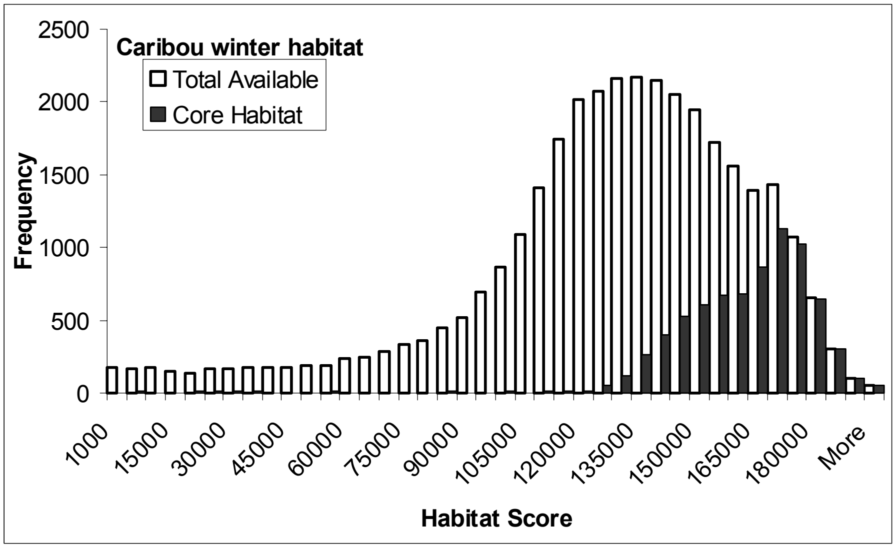


Figure 6.7 Caribou winter season habitat distribution with caribou core habitat.

Histogram of the Planning Unit summed woodland caribou winter season habitat suitability score (0-200,000), indicated by "Total Available" across the study area. The PU scores that were selected to be included within the Caribou Core Habitats are identified by "Core Habitat".

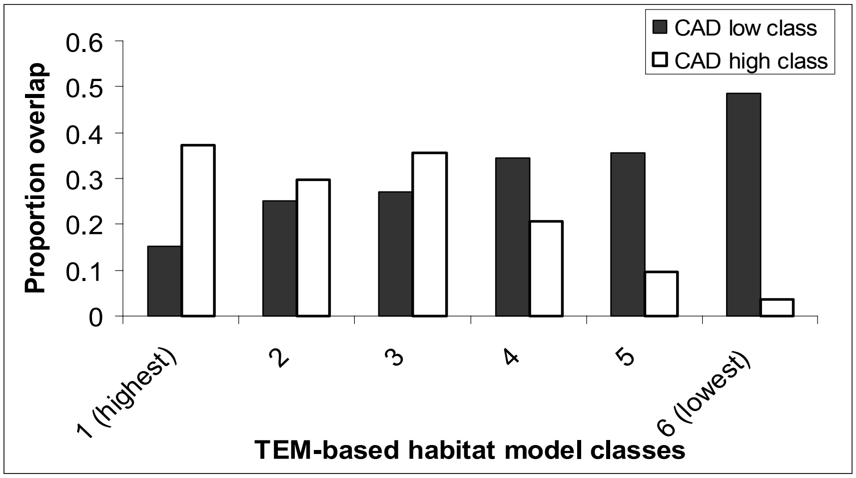


Figure 6.8 Overlap between TEM predictions and CAD moose habitat suitability model.

Relative proportion of our class 1 (low) and class 5 (high) habitat classes that overlap with TEM-based habitat suitability models for moose in the BP region. TEM-based models rank habitats opposite to our scaling, so that their "1" is equivalent to our highest rated habitat class and their habitat class "6" would be approximately equivalent to our "Class 1" habitat.

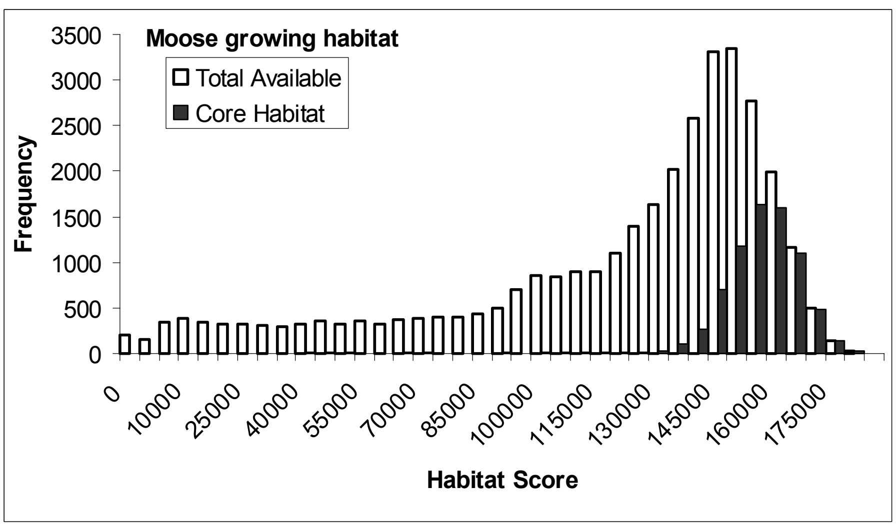


Figure 6.9 Moose growing season habitat distribution with moose core habitat.

Histogram of the Planning Unit summed moose growing season habitat suitability score (0-200,000), indicated by "Total Available" across the study area. The PU scores that were selected to be included within the Moose Core Habitats are identified by "Core Habitat".

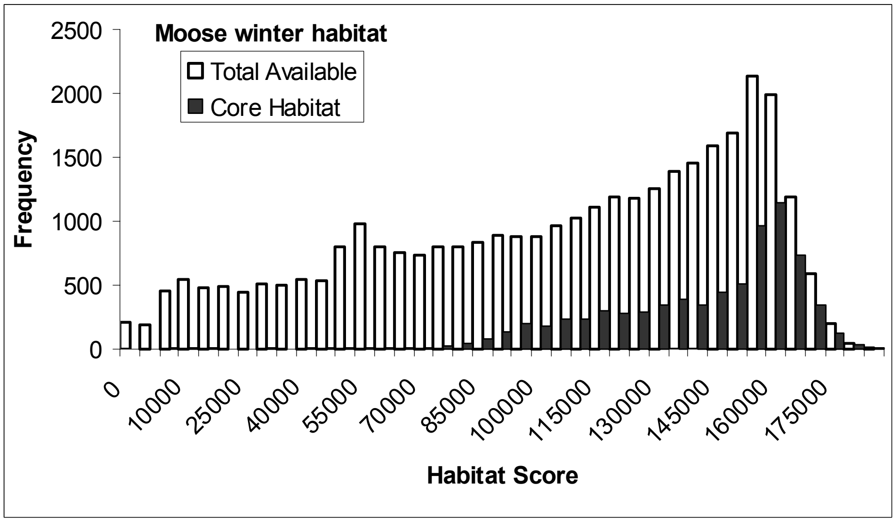


Figure 6.10 Moose winter season habitat distribution with moose core habitat.

Histogram of the Planning Unit summed moose winter season habitat suitability score (0-200,000), indicated by "Total Available" across the study area. The PU scores that were selected to be included within the Moose Core Habitats are identified by "Core Habitat".

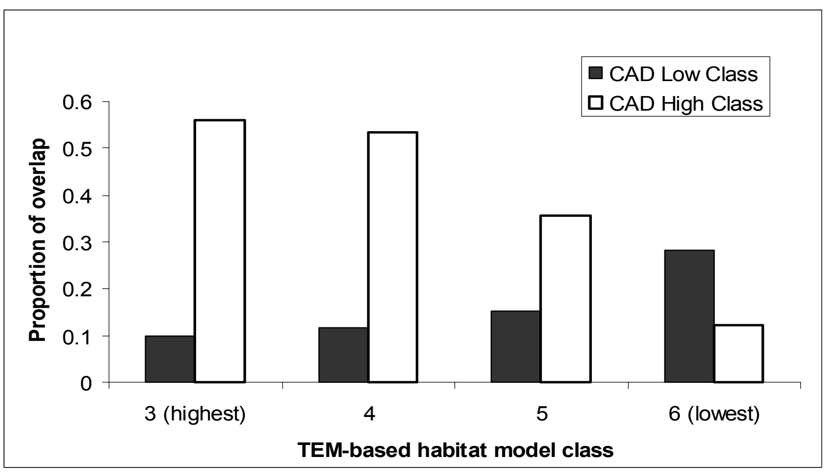


Figure 6.11 Overlap between TEM predictions and CAD goat habitat suitability model.

Relative proportion of our class 1 (low) and class 5 (high) habitat classes that overlap with TEM-based habitat suitability models for mountain goat in the BP region. TEM-based models rank habitats opposite to our scaling, so that their class "3" (highest predicted in the area) is equivalent to our highest rated habitat class and their habitat class 6 would be approximately equivalent to our Class 1 habitat.

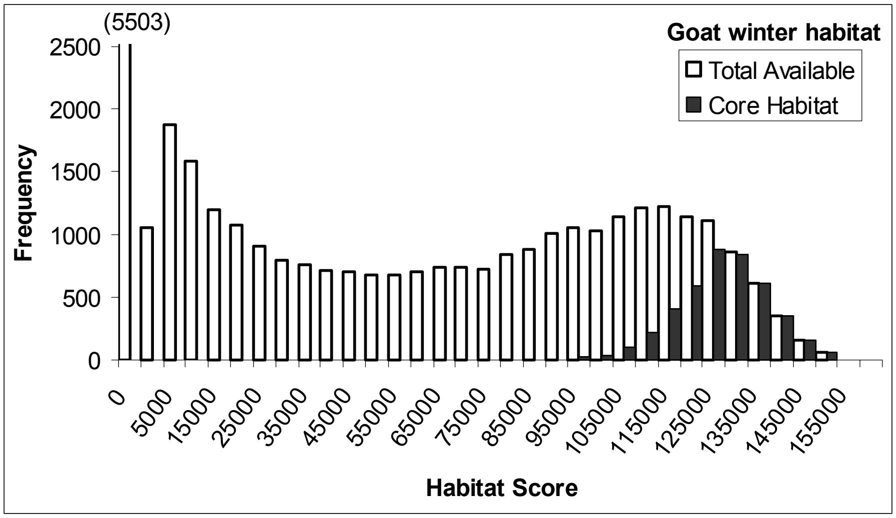


Figure 6.12 Goat winter season habitat distribution with goat core habitat.

Histogram of the Planning Unit summed mountain goat growing season habitat suitability score (0-200,000), indicated by "Total Available" across the study area. The PU scores that were selected to be included within the Goat Core Habitats are identified by "Core Habitat".

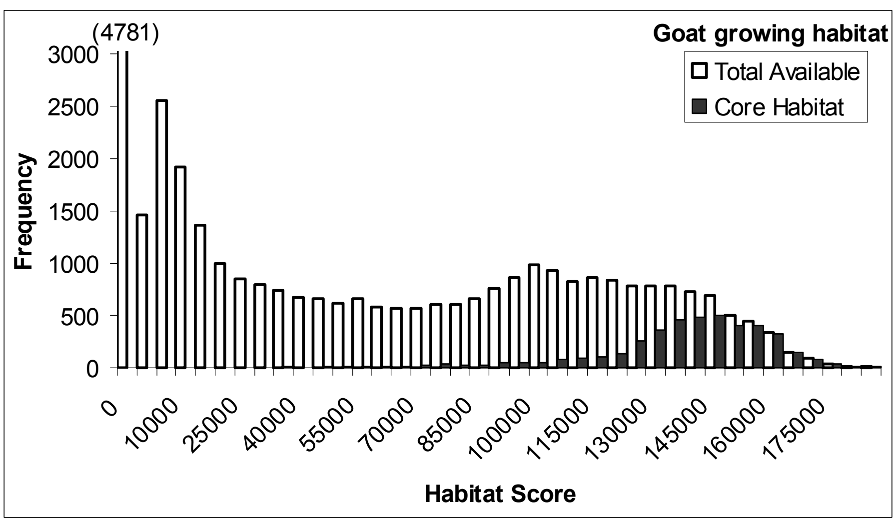


Figure 6.13 Goat growing season habitat distribution with goat core habitat.

Histogram of the Planning Unit summed mountain goat winter season habitat suitability score (0-200,000), indicated by "Total Available" across the study area. The PU scores that were selected to be included within the Goat Core Habitats are identified by "Core Habitat".

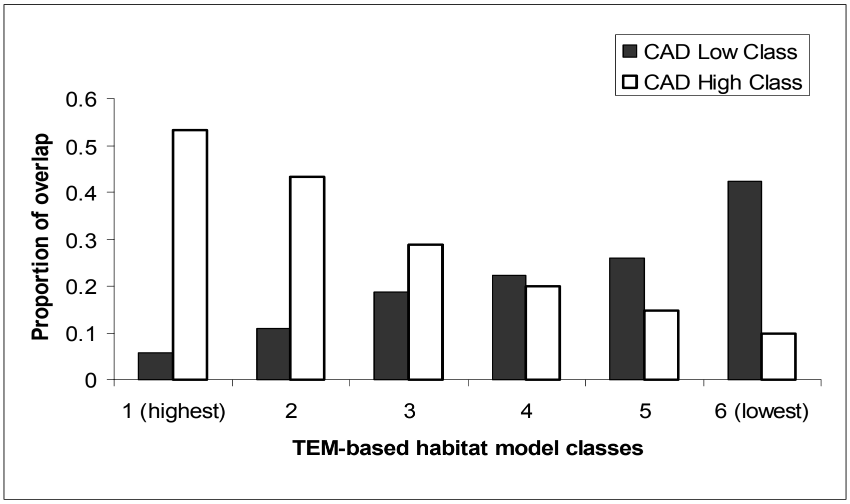


Figure 6.14 Overlap between TEM predictions and CAD elk habitat suitability model.

Relative proportion of our class 1 (low) and class 5 (high) habitat classes that overlap with TEM-based habitat suitability models for Rocky Mountain elk in the BP region. TEM-based models rank habitats opposite to our scaling, so that their class "1" is equivalent to our highest rated habitat class and their habitat class "6" would be approximately equivalent to our Class 1 habitat.

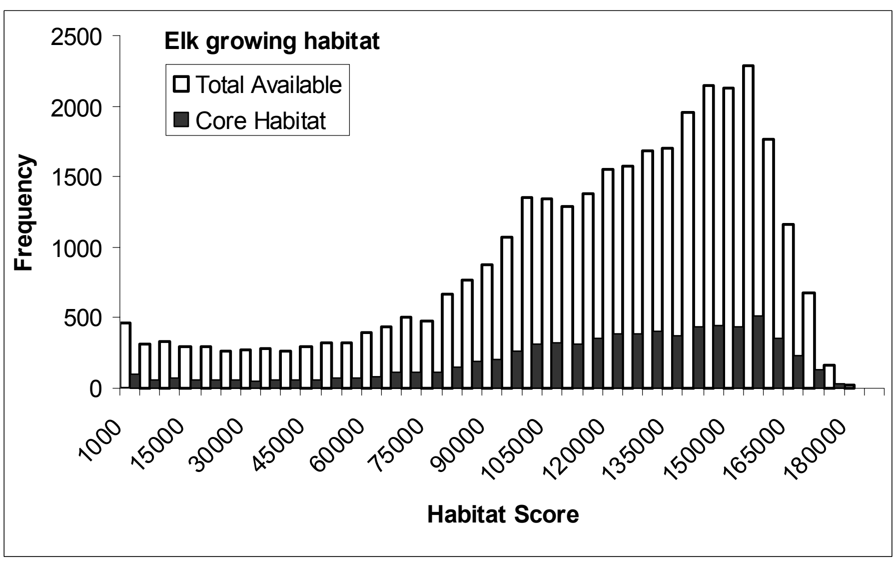


Figure 6.15 Elk growing season habitat distribution with elk core habitat.

Histogram of the Planning Unit summed elk growing season habitat suitability score (0-200,000), indicated by "Total Available" across the study area. The PU scores that were selected to be included within the Elk Core Habitats are identified by "Core Habitat".

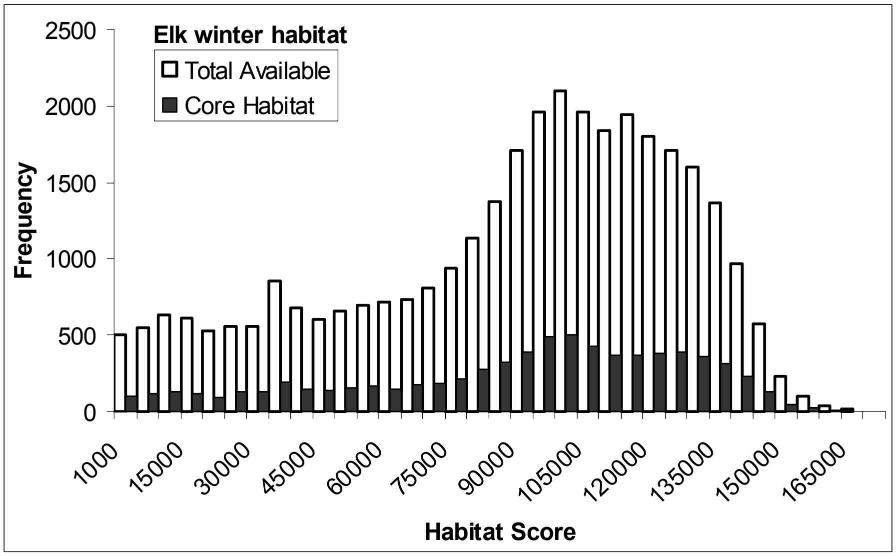


Figure 6.16 Elk winter season habitat distribution with elk core habitat.

Histogram of the Planning Unit summed elk winter season habitat suitability score (0-200,000), indicated by "Total Available" across the study area. The PU scores that were selected to be included within the Sheep Core Habitats are identified, as well, by "Core Habitat". Core Areas preferentially select the best available habitats for each season, while avoiding human use areas.

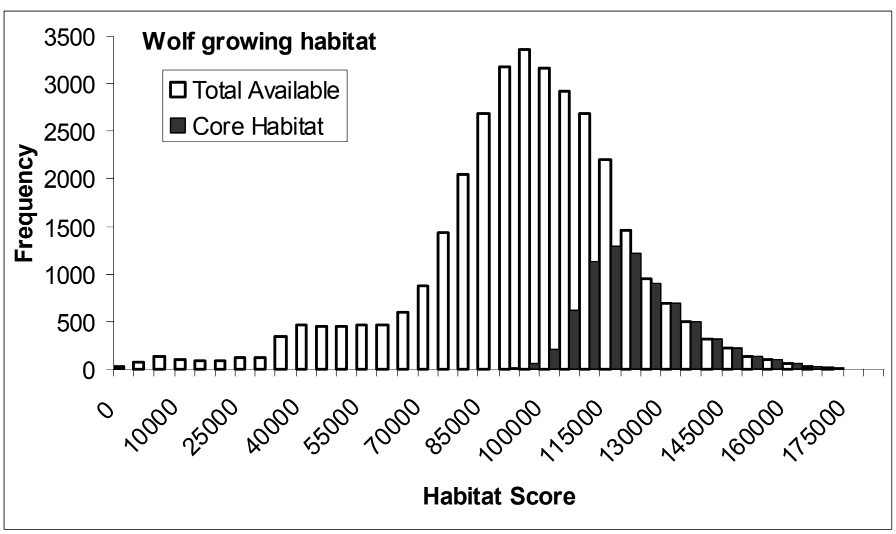


Figure 6.17 Wolf growing season habitat distribution with wolf core habitat.

Histogram of the Planning Unit summed wolf growing season habitat suitability score (0-200,000), indicated by "Total Available" across the study area. The PU scores that were selected to be included within the Wolf Core Habitats are identified by "Core Habitat".

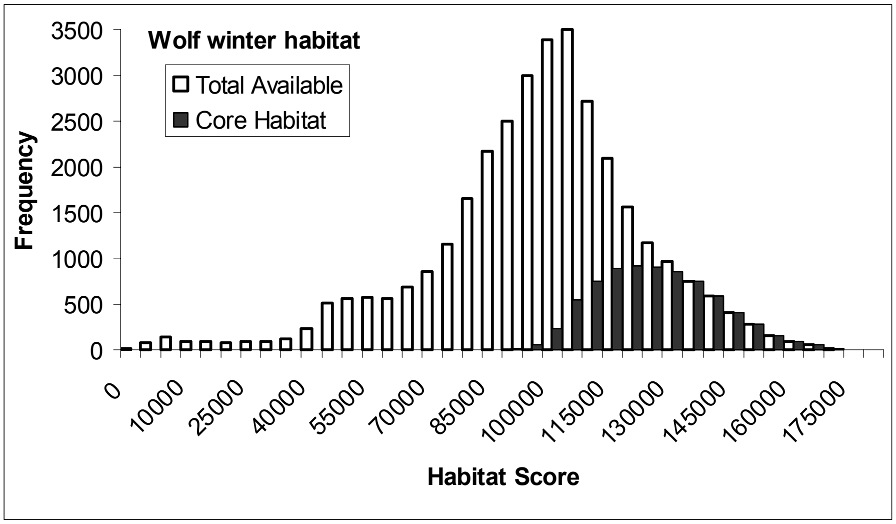


Figure 6.18 Wolf winter season habitat distribution with wolf core habitat.

Histogram of the Planning Unit summed wolf winter season habitat suitability score (0-200,000), indicated by "Total Available" across the study area. The PU scores that were selected to be included within the Sheep Core Habitats are identified by "Core Habitat".

7 AQUATIC FOCAL SPECIES ANALYSES

7.1 Background and Introduction

Similar to terrestrial focal species, aquatic focal species are selected to serve as umbrellas for aquatic biodiversity. We selected two species that have distinctly different ecological requirements: bull trout (*Salvelinus confluentus*) and arctic grayling (*Thymallus arcticus*). These species may broadly serve to identify the diversity of freshwater stream ecological values in the region. In addition to these species, we have completed a freshwater stream and lake classification for coarse-filter representation of aquatic diversity (see Section 5) and have included several rare, sensitive or listed fish species as special elements in our analyses (see Section 8). There are over 30 special element fish species which include Arctic Cisco, lake trout, rainbow trout, chum salmon, kokonee, and a variety of whitefish. As with terrestrial approaches, a combination of coarse-filter, fine-filter and focal species approaches provides increased ability to identify the diversity and importance of aquatic systems.

The purpose of aquatic focal species modeling is to identify which watersheds in the MK CAD study area are likely to support populations of either of two focal fish species. The sequence of steps involved in the effort include: identifying pertinent data, mapping the observed occurrence, identifying watersheds that are adjacent to observed occurrences, quantifying the physical characteristics of watersheds where a species has typically not been observed and extending these conclusions to unsampled watersheds.

7.1.1 Species Ecology

7.1.1.1 Bull Trout

Bull trout is a char endemic to western North America. It has recently been distinguished from Dolly Varden (*Salvelinus malma*). For the purposes of this study, both bull trout and Dolly Varden data were incorporated into the habitat suitability model for bull trout.

Bull trout spawn in the fall in flowing water. The female digs the redd. Fry emerge approximately 220 days after egg deposition and hide in gravel along stream edges and side channels. Juveniles are found in pools, riffle and runs and are strongly associated with instream and overhead cover. Juveniles feed on aquatic insects and as they mature into adults, their diet shifts to fish (McPhail and Baxter 1996).

Bull trout have a number of life-history forms; three of which are expressed within the MKMA. The stream-resident form lives out its life in small headwater streams. The fluvial form lives in large rivers as an adult but migrates to spawn in small tributary streams. Lastly, the lacustrine-adfluvial form spawns in tributary streams but lives a an adult in lakes (McPhail and Baxter 1996).

7.1.1.2 Arctic Grayling

Arctic grayling occur throughout northern drainage systems. They spawn in the spring in small gravel or rock bottomed tributaries or in mainstream rivers. They make no redd or nest. The fry emerge within 30 days. Fry and juveniles eat zooplankton and aquatic insects. Most fish are mature by 6 to 9 years of age and their diet shifts to aquatic and terrestrial insects, fish, and fish eggs. Arctic grayling are known for migrating long distances between spawning, summer feeding and overwintering areas. They prefer clear waters of large, cold rivers, rocky creeks and lakes (Scott and Crossman 1973).

7.2 Aquatic Focal Species: Methods

7.2.1 Data Sources

The units of analysis were based on watershed boundaries defined in the BC100WD Watershed Atlas and as described by GIS files from MSRM. Occurrence data was derived from the MSRM/DFO Fisheries Information Summary System (FISS; Department of Fisheries and Oceans Canada, British Columbia Ministry of Environment et al. 2001). Watershed characteristics are mainly from the Watersheds BC Data Base (Gray 2002) linked to BC100WD through the GISTAG field.

Connectivity among watersheds was derived from a revised watershed code (PCODE) provided by Art Tautz (pers. comm., University of British Columbia, BC Ministry of Water, Land & Air Protection). Each watershed also had the PCODE of the watershed directly downstream (PCONTO) and the streamline distance in meters (measure) from the mouth of that watershed (PCONAT). Since each occurrence was associated with a PCODE and a measure, each tributary watershed could be ranked as being above or below each occurrence.

Additional fields were attached to each watershed including: Count of fish samples, fish observed, bull trout or Dolly Varden observed (BT/DV present=1) or absent from the drainage (BT/DV present=-1). BT/DV adjacent indicated an observation of BT/DV upstream of a watershed (1) or immediately downstream of a watershed (3). Similar fields and codes record information for Artic grayling (AG) and any fish species (Spp).

7.2.2 Species Ranges

The entire MK CAD study area is within the range of bull trout, but artic grayling are absent from the Skeena watershed. Both species commonly occur in fish samples and make up 11% (Arctic grayling) and 18% (bull trout) of the 6693 fish species occurrences recorded from this area (Department of Fisheries and Oceans Canada, British Columbia Ministry of Environment et al. 2001).

7.2.3 Watershed Groups

Bull trout are generally absent from the Boreal Plains east of the study area (Department of Fisheries and Oceans Canada, British Columbia Ministry of Environment et al. 2001). Within the study area, they are probably absent from the Dunedin (0/385 species), Lower Fort Nelson 0/109), and Lower Sikanni Chief (0/101) drainages, which are predominantly on the Boreal Plains. In addition, bull trout appear to be a minor component of the fish fauna in four other adjacent drainages: the Upper Fort Nelson (0/29), Upper Beaton River (1/172), Upper Sikanni Chief (1/102) and Lower Muskwa (4/357) rivers.

With the exception of the Skeena drainage, there are no clear patterns of Arctic grayling absence in the 50 other watershed groups that intersect the MK CAD study area (Department of Fisheries and Oceans Canada, British Columbia Ministry of Environment et al. 2001).

7.2.4 Observed Presence

The next step in modeling the distribution of bull trout and grayling was to identify watersheds that could be connected to actual observations. Watersheds were classified as either having an observed species presence, being downstream of an observed presence, or immediately upstream of an observed presence. The species clearly has access to downstream watersheds and would likely be present if suitable habitat is available. Species also have access to the lower reaches of watersheds that are immediately upstream of an occurrence unless there is an obstruction between the mouth of the upstream watershed and the observed species presence. Watersheds that cannot be connected to bull trout and Arctic grayling observations were also classified according to their connections to occurrences of other species. Both bull trout and Arctic grayling are headwater species and the presence of other fish species indicates, with the exception of introductions, that a watershed has at some point been accessible to fish colonization.

Bull trout are believed to be absent from 13% of the study area (Figure 7.1). However, when they are present, they make up 21% of the species occurrences and form an important component of the fish fauna. Sixty-eight percent of the watershed area, but only 45% of the number of watersheds, can be geographically connected to actual observations of bull trout. This discrepancy is due to large numbers of small watersheds that have not been sampled for fish presence or absence. An additional 9% of the area (12% of watersheds) is connected to observations of another species. This leaves 18% of the area (36% of watersheds) where there are no direct connections to observation data.

Arctic grayling are known to be absent from 2% of the study area (Figure 7. 2). Arctic grayling form an important component of the fish fauna, making up 12% of the species occurrences in this region. Sixty-five percent of the watershed area, but only 39% of the number of watersheds, can be geographically connected to actual observations of arctic grayling. This is mostly due to large numbers of small watersheds that have not been sampled for fish presence or absence. An additional 15% of the area (20% of watersheds) is connected to observations of another species. This leaves 19% of the area (41% of watersheds) where there is no direct connection to observation data.

7.2.5 Identifying Suitable Watersheds

Using a Principle Components Analysis (PCA), 29 watershed characteristics were compressed down into 3 principle components (Table 7.1). These components can be used to rank watersheds along axes that capture differences in elevation, size and gradient among watersheds.

The characteristics of watersheds where bull trout were observed overlapped broadly with watersheds containing at least one sample event but no bull trout observed (Figure 7.3). Watersheds where bull trout were absent were generally low elevation, low gradient watersheds. This is consistent with our expectations based on general bull trout ecology.

The characteristics of watersheds where grayling were observed also overlapped broadly with watersheds containing at least one sample event but no grayling observed (Figure 7.4). In contrast to bull trout, Arctic grayling were clearly concentrated in low elevation watersheds. This is consistent with our expectations based on general Arctic grayling ecology.

Sampled watersheds are not a random sample of all watersheds. Small, high elevation watersheds, with either very high or very low gradients are under represented (Figure 7.5). The suitability of these watersheds to support bull trout and Arctic grayling was derived by grouping watersheds along the 3 PCA gradients and comparing the number of watersheds where each species was observed, or not observed, within each group.

7.2.6 Habitat Suitability of Unsampled Watersheds

The suitability of watersheds to support a given species can be evaluated by comparing the characteristics of watersheds where the species has been observed with watersheds which have been sampled but the species has not been observed. Each watershed was first assigned a value for each of the first 3 PCA components using the coefficients given in Table 7.1. For each principle components (PC), watersheds were first ranked with respect to that component and then divided into 12 bins with equal numbers of watersheds. For each bin, the number of watersheds where at least one fish sample was available, the number of watersheds where at least one bull trout (or Dolly Varden) had been observed, and the number of watersheds where at least one Arctic grayling had been observed were counted (Table 7.2). These numbers were used to calculate the relative proportion of watersheds where a species was observed across the range of each PCA habitat descriptor (Figure 7.6). This proportion was used as a score to indicate the relative suitability of watersheds with respect to the habitat variation captured by each PC.

This line of reasoning suggests that higher elevation, higher gradient and larger watersheds are better bull trout habitat (Figure 7.7 and Map 7.1). For each watershed, a habitat suitability score was calculated for each PC, using the empirical relationships in Figure 7.6. The overall habitat suitability of a watershed was calculated as the mean of the 3 component scores. This analysis suggested that bull trout were rarely observed in watersheds with mean scores of < 0.42, but were frequently observed in watersheds with mean scores > 0.52. A map of these scores, suggests that many of the unsampled watersheds in the headwaters of the Kechika River are suitable for bull trout and are likely to support this species unless there are permanent barriers to fish movement (Map 7.1).

Relative suitability for Arctic grayling was independent of gradient and size but was strongly dependent on elevation (Figure 7.6). Arctic grayling are much more frequently observed in the warmer, lower-elevation watersheds with PC1 scores > 0.46 and are almost absent from watersheds with PC1 scores < .17 (Map 7.2 and Figure 7.8).

7.3 Aquatic Focal Species: Discussion

Neither bull trout nor grayling are extreme habitat specialists suggesting that a high proportion of the watersheds in this area appear to be capable of supporting populations of one or both of these species. The distributions of the two species are complementary in that grayling are common in low elevation, warmer watersheds where bull trout are rare or absent. Small, headwater watersheds with either very high or very low gradients have not been adequately sampled. Obstructions may limit access to these watersheds but habitat suitability evaluation suggests that small, high-gradient, high-elevation watersheds are capable of supporting bull trout while small, low-gradient, low-elevation watersheds can support grayling. Large areas in the upper Liard and, especially, the upper Kechika, watersheds are poorly sampled. Suitable habitat for both species appears to be present in these areas and, barring the presence of permanent obstructions, these areas are likely to support viable populations of one or both species.

7.4 Tables

Table 7.1 Principal component loadings of the variables associated with each watershed.

Component	*PC1*	*PC2*	*PC3*
Characteristics of watersheds with higher values of the component	Lower Elevatjon, Warmer	Larger Watersheds	Lower Gradient
Temperature Maximum	**0.939**	0.164	0.002
Temperature Mean	**0.914**	0.077	0.237
Elevation Minimum	**-0.838**	-0.272	-0.103
Mean Elevation	**-0.817**	-0.126	-0.422
Temperature Minimum	**0.81**	-0.151	0.373
Water Yield (Church K Factor)	**-0.793**	0.001	-0.112
Alpine % of Area	**-0.772**	-0.112	-0.338
Elevation Maximum	**-0.666**	0.18	-0.533
Medium Elevation 300-600 m % of Area	**0.6**	0.108	0.266
High Elevation >600 m % of Area	**-0.599**	-0.113	-0.264
Perimeter (m)	0.112	**0.956**	0.009
Total Area (hectares)	0.108	**0.955**	0
Land Area (hectares)	0.113	**0.946**	-0.002
Maximum Stream Order	0.063	**0.839**	0.007
Maximum Stream Magnitude	0.014	**0.599**	0.029
Gradient 61-70 % of Area	-0.208	-0.101	**-0.868**
Gradient 9-15 % of Area	0.025	0.044	**0.861**
Gradient 51-60 % of Area	-0.197	-0.132	**-0.855**
Gradient 71-UP % of Area	-0.291	0.015	**-0.709**
Gradient 3-8 % of Area	0.247	0.054	**0.67**
Gradient 31-50 % of Area	-0.161	-0.111	**-0.609**
Elevation Standard Deviation	-0.247	0.346	**-0.59**
Avalanche Chute % of Area	-0.392	-0.044	**-0.58**
Gradient 16-30 % of Area	-0.077	0.005	0.449
Gradient 0-2 % of Area	0.362	0.148	0.216
Wetlands % of Area	0.008	0.142	0.262
Low Elevation (<300 m) % of Area	0.094	0.11	0.002
Bare ground % of Area	0.016	0.089	0.047
Ice % of Area	-0.411	0.016	-0.025
Variance Explained by Rotated Components	6.957	4.384	5.499
% of Total Variance Explained	23.189	14.614	18.331

Table 7.2 Numbers of watersheds in each PCA bin where a bull trout observation, an Arctic grayling observation or a sampling event have been recorded.

Bin Number	1	2	3	4	5	6	7	8	9	10	11	12
Total Number of watersheds	300	300	300	300	300	300	300	300	300	300	300	95
Lower Elevation (PC1)												
Bull Trout Present	12	21	33	24	16	25	24	40	43	34	18	1
Grayling Present	1	8	6	6	11	12	19	27	32	50	57	14
Sampled	17	35	49	34	36	34	42	67	77	80	67	18
Increasing Size (PC2)												
Bull Trout Present	3	2	4	3	11	13	14	22	29	45	93	52
Grayling Present	6	4	5	3	13	9	9	15	24	31	70	54
Sampled	14	8	13	11	26	28	33	45	64	85	156	73
Lower Gradient (PC3)											395	
Bull Trout Present	18	22	26	25	39	35	41	32	21	25	7	
Grayling Present	12	8	10	7	18	23	39	41	40	34	11	
Sampled	22	25	36	42	56	62	77	74	65	65	32	

7.5 Figures

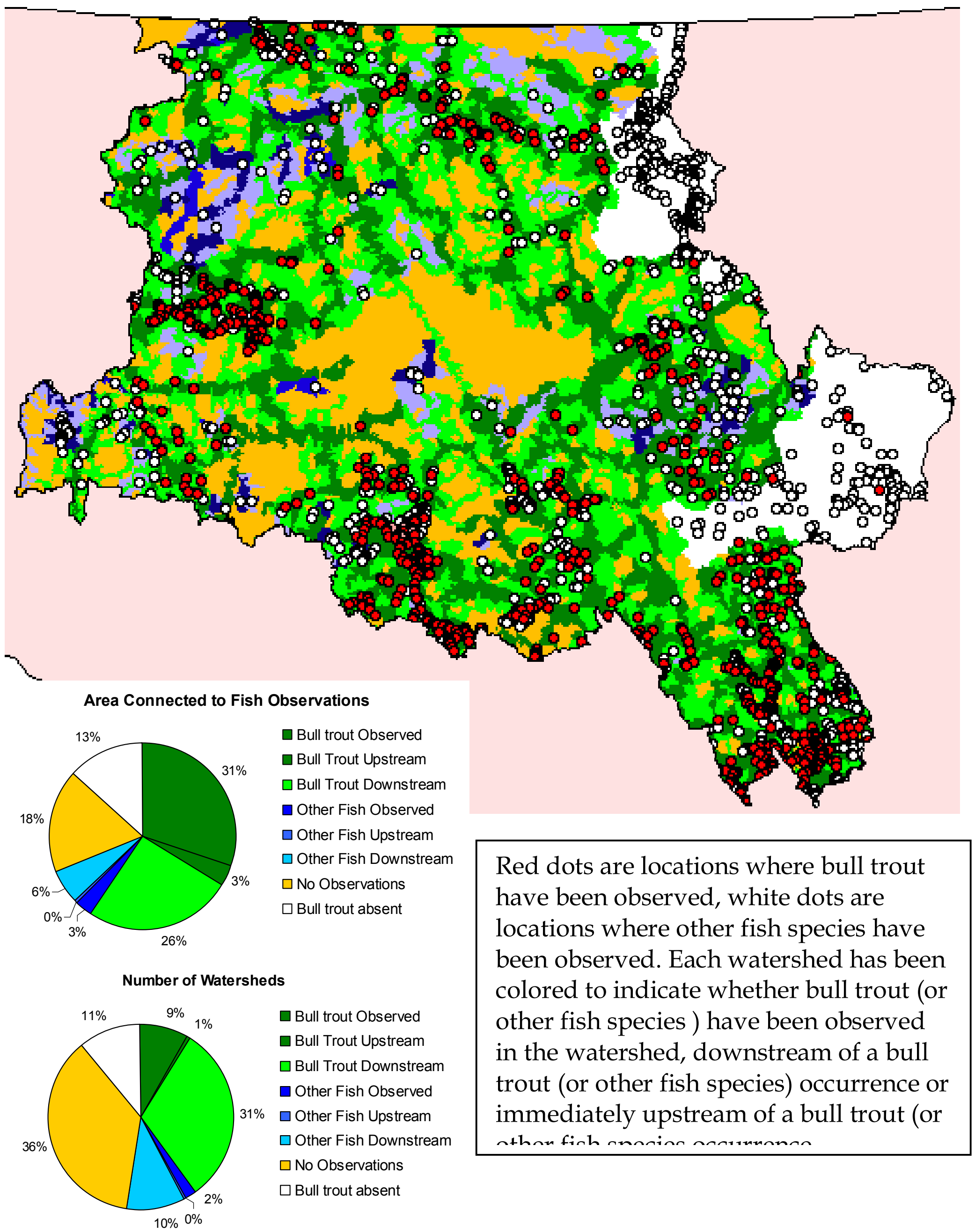
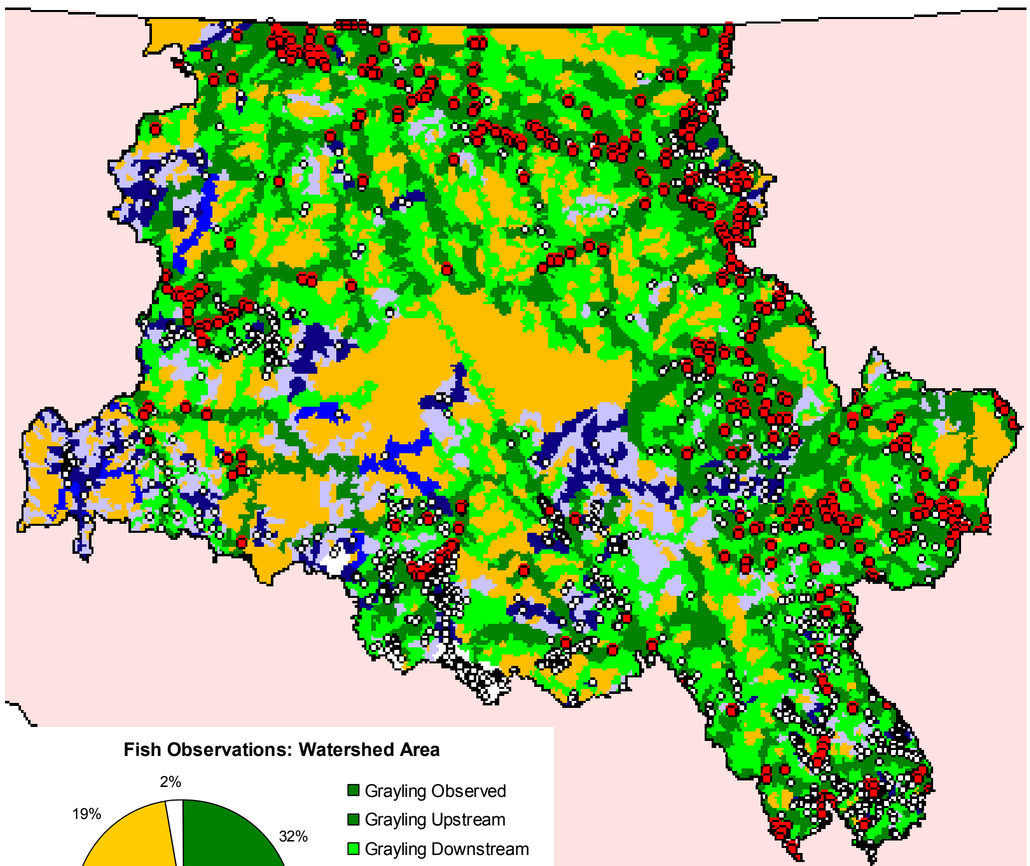
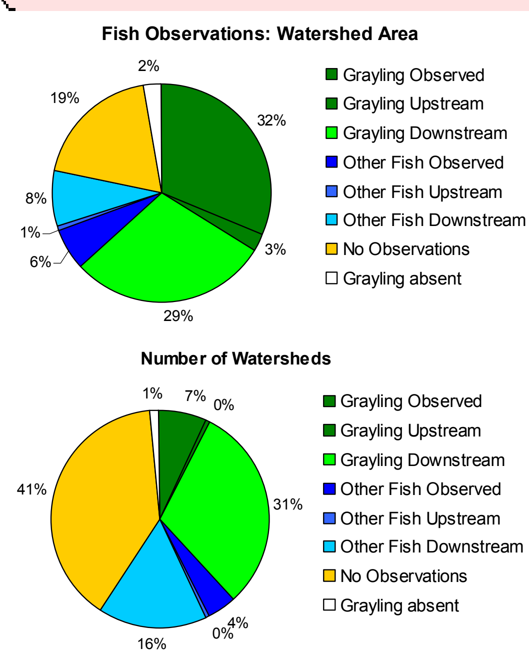


Figure 7. 0 Watersheds where bull trout and other fish have been observed in.





Red dots are locations where Arctic grayling have been observed, white dots are locations where other fish species have been observed. Each watershed has been colored to indicate whether Arctic grayling (or other fish species) have been observed in the watershed, downstream of a Arctic grayling (or other fish species) occurrence or immediately upstream of a Arctic grayling (or other fish species occurrence.

Figure 7. 1 Watersheds where Arctic grayling and other fish species have been observed in.

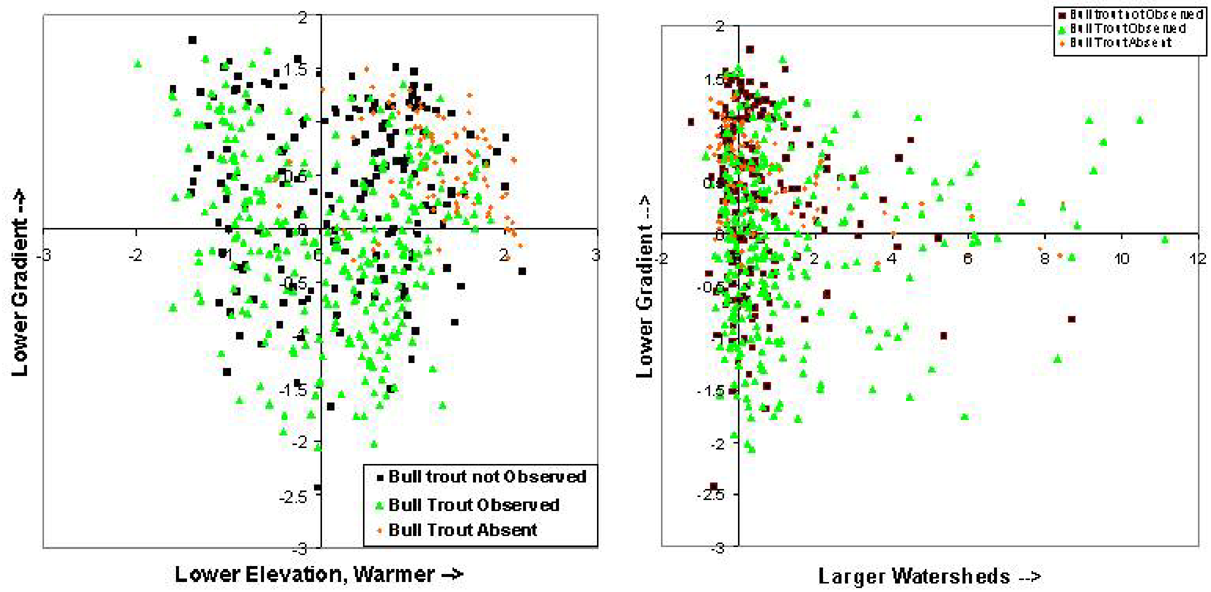


Figure 7. 2 Scatterplots of habitat characteristics of watersheds where bull trout have been observed, sampled but not observed, sampled but bull trout are absent from the whole drainage.

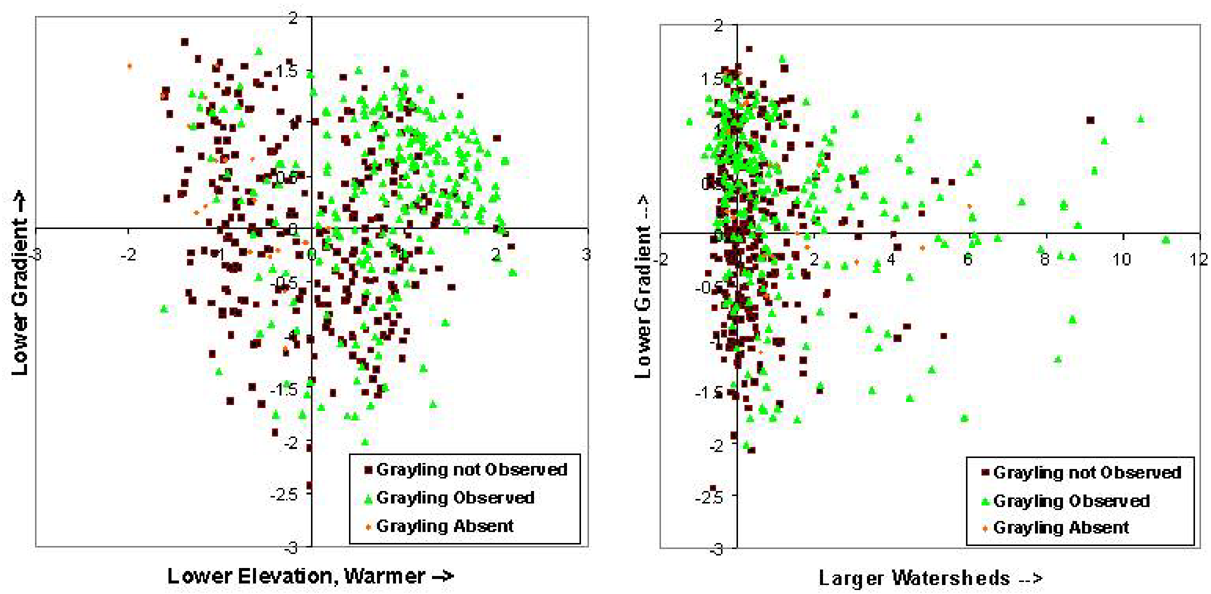


Figure 7. 3 Scatterplots of habitat characteristics of watersheds where grayling have been observed, sampled but not observed, sampled but grayling are absent from the whole drainage.

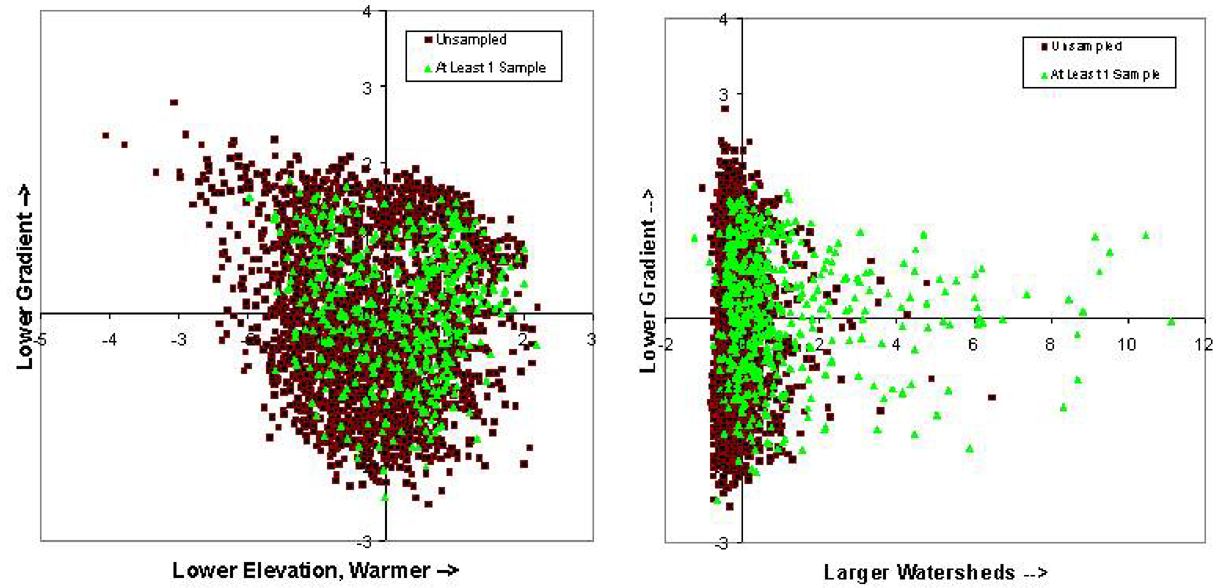


Figure 7. 4 Scatterplots of habitat characteristics of sampled and unsampled watersheds including only major watersheds where bull trout are a significant component of the fish fauna.

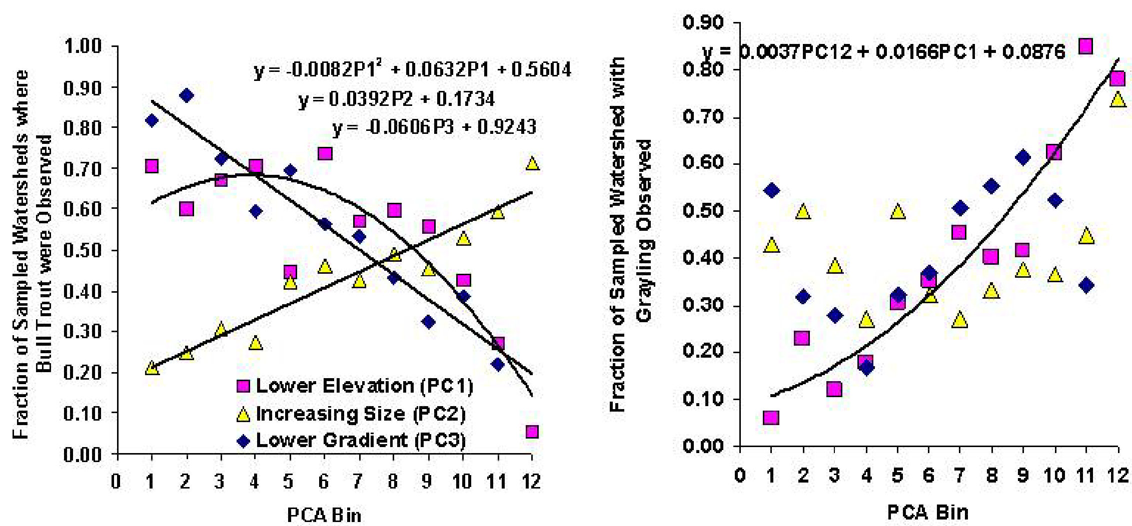


Figure 7. 5 The proportion of sampled watersheds within PCA bins with either bull trout or grayling observations. Trend lines are used to develop a functional relationship between bin number and the proportion of watersheds in which a species was observed.

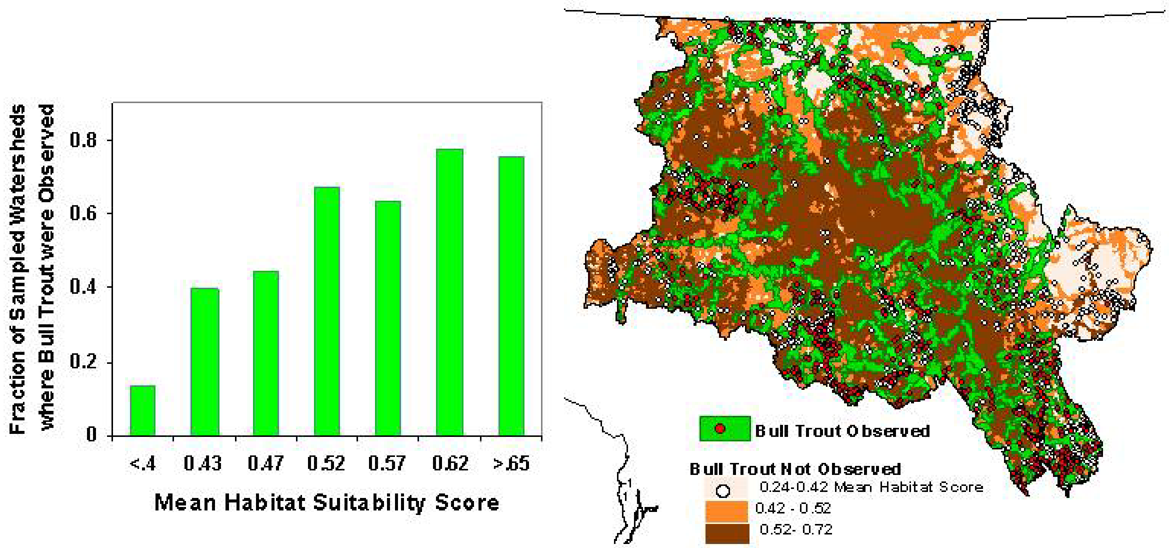


Figure 7. 6 The relative suitability of watersheds for bull trout as indicated by the mean of three habitat suitability scores derived from the empirical relationships in Figure 6 (also see Map 7.1).

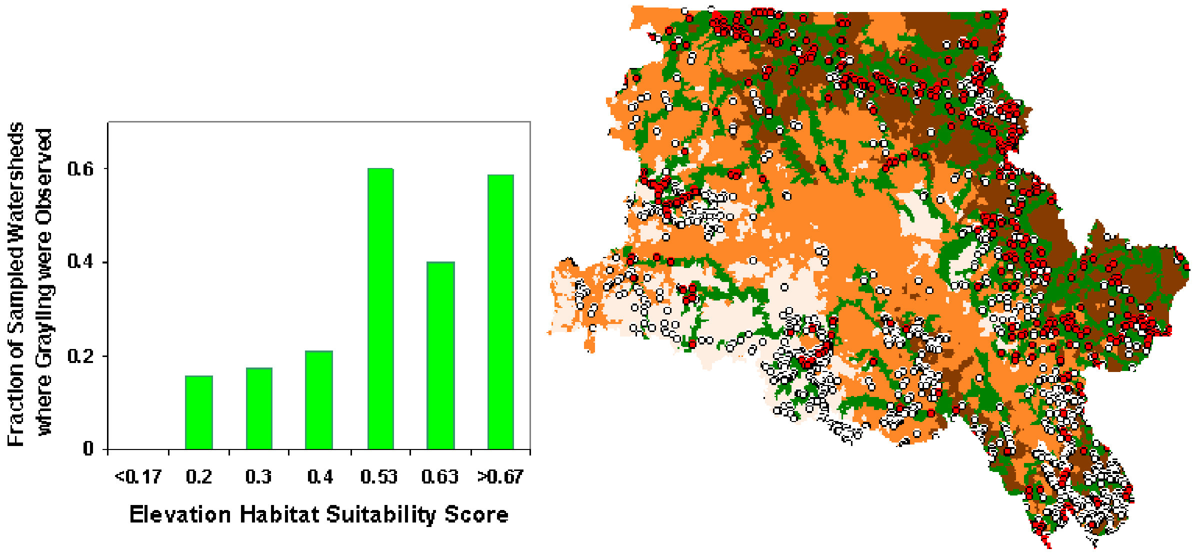


Figure 7. 7 The relative suitability of watersheds for grayling as indicated by the elevation/temperature suitability scores derived from the empirical relationship in Figure 6 (also see Map 7.2).

8 FINE-FILTER TARGETS

8.1 Background

The "fine-filter" approach to conservation planning works in conjunction with the coarse-filter representation analysis and focal species approach. A fine-filter analysis helps planners and managers to identify species and plant communities that may not be captured by the umbrella approaches of the CAD, or that are sensitive and/or rare enough that specific identification of examples and occurrences is important and necessary. Fine-filter targets can include rare species, hot spots, endangered habitats, imperiled natural communities, and other sites of high biodiversity value.

8.2 Selection of Special Elements and Features

Special elements were selected as targets for conservation planning based on global, national, and provincial conservation status. Also targeted were "Species of Special Concern" - species or subspecies that globally are apparently secure and/or abundant (ranked G3-G5 by Conservation Data Centres and Natural Heritage Programs), but when viewed from a sub-continental ecological context (Northern Boreal Mountains Ecoprovince, and to a lesser extent, the Sub-Boreal Interior and Taiga Plain Ecoprovinces;[5] and Bird Conservation Region (BCR) 4 – Northwestern Interior Forest[6]) have the following characteristics:

- exhibit significant, long-term declines in habitat and/or numbers, are subject to a high degree of threat, or may have unique habitat or behavioural requirements that expose them to great risk;
- are restricted to the ecoprovince or a small geographic area within the Ecoprovince), depending entirely on the ecoprovince for survival, and therefore may be more vulnerable than species with a broader distribution;
- have populations that are geographically isolated from other populations;
- are more widely distributed in other ecoprovinces but have populations in the study area at the edge of their geographical range;
- are usually abundant and may or may not be declining, but some aspect of life history makes them especially vulnerable – e.g., migratory concentration or rare/endemic habitat;
- have spatial, compositional, and functional requirements that may encompass those of other species in the region and may help address the functionality of ecological systems;
- are unique, irreplaceable examples for the species that use them, or are critical to the conservation of a certain species or suite of species;
- are critical migratory stopover sites that contain significant numbers of migratory individuals of many species.

Additionally, species and plant communities at risk designated as Identified Wildlife in BC were selected. These are species designated by the Deputy Minister of Water, Land and Air Protection as requiring special management attention under the *Forest and Range Practices Act (FRPA)*. Under

[5] For an overview and description of these Ecoprovinces refer to BC MSRM webpage: http://srmwww.gov.bc.ca/ecology/ecoregions/polareco.html
[6] For an overview and description of Bird Conservation Regions refer to North American Bird Conservation Initiative webpage: http://www.nabci-us.org/map.html

this legislation, the definition of species at risk includes endangered, threatened or vulnerable species of vertebrates, invertebrates, plants and plant communities. Regionally important wildlife include species that are considered important to a region of British Columbia, rely on habitats that are not otherwise protected under FRPA, and are vulnerable to forest and range impacts (BC Ministry of Water 2004). A full summary of criteria is described in Table 8.1.

8.3 Data Sources

An initial list was generated by the BC Conservation Data Centre (CDC) (Ministry of Environment 1997) - derived from Forest District lists of rare and endangered species. The lists were separated into "Potential" species that were likely to exist in the CAD study area, and "Unlikely," referring to species that were included in the Forest District lists, but in the opinion of the CDC zoologist were unlikely to exist in the study area. Subsequently, a database was created with information on species and communities obtained from CDC (British Columbia Conservation Data Centre (BC CDC) 2003; British Columbia Conservation Data Centre (BC CDC) 2003), BC Ministry of Forest (British Columbia Forest Service and British Columbia Ministry of Environment 1999), Committee On the Status of Endangered Wildlife In Canada (COSEWIC), Partners In Flight, and NatureServe (NatureServe 2004) databases; additionally, through a review of BC land use planning documents, ftp sites, and pertinent research. Special features targets were selected in part using expert input.

Data were obtained from the BC provincial government (Conservation Data Centre element occurrence records; Terrain Resource Information Management (TRIM 1:20,000) polygons for swamps and marshes and point data for hot springs; Ministry of Forests (Province of British Columbia 2001) for karst mapping; federal government (Canadian Wildlife Service Critical Waterfowl Habitat polygons; and COSEWIC species at risk range maps); Environmental Non-Governmental Organizations (Grasslands Conservation Council of BC grassland polygons; Bird Studies Canada and the Canadian Nature Federation Important Bird Areas), National Topographic Series (NTS) mapped points for waterfalls and rapids, and Fisheries Information Summary System (FISS) (FISS; Department of Fisheries and Oceans Canada, British Columbia Ministry of Environment et al. 2001) for presence/absence data, and FISS valley bottom model used to assist in identifying potential riparian areas. Riparian model then combined the FISS valley bottom model with FIP data to identify coniferous, deciduous, coniferous-deciduous mixed forested riparian habitats and nonforested riparian habitats.

Refer to Appendix H for detailed descriptions of selection criteria and datasets.

8.4 Results

The special elements database consists of 138 plant and animal targets, with spatial data obtained for 123 of them:

- 1 invertebrate (Lepidoptera)
- 83 plants (58 dicotyledons, 3 filicopsida, 21 monocotyledons, 1 ophioglossopsida)
- 54 vertebrates
    - 12 birds
    - 9 mammals
    - 33 fishes

The data on the occurrences of these are quite limited within the study area. A combination of CDC data and FISS data (for the fish occurrences) provides a limited set of information on the known occurrences of each species (Map 8.1). Given the limitations of these data, we did not set explicit targeted goals on the inclusion of these special elements in the site selection process leading to Primary Core Areas (PCAs). We did set goals on the representation of CDC species occurrences in the selection of Secondary Core Areas (Section 10). We report representation of all special elements.

Additionally, we have reviewed key habitat requirements for red and blue-listed birds and mammals, identifying which we feel will be met through either focal species targets or coarse-filter targets. We have identified additional special features, when possible, to increase our ability to include or identify some specialized habitat requirements for these red or blue-listed species, as described below and in Appendix H.

Also targeted were 17 special features, with spatial data obtained for 12 of them:

- critical waterfowl habitat
- swamps and marshes ≥10 ha
- swamps and marshes <10 ha
- marsh adjacent to lakes
- marsh adjacent to streams or rivers
- forested riparian
- nonforested riparian
- waterfalls
- hot springs and mineral springs
- grasslands
- lakes with known occurrences of lake trout
- 4 terrestrial ecological land unit types (see Section 4 for description)
- caves and karst features (insufficient data)
- canyons (insufficient data)
- mineral licks (insufficient data)
- Important Bird Areas (insufficient data)
- lakes with early open water in spring (insufficient data)

Special feature selections targeted habitat types for features which may be limited within the region or known to support rare biodiversity elements. Regionally rare or spatially-limited habitats include critical waterfowl habitat, grasslands, waterfalls, mineral licks, hotsprings and mineral springs, canyons and a few potentially rare ELU types. Habitats potentially important for red or blue-listed species are described in Appendix H, and include larger swamps and marshes, marshes adjacent to water bodies, forested and non-forested riparian habitats, and grasslands. Additionally all wetland and riparian habitats are considered to be highly productive, regionally limited and potentially important hotspots for biodiversity.

The extent and completeness of the existing data on special features determined whether we set targeted goals for the inclusion of special features within PCAs. Sufficient data allowed the inclusion of grasslands, swamp and marsh features, riparian features, lake trout lakes and ELU types (Map 8.2) as targets with explicit representation goals within Primary Core Areas. Additional special elements and features had goals established for inclusion within the Connectivity-Secondary Core Areas, as described in Section 10.

8.5 Tables

Table 8.1 Special elements target selection criteria (Groves et al. 2002, TNC 2000).

Criteria	Rank	Description
Global conservation status Provincial conservation status	G1-G3; T1-T3 S1-S3	1 = Critically Imperilled either because of known threats or declining trends, or because extremely restricted breeding or non-breeding range make the element vulnerable to unpredictable events, a candidate for 'endangered' status; 2 = Imperilled, a candidate for 'threatened' status; 3 = Vulnerable – usually more abundant or widespread than 1 or 2, but sensitive to threats, perhaps declining (BC CDC, NatureServe)
National conservation status (COSEWIC)	E	Endangered (E) – A species facing imminent extirpation or extinction.
	T	Threatened (T) – A species likely to become endangered if limiting factors are not reversed.
	SC	Special Concern (SC) – A species that is particularly sensitive to human activities or natural events but is not an endangered or threatened species (COSEWIC 2003).
Provincial listing (BC CDC)	Red Blue	Red – includes any indigenous species or subspecies that have, or are candidates for Extirpated, Endangered, or Threatened status in British Columbia. Extirpated taxa no longer exist in the wild in British Columbia, but do occur elsewhere. Endangered taxa are facing imminent extirpation or extinction. Threatened taxa are likely to become endangered if limiting factors are not reversed. Blue – includes any indigenous species or subspecies considered to be of Special Concern (formerly Vulnerable) in British Columbia. Taxa of Special Concern have characteristics that make them particularly sensitive or vulnerable to human activities or natural events. Blue-listed taxa are at risk, but are not Extirpated, Endangered or Threatened.
Partners In Flight Score (for Bird Conservation Region 4 – Northwestern Interior Forest)	Sum of Vulnerability Factors. Scores for each factor range from 1 (low vulnerability) to 5 (high vulnerability).	Relative Abundance – reflects the abundance of breeding individuals of a species, within its range, relative to other species; Breeding Distribution – reflects the global distribution of breeding individuals of a species during the breeding season; Non-breeding Distribution – reflects the global distribution of a species during the non-breeding season; Threats to Breeding – reflects the effects of current and future extrinsic conditions on the ability of a species to maintain healthy populations through successful reproduction. Threats to Non-breeding – reflects the effects of current and future extrinsic conditions on the ability of a species to maintain healthy populations through successful survival over the non-breeding season; Population Trend – reflected by the direction and magnitude of changes in population size over the past 30 years; Area Importance – reflects the relative importance of an area to a species and its conservation, based on the abundance of the species in that area

		relative to other areas.
Species of Special Concern	Declining Endemic Disjunct Peripheral Vulnerable species Species aggregations	Declining - exhibit significant, long-term declines in habitat/and or numbers, are subject to a high degree of threat, or may have unique habitat or behavioural requirements that expose them to great risk; Endemic – are restricted to the ecoprovince or BCR (or a small geographic area within the ecoprovince or BCR), depending entirely on the ecoprovince or BCR for survival, and therefore may be more vulnerable than species with a broader distribution; Disjunct – have populations that are geographically isolated from other populations; Peripheral – are more widely distributed in other ecoprovinces but have populations in the ecoprovince at the edge of their geographical range; Vulnerable – are usually abundant and may or may not be declining, but some aspect of life history makes them especially vulnerable – e.g., migratory concentration or rare/endemic habitat; Umbrella species – have spatial, compositional, and functional requirements that may encompass those of other species in the region and may help address the functionality of ecological systems; Species aggregations – are unique, irreplaceable examples for the species that use them, or are critical to the conservation of a certain species or suite of species; Globally significant examples of species aggregations - are critical migratory stopover sites that contain significant numbers of migratory individuals of many species.
Special Features		Habitats or species considered sensitive, spatially-limited or of high value for biodiversity (biodiversity hotspots) or other special element targets (e.g., habitats identified for red or blue-listed species.

9 REGIONAL CONNECTIVITY ANALYSES

9.1 Introduction and Background

Explicit consideration of connectivity is required when considering large study areas that will likely support multiple core conservation areas. Maintenance of ecological linkages is critical to the long term viability of all species, as well as key ecological processes. The value of connectivity is reviewed in several publications (e.g., Andreassen, Fauske et al. 1995; Collinge 1996; Beier and Noss 1998). A primary consideration in the selection of the MK CAD study area boundaries was to more effectively account for regional connectivity or movement across the MKMA boundaries. We represented regional connectivity through predictions of potential movement paths or movement corridors across the extent of the MK CAD study area. Our methodology is based upon the use of least-cost path modeling, which determines the permeability of landscapes based on relative "costs" including potential energetic, mortality or behavioral costs. While least-cost modeling has been used in a variety of studies on connectivity (Meegan and Maehr 2002; Ray, Lehmann et al. 2002; Singleton, Gaines et al. 2002; Sutcliffe, Bakkestuen et al. 2003; Larkin, Maehr et al. 2004), they remain exploratory in nature due to our poor understanding of the primary drivers determining animal movement decisions.

In this section, we describe 3 analyses completed to provide predictions about movement potential across the region. While all use the least-cost path modeling approach, each provides distinctively different information. The Permeability analysis was completed across the study area to provide an index representing the value of a Planning Unit for general movement ease or permeability. We conducted additional modeling to explicitly identify potential Core Connectivity Areas between our recommended Primary Core Areas (PCAs). Finally, due to the special habitat requirements of sheep (and goats), we conducted additional Sheep Core Connectivity modeling to identify areas potentially important for maintaining regional connectivity for these alpine species. The section describes the general modeling framework, which is similar across all analyses, with specific information about differences between the three efforts provided. The methods and results of each modeling effort are provided in the sections that follow. Primary Core Connectivity Analyses builds upon PCA results presented in Section 10, and this connectivity analysis is also subsequently used to identify our Connectivity-Secondary Core Areas (CSCAs). As a result, it may be necessary to refer to Section 10 to obtain further insights into the PCA Connectivity analyses.

As with any modeling of this sort, the results of our models are most applicable to the more central regions of the study area, and apply less well to the boundary regions because connectivity values outside of our boundary were not incorporated.

9.2 Connectivity Modeling Methods

We used a least-cost path modeling approach for all analyses (Permeability model, Primary Core Connectivity Area model, and Sheep Core Connectivity model). This approach models potential movement paths or corridors as most cost-effective route connecting two points. The "cost" of movement is modeled as a combination of total distance (horizontal movement distance), topographic considerations and habitat values (based on generalized habitat values and on the avoidance of human development features). While referred to as "cost", we do not have actual energetic estimates or costs, but use the terminology and the approach as an effective modeling framework for identifying routes that may be selected by a diversity of species assuming a suite common decision rules. For example, under our least-cost modeling approach, shorter distances are preferred, but this is moderated by the cost of traversing across steep topography, a preference for higher quality habitats and an aversion (cost) to moving through landscapes with human development features. We describe the cost functions below.

9.2.1 Least-Cost Path Model Parameters

The actual movement routes are determined based upon a grid, with costs of selecting a cell to move into based on a cost score. Four factors determine the cost score of movement from one cell to another:

distance cost modified by surface distance
vertical cost
impact cost
habitat cost

The cost to moving to a surrounding cell is determined by these costs, in the following formula:

Cost = (distance cost modified by surface distance) * vertical factor * (impact cost* habitat cost).

We describe each of the cost variables below, and how they were calibrated to achieve a cost proportional to the assumed influence of each factor on movement decisions.

9.2.1.1 Distance Cost

On a flat surface, the distance cost is set at 1 for movement between the 4 adjacent cells and is 1.41 to move to diagonal cells. Additional realized surface distance is also added if moving up or down a slope. This is calculated as the length of the hypotenuse of a right triangle calculated based on the opposite angle being set equal to the degrees slope as calculated between the center points of the cells. For movement to diagonal cells the adjacent leg of the hypotenuse is lengthened to 1.41, as compared to 1 for the distance to adjacent cells and the total hypotenuse length calculated as above.

9.2.1.2 Vertical Factor

Vertical factor adds additional cost to account for the additional energy or effort required to move up a slope (or saved when moving down a slope). The average slope across the study area, given the resolution of the 250 m cell surface grid used, is 12°, with a standard deviation +/- 9°. Thus, we can expect approximately 95% of the slopes to fall within mean +/-2 stdev, or under 30° slope. Checking this, we found only 3.8% of the study area had slopes of greater than 30° using the 250 m grid cell resolution.

Permeability and Primary Core Area Analyses. For the regional permeability and the Core Connectivity Area modeling, we have estimated this as a simple linear function:

Vertical factor = 1 + 0.033x

Where x is the slope in degrees and 1 is intercept at 0 slope. This multiplies the horizontal factor by a value between 0 and 2, with 1 equal to a flat slope (i.e., no additional cost), values less than 1 for downhill slopes (thus reducing the cost) and values greater than 1 for uphill slopes with larger values (i.e., more costly) for steeper slopes.

Given the range of slope values found in the study area at the resolution of the modeling, we used 30° as a threshold slope value in our cost calculations. At the threshold value of 30°, the vertical factor is 1.98 (high cost) and at -30°, the vertical factor is 0.01 (low cost). Costs become infinitely large for any movement on slopes greater than 30°. As described above, downhill slopes (i.e., negative slopes in the above equation) have fractional vertical costs which reduces the overall cost of movement to downhill cells; values above 1 lead to additional costs for moving to cells upslope.

Sheep Core Connectivity Analyses. For the Sheep Core Connectivity analyses, we assumed the inverse relationship with steeper slopes being preferred over shallower slopes. For the sheep analysis, we did not differentiate between moving up or down a steep slope:

Vertical factor = 2 - (0.066*absolute[x])

Where x is the slope in degrees and 2 is the intercept at 0 slope and the maximum cost value. Thus, in the Sheep Connectivity model, it is most costly to move across flat slopes and there is an reduced cost of moving across increasingly steep slopes. Cost is near zero for slopes of 30°. We did not differentiate the costs of moving up or down slopes, and costs ranged from a maximum of 2 at zero slope to a minimum of 0 for threshold slopes 30° or steeper.

9.2.1.3 Impact Costs

Impact costs reflect the friction of moving through cells with human developments. We have scaled impact costs relative to other costs to encourage movement around high density developments. To do this, we set an upper avoidance threshold impact cost based on known avoidance behaviors of wildlife. We used the same impact costs and thresholds across all three analyses, as we do not have specific information to inform varying the parameters.

Documented reductions in habitat effectiveness or habitat use have been documented for a diversity of wildlife species at road densities at or greater than 0.6 km/km^2. This includes information pertaining to elk (Lyon 1984; Rowland, Wisdom et al. 2000), wolves (Thiel 1985; Mech 1989) and grizzly bears (Servheen 1993; Mace, Waller et al. 1996; British Columbia Forest Service and British Columbia Ministry of Environment 1999). We used this information for scaling our impact costs, such that there was a high cost (strong avoidance) of areas with road densities >1 km/km^2, and decreasing avoidance of areas with lower road densities. Within our impact analyses (Section 3), this open road (i.e., paved, gravel or unimproved road classes) density would receive a score of 0.2 (range 0 – 1.0). We rescaled this score to be equivalent to the impact cost needed to ensure movement around cells containing this or higher levels of impacts. We describe how we calibrated the human use scores to achieve this scaling in Section 10.2, below.

9.2.1.4 Habitat Costs

In addition to the influence of human use or infrastructure, vegetative characteristics can have a potentially strong influence in the paths animals choose across landscapes. The specific influence of vegetative habitat characteristics can be highly species-specific and is difficult to capture within generalized connectivity modeling efforts, such as the permeability Analysis and the Primary Core connectivity analysis.

Permeability and Primary Core Connectivity Analyses. For these modeling efforts, habitat costs are based on a simple habitat model that values ecotone habitats between open and forested landscapes, as many species of animals prefer to move along such edges. The habitat model scores are the density of edge habitat within 1 sq. km, calculated through a 1 sq. km. moving window. Average edge or ecotone density per cell determines the habitat cost, such that high amounts of ecotone habitats result in a lower habitat cost. As with impact costs, we scaled habitat costs relative to other costs. Unlike impact costs, we do not have any upper or lower thresholds on habitat costs, and we scaled this variable so as to ensure that, while it influenced movements, it did not carry equivalent weight as either topographic variables or impact variables (see Section 10.2, below).

Sheep Core Connectivity Analysis. We used the sheep habitat suitability model for the growing season (Section 6.2) within the sheep connectivity modeling effort. We assume that this model can effectively identify those habitats preferred by sheep, both for living and for movements across landscapes. Within the connectivity analysis, identified high value habitats receive no cost for movements, and habitat costs for less suitable habitats are scaled, as described below.

9.2.2 Scaling cost factors

A critical step in the connectivity analyses is to calibrate and scale the suite of cost inputs relative to each other. We have built upon a suite of baseline analyses completed, such as the human use analysis and habitat modeling; each of these results in scoring across the landscape to indicate the relative value of the modeling outputs. We have rescaled these values to form appropriate inputs into the connectivity analyses that match our assumptions about the importance of each factor in influencing landscape-scale movements.

9.2.2.1 Habitat Costs

All other costs being equal, movement should follow high habitat values, as predicted based upon vegetative characteristics. Alternatively, we assume most large mammals would not incur high costs in order to avoid low value habitats (as determined by vegetative characteristics, not human uses). We calibrated the vegetative habitat costs for all analyses based on this assumption and using the suite of costs we have incorporated into the models. In the equation described below, we describe the trade-off of moving straight ahead onto a steep slope with high habitat value (i.e., no habitat cost) on the left side of the equation with the alternative to move diagonally along flat ground but in poor value habitat. We would want the animal to move diagonally to avoid the excessive cost of climbing up a 30 degree slope, even if that meant moving into poor quality habitat. Thus we would want our maximum habitat cost to be equal or less than the cost of moving up the steep slope:

Max habitat cost * diagonal distant cost * 1 (which is cost of moving on flat slope) = adjacent distant cost (modified by surface distance) * vertical cost * 1 (which is the cost of moving through high value habitat)

Where,
Diagonal distance cost = 1.41 (see Section 10.2)

Adjacent distance cost = hypotenuse of 30 degree right triangle with adjacent leg of 1 = adjacent/cosine 30 = 1/cos30 = 1.15

Vertical cost is determined by a linear equation: 1 + 0.033*slope = 1 + 0.033*30 = 1.99

Therefore, we can calculate the maximum habitat cost we would want as:

Max habitat cost * 1.4 = 1.15 * 1.99

Max habitat cost = 1.6

At the low end of the habitat cost scale, we would want the animal to choose to move diagonally to stay within high quality habitat, if slope factors were not an issue:

Low habitat cost * 1.41 < high habitat cost * 1

Scaling habitat cost from 1 – 1.6 provides a range of habitat costs that approximately matches our assumptions regarding the limited influence of vegetative characteristic on movement decisions, relative to the importance of topography and distance. We rescaled habitat costs to this range for all analyses.

While the specific trade-off equation used would, obviously, not apply to sheep habitat preferences, an equivalent result would be obtained through inverting the topographic costs and solving the resulting equation. For simplicity and consistency, we use the same range of habitat values across all connectivity modeling. Thus, for the permeability and Primary Core Connectivity analyses, we rescaled the ecotone habitat values and for the Sheep Core connectivity analyses, we rescaled the sheep growing season habitat suitability values.

9.2.2.2 Impact Costs

We scaled human use or impact costs (based on our human use analyses, see Section 3) to derive predictable responses given known human use levels, topographic and habitat costs. We have based this work on responses of a variety of large mammals to open road densities, as a means of calibrating the range of impact costs. We have assumed that an animal will avoid moving through cells with >1 km/km^2 of open road densities, and will instead incur substantial costs to avoid these areas. We have translated this open road density into its impact score within our linear impact submodel (Section 4.2.1), and used this score to describe an overall impact score (Section 4.2.5) that approximates this level of impact. Thus, we have assumed that cumulative human uses including features other than open roads result in similar avoidance behavior as open road density.

A human use score of 0.2 is given to a road density of 1 km/km^2 or the equivalent sum of impacts across linear, area and point features. We scaled this score within our connectivity analyses such that an animal would choose to incur substantial costs to avoid moving through a cell of this level of human uses. To achieve the rescaling, we calculated the threshold cost value that would be equivalent to the cost of the animal moving diagonally, and climbing a steep slope (30°) in habitat of high cost. Therefore, the cost incurred in areas of high human uses (i.e., equivalent to a road density of 1 km/km^2) can be calculated as:

Human Use Threshold Cost = Max[distance cost * vertical cost * habitat cost]

Where

Distance Cost = cost of moving diagonal plus additional surface distance of moving up a 30 degree slope (hypotenuse of right triangle with 30 degree angle and adjacent leg of 1.4) = 1.63

Vertical cost of climbing a 30 degree slope = 1 + 0.033 * 30 = 1.99
Max habitat cost = 1.6, as per above

Human Use Threshold Cost = 1.63 * 1.99 * 1.6 = 5.2

Therefore, if we scaled an impact score of 0.2 to equal the Human Use Threshold Cost of 5.2, and with the lowest human use cost (i.e., 0 in Section 3) to equal 1 (i.e., no cost to movement).

9.2.2.3 Horizontal Cost Surface

The function used in ArcInfo GRID to calculate paths (PATHDISTANCE) only allows a single horizontal cost grid which accounts for influences of physical characteristics such as vegetation structure or human uses. Thus, we had to combine the habitat cost grid and the impact cost grid into a single input grid by multiplying the cell values of each input, as per the equations presented.

9.2.3 Identifying Least-Cost Paths

To identify paths and associated corridors, we established start/end points or nodes across the study, with locations determined by the goals of the analysis (see below). For each analyses (permeability, core connectivity or sheep connectivity), path cost grids were created for each point or node. Path cost grids calculate costs of moving to the source node, starting from the cells adjacent to the source and calculating grid cell-specific costs by sequentially moving outward. Each grid cell stores its cost value, accounting for distance from the source node, as well as characteristics that define additional costs (vertical factor, habitat costs, etc) specific to that cell. These grids store costs encountered in movements towards the specified source node, and can be used to determine the least cost path originating anywhere on the cost grid and ending at the source point.

9.2.3.1 Regional Permeability Analysis

For the permeability analysis, 116 points were uniformly distributed across the study area at a density of 1 node/500 sq. km. We identified the least-cost paths connecting all 116 nodes, creating over 6,500 least-cost paths across the study area (Figure 9.1). Given the uniform distribution of nodes, these paths could be rather short if moving to an adjacent source node, or could be forced to traverse the extent of the study area. We only connected any two points using a path in a single direction, due to limitations in computing time and storage capacity.

9.2.3.2 Primary Core Connectivity Analyses

For the Primary Core connectivity analysis, we established a central node (centroid) within each PCA. For large, irregularly shaped Core Areas, we manually added additional points to more fully account for the Core. A total of 72 nodes were created within PCAs. For every core node, we identified least-cost paths to 3 Cores (core nodes) that were the least costly to move to, based on the cost grid created for each node. The connecting Cores could be the closest (in distance) to the source Core, but in many cases were not. Because we generated paths between every Core and its 3 least-cost neighbors, all cores had a minimum of three corridors identified to near-by Core Areas. Larger Cores, with multiple nodes have more than 3 corridors identified, and often greater than three corridors per Core Area were identified after combining least-cost neighbor analyses across all Cores.

9.2.3.3 Sheep Core Connectivity Analyses

Similar to Primary Core connectivity analyses, centroid nodes were selected within each Sheep Core Area ≥5000 ha (see Section 6.2.7), resulting in the identification of a single source node within 216 sheep core areas. Each sheep core node was connected to its three least-cost neighbors, based on cost grids created for each node. In many cases, these were not the closest neighbors by distances, as topography and habitat have substantial influence on the cost of movements. The analysis identified at least three potential corridors from of every >5000 ha Sheep Core Area to three neighboring Cores.

9.2.4 Defining Least-Cost Path Corridors

To identify the corridors associated with the least-cost paths, we defined a path-specific threshold cost value using the highest cost accepted by the least-cost path connecting two points (Figure 9.1a). The potential corridors between the two points were defined by selecting grid cells with cost values that were less than or equal to this threshold value; these areas identified linkage habitats of relatively low movement costs between the two points (Figure 9.1b). This method was used across all three modeling outputs to identify corridors associated with each path. This identified 6,670 corridors for the Permeability modeling, 258 corridors for the Primary Core Connectivity modeling and 216 corridors for the Sheep Core connectivity modeling.

9.3 Planning Unit Permeability Score Results

We calculated least-cost path corridors associated with the more than 6,500 paths generated for the regional permeability analysis. Each corridor was identified within a binary (1=corridor) grid, and we combined all corridor grids to create a connectivity value surface for the study area, with cell values representing the number of overlapping corridors. Because sampling intensity varied across the study area, we used a 4 km^2 moving window to standardize values to range between 0 and 1 by dividing the score of each cell by the maximum cell value in the 4 km^2 moving window. This provided a permeability index score standardized to the local region for evaluating connectivity values across the study area (Map 9.1).

All areas across the study area are predicted to have some value for animal movements. Some areas are predicted to be more important for connectivity, or, in other words, more permeable. To provide an index of this ecological value, we attributed all Planning Units with a permeability score, which is simply the average connectivity index score of the connectivity grid cells falling within the Planning Unit. These attributes can be used in planning and management to understand the ecological values of the PU, as well as within the Toolkit functions including development scenarios and replacement (see Section 11).

9.4 Primary Core Connectivity Results

The permeability score provides a PU attribute related to the general or average ease of movement through the PU. The identification spatially-explicit "CAD Connectivity Areas" through least-cost neighbor analyses between Primary Cores provides an important CAD classification. These Connectivity Areas represent regions potentially important to maintain connectivity across the study area, and specifically, to maintain connectivity between identified PCAs (Section 10). The analyses identified at least 3 Connectivity Areas from each Core Area, connecting it to 3 of its neighbors. We show this on Map 9.2, with Primary Core Areas shown (see Section 10). The total area identified for Core Connectivity Areas is 4.44 m ha. We have combined these identified Core Connectivity Areas with additional representation rules to explicitly increase the overall representation of conservation targets within with the CAD; the results of this analysis, leading to the identification of the final classification of "Connectivity-Secondary Core Areas" is described in Section 10.

9.5 Sheep Core Connectivity Results

Least-cost path analysis identified sheep connectivity areas between sheep core areas ≥5000 ha. Connectivity to at least three neighboring sheep cores ≥5000 ha was identified for every sheep core >5000 ha. The resulting connectivity areas are shown in Map 9.3, and PUs with ≥50% of their area within an identified sheep corridor are identified in the PU attribute table. As can be seen on the map, the sheep connectivity areas connecting larger sheep core areas tend to encompass smaller core areas. These areas, perhaps too small to maintain permanent sheep subpopulations, may be important "stepping stone" habitats for sheep moving between larger blocks of habitat. Additionally, some regions with notable amounts of core habitats were not included in the analyses, because the fragmented nature of the identified core habitat resulting in no core clusters meeting our ≥5000 ha size limit rule.

9.6 Discussion

As with other analyses presented in this report, the suite of connectivity analyses are limited both by the underlying data and by the assumptions of the models. These efforts, in particular, make several assumptions about how movements may be influenced by a diversity of conditions across the landscape, including topography, habitat characteristics and human use patterns. For example, for Permeability and Core Connectivity analyses, we assumed that "animals" would avoid moving up steep slopes, but may move readily down these slopes (except the steepest of slopes, which were very costly to move up or down). We assumed that our "animals" would have some preference for moving along or near ecotone habitat between forested and non-forested habitats, but that this preference was not strong enough to over-ride an avoidance of such factors as steep slopes. For the sheep connectivity analyses, we made different assumptions, including that sheep would prefer to move within steeper habitats, and be within preferred habitats, based on our growing season habitat suitability model.

For all modeling efforts, we assumed that human uses on the landscape would deter movements, particularly higher levels of human uses. We attempted to calibrate this avoidance response based on reduced habitat effectiveness documented for a diversity of species in areas with moderate to high road densities (i.e., ≥1 km/km^2). While some species may actually use roads for traveling, this is typically limited to roads with little or no disturbance, and this use may represent a negative population influence (e.g., individuals may experience higher mortality on or near roads). None of the models assumptions have been tested in this study or in the study area, nor has the resulting predictions of the least-cost path modeling completed here been tested or field validated.

Still, if the assumptions of the modeling appear valid, the resulting analyses should provide useful regional assessment of connectivity values. It indicates that connectivity or permeability values are not uniform across the study area, but vary regionally in a few notable patterns. In particular, the Permeability and (to some extent) Primary Core Connectivity Areas results shows that areas in the north and north eastern portions of the study area have a diffuse pattern of high connectivity. This is likely due to these areas having less topographic relief and more contiguous forested cover such that movement tends to be less restricted and more diffuse. Basically, in these areas, it predicts that there are few movement barriers. Alternatively, within the mountainous portions of the study area, the modeling predicts more restricted or concentrated areas of movement. This is likely due to the funneling effect of the topographic relief, and possibly habitat edge effects. In these regions, it predicts high levels of movement along valley bottoms, across more gentle slopes and through saddles on ridges.

The sheep connectivity analysis represents an initial attempt to explore regional patterns in potential sheep connectivity, and needs additional development to explore assumptions, habitat attributes and modeling parameters. Still, the analyses may provide some insight into regional patterns of sheep connectivity patterns and areas that may be prone to isolation. For example, connectivity across the Rocky Mountain Trench appears to be most likely within a few limited regions (Map 9.3). Additionally, spatial patterns in the modeled potential for movement are apparent in several areas, following bands of good habitat (often in a north-south direction), with low potential for movement between relative close (by distance) habitat patches separated by poor sheep habitats. This analysis may be useful in identifying potential "pinch-point" areas or bottlenecks in potential connectivity areas through potentially limiting habitats, and can identify areas where ground-truthing and additional modeling work may be focused.

9.7 Figures

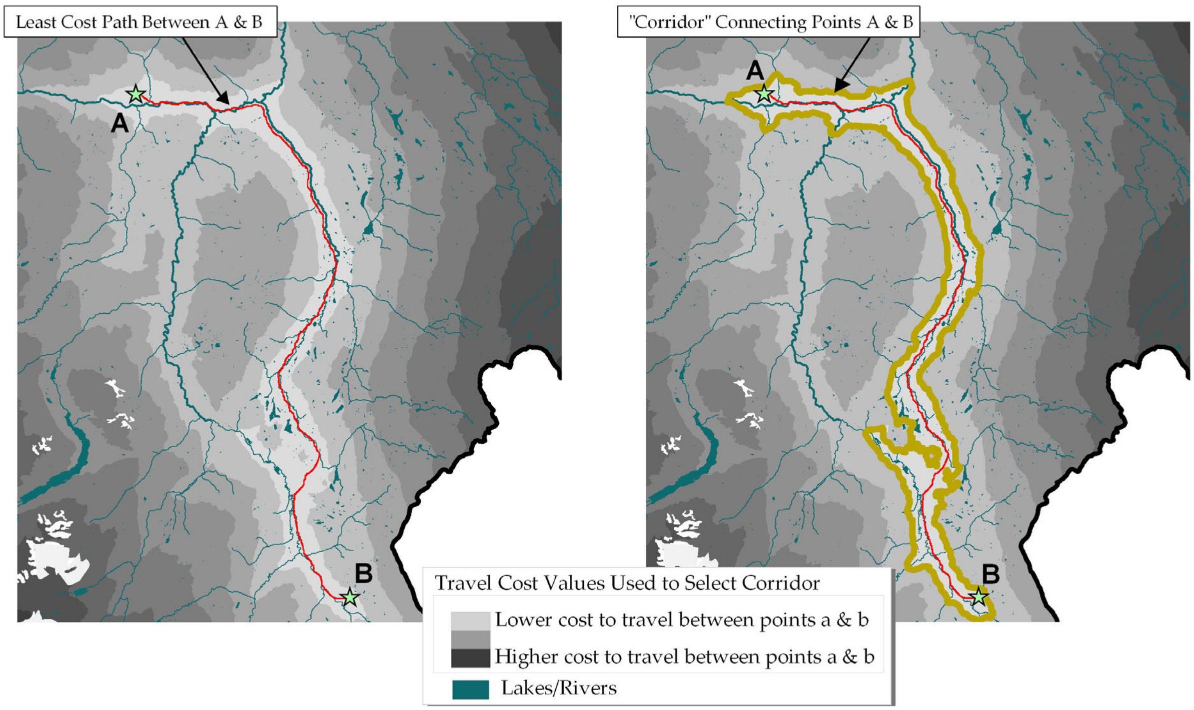


Figure 9.1 Least-cost paths were used to identify thresholds in corridor costs

The highest cost accepted by a path was initially identified (A), and the corridor cost values that were less than or equal to this value were identified and defined as the potential linkage habitats (B).

10 CONSERVATION AREA DESIGN

10.1 Introduction and Background

Measuring success at maintaining long term ecological functions and biodiversity in any region has proven difficult and elusive. To provide more tangible measures of success, scientists have proposed sets of conservation and management goals. Noss (1992) and Noss and Cooperrider (1994) stated four goals of regional conservation to be satisfied to achieve the overarching mission of maintaining biodiversity and ecological integrity, into perpetuity. These goals are:

1. Represent, in a system of protected areas, all native ecosystem types and seral stages across their natural range of variation.
2. Maintain viable populations of all native species in natural patterns of abundance and distribution.
3. Maintain ecological and evolutionary processes, such as disturbance regimes, hydrological processes, nutrient cycles, and biotic interactions.
4. Design and manage the system to be resilient to short-term and long-term environmental change and to maintain the evolutionary potential of lineages.

The selection of "Primary Core Conservation Areas" forms a cornerstone around which a CAD addresses these goals. Primary Core Area selection attempts to meet minimum representation goals for all species and ecosystem targets through the selection of a suite of conservation areas or sites. Ideally, these areas should be sufficiently large so as to maintain populations of most target species and ecological communities, and where possible, should support intact, functioning natural dynamic processes and provide secure areas for individuals of wider-ranging species including ungulates and large carnivores. An additional requirement of these Core Areas is that they are contiguous with one another or connected by Connectivity Areas such that together, the Cores and Connectivity Areas form a cohesive network of conservation areas.

While ideal Core Area sizes would maintain viable examples of all biodiversity elements, this is often an unrealistic goal given the management intent and existing extent of human activities. This is particularly true in northern regions where wide-ranging species such as grizzly bear, caribou and wolf have extensive area and habitat requirements. In such situations, a CAD can provide analyses leading toward the maintenance of ecological function across the study area through an emphasis not only on Core Areas but also, equally, on Connectivity Areas that connect Core Areas to provide a robust regional conservation strategy.

Connectivity Areas provide key linkage areas, but also increase total representation goals across a wide suite of conservation targets. We have built upon this inherent value of Connectivity Areas, by explicitly ensuring representation of conservation targets is increased in these areas to levels that should provide more robust conservation. Therefore, we call this MK CAD class "Connectivity-Secondary Core Areas" or CSCAs. This analysis also led to identification of a small suite of "Supplementary Sites", needed to increase representation of relatively rare conservation targets.

10.2 Core Area Selection Methods

Recent development of spatial optimization tools such as SITES and MARXAN (Ball and Possingham 2000; http://www.ecology.uq.edu.au/marxan.htm) have advanced our ability to meet multiple conservation targets simultaneously in a spatially "efficient" manner. Using spatial optimization algorithms provides a powerful approach to minimizing the amount of area needed to reach the representation goals for suites of focal species, ecosystems, and fine-filter targets.

We used the MARXAN application to assist us in designing and analyzing alternative site selection scenarios. The MARXAN program works as a stand-alone application that receives spatially-explicit data generated through GIS. Goals for the representation of various conservation elements (e.g., focal species habitats or ecological communities) are user-defined, as are costs associated with selection of Planning Units (PUs). Cost includes edge-related costs that favor solutions with clustered Planning Units that reduce total boundary or edge length, and costs associated with the level of existing human uses on the land base. We used the MARXAN "greedy heuristic" algorithm to identify clusters of sites or Planning Units that meet established goals while minimizing the cost required. Greedy heuristic is a step-wise iterative process by which the Planning Unit that improves the portfolio the most is sequentially added at each step. Improvement is based on the targets contained within the Planning Units and the level of representation achieved relative to the goals for each target and the cost of adding the PU. This continues until additional PUs do not improve the solution (e.g., all goals are met). Stated simply, the greedy heuristic iteratively adds whichever PU has the most unrepresented targets. Other optimization algorithms, such as simulated annealing, may result in more "efficient" solutions, but the greedy heuristic iterative selection of the next best PU increases the probability that we have selected the set of sites that offers the highest quality representation of the conservation targets.

10.2.1 Greedy Heuristic Parameters

Several factors besides the number and type of targets influence the results of the site selection process. These include the spatial extent of the analyses units or planning areas, type of Planning Units, Planning Unit cost measures, penalty applied for dispersed rather than clustered Planning Units in results ('boundary length modifier'), and the number of repeat runs of the algorithm (and number of iterations within each run).

10.2.1.1 Spatial stratification

To ensure that the selected sites, and thus the ecological values of the region, were well distributed across the study area, we divided the MK CAD study area into seven ecological strata, based on the seven major river systems of the region (see Section 2.4.1). Goals for representing species and ecosystems were then set for each of these individual strata.

10.2.1.2 Planning Units

We used 500-ha hexagons to create uniform sized Planning Units to minimize the influence of underlying spatial data errors and to reduce the edge-area ratio by approximating a circle. Planning Unit size was determined partly by the resolution of the underlying data and models and primary by computing limitations; 500 ha represents the smallest Planning Unit size we could use within our site selection analyses (see Section 2.4.2).

10.2.1.3 Impacts Layer

In addition to an area-based cost in MARXAN, we also imposed a cost based on existing human uses. These are identified as existing human developments including urban areas, residential areas, roads, camps, mining areas, etc and are quantified as described in Section 3. Importantly, areas of higher levels of human use represent both present impacts, as well as regions where continued development, use and resource extraction are likely to occur based upon the presence of existing infrastructure. Thus, these areas may have experienced or may experience reduced habitat effectiveness for many wildlife species. Additionally, using existing human uses to guide the selection of sites should also minimize future potential conflicts between ecological values identified in the MK CAD and human use and development of those sites.

We calibrated the relative level of the human-use cost to reflect a reasonable trade-off with the boundary cost such that, all other ecological values being the same, the selection of sites would avoid Planning Units with high levels of human use, even if that Planning Unit was adjacent to an already selected site.

10.2.1.4 Number of intermediate solutions and iterations

The final site selection scenario provided by the MARXAN greedy heuristic algorithm was based upon replicating the selection process a number of times. Each selection process included 1 million selection iterations, repeated a total of 10 times. Because the selection process is based upon a simple iterative process of selecting the next best Planning Unit, results between runs do not tend to vary substantially, and we ultimately found that repeating runs multiple times (i.e., >10) provided little additional value to the analysis.

10.2.1.5 Boundary Length Modifiers

The boundary length modifier (BLM) is a user-defined parameter input into the MARXAN application that determines the patchiness of conservation solution outputs. The BLM adjusts the cost of the boundary length or the amount of edge present in a potential solution, with lower BLM values resulting in highly fragmented solutions (many, smaller areas) that have a very high edge to area ratio. Such solutions perform very well at satisfying conservation goals for all targets with a minimum of area swept into the solution. However, the fragmented nature of the solution provides a limited framework from which to design a connected, network of conservation areas that could be expected to provide the habitat security or effectiveness needed for conservation targets. On the other end of the spectrum, high BLM values generate highly clumped conservation solutions with fewer, larger areas with low edge to area ratios. Areas selected in such solutions are more likely to meet size and connectivity requirements for CAD conservation targets. However, the high clumping factor will sweep areas into a conservation solution less because of inherent conservation values, and more because of the position or location of Planning Units relative to the objective of reducing boundary length. Thus, highly clumped solutions tend to be 'inefficient' from the perspective that more area contains less conservation value than a more fragmented solution.

In order to explore the balance between efficiency and contiguity, we established an initial BLM determined by the trade-off cost of selecting a PU adjacent to a selected set that contains high human uses versus the cost of selecting an isolated PU with no human uses. The human use threshold was based on our human use analysis (Section 3), and represented relatively high human use activities, such as those associated with developments along the Alaska Highway south of Ft. Nelson. We varied the BLM parameter through a series of trial runs, while maintaining the relative contribution of human use costs. The selected BLM modifier variable (0.003) was found to provide a balance between the increased regional and system values of high contiguity and the selection of PU representing high values for conservation targets. For species-specific cores, we set a low boundary length modified (0.0003), as the primary goal of the analyses was to identify those areas containing the best habitats for each species, but not necessarily large, contiguous habitats. The resulting portfolios successfully select the highest quality habitats (see Section 6), but also have a relatively fragmented spatial distribution (see Maps as identified in Section 6).

10.2.2 Targets and Goals

The site selection procedures for core area selection were driven by the goals set for representation of the ecological values of the study area, as described by the focal species, ecological systems and special models and data. For all conservation targets, goals were set within each River System strata that the target was found within (Section 2.4.1). The measures of relative abundance within Planning Units vary between target types and are discussed below, as are the goals established for both the PCAs and CSCAs (Table 10.1). Connectivity-Secondary Core Area goals subsume and account for the representation within Primary Core Areas. For example, a 60% goal for CSCA representation includes the representation achieved within PCAs and adds to that representation until a total 60% goal is sought across all CAD classes. In some cases, additional areas, called Supplementary Sites, are distinguished as isolated PUs that have been identified as important to meet representation goals of relatively rare conservation targets. These are identified as part of the Secondary Core analyses, and are not distinguished separately from this in the targets and goals discussion below.

10.2.2.1 Goal-Setting for Terrestrial Focal Species Habitat and Core Areas

As described in Section 6, seasonal habitat maps and core area maps were generated for each focal species, with the latter being selected through a stepwise optimization process that captured 'best' habitats for a species. For the purposes of PCA selection, goals were set for both the habitat values themselves and the species-specific core areas that had been generated. In the case of the former, Primary Core Area selection was driven by a 30% representation goal based on the cumulative habitat values available for the species in each RS strata. Cumulative habitat value within a RS is the summed habitat scores of the underlying 50 m grid (see Sections 6.1.9 and 6.1.10). To ensure that the Primary Core Areas included the best habitats for each species, we "locked in" Planning Units that were classified as Class 10 for focal species seasonal habitats (Section 6.1.9) The PCA habitat value goals were supplemented by setting a 60% representation goal for each species core area. In other words, to meet goals for each focal species, Primary Core Areas needed to contain at least 30% of all habitat values available for the species in the strata, and 60% of the total area that had been identified as core for the species. Species habitat goals were increased to 60% for total representation within CSCAs. This means that the total representation goal with PCAs as well as the CSCAs was 60%. We did not set an additional species core area goal for the Connectivity-Secondary Core Areas.

10.2.2.2 Goal-Setting for Aquatic Focal Species Habitats and Locations

Planning Units were attributed with the length of stream (in meters) of aquatic focal species habitat value class (1, 2 or 3 with 3 indicating the highest value class) such that each Planning Unit had 3 target attributes per aquatic focal species (habitat class 1, habitat class 2 and habitat class 3). We set 30% and 60% goals on habitat classes 2 and 3 for each aquatic focal species for the selection of Primary Cores and Connectivity-Secondary Core Areas, respectively. Additionally, we set a 30% representation goal for class 1 habitat in CSCAs. The goals were set as percentages of total stream length in each habitat class within each of the River System strata.

10.2.2.3 Goal Setting for Coarse-Filter Representation (ELU, Freshwater, Lakes)

Planning Units were attributed with the amount of area (ha) of each umbrella terrestrial system or umbrella ELU (Section 4.3) found within the PU. A 30% goal within each River System was established for PCA representation of umbrella ELUs. Goals were increased to 60% for Connectivity-Secondary Cores Areas umbrella ELU representation. In addition to umbrella ELU targets, a small suite of ELU types have been identified as particularly rare or sensitive and have been included within our Special Features category (Section 4.4, Section 8). Representation goals for these special feature ELU types were also established at 30% and 60% within each River System in which they were found for PCAs and CSCAs, respectively.

Freshwater ecological systems (Section 5) PU summaries are by the length (m) of stream within each class. We established 30% total length goals for each of the freshwater stream classes within each RS for representation with our Primary Core analyses. We established a 60% goal for each freshwater stream type for total representation when identifying Connectivity-Secondary Core Areas.

Lake systems classification results in the identification of 140 potentially unique lake types (Section 5). Planning Units are attributed with the amount of area (ha) within each lake type. We set 30% Primary Core Area representation goals within each RS for types that occurred within the RS. Representation was increased to 60% with the inclusion of CSCAs.

10.2.2.4 Goal Setting for Fine-Filter Targets

Goals for representation of fine-filter targets with limited data were not established for PCA selection, as the spatial data on occurrences can unduly bias the selection of sites to areas of higher human uses (e.g., adjacent to roads or trails) where observations tend to be documented. We did, however, set goals on a suite of special features that include habitat classifications available across the study area. These special features include identified grasslands, marshes, swamps, predicted riparian habitat types, lakes with lake trout present and special feature ELU types. For all targeted special features, we set minimum Primary Core representation goals of 30% within River System with occurrences, and increased the minimum representation goal to 60% with the addition of CSCAs. We also set Connectivity-Secondary Core Area goals on all fine-filter occurrences with sufficient data, even if these may show spatial bias. Goals for each fine-filter target are listed in Table 10.1.

10.2.3 Primary Core Area Selection

For the regional PCA analyses, priority was placed on capturing the highest value examples of key targets as well as ensuring the spatial contiguity results in sufficiently large Core Areas for high system resilience. To that end, we selected Core Areas through an iterative, multi-step process of selecting sites based on goal-setting across the conservation target groups described above. Explicit representation goals are provided in Table 10.1. Final core area selection was based on establishing a set of seed sites locked into the portfolio and then building off of these sites to meet goals across all targets. The seed set consisted of sites supporting the highest value terrestrial focal species habitats within species-specific core areas. To achieve contiguity, we varied the BLM parameter through a series of trial runs, while maintaining the relative contribution of human use costs (see Section 3, above).

As described above, we established 30% representation goals across key conservation targets to define an initial set of Planning Units for inclusion into the Primary Core classification. We then removed small fragmented selections of <5000 ha, and "locked" these into the Secondary Core Area class. Unfortunately, guidelines on minimum patch size requirements do not yet exist for the region. We chose ≥5000 ha as sufficiently large to represent potential core daily activity areas for a diversity of wide-ranging species such as grizzly bears or wolves. Additionally, we "smoothed" the Core Areas by reclassifying any unselected islands within PCAs as Primary Core.

10.2.4 Connectivity-Secondary Core Area Selection

Secondary Core representation goals built off of the representation of targets already achieved within Primary Core Areas, and added to this representation until Secondary Core goals were satisfied. Thus, Secondary Core representation goals represent the goals sought for the full suite of MK CAD classes, combined. To meet the Secondary Core representation goals, we "locked in" the representation already achieved within both the PCAs and the Core Connectivity Areas (Section 9). The greedy heuristic algorithm in MARXAN was used to identify the additional next best suite of Planning Units needed to meet Secondary Core representation goals.

By "locking in" the Primary Core Areas and Core Connectivity Areas, we not only accounted for the representation achieved within these classes, but we also encouraged the selection of PUs that were located adjacent to these selected sets (i.e., to reduce the edge: area cost). Because the Core Connectivity Areas are important for both connectivity and representation, and because newly selected Secondary Core Areas that are contiguous with Primary Core Areas or Core Connectivity Areas provide added connectivity values, we combined these two classes into a single "Connectivity-Secondary Core Area" class. Therefore, this class represents those areas that are important both for connectivity and representation. In addition, areas selected through the Secondary Core analyses that were disjunct for Primary Core Areas and Core Connectivity Areas but ≥5000 ha in size were included within the Connectivity-Secondary Core Area (CSCA) class, similar to the rule used for the selection of PCAs. These island cores are likely large enough to maintain significant ecological values and functions. Also similar to the PCA analyses, we reclassified any islands of unclassified habitats surrounded by CSCAs and/or PCAs, but limited this "smoothing" to those islands that were <5000 ha in size.

Some overall representation goals could not be met through the selection of PUs adjacent to Core or Connectivity Areas or within larger blocks of habitat, resulting in a suite isolated PUs <5000 ha being selected to meet representation goals for Secondary Core. These isolated PUs or blocks of PUs were examined individually for the conservation targets represented. We retained any of these PUs that contributed ≥1% representation of coarse-filter or fine-filter targets, and have called these sites "Supplementary Sites" to indicate their importance in supplementing representation of potentially rare or spatially-limited conservation targets.

10.3 Conservation Area Design Results

The final identification of CAD classes includes Primary Core Areas, Connectivity-Secondary Core Areas, and Supplementary Sites (Map 10.1). Primary Core Areas contain the highest value representation of ecological values, as predicted by our various modeling efforts. Connectivity-Secondary Core Areas are important both for providing linkages between PCAs and for adding substantially to the representation of conservation targets achieved within the CAD. Supplementary Sites identify those small or isolated areas needed to increase representation of relatively rare or spatially-limited coarse-filter or fine-filter conservation targets. The MK CAD identifies approximately 75% of the study area as either important to meet representation goals or maintain connectivity (Table 10.2).

10.3.1 Primary Core Areas

The greedy heuristic selection analysis resulted in the selection of an area approximately 6.8 m ha to meet the suite of representation goals established. The removal of all areas <5000 ha from the PCA selections resulted in the reclassification of approximately 680,534 ha of the Primary Core area to Secondary Core area. This removed several hundred small patches that ranged from less than 1 ha (fragment of PU along study area boundaries) to 5000 ha. The reclassification of islands within Primary Cores resulted in the addition of 104,500 ha. The final Primary Core Areas cover 6.2M ha or approximately 38.4% of our 16.2M ha study area. There are 101 individual core areas that range in size from 5000 ha to 1,127,000 ha (Table 10.2). The average (+/- standard deviation) core area size is 61,450 ha (+/- 152,744 ha). The majority (n=78) of the PCAs are less than 50,000 ha. There are 10 core areas greater than 100,000 ha, with 4 core areas greater than 500,000 ha in the region (Map 10.1).

10.3.2 Connectivity-Secondary Core Area and Supplementary Sites

The original Core Connectivity Areas identified 4.44 m ha needed to provide regional linkages between the PCAs. We added an additional 1.59 m ha to this to meet Secondary Core representation goals. We reclassified any unclassified islands surrounded completely by Connectivity-Secondary Core Areas and/or Primary Core Areas, resulting in an addition to the CSCA class of 13,000 ha. We also removed isolated clusters of PUs with total areas <5000 ha, resulting in the reclassification of 227,000 ha into potential Supplementary Sites. The resulting

Connectivity -Secondary Core Area identifies 5.82 M ha or 36% of the study area (Table 10.2; Map 10.1).

Potential Supplementary Sites were individually examined, and those representing $\geq$1% of either any coarse-filter or fine-filter target were retained. Our final Supplementary Sites class covers 88 sites, varying in size from 195 ha to 2500 ha and covering a total of 64,732 ha (Table 10.2).

10.3.3 Muskwa-Kechika Management Area

The MKMA covers 39% of our MK CAD study area. The MK CAD identifies 2.7 m ha of Primary Core Area within the MKMA, with represents 42.3% of the MKMA area (Table 10.3). Additionally, there is 2.1 m ha (33.1% of MKMA) of Connectivity-Secondary Core Area and 30 Supplementary Sites covering 16,751 ha in the MKMA.

10.3.4 Representation of Conservation Targets

Representation of targets within the MK CAD are presented in Table 10.4. Representation is quite high, with most conservation targets achieving >75% representation. The efficiency of the solution is notable, given the diverse set of target types, from terrestrial focal species through aquatic freshwater classifications. The MK CAD meets representation goals set on seasonal habitats and core habitats for 7 terrestrial focal species, habitat for 2 aquatic focal species, 174 terrestrial umbrella ecological land unit types, 46 freshwater classes, 140 lake classes, 16 special features and 80 CDC special elements. When stratified by the seven major River Systems, this equates to meeting representation goals for well over 1,000 conservation targets. In addition, connectivity between all PCAs has been identified, with a minimum of three Connectivity Areas from each Core to adjacent Cores. Full representation tables across all targets stratified by the River Systems are provided in Appendix I.

MK CAD representation of terrestrial focal species habitat values range for 73.5% to 76.5%, while representation of core habitats range from 79.2% to 84.9% (Table 10.4). Similarly, aquatic focal species habitat representation ranges from 77.1% to 79.6% for the most suitable habitats (classes 2 and 3). Average representation of coarse-filter targets, including umbrella ecological land units, all ecological land units, freshwater stream classes and lake classes ranged from 73.1% to 93.5%.

Individual representation of umbrella ELUs, all ELUs, freshwater stream classes and lake classes can be variable, and these are shown in Figures 10.1-10.4. For each coarse-filter classification, the majority of the individual types exceeded our minimum of 30% representation and most individual types have representation within the full CAD exceeding 60%. Representation exceeds 60% for 84% of the 1,946 ELU types and exceeds 30% for 93% of them. The umbrella ELU types, freshwater stream classes and lake classes are all well-represented, with representation exceeding 70% in all but a single freshwater stream class (53%).

Fine-filter targets are well-represented within the MK CAD. Special feature representation is provided in Table 10.4, and ranges from 64% to 89.5%. The representation across the suite of 80 identified fine-filter species targets (CDC occurrences) all exceeded 40% (Figure 6.5). The MK CAD succeeded in well-representing even fine-filters with inadequate data to set explicit goals. For example, 20 of the 21 special element fish species occurrences identified in the FISS data were represented by >40%. The single un-represented FISS species is the pygmy whitefish, identified in 2 locations in the study area.

10.3.4.1 Primary Core Area Representation

As anticipated, the Primary Core Areas selected represent an 'efficient' portfolio of sites; the 38.4% of the study area that was selected contains an average of 40.5% ($\pm$11.45 standard deviation) of the area's large suite conservation target values, as predicted by our various modeling efforts. Average representation achieved within each target group type exceed minimum representation within each River System strata as well as study area-wide (Table 10.4). The individual target representation also exceeds minimum representation goals in most cases (Appendix I). The reclassification of areas <5000 ha from Primary Core resulted in the loss of representation of a handful of coarse-filter target class types (e.g., some individual umbrella ELU types, for example) within the Primary Cores.

Representation achieved with Primary Core Areas for suites of targets is presented in Table 10.3. Representation within Primary Core Areas captures 39.5 – 41.5% of the MK CAD study area wide seasonal habitat values of terrestrial focal species, with 46-60% species-specific core areas represented as well. Across all River Systems, representation of habitats is high, ranging from a low of 33.2% to a high of 50.0% for individual species seasonal habitats within specific River Systems (Appendix I). Additionally, Primary Core Areas represented 37.8 – 42.7% of the study area-wide targeted arctic grayling and bull trout 'high value' habitats (classes 2 and 3). Representation for Arctic grayling and bull trout suitable habitats is consistently high across all River Systems and ranges from 31.5% to 56.1 (Appendix I).

The majority of umbrella ecological land unit types, primary ecological land unit types, freshwater stream and freshwater lake classes had at least 30% representation in the Primary Core Areas (Figures 10.6 – 10.9). Under-representation of some classes is due to the reclassification of isolated Primary Core selections <5000 ha to Secondary Core. Thus, the majority of coarse-filter types with low representation within Primary Cores are well-represented within the Connectivity-Secondary Core Areas. Average class and individual target representation within each coarse-filter type (e.g., ELU, freshwater lakes) within the River Systems and across the study area is shown in Appendix I. Umbrella ecological land unit type representation across the seven River Systems range from 33.9% to 43%. Freshwater class representation averages range from 35.5% to 45.1%. Lake classes show a variable average representation, ranging from 24.2% to 47.7%.

Representation across fine-filter targets that had Primary Core Area goals established is somewhat variable (Table 10.4), but ranges from 31.2% for grassland habitats to 49.7% for large swamps (defined as wetlands with shrubby or treed canopy $\geq$10ha).

10.3.4.2 Connectivity-Secondary Core Area Representation

Connectivity-Secondary Core Areas are important both for identifying potential linkages between PCAs and providing additional representation of conservation targets. Conservation target representation goals set for this class are listed in Table 10.1. As described earlier, the Secondary Core goals are global in that they first account for representation achieved with Primary Core Areas and Core Connectivity Areas before selecting additional areas needed to meet representation minimums for Secondary Core. The analyses leading to the identification of CSCAs also leads to the classification of Supplementary Sites, needed to meet the representation goals set for Secondary Core.

Connectivity-Secondary Core Areas and Supplementary Sites brought total representation of conservation targets well above the global minimums established (Table 10.4). From 34.6 – 36.3% of total terrestrial focal species habitat values were represented within CSCAs, including 23.0 - 33.1% of the core habitats identified for these focal species. There are 33.9 – 36.7% of the identified aquatic focal species habitats within CSCAs. Coarse-filter representation averages across each classification ranges from 35.7% to 38.1%.

Fine-filter representation within CSCAs is high, ranging from 21.5% for waterfowl habitat to 57.7% for identified waterfalls (Table 10.4). Given that many fine-filters did not have explicit goals established in Primary Core Area selections, but did have goals set in CSCAs, the resulting CSCA representation is particularly important. For example, waterfalls did not have goals set for PCAs and have zero representation within them (57% in CSCAs). Additionally, 41.2% of stream rapids habitats are represented within CSCAs, while only 13.8% are within PCAs. Representation of CDC special element occurrences with CSCAs is 43.8% due to an explicit goal being set; Primary Core Areas included 28.5% of these occurrences (even without a goal being set). Additionally, targets that did not have explicit goals in either PCAs or CSCAs analyses show significant representation in CSCAs, including potential karst regions (73.7% represented) and FISS fish occurrences (average of 34.9% represented).

Supplementary Sites provide important representation for a limited suite of conservation targets. They add an average of 5% and 2% to the representation achieved for Lake classes and Freshwater stream classes, respectively. Supplementary Sites provide 11.6% representation of lakes with known lake trout presence. 42.3% representation of the stream waterfalls and 8.9% representation of stream rapids. They also add important representation for a number of individual umbrella ELU types.

10.3.4.3 MKMA Representation

The MKMA covers 39% of our MK CAD study area and contain equivalent amounts of the total MK CAD area (40%) and the representation (40.6%) of conservation targets. Examining only the conservation targets and MK CAD classes within the boundaries of the MKMA, we find that representation averages 85% (Table 10.5). This includes an average of 42.6% representation of conservation targets within Primary Core Areas, and average of 40.3% representation within Connectivity-Secondary Core Areas and an average of 2.35% representation of conservation targets within Supplementary Sites.

MK CAD representation of terrestrial focal species habitat values range from 73.2% to 79.4% within the MKMA, representation of species core habitats ranging from 80.1% to 88.3%. Aquatic focal species suitable habitats within the MKMA are also well representation with the MK CAD, ranging from 70.0% to 81.6%. Similarly, coarse-filter targets within the MKMA are represented at high levels, averaging 87.84%, 79.5%, and 90.1% for umbrella ELU classes, freshwater stream classes, and lake classes, representatively. Special features within the MKMA achieved 77.48% representation, while special elements (CDC species occurrences) achieved 87.31% representation. Even the FISS special element fish occurrences, for which we did not set explicit goals, are well-represented at 65.31%. Full representation of all targets within the MKMA boundaries is provided in Appendix I.

10.3.5 Planning Unit Attributes

Each MK CAD 500-ha Planning Unit within the study area has an associated attribute table, which provides a summary of the conservation values contained within the 500-ha PU. These attributes include the CAD classification of Primary Core Area, Connectivity-Secondary Core Area and Supplementary Sites. Anything outside of these CAD classes is identified as “Matrix”. Planning Unit attribute tables also provide the PU summary values from all of our individual analyses, including terrestrial and aquatic focal species habitat suitability value summaries and whether the PU was identified as core habitat for any of the terrestrial focal species. Attribute tables also provide the number of hectares of each umbrella ELU terrestrial type and lake class, as well as the meters of each freshwater stream class in the PU. The presence (number of occurrences or hectares) of any special elements or features within the PU will be noted.

10.3.6 Spatial data

The results of each of the analyses have been provided in the form a spatial dataset independent of the PU attribute summaries. These underlying analyses form stand-alone products and each is provided at the original resolution of analysis. Most of these analytical products were developed using ArcGrid and are provided as grid coverages. A list of each analysis provided in the form of a stand-alone product, along with the data format is provided in Appendix J. Meta-data is provided with the spatial data, while details of the analytical procedures are presented in this report. All analyses are also accessible through the Planning Unit summaries, best accessed through the GIS Toolkit, but also available as a suite of look up tables that can be joined to the Planning Unit polygon coverage.

10.4 Discussion

The MK CAD represents a suite of modeling and analytical outputs that form a strong integrated result, as well as useful stand-alone products that provide insights into specific targeted conservation values across the region. We have engaged extensive peer-reviews for most analyses, and have made concerted efforts to ensure that the models and the data upon which they are based represent the best available information sources at the time of the analyses. Still, we emphasize the preliminary nature of the CAD products, including analyses and results. None of the underlying models have been validated, tested or checked for sensitivity to estimated parameters. Additionally, most models are built upon data that also have underlying weaknesses and spatial resolution limitations. Recommendations for further work and research are presented in Section 12, and are based in part upon our experience using the existing data and models available for the region. These recommendations include periodic updating of the MK CAD analyses and models to allow for the incorporation of data upgrades, modeling improvements and new information.

10.4.1 Spatial Stratification: Defining Relative Conservation Values

The ability to effectively identify the relative importance of any spatially-distributed value is partially determined by the spatial resolution used to summarize that value. While we focus on ecological or conservation values, this would be true for any spatially-distributed resource. For example, across British Columbia, the wetland complex found within the Besa-Prophet River System would seem relatively unimportant. But, when compared within the MKMA, this wet valley bottom increases in importance, and when viewed from the lens of the Besa-Prophet pre-tenure planning, it may be seen as one of the most important or sensitive ecological values in the local landscape.

The ability to capture the importance of ecological values across multiple spatial scales represents a significant analytical challenge in developing a CAD. We approach this challenge in several ways. First, our multiple layers of spatial stratification provide divisions of the study area into incrementally smaller spatial units that provide a cascading evaluation of ecological importance across multiple scales. The primary levels of stratification are: study area defined by ecosections boundaries to place the MKMA within a regional ecological context; stratification of the study area into seven River Systems which help ensure we meet our goals of maintaining distributions of targets across the larger landscape; Watershed Group, which provides an intermediate spatial scale of relative distribution of conservation targets for planning and management (as described in Section 12); 500-ha Planning Units provide the finest level of data summary and regional analyses; and finally, the underlying models which are all developed using 50 m grids to assure we capture the finest site-level values available within the existing data sets (with the exception of connectivity, see Section 9).

Our use of multiple types of conservation targets (coarse-filter ecosystem classification, fine-filter special elements, focal species) provides an additional strategy to assist us in capturing and identifying values across multiple spatial scales. Within coarse-filter and habitat modeling analyses, recognition of spatial scale is captured through tiered classification schemes that begin with ecosection and/or BEC zones and move through finer-resolution spatial data to site-level information on vegetation and topographic variables as available through the data.

Regardless of the multiple efforts we undertake to transcend spatial scale issues, the CAD analysis is a regional strategic effort and will operate best at this scale. We expect that it will have increasingly limited power to predict the distribution of conservation target values at finer resolutions; this tool has not been developed and is not suitable for site-level predictions below the 500-ha Planning Unit.

10.4.2 Systematic Conservation Area Design

Most recent conservation area selection methods use systematic site selection algorithms to assist in identifying areas of high conservation priority (e.g., Bedward, Pressey et al. 1992; Lombard, Cowling et al. 1997; Margules and Pressey 2000; McDonnell, Possingham et al. 2002; Rothley 2002; Airame, Dugan et al. 2003; Carroll, Noss et al. 2003; Cowling, Pressey et al. 2003). Presently, the most commonly used optimization procedures for conservation area selections are "simulated annealing" and "greedy heuristic" algorithms, each of which iteratively selects planning units to identify the set of sites that achieves the prescribed goals with a high level of efficiency (Pressey, Possingham et al. 1996; Csuti, Polasky et al. 1997). Site selection algorithms have received criticism for not identifying truly optimal solutions, for high data quality requirements and for sensitivity to potentially arbitrary selection of parameters by the user that can strongly influence the resulting site selections (Underhill 1994; Cabeza and Moilanen 2001; Warman, Sinclair et al. 2004). Still, the use of optimization processes provides a systematic site selection tool that has proved valuable to increase the efficiency of site selections that represent high conservation value across a diversity of targets and goals (Bedward, Pressey et al. 1992; Pressey, Humphries et al. 1993; Margules and Pressey 2000).

However, optimization algorithms do not provide a panacea for Core Area selections. Recognizing potential problems associated with scale, resolution and the bias towards selection of sites that have many overlapping but potentially moderate conservation values, we have used the selection tools of spatial optimization carefully. Planning unit size is the smallest feasible for the area covered to reduce averaging ecological values within Planning Units. Additionally, we used a stepwise process, to reduce the number of simultaneous target goals sought. In this manner, we have created, for example, the focal species-specific cores presented in Section 6, and used those both as stand-alone products of the CAD projects as well as to assist in prioritizing site selections. Additionally, we have "locked" some sites into the solution, assuring that predicted highest quality habitats are included. We have also opted to use the greedy algorithm, due to the more transparent, interpretable and repeatable application which focuses on iteratively selecting the "next best" site in creating conservation solutions. All of these decisions may reduce the overall "efficiency" of the resulting CAD core selection process, but increase our ability to effectively represent the conservation targets as intended and to meet the fundamental objectives described by regional conservation area design.

10.4.3 Goal-Setting and Area Requirements

The Primary Core Area analysis provides a step towards the prioritization of landscapes for the conservation of biodiversity. The decisions of where and how much habitat to conserve represent trade-offs (if it is below 100%) of increasing risk versus precautionary management. However, using the best available science to determine where and how much land should be identified for conservation management can minimize biological risks and optimize the spatial configuration of conservation efforts. Because the proposed system of Primary Core Areas is unlikely to be large enough to meet long-term conservation goals, the conservative management of Primary Core Areas with Connectivity-Secondary Core Areas and Supplementary Sites is likely required to maintain ecological integrity. It must also be recognized that all analyses presented, while based on the best-available information and analytical techniques, are simply predictions or "hypotheses" about how biodiversity may be maintained across study area landscapes, and have not been tested or validated. Given the uncertainty inherent in such regional scale analyses, "matrix lands" surrounding the CAD designations should also be managed to maintain the local integrity of landscapes or sites.

A diversity of scientists and research efforts has proposed minimum goals for the representation of biodiversity, either generally or for specific regions (Table 10.6). The implicit objective of these recommendations is to reduce extinction rates to near-background levels and maintain the integrity of ecosystems and ecological functions on a regional scale. Generally, most experts have reported that protection for at least 40-60% of the terrestrial lands and fresh waters would be required to sufficiently protect biodiversity (Table 10.6). Within their historic range, grizzly bears are particularly suitable for insights into the spatial requirements for biodiversity maintenance, because their area requirements are large. If landscapes are managed for the spatial requirements needed to maintain viable and well-distributed grizzly bear populations, this management is likely sufficient for a large proportion of other biodiversity elements.

Recent research on the minimum requirements to maintain grizzly bear populations across British Columbia provides potential relevant insights into the area requirements for short-term population viability within British Columbia. Wielgus (2002) estimates that the maintenance of a single population of grizzly bears with relatively low risk of extinction over the *short term* (20 years) would require a starting population of at least 250 bears. Wieglus recommends buffers around these secure areas, increasing total area requirements. In order to minimize edge effects, Wieglus clearly cautions that a population of this size (i.e., 250 bears) can not be expected to be viable in isolation, and should be protected within a matrix of landscapes that supports a larger, contiguous population. Finally, he recommends this would be consistent with a precautionary approach to provide protection for several of these populations, distributed across the region and connected through linkage zones (Wieglus 2002).

We can roughly estimate the recommended bear conservation area size needed in the MK CAD study area to maintain this minimum population size recommended Wieglus (2000), based on recent grizzly bear population density estimates for the region. Mowat et al. (2004) used habitat productivity estimates to general grizzly bear density estimates across BC, including within 14 identified "bear management units" within our study area. The average (+/- standard deviation) estimated bear density across these units is 21 (+/- 5) bears/1000 sq. km, or 21 bears/100,000 ha. Resulting bear conservation units potentially supporting 250 bears, as recommended by Wieglus (2002) for short term conservation of populations would range between 926,000 ha and 1,562,500 ha with an average of 1,190,500 ha.

Comparing these suggested conservation area sizes to the proposed PCAs can provide a context for our recommended Core Areas. Only one of the Primary Core Areas approaches the size needed to ensure the short-term viability of grizzly bears, as proposed by Weiglus. It is likely that none of the Cores are sufficiently large to maintain grizzly bears or other wide-ranging species in the longer term. To maintain functioning ecosystems and viability across a broad suite of biodiversity, connectivity must be maintained across the region.

10.4.4 MKMA Conservation Values

Approximately 43.4% of the Primary Core Areas and 36.3% of the Connectivity-Secondary Core Areas are found within the MKMA; the MKMA is approximately on 39.4% of our study area. We also found the proportional representation of conservation targets within the MKMA is equivalent to the area covered by the Management Area. These findings reveal that, while the MKMA contains significant ecological values, they may not be viewed in isolation of the surrounding landscapes. These surrounding landscapes are important for the diversity of habitats and habitat qualities they represent and the regional connectivity values that connect the MKMA to adjacent regions.

Our Human Use Analysis clearly indicates that the MKMA has a lower density of human use compared to the rest of the study area, and as such, would have been scored as a lower 'cost' area for site selection based on the parameters of our site selection algorithm. It is interesting to note then that our greedy heuristic selections did not disproportionably favour sites within the Management Area. At this point in time, it would appear that the distribution of targets and the stratification of goals by River Systems have a stronger influence on site selection than existing human impacts. Indeed, high quality low elevation habitats are more pervasive in the surrounding study area than in the high elevation, rocky terrain typical of the MKMA. Conversely, the importance of the MKMA for sheep habitat and goat is apparent, and expected given that the MKMA holds a large majority of core habitat for these alpine specialists.

However, it is likely that human uses will increase both in and around the MKMA over the coming decades, and with few legislative tools to protect biodiversity outside of the MKMA, we would expect the discrepancy in intactness between the MKMA and the surrounding areas to become more pronounced. Through successive iterations of the CAD, it will be important to track the efficacy of the MKMA's legislative and management framework in keeping human impacts minimized in the Management Area and to track how any growing imbalance between development within and without the MKMA affects the distribution of future site selections. This effort will need to be supported by ongoing research into the relationship between human use and habitat suitability in order to help managers better understand the dynamics of changing habitat values and site selection on either side of the MKMA boundary over time.

10.5 Tables

Tables

Table 10.1 Goals for representation within Primary Core Areas and Connectivity-Secondary Core Areas

Feature Group	Primary Core Goal	Secondary Core Goal
Caribou growing	30%	60%
Caribou winter	30%	60%
Sheep growing	30%	60%
Sheep winter	30%	60%
Goat growing	30%	60%
Goat winter	30%	60%
Moose growing	30%	60%
Moose winter	30%	60%
Elk growing	30%	60%
Elk winter	30%	60%
Grizzly early	30%	60%
Grizzly mid	30%	60%
Grizzly late	30%	60%
Wolf growing	30%	60%
Wolf winter	30%	60%
grayling type1	0%	30%
grayling type2	30%	60%
grayling type3	30%	60%
bulltrout type1	-	30%
bulltrout type2	30%	60%
bulltrout type3	30%	60%
ELU classes	30%	60%
Freshwater classes	30%	60%
Lake classes	30%	60%
open grassland	30%	60%
waterfowl habitat	-	30%
marsh <10 ha	-	30%
marsh ≥10 ha	30%	60%
marsh next to streams	-	30%
marsh next to lakes	-	30%
swamp < 10 ha	-	30%
swamp ≥10 ha	30%	60%
falls	-	30%
rapids	-	30%
karst	-	-
broadleaf riparian	30%	60%
coniferous riparian	30%	60%
mixed riparian	30%	60%
nonforest veg riparian	30%	60%
hotsprings	-	30%

Lake trout lake	30%	60%
FISS fish occurrence	-	-
CDC SE occurrences	-	30%
Lake classes	30%	60%
Caribou core	60%	-
Sheep core	60%	-
Elk core	60%	-
Moose core	60%	-
Goat core	60%	-
Grizzly core	60%	-
Wolf core	60%	-

Table 10.2 Summary of area statistics for MK CAD classes, including Primary Core Areas, Connectivity-Secondary Core Areas and Supplementary Sites.

MK CAD Class	Total No. of Areas	Total Area	Average Area	Smallest Area	Largest Area
Primary Core Area	101	6,206,461	61,450	5,000	1,127,000
Connectivity-Secondary Core Areas	153	5,815,140	38,007	25	916,766
Supplementary Sites	88	64,732	735	195	2500

Table 10.3 Summary of area statistics for MK CAD classes within MKMA, including Primary Core Areas (PCAs), Connectivity-Secondary Core Areas (CSCAs) and Supplementary Sites (SS).

MK CAD Class	number	Size (ha)	% of MKMA
PCA	84	2695851	42.31
CSCA	81	2110968	33.13
SS	30	16751	0.26
CAD	-	4823570	75.71

Table 10.4 Summary of Primary Core Areas (PCAs), Connectivity-Secondary Core Areas (CSCAs), Supplementary Sites (SS) and MK CAD representation results.

Feature Group	% in PCAs	% in CSCAs	% in SSs	% in MK CAD
Terrestrial Focal Species:				
Caribou growing[1]	41.12	34.09	0.32	75.53
Caribou winter[1]	40.53	34.71	0.35	75.59
Sheep growing[1]	40.43	33.77	0.25	74.46
Sheep winter[1]	40.71	33.84	0.24	74.79
Goat growing[1]	39.54	33.66	0.27	73.47
Goat winter[1]	41.07	33.73	0.3	75.09
Moose growing[1]	40.56	35.65	0.4	76.61
Moose winter[1]	39.7	36.34	0.42	76.45
Elk growing[1]	41.5	34.59	0.37	76.46
Elk winter[1]	40.72	35.31	0.4	76.44
Grizzly early[1]	40.65	34.79	0.34	75.77
Grizzly mid[1]	40.19	34.95	0.35	75.49
Grizzly late[1]	40.2	35.14	0.35	75.7
Wolf growing[1]	40.51	35.39	0.39	76.29
Wolf winter[1]	40.2	35.65	0.4	76.24
Aquatic Focal Spp				
grayling type1[2]	38.17	33.93	0.7	72.8
grayling type2[2]	42.68	35.28	0.45	78.41
grayling type3[2]	40.01	36.69	0.46	77.15
bulltrout type1[2]	37.84	35.73	0.32	73.89
bulltrout type2[2]	42.64	36.48	0.49	79.61
bulltrout type3[2]	41.15	35.45	0.5	77.1
Coarse-Filters:				
159 Umbrella ELU classes[3]	43.84	38.43	0.57	82.85
1,946 ELU Types[3]	32.89	39.22	1.02	73.13
46 Freshwater classes[2]	41.49	35.68	2.06	79.23
140 Lake classes[2]	50.46	38.06	4.97	93.49
Fine Filters:				
open grassland[3]	31.71	51.25	0	82.96
waterfowl habitat[3]	67.32	21.49	0	88.81
marsh lt10 ha[3]	41.97	35.77	0.66	78.41
marsh gte10 ha[3]	49.65	28.95	1.09	79.69
marsh adj2streams[3]	46.65	31.95	0.89	79.49
marsh adj2lakes[3]	47.27	31.62	1.18	80.07
swamp lt10 ha[3]	40.39	37.79	0.57	78.75
swamp gte10 ha[3]	49.45	29.4	0.27	79.12
falls[2]	0	57.72	42.28	100
rapids[2]	13.84	41.2	8.94	63.98
karst[3]	0	73.69	3.45	77.14
broadleaf riparian[3]	35.54	45.38	0.5	81.42
conifer. riparian[3]	40.47	38.6	0.24	79.3
mixed riparian[3]	37.26	44.68	0.31	82.25
nonforest riparian[3]	42.08	38.96	0.54	81.58
hotsprings[4]	50	30	0	80
Lake trout lake[3]	38.09	39.79	11.6	89.47

FISS fish occurrence[4]	37.8	34.91	0.22	72.93
CDC Spp occurrences[4]	28.53	43.82	8.44	80.8
FS Core Habitats:				
Caribou core[5]	56.72	24.91	0.2	81.83
Sheep core[5]	58.57	24.45	0.08	83.09
Elk core[5]	60.02	22.98	0.12	83.12
Moose core[5]	57.25	27.43	0.24	84.92
Goat core[5]	53.59	27.52	0.07	81.18
Grizzly core[5]	45.93	33.12	0.14	79.19
Wolf core[5]	50.01	31.79	0.34	82.15
Total Average Representation	42.62	38.51	3.26	84.39

[1] Unit of measurement is total summed habitat score in Planning Unit (PU)
[2] Unit of measurement is total length (meters) in PU
[3] Unit of measurement is total area (hectares) in PU
[4] Unit of measurement is number of occurrences (points) in PU
[5] Unit of measurement is number of PU classified as species core

Table 10.5 Summary of Primary Core Areas (PCAs), Connectivity-Secondary Core Areas (CSCAs), Supplementary Sites (SS) and MK CAD representation results within the MKMA boundaries.

Feature Group	% in PCAs	% in CSCAs	% in SSs	% in MK CAD
Terrestrial Focal Species:				
Caribou growing[1]	44.40	31.03	0.22	75.65
Caribou winter[1]	44.74	31.40	0.22	76.36
Sheep growing[1]	43.18	31.78	0.19	75.15
Sheep winter[1]	43.65	31.73	0.19	75.58
Goat growing[1]	41.61	31.35	0.20	73.16
Goat winter[1]	44.10	31.29	0.20	75.59
Moose growing[1]	46.24	32.61	0.24	79.09
Moose winter[1]	45.42	33.47	0.25	79.14
Elk growing[1]	46.05	32.45	0.21	78.71
Elk winter[1]	46.18	33.00	0.21	79.39
Grizzly early[1]	44.51	31.97	0.22	76.71
Grizzly mid[1]	44.07	32.16	0.22	76.46
Grizzly late[1]	44.30	32.28	0.22	76.80
Wolf growing[1]	44.57	32.71	0.25	77.53
Wolf winter[1]	44.66	32.82	0.25	77.73
Aquatic Focal Spp				
grayling type1[2]	39.42	35.92	0.00	75.34
grayling type2[2]	45.77	32.10	0.26	78.13
grayling type3[2]	45.77	34.11	0.33	80.21
bulltrout type1[2]	40.14	29.08	0.84	70.05
bulltrout type2[2]	49.43	31.96	0.24	81.63
bulltrout type3[2]	45.30	33.32	0.25	78.86
Coarse-Filters:				
140 Umbrella ELU classes[3]	42.50	33.17	0.23	75.91
34 Freshwater classes[2]	45.62	32.92	0.28	78.82
55 Lake classes[2]	47.13	31.49	5.17	83.79

Fine Filters:				
open grassland[3]	40.34	47.54	0.00	87.88
waterfowl habitat[3]	0.60	63.19	0.00	63.79
marsh lt10 ha[3]	51.17	27.72	0.24	79.13
marsh gte10 ha[3]	57.35	22.71	0.53	80.59
marsh adj2streams[3]	54.80	24.67	0.44	79.90
marsh adj2lakes[3]	56.00	23.00	0.70	79.70
swamp lt10 ha[3]	47.97	30.05	0.41	78.43
swamp gte10 ha[3]	49.01	32.69	0.44	82.13
falls[2]	0.00	0.00	100.00	100.00
rapids[2]	7.19	42.73	7.99	57.91
karst[3]	NP	NP	NP	NP
broadleaf riparian[3]	39.75	44.97	0.22	84.94
conifer. riparian[3]	45.24	34.94	0.14	80.33
mixed riparian[3]	36.96	46.83	0.28	84.06
nonforest riparian[3]	47.16	36.11	0.17	83.44
hotsprings[4]	40.00	40.00	0.00	80.00
Lake trout lake[3]	42.70	36.11	12.59	91.40
FISS fish occurrence[4]	36.55	32.41	2.07	71.03
CDC Spp occurrences[4]	23.96	40.09	0.47	64.53
FS Core Habitats:	60.84	22.97	0.18	83.99
Caribou core[5]	61.44	21.61	0.08	83.13
Sheep core[5]	61.22	24.57	0.12	85.91
Elk core[5]	69.54	18.74	0.05	88.34
Moose core[5]	55.36	24.86	0.08	80.30
Goat core[5]	50.71	29.31	0.09	80.11
Grizzly core[5]	53.69	28.99	0.25	82.93
Wolf core[5]	60.84	22.97	0.18	83.99
MKMA Average Representation	42.66	40.30	2.35	85.04

[1] Unit of measurement is total summed habitat score in Planning Unit (PU)
[2] Unit of measurement is total length (meters) in PU
[3] Unit of measurement is total area (hectares) in PU
[4] Unit of measurement is number of occurrences (points) in PU
[5] Unit of measurement is number of PU classified as species core

Table 10.6 Percentage of land recommended for protection in a number of regions.

Source	Region	Recommended Area
Odum (1970)	Georgia	40%
Odum and Odum (1972)	General	50%
Noss (1993)	Oregon Coast	50%
Cox et al. (1994)	Florida	33.3%
Mosquin et al. (1995)	Canada	35%
Ryti (1992)	San Diego Canyons	65%
Ryti (1992)	Islands in Gulf of California	99.7%
Margules et al. (1988)	Australian river valleys	44.9% - 75.3%
Noss (1996)	General	25% – 75%
Noss et al. (1999)	Klamath-Siskiyou	60% – 65%
Hoctor et al. (2000)	Florida	50%
Rodrigues & Gaston (2001) (2001)	Tropical region	93%
Rodrigues & Gaston (2001)	Globally	74%
Noss et al. (2002)	Greater Yellowstone Ecosystem	43%
Solomon et al. (2003)	South Africa	$\geq$50%
Carroll et al. (2003)	US-Canada Rocky Mnts	37%

10.6 Figures

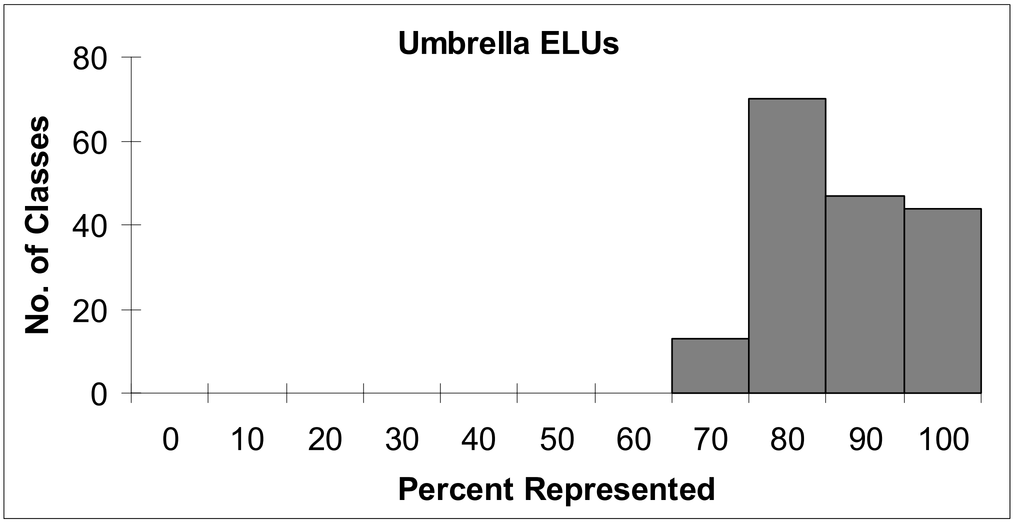


Figure 10.1 Representation achieved within the MK CAD of the Umbrella ELU classes.

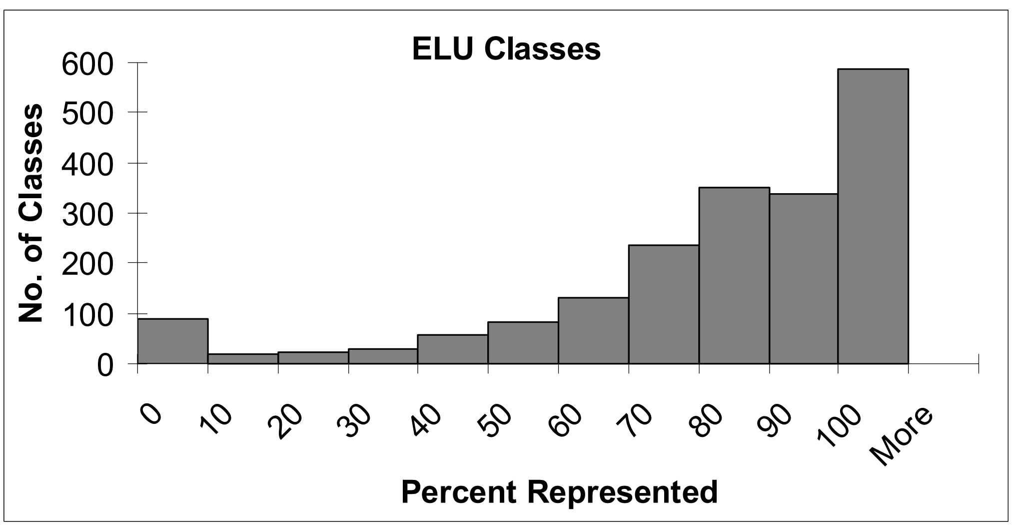


Figure 10.2 Representation achieved within the MK CAD of all ELU classes.

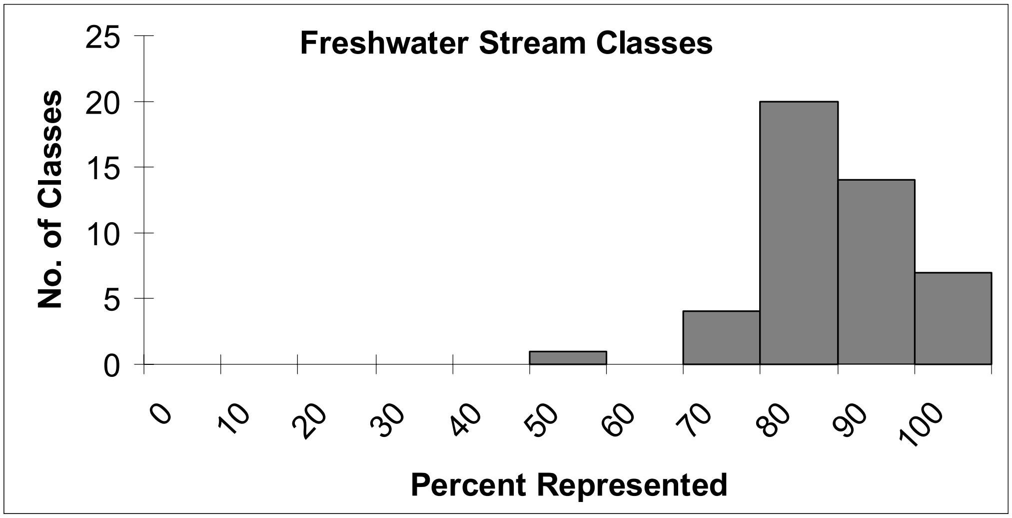


Figure 10.3 Representation achieved within the MK CAD of coarse-filter freshwater stream classes.

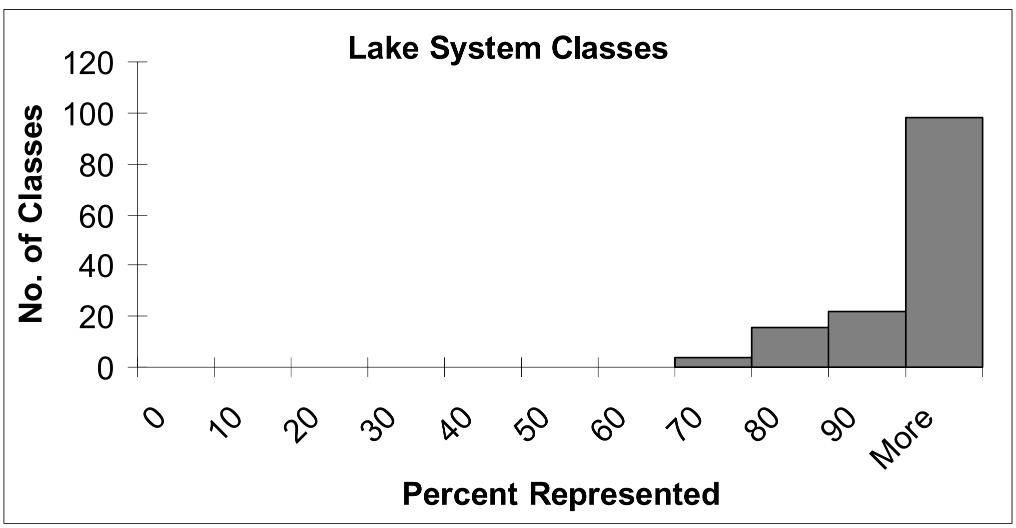


Figure 10.4 Representation achieved within the MK CAD of freshwater lake classes.

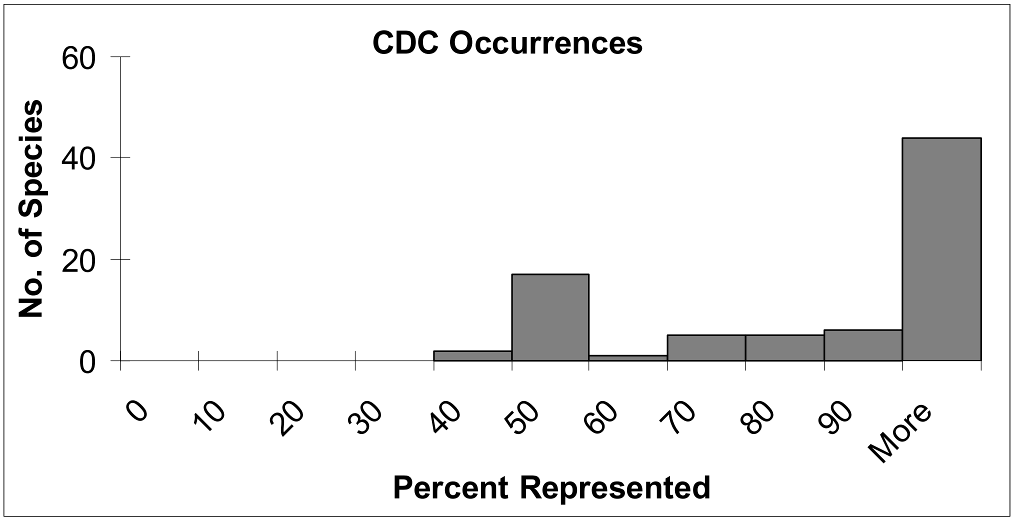


Figure 10.5 Representation achieved within the MK CAD of fine-filter species targets identified in the CDC data.

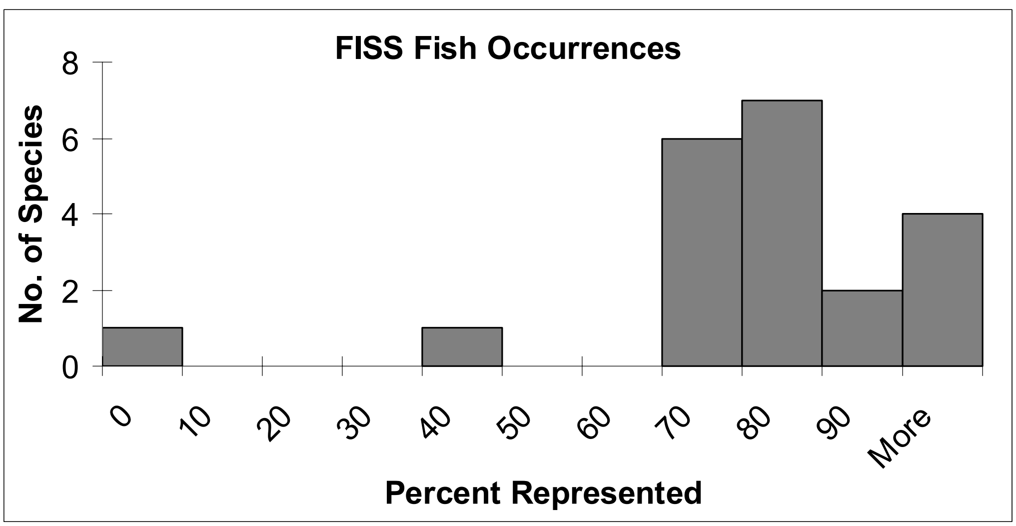


Figure 10.6 Representation achieved within the MK CAD of special element fish species identified in the FISS data for which representation goals were not established.

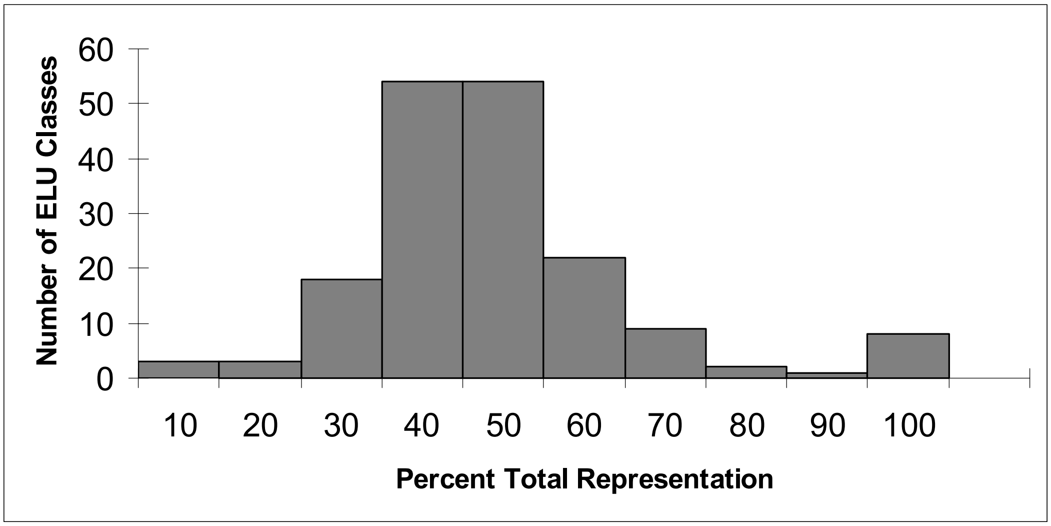


Figure 10.7 Representation of terrestrial ELU types in Primary Core Areas.

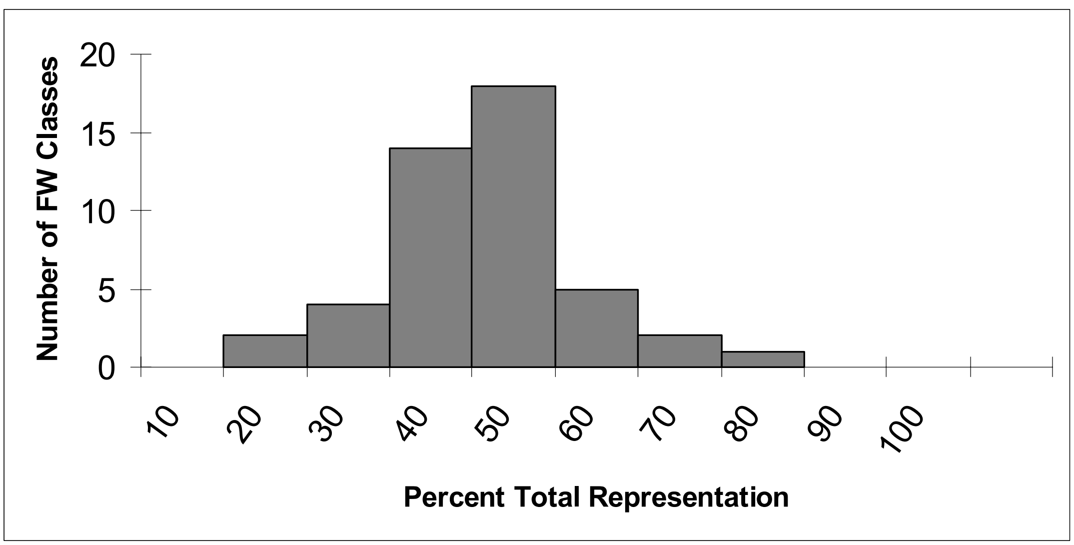


Figure 10.8 Representation of freshwater stream classes in Primary Core Areas.

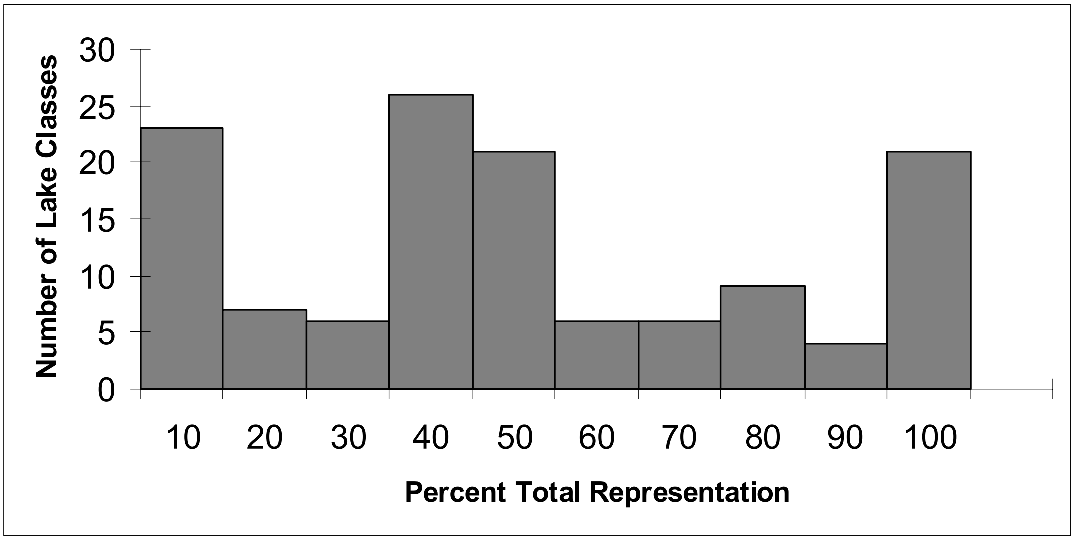


Figure 10.9 Representation of freshwater stream classes in Primary Core Areas.

11 CAD GIS TOOLKIT

11.1 Background and Purpose

The MK CAD GIS Toolkit allows managers, planners, project proponents and other stakeholders convenient access to CAD models and analyses. The Toolkit is spatially-explicit and graphic: the datasets are viewed in a GIS environment as georeferenced maps of the MK CAD study area with roads, rivers and other features displayed for reference. It is dynamic: the user can pick datasets and change viewing areas and scale of view. It is analytical: users may explore the ecological consequences of potential development projects and gain insights into the ecological costs and benefits of alternative scenarios. It is regional in scope: data summaries and scenario analyses are evaluated and reported at a regional scale. Finally, the MK CAD GIS Toolkit is easy to use; it allows non-technical personnel access to sophisticated GIS functions, without reducing the utility of the product for the professional analyst. While the digital data provided with this report (see Appendix J for a list of these data sets) can be accessed directly through ArcGIS or ArcView, the MK CAD GIS Toolkit provides a simple interfacing and analysis interface.

11.2 Toolkit Interface

The CAD GIS Toolkit is implemented through an ArcGIS-based project (.mxd file). This project has been modified to serve as a user interface for non-GIS personnel and ensure that they are not overwhelmed by the complexity of the full ArcGIS interface. Our custom analysis tools go beyond the basic GIS functions and allow non-GIS users and professionals alike to perform planning analyses based on the MK CAD models and data. The Toolkit retains the full functionality of ArcGIS so that the GIS professionals will not be hampered if they choose to use the Toolkit in concert with more sophisticated GIS functions. Both the Users Manual (Appendix K and the Developer's Guide (Appendix L) provide technical details of the Toolkit.

11.3 MK CAD GIS Toolkit Functions

The Toolkit is comprised of three basic functions within a custom ArcMAP interface: data viewing, data summary and scenario analysis tools. We describe the basic functions and utility of each tool, as well as the irreplaceability index that provides additional insights into the ecological value or irreplaceability of Planning Units.

11.3.1 Data Viewing Tool

The GIS Toolkit allows the user to easily view the suite of CAD models and analyses without being a trained GIS technician. Additionally, accessing the digital data through the Toolkit allows exploration and viewing of the information in more detail than would appear on a paper map. Accessing the digital data allows users to focus on a specific area of interest at whatever scale they choose. They may also view different combinations of data than those presented in this report, and adjust their view choices as they explore the data. Accessing the MK CAD digital data directly through the Toolkit allows users to create and customize the look of maps and print them for incorporation into reports, distribute them for discussion or include them in oral presentations. These capabilities are not unique to the Toolkit, they are part of any good GIS system. Simplifying these tasks within the Toolkit necessarily limits the versatility over a full GIS, but also provides a useful suite of basic viewing and mapping tools to users with little or no GIS experience.

The Toolkit starts with a pre-selected set of base data layers loaded and displayed. A number of others are loaded for convenience, but not displayed to avoid undue cluttering of the viewing window. The legends and symbology for these data layers have been created by our GIS analysis team, and are automatically available to the user to assist in the viewing and interpretation of the data. A select number of easy-to-use standard data viewing tools such as pan, zoom, return home and a ruler are available in a custom toolbar. More complex tools of ArcGIS are not displayed on the toolbar, but are all still available for advanced users through the drop-down menus.

11.3.2 Data Summary Tool

An important utility of the GIS Toolkit is facilitating exploration of the CAD results, including the full suite of component analyses (focal species models, coarse-filter classification, fine-filter occurrences, connectivity analyses) and the CAD class designations (Primary Core Areas or PCAs, Connectivity-Secondary Core Areas or CSCAs, Supplementary Sites or SSs). Users can select to load an analytical component at its original resolution for viewing and querying; this provides the highest resolution presentation of the component analyses (e.g., focal species habitat model). Alternatively, the user can summarize all of the conservation target values within a selected area through the GIS Toolkit data summary tool, which operates through summaries linked to the 500-ha Planning Units (PUs). Through the summary tool, the full suite of conservation target values found within an area can be quickly and easily summarized and presented through tables and spreadsheets. The values are automatically stratified by the MK CAD classes (PCAs, CSCAs and/or SS), though global summaries are easy to generate as well. The summary function of the Toolkit will be useful for assessing the full suite of conservation target values (e.g., focal species habitats, coarse-filter class types and amounts) within a specific project area or for comparison of relative values across a suite of project alternatives. Users interested in specific target value (e.g., Stone's sheep habitat) can use the summary function and pull out just the applicable table sections from of the MS Excel file that the tool automatically exports.

There are two ways to select a Project Area for data summary. The first is an easy-to-use interactive editing tool which allows Planning Units to be defined by the user (Figure 11.1). The second method allows the user to select a feature such as a landscape unit, trapline area, or watershed from a pre-existing data layer (Figure 11.2). This second method allows the user to easily and quickly define a Project Area with a complex boundary and receive a detailed summary of the entire suite of CAD values. In addition to providing the amount of each conservation target within the identified Project Area, the summary tool also provides the proportion of that target for the intersecting River System strata (Section 2.4.1). For example, the output would contain:

- # ha of marsh,
- % representation of total marsh within the River System.

The percent of a conservation target that is represented with a Project Area provides important insights into the relative importance of the Project Area for the maintenance of the target within the region (i.e., River System).

11.3.3 Development Scenario Analysis Tool

The development scenario analysis tool is a custom designed function that can be used in conjunction with the rest of the Toolkit by non-GIS users, or independent of the Toolkit interface by experienced GIS professionals. The development scenario analysis tool allows the user to compare the conservation target values and the amount of each CAD class across up to 3 different potential development configurations within an identified Project Area. These development scenarios can consist of both linear features (e.g., roads) and area features (e.g., cut-blocks, oil pad clusters, etc), and can be digitized directly through the Toolkit functions or imported from existing spatial data. Thus, the analysis requires the definition of a Project Area, and each development scenario either through interactive digitizing through the tool or by importing previously created files. The different scenarios are automatically compared graphically and in tables so that the user can see the conservation targets potentially affected by each scenario, as well as the amounts of Primary Core Area, Connectivity-Secondary Core Area, or Supplementary Site affected. In addition, the tool reconfigures the original CAD by reclassifying any PCA, CSCA or SS class Planning Units that are intercepted by the linear or area features of a scenario to "matrix" (i.e., not a CAD class). It then uses a greedy heuristic search to replace the target values for each affected (reclassified) PU within each CAD class. The search for replacement is limited to the defined Project Area. If replacement PUs can be found, the total amount of conservation target values within each CAD class is restored, though efficiency and integrity of the CAD could be reduced. If the lost target values were within PCA, the tool replaces the values by reclassifying selected CSCA or matrix PUs to PCA. If the lost target values were within CSCA, searching for replacement values is restricted to matrix areas (i.e., it will not reclassify PCA to CSCA). Target values lost within the matrix PUs are not replaced.

Because the original CAD analyses preferentially selected the highest value PUs available (given the diversity of targets and cost constraints, see Section 10), the total number of PUs needed to fully replace the values removed from CAD classes would be expected to be higher than the number actually affected. The replacement analysis replaces the amount of value lost, not just the amount of area lost. Thus, the replacement of 3 PUs of high value moose winter habitat may require the selection of 6 PUs of moderate quality moose winter habitat to replace the total habitat value. The replacement area needed will vary according to the values that need to be replaced and those available to use for replacement. Generally, the loss of higher quality PUs will require larger numbers of replacement PUs.

The greedy heuristic algorithm attempts to minimize the potential fragmentation during the reconfiguration analysis by searching for PUs that are adjacent to (unaffected) CAD classes. While this is effective at reducing selection of isolated PUs, it can result in long fingers of replacement PUs and a higher the edge: area ratio of the CAD class.

The results of development scenario analysis are displayed in the viewing window and are exported as an MS Excel file report. The graphic display shows the original CAD configuration and the new configuration with converted Planning Units of each type (PCA and CSCA; Figure 12.3). All development options and option-specific reconfiguration can be displayed or the display turned off for individual options. They may also be printed for side-by-side comparison across the options. The report will describe the conservation values impacted by each option, the area needed to replace the impacted values (if replaceable) and the conservation values of the newly generated PCAs, CSCAs and matrix areas. These will be reported as absolute units and as proportions of total available.

The development scenario tool allows the user to see what targets were replaceable within the user-defined Project Area, and which values were not replaceable. They will also gain insights into the relative importance of each affected Planning Unit and individual conservation targets within the Project Area and the region. These outputs are useful for comparing the relative impact of development options both in terms of the values impacted and the additions to the CAD classes that are needed to replace target values. The Project Area boundary can be expanded to encompass a wider area such as a watershed, a watershed group or a River System to explore regional replaceability (or irreplaceability) of affected conservation target values.

11.3.4 Irreplaceability Index

To provide insights into ecological values affected by a potential development, we generate an "irreplaceability index" for each Planning Unit and a summary of this index for the watershed group to which the Planning Unit belongs. This index is simply the number of Planning Units needed to replace the conservation values found in any particular Planning Unit. This is different than trying to find the best reconfiguration in that adjacency is not a concern and only one Planning Unit at a time is being replaced. Including adjacency concerns (that is assuring that a PCA PU is replaced adjacent to existing PCA) would limit the index to the current CAD configuration. By relaxing the adjacency rule, the index is generalized to any number of possible CAD configurations. This index is relative and even though it is calculated as "replacement value", it may take more (or less) Planning Units to actually replace it in a real scenario analysis due to the adjacency rule applied in development scenario analyses. The best irreplaceability index value (i.e., lowest potential impact) would be one, implying that the Planning Unit can simply be replaced with one other PU, and therefore there is no management cost in the amount of area needed to replace the PU. Conversely, it might take several PUs to replace the values in one Planning Unit. If the features within the PU are unique, they would be irreplaceable even searching the entire study area.

The irreplaceability index is dynamically and temporarily updated after each development scenario option analysis as affected PCA and CSCA PUs are reclassified and new PCA and CSCA PUs are generated. This allows the implications of each development scenario to be assessed in terms of future flexibility; increasing the number of PUs that have high irreplaceability indicates reduced flexibility for management that maintains the conservation target representation and integrity goals the MK CAD. These adjustments to PCA, CSCA and the irreplaceability index are stored in temporary files (although the user can save them); the underlying CAD classes and PU irreplaceability index scores are not altered. The irreplaceability index displayed is aggregated into high, medium or low for ease of viewing, but the underlying values are reported in the accompanying excel data file.

11.4 Appropriate scale and limitations

The re-analysis undertaken by the development scenario tool of the Toolkit lacks the robustness of the original CAD analysis, as it cannot repeat the sophisticated set of methodologies used for the CAD site-selection analyses. Within these limitations, the tool serves as a convenient and relatively immediate means for exploring and comparing data and development options, but it should not be construed as a means to create an alternative CAD classification. The insights gained through these explorations are primarily relative to each other. They also present a simplified version of how the CAD is changing through time, allowing the user to decide the merits of developing particular areas. This can provide insights about risks to successful management that achieves the conservation intent of the MKMA, as outlined in the MK Act. It may also provide an indication of when the MK CAD or some of its component analyses may need updating (see Section 12).

Additionally, the CAD analyses, and thus the Toolkit, are not designed to support operational or site-level planning, or to provide economic or technical feasibility analyses. The scale of the Planning Units employed in our analyses is 500 ha, allowing for regional and landscape-scale analyses but not fine-scale site decision support. The CAD analyses and data attributed to these 500-ha PUs are available for query and summary, and these summaries can inform the types of investigations or ecological sensitivities that should be considered for additional site-level planning.

11.5 CAD GIS Toolkit Utility

There are a number of uses of the Toolkit for potential users, including managers, planners, technical support personnel and stakeholders. A few of the most apparent uses of the Toolkit to provide interactive and dynamic use of the MK CAD are described here and summarized in Table 12.1.

11.5.1 Providing Baseline Measures

The set of CAD analyses provide a reference model of the conservation status of the MK CAD study area in 2004 using current data and methodologies. As development and natural changes occur in the region, and as new studies provide additional data, the reference model can serve as a framework for guiding research, projects and data collection. For instance, if funds are to be allocated towards gathering additional data on species habitat use and availability, the MK CAD focal species modeling and CAD analyses can provide insights about stratifying the effort towards the most important data gaps or spatially to areas where model validation may be particularly useful. Moreover, it will allow these decisions to take place in the context of the whole MKMA, and even within the broader context of the ecological boundaries of the MK CAD study area. In the medium and longer term, the CAD suite of analyses and tools will allow meaningful measures of how much change has occurred across a number of ecologically important characteristics. For example, one might find 20 years from now, that fire suppression efforts have reduced the quantity of early seral stage forest to 30% of its 2004 level for particular management unit. This result may trigger changes to management regimes. We provide readily available data and analyses for the entire MKMA and the surrounding region that is in a format amenable to future analyses and reporting. This will be particularly important in understanding regional cumulative effects to the conservation targets. While we recommend and encourage the updating of all the data and analyses to maintain the relevance of the CAD to present management, we also encourage the longer term reference to the present 2004 product as a baseline analysis

11.5.2 Convenient Data Viewing and Summary

The datasets provided with the MK CAD include over 100 different GRIDS, coverages or shapefiles (Appendix J). Each covers the full extent of our 16 million ha MK CAD study area and can be quite large. The viewing tool provided in the Toolkit allows the user to seamlessly navigate through these large datasets and explore specific areas at various spatial scales. Any of the multiple data layers can be viewed in combination or separately, including the results of our CAD analyses at their original resolution or summarized to PU, the background data (e.g., infrastructure, physical and administrative boundaries) and any user-generated scenario analyses. The summary tool provides the user with the ability to summarize the broad suite of conservation target values across the different CAD classes within user-defined Project Areas. This tool will be an invaluable resource to users attempting to summarize across the more than 500 conservation targets identified through the MK CAD.

11.5.3 Comparison of Proposed Resource Development Options

The development scenario analysis tool (Section 11.3.3) will provide the ability of users to compare across different potential configurations of developments within an identified Project Area quickly and easily. The suite of conservation target values potentially impacted by a particular project configuration are summarized and compared. Additionally, the ability to "replace" those values within the extent of the identified Project Area is assessed, with the replacement areas explicitly identified. This tool provides not only the identification of areas that can potentially replace impacted values, but, as importantly, it identifies which values cannot be replaced or cannot be fully replaced within the Project Area.

11.5.4 Early Indicators of Change in System Resilience

Indication of changes in system resiliency can be seen by the extent of change in PCA and CSCA needed to replace the conservation values affected by a potential development. Perhaps even more telling are the results that demonstrate the change in the number of conservation values that are not able to be replaced if certain developments proceed. As a general principle, development of any area will increase the irreplaceability value of remaining ecological values in an area. This is captured both through the number of PUs required to replace those values within a specified Project Area as well as the irreplaceability index of the PUs. Development of high conservation value areas will trigger much broader and more significant increases of irreplaceability, compared to development of lower value areas. Whether development occurs in a very few, high value areas, or very many, low value areas (or, as is likely, as a combination of both), at certain development levels, options for replacement of conservation values become very limited. At these thresholds, constraints on subsequent developments will be unavoidable if the conservation of the biodiversity targets are to be maintained.

11.5.5 Monitoring Regional Cumulative Effects

The MK CAD GIS Toolkit can provide a regional or Project Area monitoring tool across multiple development projects. As individual projects proceed within an area, they can be included within the development scenario analyses, or suites of potential projects can be simultaneously assessed within the tool. Analyzing projects individually allows the user to understand the implications of a specific project. Insights into the cumulative effects of multiple projects can be obtained through the scenario analysis tool by creating an appropriate Project Area for analysis, including all projects of interest and evaluating the changes in CAD configuration and the replaceability and irreplaceability of affected PUs.

11.6 Conclusions

The GIS Toolkit significantly advances the accessibility and utility of Conservation Area Design to managers, planners and stakeholders. While the spatial data provided with the MK CAD can be accessed through any GIS, the GIS Toolkit provides this access to non-GIS users through a simple interface. Both advanced GIS analysts and non-GIS users will find utility in the data summary tool as a seamless and efficient analysis across multiple large and complex data sets. Additionally, the development scenario analysis tool allows dynamic interaction and exploration with the MK CAD information that would not be easily available through any GIS. Importantly, it provides insights into the potential implications of development projects within the MKMA, as well as across the extent of the MK CAD study area. These analyses can be used to explore development options, as well as maintain a record of the changes to conservation value targets in the face of increasing development pressures. It expands the capabilities of the CAD modeling and results beyond a static report and map by including managers, planners and other stakeholders in an interactive process that incorporates real-world changes in the study area. This extends the useful life of the CAD products and ensures that project development is informed in a biologically meaningful way by the CAD analyses.

11.7 Tables

Table 11.1 Short list of potential utility of CAD GIS Toolkit.

Function	Basic tool
Provide a dataset of baseline conditions	Viewing tool
View data	Viewing tool
Summarize data	Summary tool
Provide regional-scale context for projects	Summary tool, Scenario tool
Compare project options	Scenario too
Provide indicators of change in system resiliency	Scenario tool
Facilitate understanding of effects through time	Scenario tool, viewing tool

11.8 Figures

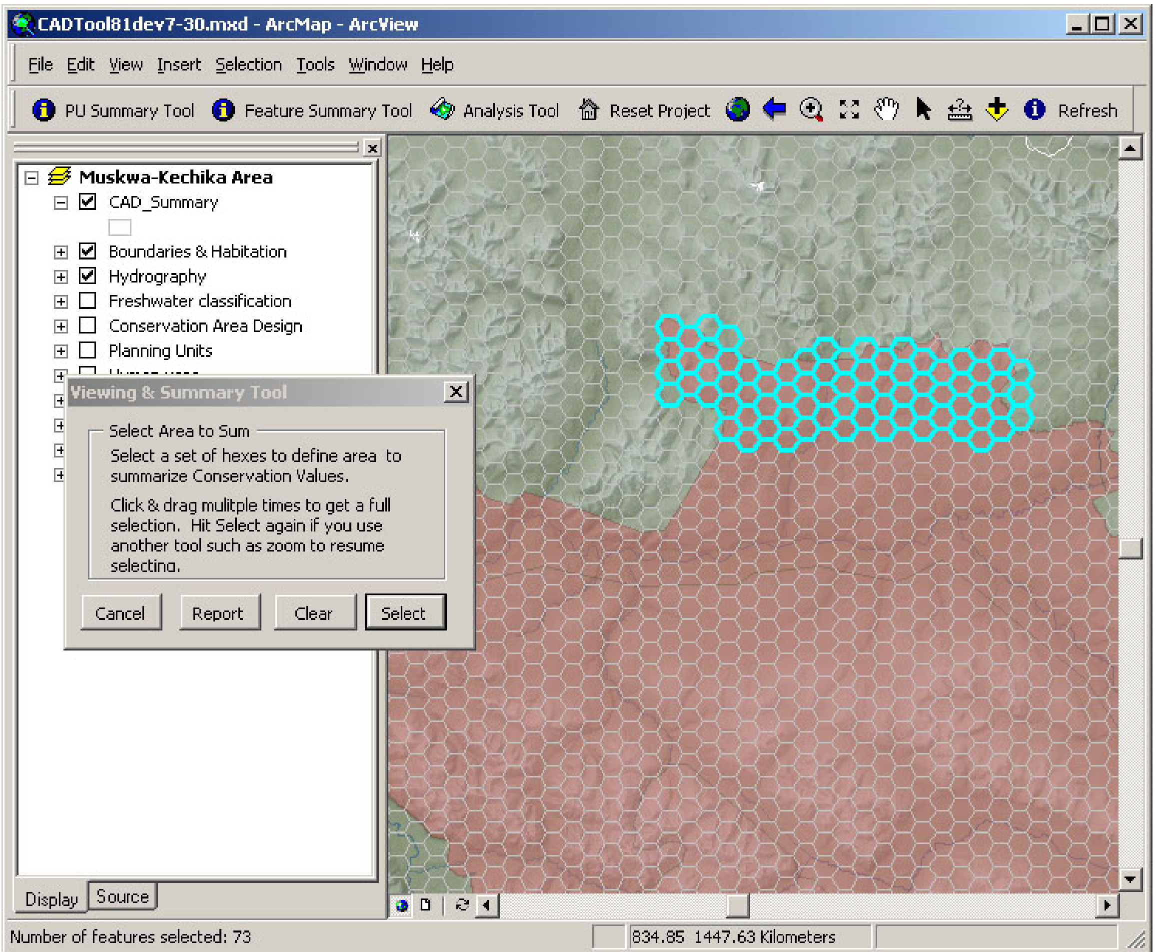


Figure 11.1 Selecting Planning Units by the GIS toolkit summary tool.

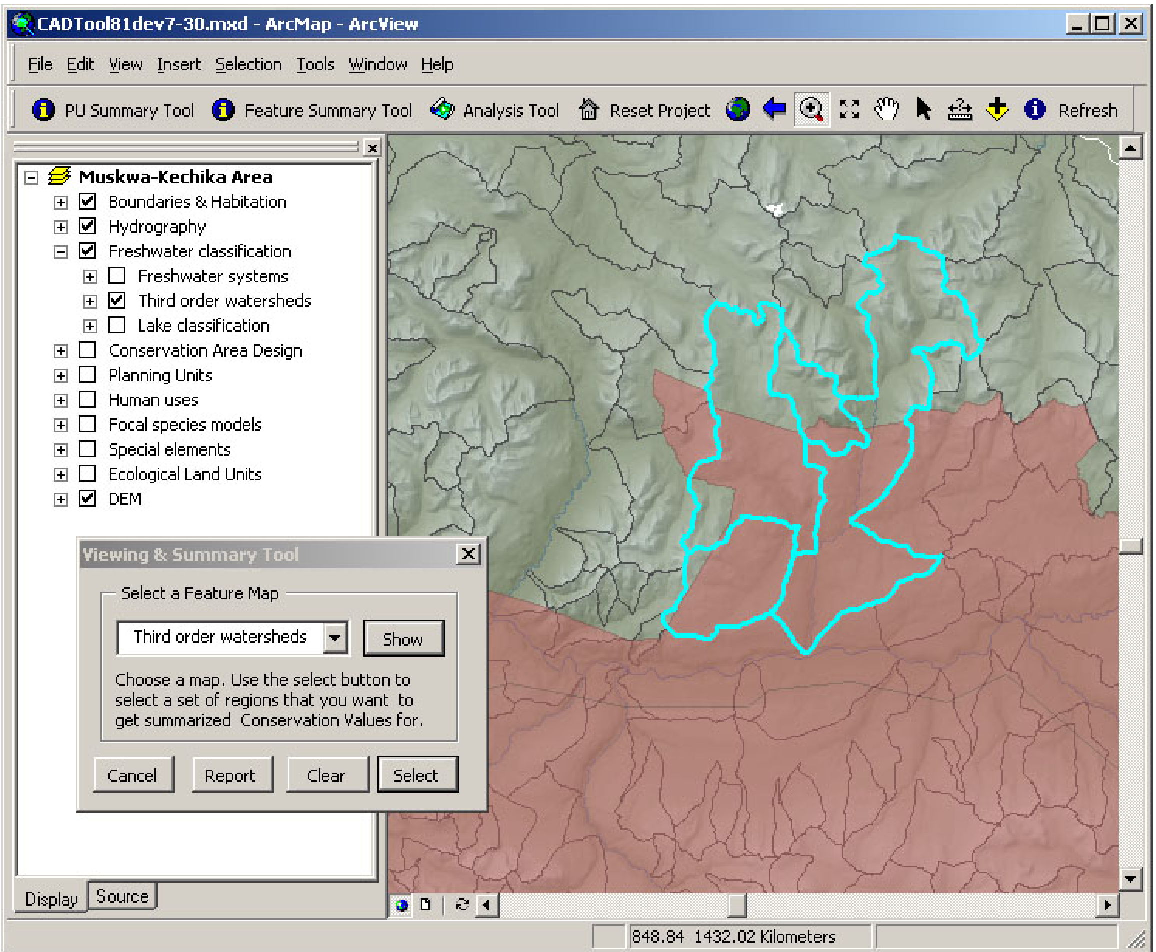


Figure 11.2 Example of selecting third-order watersheds to define a Project Area.

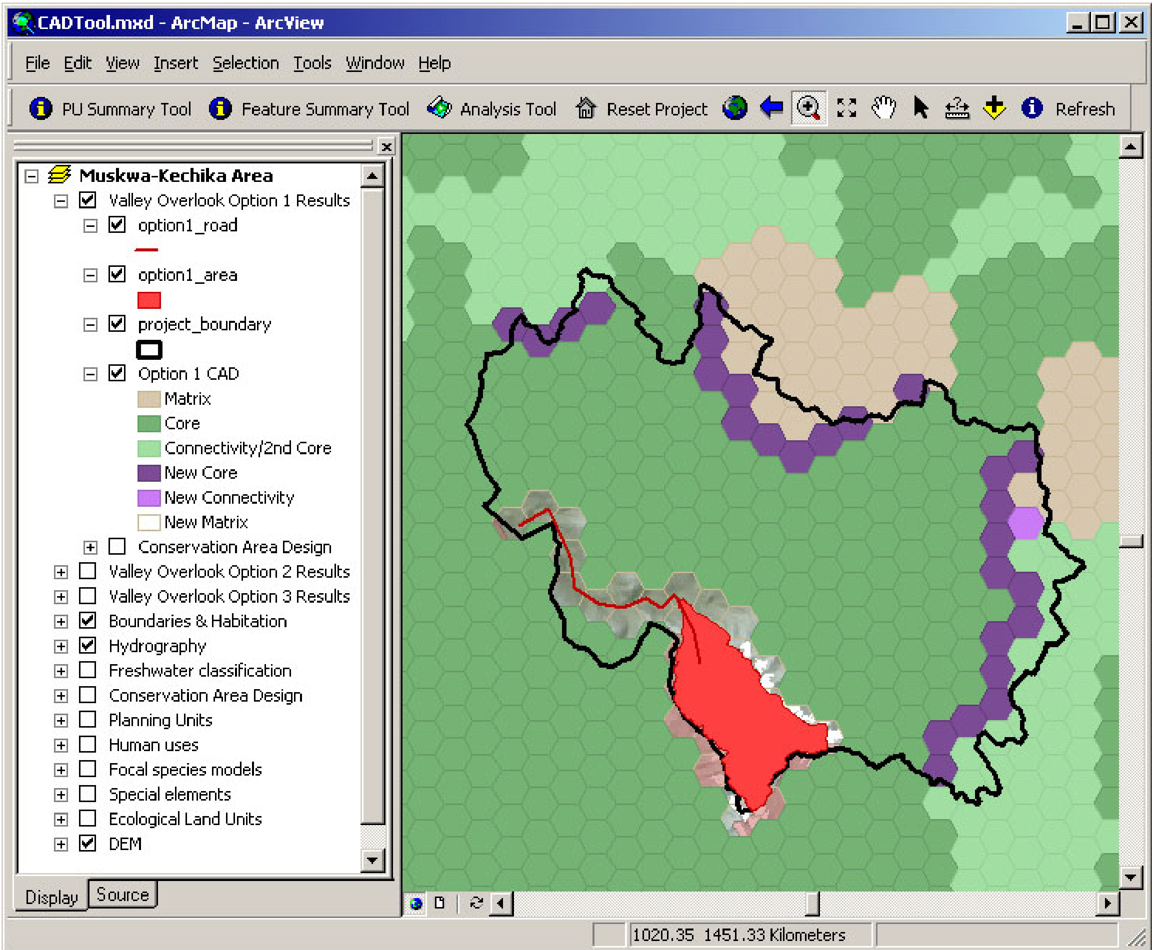


Figure 11.3 Example of the visual display resulting from a single-option scenario tool re-configuration of the CAD*.

*The red polygon and line represent the development option that has been analyzed. All PUs intercepted by the option are classified as "matrix", and replacement values for PCA and CSCA are sought within the Project Area (black outline). Replacement PUs shown in dark and light purple (PCA and CSCA replacement, respectively)

12 RECOMMENDATIONS: IMPLEMENTATION AND NEXT STEPS

12.1 *Implementation*

12.1.1 Anticipated Utility

The Project Team maintained close liaison during the development of the MK CAD to ensure that CAD products were tailored to match intended use. In several cases, detailed discussions on analytical components and the GIS Toolkit interface led to significant refinements and improvements. It is recognized, however, that the planning and management regime for the MKMA continues to evolve, and that such evolution in approaches can be expected to accelerate as the pace of industrial development in the MKMA increases over time. In light of that, the MK CAD has been framed so as to be amenable to a diversity of applications, as well as refinements as new data and techniques become available. Because the MK CAD study area covers a substantial area surrounding the MKMA, it should have utility to both to managers of the MKMA as well as in these surrounding regions. Additionally, it provides the ability to assess potential implications of activities occurring on either side of the MKMA boundary.

In the current planning and management environment, the MK CAD has utility for a range of applications, as set out below.

- *Consistent regional data coverage*: At its most basic level, the MK CAD has assembled data from across the MK study area in a consistent and transparent fashion. This is particularly valuable given the range of data sets and the complexity of data access for different agencies under existing information management systems.

- *Identify scope of values in a project area:* The MK CAD enables individuals (e.g., agency staff, third parties with licensed access to the data) to extract information on a large suite of conservation values within a defined project area, and to link strategic-level and operational-level resource management issues. This functionality may be of particular use in the development of overview assessments or development plans for oil and gas proponents, and for the development of *Forest Stewardship Plans*. The MK CAD may also be of future utility as a tool to assist with management of species at risk, as required under the federal government's Species at Risk Act.

- *Set local areas in regional context*: The MK CAD analyses and spatial data, particularly as accessed through the GIS Toolkit, provide a consistent and transparent regional context for assessment of values in a local area. This functionality informs decisions regarding the pace of development and the distribution of impacts across the landscape, and thereby could contribute to discussions regarding cumulative impact management at the screening level.

- *Transparency for regulatory decision-making*: The MK CAD can increase the transparency of reviews and refinements of planning documents, permitting processes or tenuring decisions. The data summary functionality of the GIS Toolkit provides an efficient summary of the MK CAD data and analyses for any project area, and enables regulators to provide an easily documented and definitive rationale for decisions, and to share the information with users and stakeholders. Agency staff suggested, for example, that the CAD may be used over time for review and refinement of park management plans in the MKMA.

- *Scenario analysis*: The GIS Toolkit scenario tool provides managers and regulators with the ability to simulate and compare various alternative configurations of potential projects, assess the implications of each scenario on the regional conservation values, and inform discussions of trade-offs and risks. One possible application in this regard is strategic access coordination in areas where multiple industrial users (e.g., forestry, oil and gas) may be proposing road development.

- *Monitoring in the MKMA:* The MK CAD can be used over time as a vehicle to maintain up-to-date information on landscape changes from development, and to facilitate the coordination of monitoring by such bodies as the Integrated Agency Management Committee (IAMC).

12.1.2 Presentation to Third Parties

As noted above, the development of the CAD included close liaison with agency staff. The potential of the MK CAD may be augmented over time, however, by additional data from third parties, and by incorporating other analytical and assessment tools under development or already in place.

We recommend that early efforts be made to engage First Nations, industry associations, user groups and other interested parties in dialogue over the MK CAD and its utility now and in the future. Such discussions would include a review of the various elements of the CAD (e.g., data layers, analytical components, CAD design, GIS Toolkit), demonstrations of functionality, and discussion over current and potential applications.

Following such presentations, more detailed discussions are needed within Ministry of Sustainable Resources (MSRM) and other agencies to determine a clear strategy for the integration of MK CAD with various analytical, planning and management tools for the MKMA. This follow up may be a complement to the review of completed local strategic plans and management tools for the MKMA, as recently proposed by the MK Advisory Board.

12.1.3 Accessibility to CAD Products

The CAD GIS Toolkit will be the primary access point for CAD data, analytical components, results, and data access, summary and scenario tools (see Section 11). The Toolkit is designed to be deployed through an ArcGIS interface, supported by MSRM's Business Solutions Branch. While all CAD elements will be stored centrally by the province and remotely accessed by both existing and custom software tools, consideration should also be given on how best to allow third-party access to the analysis and tools. Access could be arranged through license and partnership agreements and/or the distribution of pre-packaged data sets to important MKMA stakeholders such as First Nations. Specific recommendations regarding necessary technical capacity required to house and maintain CAD and the GIS Toolkit are being defined as part of an ongoing discussion with MSRM staff.

12.1.4 Updates and Refinements

Updates to the CAD should be designed to accommodate on-going consolidation of information regarding landscape-scale changes to the MKMA and surrounding region, including the development of new roads and infrastructure, new cut blocks, burns, etc. We recommend that a detailed strategy for updates and refinements be developed and implemented through the IAMC, with refinements being made by MSRM technical staff. These updates are critical to maintain the utility of the CAD data library and analyses.

It is important to recognize that CAD updates and refinements will vary considerably in terms of complexity. Generally speaking, the more complex the update process, the less frequently it will be preformed and vice versa. Our initial suggestion for the update and refinement strategy is summarized below and in Table 12.1.

12.1.4.1 Incorporating Additional GIS Data Sets

Perhaps the simplest form of update involves bringing additional data layers (e.g., more accurate forest inventory data from forest companies, new occurrences of fine-filter species) into the CAD GIS Toolkit and using those layers to compare with MK CAD layers. Such additions and comparisons can be undertaken 'on-the-fly' and we would encourage mangers and GIS staff to engage in an ongoing, ad hoc process of introducing new data at multiple scales to review against the regional context presented in the CAD.

12.1.4.2 Refining CAD Analytical Components

Compared to the process of adding new data layers to a GIS project, the process of integrating ongoing field validation and analysis of CAD data inputs presents a more difficult challenge. Where possible, future MKMA research initiatives should be directed toward improving the underlying data supporting CAD analytical components (e.g. VRI used for the ELU analysis). As the accuracy and reliability of these data sets are improved, appropriate CAD analytical components should be evaluated relative to how well the classification or model still captures the values it is intended to describe. The timing of these evaluations will depend on the frequency and availability of ongoing research, but we would recommend that annual evaluations of CAD analytical components be undertaken where underlying data is in the process of being altered or improved.

12.1.4.3 Refining the CAD

Just as analytical components need to be evaluated relative to the changing underlying data upon which they were built, so to must the CAD be evaluated as its constituent analytical components are changed and refined. This evaluation can be performed as a fairly straightforward GIS task that evaluates how the existing design of Primary Core Areas and Connectivity-Secondary Core Areas represent the adjusted analytical layers. For example, if improvements to the VRI have triggered a re-running of the Mountain Goat model, the CAD should then be evaluated to see if the new values described by the model are still adequately represented in the CAD. The robustness of the CAD to such changes should be tracked and evaluated to provide guidance on updating the CAD. Unlike the representation check itself, we would expect that updating of the CAD will require a substantial commitment of resources. For that reason, we would expect that updates to the entire CAD to be less frequent events, but recommend that such updates be conducted at a minimum every 5 years.

12.1.5 Capacity for On-going Management of MK CAD Elements

The long-term maintenance of the CAD and its constituent elements will depend on a continued commitment by government to manage access to the CAD, and to update and improve the product. We predict that maintenance and delivery of the CAD will require approximately an ongoing 5% FTE commitment by GIS staff. Necessary capacity for updates of any single CAD component (e.g. a focal species model) will vary considerably depending on the nature of the update. Such updates will certainly require time commitments from both a staff biologist and a GIS technician. Meanwhile, a full re-running of the entire CAD will require commitments from planners, GIS technicians and scientists with experience in wildlife biology, freshwater ecology, plant community ecology, data management, computer programming, and modeling. While this version of the MK CAD involved an 18 month commitment from the Project Team, we would expect subsequent iterations to have substantially decreased the time commitments. Table 12.2 provides an overview of skills necessary for re-running the CAD while Table 12.3 provides a rough approximation of the time commitments required by staff under the assumption that future CAD iterations would be carried out in a 12-month planning period.

12.1.6 Limitations of Use

Despite the breadth of potential utility described above for the MK CAD, several over-arching limitations need to be articulated. Substantial challenges were faced in the production of the CAD, not the least of which involved data and technical limitations posed by undertaking a planning initiative for such a large study area. In particular, it must be understood that the CAD analysis was developed based upon existing data sets that were made available by government and other stakeholder groups. Further, while future work will be aimed at creating dynamic models which attempt to predict change in conservation values over time, this version of the MK CAD represents a static assessment of conservation values as they currently exist on the landscape. Additionally, the models for focal species and ecosystems must be recognized as being regional in scale and the information is not appropriate, or intended for, decision-making at stand or operational scales. Unfortunately, the scope and timing of the MK CAD project prohibited any substantial validation efforts or ground-truthing. While some models had tested with independent data (e.g., terrestrial focal species), none of the models presented have been adequately validated or ground-truthed.

12.2 Next Steps

The planning team strongly recommends that follow-up be undertaken to continue to improve the robustness of the CAD. This work should include field studies to validate CAD models, as well as the targeted collection of traditional and indigenous knowledge (TEIK) from First Nations to assist in refinement of ecosystem and focal species models and further identification of special elements and features. We also recommend that further implementation support be directed toward integration of CAD products with evolving adaptive management, cumulative effects and monitoring approaches. Finally, in order to advance implementation of the CAD, we suggest the design of 1-2 focused pilot studies where development is anticipated within the MKMA (e.g. forestry, oil and gas).

12.2.1 Research Priorities for CAD Refinement and Validation

12.2.1.1 Incorporating traditional and indigenous ecological knowledge

Traditional and indigenous knowledge forms a critical underpinning for understanding land use within the MKMA. We recommend that a process for integrating Traditional and indigenous ecological knowledge (TIEK) be initiated as part of a targeted effort to bring important and vital information into the CAD's description of ecological values in the MKMA. In particular, TIEK can play an important role in the validation and refinement of CAD models and classifications. TIEK can also substantially improve the CAD's fine-filter database by identifying unique, rare, or keystone habitats and features, as well as occurrences of species, and/or hotspots.

12.2.1.2 Validation and ground-truthing of CAD component analyses

All analytical components that predict ecological values should be validated using independent data sources and ground-truthing. Unfortunately, constraints within the MK CAD project limited the ability of the Project Team to undertake this critical step, and all CAD analyses need to be tested against validation data. This includes the aquatic and terrestrial focal species habitat suitability models, the terrestrial and aquatic coarse-filter classifications, and the CAD analyses of connectivity and core habitat values.

While a substantial amount of validation was completed for the terrestrial focal species models, the attribute information provided with the GPS collars was inadequate to enable a rigorous testing the models. Additionally, these animal locations are spatially-limited relative to the extent of the MK CAD study area. Given the importance of the terrestrial focal species in the CAD analyses and in the region, we would strongly recommend that further validation and refinement efforts be focused on these models.

In addition, we would strongly recommend that, in combination with the recommendations below regarding improved land classification data, that validation and ground-truthing focus on the terrestrial ecological land unit model. This model provides a uniform land cover map at a relatively fine-scale across the extent of the region, and as such, is a valuable stand-alone product of the MK CAD effort. Unfortunately, the underlying data are problematic in areas of accuracy and resolution, and the predictions of the ELU model should be evaluated based on other, independent data sources.

Field validation efforts can be combined across many of the models so that data collected could be used to check multiple predictions of focal species habitat quality, ELU classes, etc. As such, investment in field validation represents a solid investment in testing and refining the MK CAD analyses and the data upon which they are based

12.2.1.3 Priorities for improving basic environmental data

Land cover classifications (vegetation interpretations) are critical data, not only to the MK CAD analyses, but to numerous landscape management decisions and practices. Existing uniformly available land cover data for the region is limited in resolution and accuracy, and limits the confidence that can be invested in any analysis using it. In particular, an acceptable classification of the extensive and diverse alpine and subalpine habitats of the region is lacking, and may represent one of the most critical data gaps identified through our analyses. Current alpine classification available across the region identifies that vast majority of the alpine area simply as "rock and rubble" (VRI classification). We strongly recommend that alpine vegetation classification, in particular, be undertaken. While the region would be well-served by a full investment in such a classification, even a coarse-scale evaluation using readily available satellite imagery were be a vast improvement over the currently available data.

Human use data are another critical data gap identified through our analyses. There is a lack of usefully-attributed, regionally-available spatial information regarding human infrastructure and activity levels. The human infrastructure and use data that are available are have extremely limited associated attribute information that is key to providing insights into the current and historic conditions and use of the identified features (e.g., while cutlines are identified in TRIM 1:20,000, we were unable to find documentation as to their age, width, activity levels). Most data we obtained were poorly documented with unknown or sparsely documented updating or maintenance information. Many key human infrastructure and management data were essentially inaccessible, due to poor access to them (e.g., distributed solely within a number of district or local offices, such as tenure data) or because we would be unable to amalgamate diverse data sources into a uniform regional coverage due to their patchy distribution, different resolutions and variable attributing. Given the importance of human use and infrastructure in determining the condition and sensitivity of landscapes within the region and the MKMA, investment in consolidating, maintaining, updating and providing access to human use and infrastructure data will be a key investment in the long-term management of the region.

An important human use within the MKMA, in particular, is the use of rivers as transportation corridors. We were unable to find suitability information to allow us to include this important access and use information within our analyses. Given the remote nature of the MKMA, jet-boat access into the MKMA represents one of the few motorized transportation routes that provide access into otherwise remote regions. Acquiring basic information on the navigable river routes and their use would provide insights to the human use patterns in the MKMA.

12.2.1.4 Sensitivity analyses of CAD analyses

The MK CAD analyses used a suite of modeling tools, data inputs and a wide spectrum of assumptions to provide predictions and insights into regional patterns of conservation priorities. The robustness of the suite of analyses should be tested through examining the sensitivity of the results to the underlying attributes and assumptions. This recommendation applies to both the MK CAD component analyses (e.g., focal species and coarse-filter classification models) as well as the integration of these into the CAD. Sensitivity analyses would provide insights about both the robustness and the variability in the results of analyses to changes in underlying variables, and, thus, would provide guidance on research priorities. For example, if the caribou habitat suitability model proved highly sensitive to the alpine classification used, this supports our earlier recommendation that investing in an alpine classification is a key research priority. Additionally, we have made several assumptions regarding the influence of different inputs into the site-selection process. Robustness of the MK CAD results in the face of contravening information or assumptions should be evaluated.

12.2.1.5 Testing the CAD configuration

Similar to validating, ground-truthing and sensitivity analyses, there are additional analytical steps that can be used to evaluate the potential robustness of the CAD configuration and its underlying assumptions. Testing and validating regional-scale configuration results is likely as difficult and problematic as the development of the CAD itself. Regardless, analytical efforts such as the development of focal species population viability analyses or the prediction of future environmental conditions can provide insights into the long-term suitability of the MK CAD classifications. We are currently undertaking PVA analyses of regional grizzly bear populations, explicitly to test the CAD configuration results (e.g., spatial distribution and size).

Exploration into the development of fire-modeling to predict future seral stage distributions of land cover showed the difficulty and likely limited utility of such an effort given the quality of existing data. Still, the development of alternative land cover data and the growing information and data regarding boreal ecosystem dynamics may provide new avenues for the evaluation of future landscapes under natural or existing disturbance regimes. Of particular interest would be research into understanding the range of natural variation across key ecological parameters in these boreal ecosystems. These ecological drivers would include fire regimes, forest disease influences and the combined fire and forest disease dynamics of forest seral stage distributions; and hydrologic dynamics (flood, draught, glacier dynamics). Understanding the historic population fluctuations of key wildlife species, as well as other highly interactive species (such as forest insects) would provide insights into the resilience and range of natural variation in these key populations. A greater understanding of the dynamic nature of the ecological systems will provide insights into the adequacy of the MK CAD in maintaining adequate representation levels of the existing suite of diversity and the potential configuration of diversity into the future.

12.2.2 Integration with Future Management Models

The MK CAD holds significant potential for furthering efforts by MSRM and the MKMA Advisory Board to explore and develop future management models, and in particular, Ecosystem-based Management (EBM) frameworks similar to those being developed for the BC Coast. Specifically, the CAD can serve as an integral foundation piece for the management of ecological risk at multiple scales.

12.2.2.1 Role of CAD's in Ecosystem-Based Management (EBM) Frameworks

A CAD allows for the systematic articulation of a number of EBM components including indicators (e.g. mapped habitats, species and ecosystems) and thresholds (from information on viability, connectivity, and ecological process). Further, the CAD's primary role of mapping ecological values is critical to the allocation of ecological risk. These features of a CAD allow it to be integrated into an effective scenario-building tool that allows for the ongoing exploration of risk allocation as conflicts between conservation and development needs arise in a region. In intact landscapes, there is often more than one possible conservation solution, and this spatial variability, when combined with changing conservation and development contexts through time, requires that ecosystem-based management frameworks be supported by robust and flexible databases and decision support tools at the regional scale.

In British Columbia, CAD's are already being developed with these needs in mind. For BC's Central Coast, North Coast and Haida Gwaii, CAD products developed for the Coastal Information Team (CIT) are being directly integrated into the Ecosystem-Based Management Framework under development.

12.2.2.2 Integration with Cumulative Impact Management (CIM) and Adaptive Management Frameworks

Whether as part of a more encompassing EBM framework, or some other management architecture, there is a clear necessity to integrate the current CIM and adaptive management models being considered for the MKMA. As with EBM more generally, we expect that the CAD will lend substantial analytical power to these frameworks by providing a common and comprehensive point of reference for conservation values in the region. The CAD can serve as a baseline for measuring change over time, while the GIS Toolkit should provide a facile and accessible means for evaluating the implications of that change.

12.2.3 Pilot Studies

One potentially informative approach to testing and integrating the MK CAD would involve launching several pilot studies aimed at evaluating the CAD's utility in a real world application. Such pilots would facilitate field validation efforts, create opportunities for implementation by 3rd parties, and advance discussions around future management models in MKMA. Ideally, pilots would be launched in conjunction with other management experiments related to ecosystem-base forestry initiatives and adaptive management regimes. Areas within the MKMA that are faced with a number of diverse and pressing land use priorities would be excellent candidates for pilot studies.

12.3 Tables

Table 12.1 MK CAD update and refinement strategy components

Update or Refinement	**Update Purpose and Scope**	**Update Timing**	**Responsibilities**
Data Library	Make available additional layers for the MK CAD data library; update existing data with new information Ensures accurate and up-to-date information on landscape changes is available for assessment and review	On-going Quarterly	On-going compilation of additional data layers by agencies, with notification to MSRM Decisions on additions by IAMC
Analyses: ▪ Terrestrial and aquatic focal species models ▪ ELU ▪ Freshwater Classification ▪ Lakes Classification ▪ Human use	Review analytical components, and update and refine as needed, based results of field validation, new data sets, and improved modeling techniques Note that assessments are required to determine the influence of new data inputs or improved modeling on analytical results	Annual	Under direction of IAMC, to be completed by MSRM technical staff
Conservation Area Design	Where additional data or improved modeling indicates that analytical results have been affected, re-run overall CAD and assess significance of changes in configuration of design	Each 5 years	Under direction of IAMC, to be completed by MSRM technical staff, possibly with third party assistance
GIS Toolkit	Incorporate new tools and facilitate new approaches as planning and management regime for the MKMA is refined overall	Each 2-5 years or more regularly as funding and the pace of development varies	Under direction of IAMC, to be completed by MSRM technical staff, possibly with third party assistance

Table 12.2 Core skills and competencies necessary for re-running the MK CAD

Skills Required (as per RFP)	Roles and Responsibilities for Project Team					
	Project Management	*Science*	*GIS*	*Policy Analysis and Land Use Planning*	*Expert Advisors*	*Peer Review*
GIS Analyst			√			
GIS Spatial Modeller			√			
Spatial System Modeller		√	√		√	
Conservation Biologist		√			√	√
Wildlife Biologist		√			√	√
Aquatic/Fisheries Ecologist		√			√	√
Population Ecologist/Modeller		√			√	√
Conservation/Landscape Planner		√			√	√
Land Use and Policy Analyst	√			√		
Forest and Fire Ecologist		√			√	√
Social Scientist (TEK)		√				√
Project Manager	√					

Table 12.3 Estimated work effort for full re-running of CAD over a 12 month time-frame

Team Role	% FTE
Project Manager	10%
Conservation Planner	5%
Policy/Social Analysts	5%
Senior Science Advisors	5%
Conservation Biologists	35%
Research Assistant	15%
Aquatic Ecologist	10%
Wildlife Biologist	10%
GIS Analysts	35%
Local Planner Coordinator	25%
Field Technicians	25%
Peer Reviewers	2%
Project Manager	10%

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