A CONSERVATION AREA DESIGN (CAD)
for the
INLAND TEMPERATE RAINFOREST of CANADA

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Executive Summary

This document describes an integrated approach toward developing and refining a Conservation Area Design (CAD) for the Inland Temperate Rainforest (ITR) in Canada. This Design integrated the results of several recent scientific conservation initiatives in the area including the Nature Conservancy/Nature Conservancy Canada's (TNC/NCC) Canadian Rocky Mountain (CRM) Ecoregional Plan, The Rocky Mountain Carnivore Project, and the Yellowstone to Yukon (Y2Y) Conservation Initiative. Data analysis for this project was adapted from the modeling techniques used in "The Weighted Distance and Least Cost Corridor Analysis to Evaluate Regional–Scale Large Carnivore Habitat Connectivity in Washington" developed by the US Forest Service Pacific Northwest Research Station (PNRS) in the Wenatchee National Forest, which was used to study connectivity for wildlife in Washington, Idaho, and British Columbia. Earlier conservation initiatives through the Valhalla Wilderness Society and the Applied Conservation GIS lab (including satellite imagery interpretation, forest cover/TRIM and Basic Thematic Mapping data analysis using BC government data) provided much of the baseline information that was used in this CAD modeling process, and underscored the need for this project; a rigorous scientific approach for identifying conservation priorities.

The methodology for the ITR CAD includes three areas of focus following current scientific agreement, which drove the analysis: focal species analysis, representation analysis, and special elements analysis. We paid particular attention to focal species analysis by addressing core habitat areas and connectivity habitat: critical ecological foundations that have been inadequately addressed in previous planning efforts.

To address focal species core habitat we chose a suite of six species, following the approach of the Rocky Mountain Carnivore Project, that we felt met most of the criteria desired and for which there were adequate data and scientific understanding; and we developed habitat suitability models. To address connectivity, or animal movement, we modified the methodology developed by the US Forest Service PNRS. Comparable landscape characteristics were evaluated for the ITR region in terms of land cover class, human population density, road density, slope, and elevation. Habitat Suitability Indices were assigned to six focal terrestrial species (Grizzly Bear, Wolverine, Lynx, Cougar, Gray Wolf, and Mountain Caribou) for each of the classifications within the five landscape characteristic categories from literature-based expert opinion. These were modeled and mapped for each species to delineate core areas (habitat concentration areas) and least-cost-path connectivity (corridors) between the core areas. Aquatic focal species were addressed using available data for salmon and other aquatic species-at-risk from BC government and Y2Y research efforts. We identified salmon priority watersheds based upon spawning, species diversity, and abundance; and identified watersheds supporting red- and blue-listed aquatic species. Results from all focal species results were combined (overlaid in a Geographic Information System database) to develop a cumulative solution.

To address the special elements (vulnerable, rare, or declining species and communities) and representation (threshold percentages of all natural terrestrial and aquatic habitats)

concerns, we adapted the TNC/NCC representation and special elements analyses results. These were a product of the SITES modeling process (a site selection algorithm helpful in optimizing Ecoregional conservation portfolios) as the “Tier 1 and 2 solutions” (a means to identify high vulnerability and/or irreplaceability: these are areas of high biodiversity that are especially vulnerable to development). We added the results of the Tier 1 and 2 solutions to our focal species results. The sum of the focal terrestrial species, focal aquatic species, and Tier 1 and 2 analyses form the basis of this CAD.

To adequately protect and maintain biodiversity and ecosystem function (using grizzly bears as a yardstick) we feel that it is necessary to implement a CAD that encompasses as closely as possible the areas included in our solution for at least 3 terrestrial focal species (3,4,5&6 species), connectivity, salmon, and representation; or about 10,573,500 hectares (73.9%) of the total area of the BC ITR. Adding in 445,600 ha (3%) for watersheds supporting aquatic species at risk (red-listed) results in a total of 11,019100 ha (77%). This is the minimum landscape that should be managed for biodiversity conservation. To ensure the recovery of caribou it is necessary to implement a CAD that encompasses as closely as possible the areas included in our solution for at least 3 focal species, connectivity, salmon, aquatic species at risk, caribou recovery areas, and representation; about 12,137,000 ha or 85% of the BC ITR.

Managing the landscape for biodiversity conservation does not mean ‘locking up’ 85% of the land in protected areas. In a general sense we can say that it means ensuring that the species and populations that currently exist in the 85% of the landscape delineated by the CAD are not extirpated either directly or indirectly through a variety of conservation measures ranging from full protection to scientifically adequate Ecosystem-Based Management (EBM).

To ensure viable populations of focal species, at a minimum, the areas with habitat for 4 or more focal species should be protected as parks (or the equivalent of ‘designated wilderness areas’ in the U.S.). The same level of protection should be given to priority aquatic habitat (priority salmon streams and species at risk watersheds) and the TNC Tier 1 and 2 areas. Adding these 4+ species cores, TNC Tier 1 and 2 areas, and salmon and aquatic species at risk areas results in a total of 7,873,543 ha or 55% of the ITR which should be ‘protected’. These are considered ‘High Risk’ areas. Of this about 1,070,650 ha (7.5% of the ITR area) is already under Protected Area status, leaving 47.5%, which needs to be protected to ensure maintenance of biodiversity, focal species, and species at risk.

‘Medium Risk’, areas include connectivity habitat and core areas for fewer focal species. Connectivity, or movement habitat (the green ‘corridor’ areas on the final map), should have habitat that is 'friendly' enough for animals to travel through from one core area to another, but individuals don't necessarily need to be resident and/or reproduce in those areas. The green corridor areas represent 2,884,900 ha or 20% of the ITR. In some places these connectivity areas overlap Tier 1 and 2 results and/or aquatic priority drainages. Some movement routes without man-made barriers should be maintained by management actions and/or habitat protection somewhere in those green corridors. Core area habitats for 3 focal species also are considered "medium risk" areas where ecologically sensitive development may be allowed and represent 5,736,837 ha or 40% of the ITR. We would suggest a peer-reviewed, scientifically sound, Ecosystem Based Management (EBM) approach for timber harvest, mining, and other development that identifies and maintains the best wildlife habitat in those areas on a watershed scale. In both the connectivity and medium risk core areas, roads should be restricted as much as possible. Old growth forest should be protected and roads that are constructed should be removed quickly.

In addition there are 2,688,418 ha of caribou Recovery Areas outside of our High Risk areas that need to be managed for mountain caribou recovery (18.7% of ITR). These do not necessarily need to be given full protection, but should be carefully managed on an EBM basis to restore the habitat for caribou.

This Conservation Area Design (CAD) is a coarse-scale, low resolution, analysis, which is provided to determine conservation priorities on a regional scale. The CAD provides a snapshot of the best areas for conservation activities in relation to the Inland Temperate Rainforest as a whole. The CAD is presented as a tool for large-scale planning efforts. It should be seen as a rough outline of important areas to focus on-the-ground inventories, fine-scale mapping, and local conservation efforts based upon field data and local knowledge. The CAD process is ongoing; as better information becomes available the CAD can be improved. It is a starting point to help guide decisions so that biodiversity and ecosystem services can be maintained into the future. The results of this CAD should constitute a defensible scientific basis for implementation of conservation planning and for campaigns to facilitate such implementation.

A Conservation Area Design [CAD] for the Inland Temperate Rainforest in Canada

Introduction

This document describes an integrated approach toward developing and refining a Conservation Area Design (CAD) for the inland temperate rainforest (ITR) in Canada. In a broad sense, a Conservation Area Design can be characterized as a science-based architecture for identifying and prioritizing areas for sustainable conservation of native species of plants and animals and ecosystem functions. The design is spatially explicit and is based on biological value, human impacts, and opportunity for implementation. This general approach to planning of conservation land networks is also referred to as Reserve Design, but because of possible negative connotations of the term 'reserve' in Canada by indigenous peoples, the term Conservation Area Design was decided upon following Sanjayan *et al*. (1999).

Rainforests, especially old-growth rainforests, are among the most biologically rich and diverse ecosystems in the world. In North America, the northwest coast is famous for its coastal temperate rainforests. Similar ecosystems have been documented in coastal areas in at least six widely separated regions of the world, and coastal temperate rainforests are estimated to comprise only 2% of earth's ecosystems. This analysis addresses the conservation of an even rarer type: the Inland Rainforest. Inland Rainforests occur in a small area in southeastern British Columbia and, to a lesser extent, northern Idaho, Washington and Montana. This is one of very few regions on Earth where rainforests occur in regions with prolonged winter snow cover and temperatures as low as –20 to –40C.

Located in North America's wettest inland mountain valleys, these forests are distinguished by a predominance of western red cedar, western hemlock, and many typically coastal species of lichens. They provide critical habitat for several species at risk, including grizzly bears, woodland caribou and bull trout. The oldest stands — the "antique" forests — have almost certainly been growing in place for more than 1,000 years. Several old cedar trees have been documented to be over 2,000 years old. At higher elevations this area is comprised primarily of Engelmann spruce-subalpine fir forest and alpine tundra.

The Inland Temperate Rainforest is threatened. Because of its high productivity for commercial timber, much of it has already been cut, and most of the remaining stands are targeted for harvest. Protected areas are located primarily in the higher elevations (Scott *et al*. 2001). As human populations grow and disperse, wildlife habitat is being developed particularly in the southern part of British Columbia. Unique assemblages of species, and certainly some species unknown to science, are being lost to timber harvest and development. As these trends continue, decisions must be made about what areas should be developed and what areas are critical to leave intact, so that the native fauna and flora can continue to persist. This CAD is another step towards the goal of identifying areas which should be prioritized for conservation, and it is a tool to be used for implementing conservation in those areas.

This analysis was based upon several scientific conservation initiatives in the area including the Yellowstone to Yukon Conservation Initiative, the Nature Conservancy/Nature Conservancy Canada's (TNC/NCC) Canadian Rockies Ecoregional Plan (Rumsey *et al*. 2003a), The Rocky Mountain Carnivore Project (Carroll *et al*. 1994a, 1994b), and The Weighted Distance and Least Cost Corridor Analysis to Evaluate Regional–Scale Large Carnivore Habitat Connectivity in Washington which was developed by the US Forest Service Pacific Northwest Research Station in the Wenatchee National Forest (Singleton *et al*. 2002). We incorporated data from these and other sources and developed techniques to model core habitat and identify movement corridors. Our analysis was then combined with results from the TNC/NCC representation analysis to produce a synthesis that we feel represents conservation priority areas necessary to protect and maintain biodiversity and ecosystem function. The results of this CAD should constitute a defensible scientific basis for implementation of conservation planning and for campaigns to facilitate such implementation.

Background

In order to utilize and add to the extensive work that has already been done in this area, we embraced the Nature Conservancy Canada ecoregional plan for the Canadian Rockies (CRM), which overlaps the ITR area (Rumsey *et al*. 2003a). Although we feel that this analysis has been extremely well done with the best available data and scientific expertise, we added additional analyses to address issues of habitat connectivity that we felt were necessary for a comprehensive vision of a CAD for the ITR region. We restricted this analysis to the portion of the ITR area which is within the CRM boundary, because equivalent datasets are not available for areas outside the TNC CRM analysis area. A map of the area of analysis is shown in Figure 1.

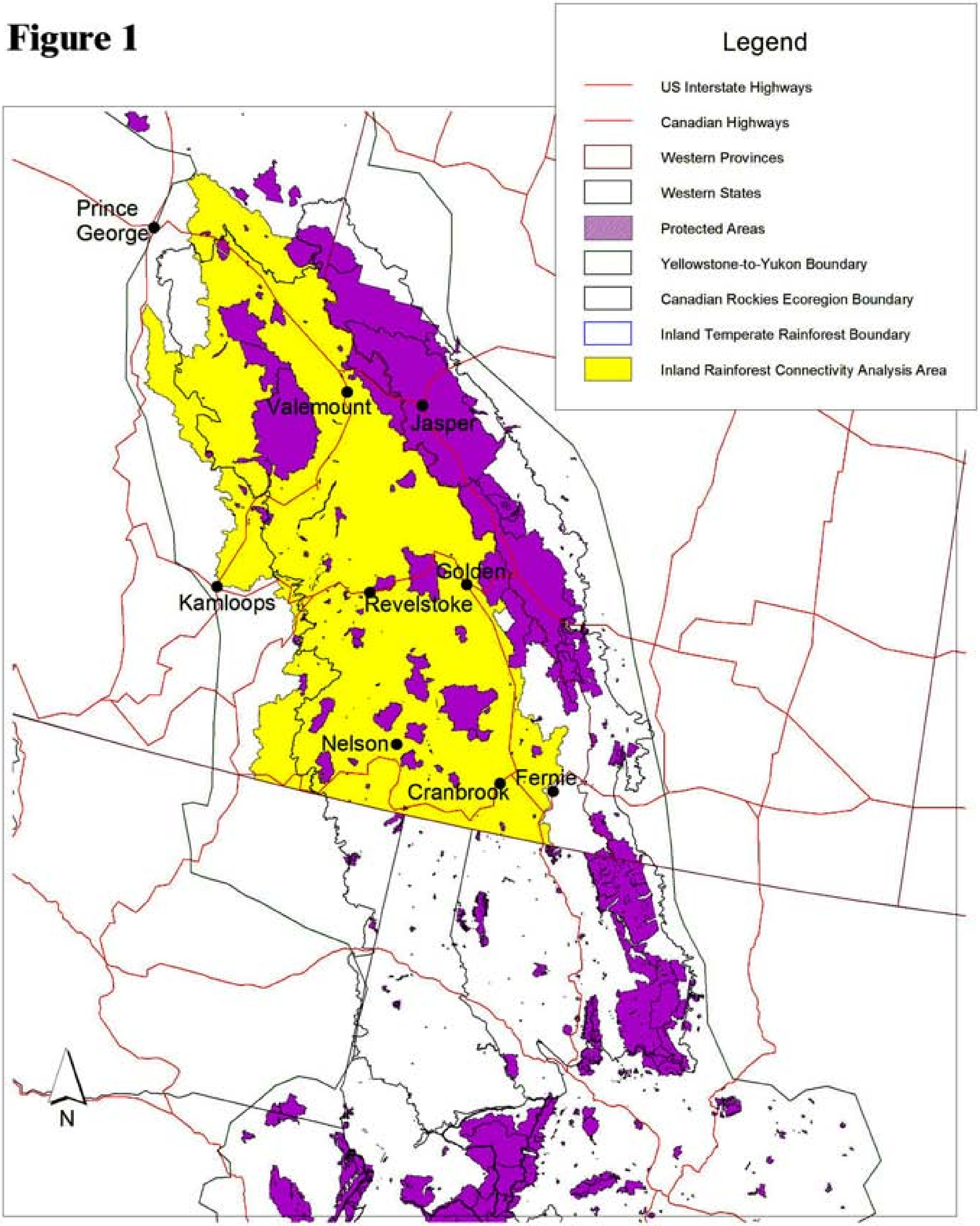
In accordance with standard CAD practices to date, the methodology for the ITR CAD includes the three tracks (Noss *et al*. 1997, Noss *et al.* 2001) of:

1. special elements,
2. representation,
3. focal species analysis

To address the tracks of special elements and representation analysis, we adapted the TNC/NCC (The Nature Conservancy and Nature Conservancy Canada) representation analysis and special elements analysis which were used in their optimization analysis using the SITES model. Results from both the "no-lock" and "locked" summed solutions and a manual override resulting in a "Tier1 and Tier 2" summed solution were assessed; and were combined with our analysis to form the basis of the CAD.

To augment the track of focal species analysis, we used the least-cost-path methodology of Singleton *et al*. (2001, 2002) to identify probable movement corridors between core

Figure 1


Legend
US Interstate Highways
Canadian Highways
Western Provinces
Western States
Protected Areas
Yellowstone-to-Yukon Boundary
Canadian Rockies Ecoregion Boundary
Inland Temperate Rainforest Boundary
Inland Rainforest Connectivity Analysis Area
Prince George
Valemount
Jasper
Golden
Kamloops
Revelstoke
Nelson
Fernie
Cranbrook
N

areas of intact habitat in the Central Columbia Mountains. We used the 'cost surface' or 'friction surface' developed by Singleton *et al*., which estimates the difficulty of transit by an animal through a landscape where preferred habitat types have lower 'friction' coefficients and human-altered habitats and disturbances increase the 'friction' value. We rated the landscape on a pixel-by-pixel basis (created from the indices for the different landscape characteristics at the 90 m scale) for this area, but modified the analysis to include:

- An index for woodland caribou using the different landscape characteristics - "land cover class," "population density," "road density," and "slope." These index values were determined by literature- and experienced-based "expert" opinion.

- Modified the indices for gray wolf, lynx, grizzly bear, mountain lion, and wolverine developed by Singleton *et al*., using expert opinion which we felt better represent habitat preferences in the ITR.

- A redevelopment of the averaged friction surface and separate friction layers for each species.

- Defined core areas for each of the focal species from species data within the ITR. Core areas were defined based upon expert opinion. As a rule of thumb the cores are contiguous patches of suitable habitat for the species in question, and encompassing existing protected areas wherever possible. A core area should be at least the size of an average female home range (carnivores) or seasonal herd range (caribou). Approximately 5-15 core areas were defined for each species within the ITR.

- Least cost path analysis to delineate habitat corridors between adjacent pairs of core areas. The least cost path can be considered an optimal route (the shortest distance through the best habitat) defined by a cost - distance surface between each pair of adjacent core areas. For each pixel, the value represents the 'difficulty' in getting to that cell from each of the core areas. The lower the value, the less the 'cost' moving through that cell between core areas. The pixel values in the defined 'corridor' were assigned to approximately 10 categories, (per Singleton *et al.*) and the pixels in the 5 lowest categories were aggregated to identify the 'least cost corridors'.

Although the resultant maps and report are based in large part upon data collected by TNC and NCC they are in no way represented as being endorsed by TNC or NCC. The maps and reports have been developed as representing the best available science for a conservation area design for the ITR area, in our opinion, and will be made available to First Nations, conservation NGOs, government agencies, and other concerned parties. Baden Cross was responsible for GIS analysis and map preparation with guidance from Lance Craighead and Wayne McCrory. Wayne McCrory and other biologists were responsible for expert opinion. Lance Craighead was responsible for directing the least-cost-path approach and for completing this final report.

The Inland Rainforest CAD is composed of many segments. The first was to identify all regions within the B.C portion of the Inland Rainforest region that had been logged since the 1960s and indicate additional areas that are under current forest development plans. The second part was to identify the remaining intact forests and their distribution in terms of protected areas and remaining old growth segments. The third step in developing a working conservation area design for the B.C. portion of the Inland Rainforest was to identify core habitat concentration areas for six focal species: grizzly bear, gray wolf, wolverine, mountain lion, lynx, and caribou, and to determine the best habitat for movement between these core areas. A fourth step involved modeling and mapping habitat for salmon species in the region. Subsequent steps will be to identify all areas of community watersheds for the area; in effect using human communities as a focal species, and to incorporate a threats layer which will include the logging data.

In developing this CAD for the CITR we began with elements described by Sanjayan (see Appendix A): using the best available knowledge, and incorporation of credible existing conservation plans. We embraced the recent Nature Conservancy (U.S.) and Nature Conservancy Canada Ecoregional Plan for the Canadian Rocky Mountains (CRM), which overlaps the ITR area to a large extent. We also adopted elements of the World Wildlife Fund (WWF) Rocky Mountain Carnivore Project (RMCP) approach (Paquet and Hackman 1995, Carroll *et al*. 2001). This analysis included habitat suitability models for a suite of five large carnivores, and determination of population goals for each large carnivore species and their associated prey species. The basis of the WWF approach is a Carnivore Conservation Strategy (WWF 1990) that proposed to establish carnivore conservation areas (CCAs) which are large enough to ensure long-term survival of free-ranging viable populations of large carnivores.

Although we feel that these analyses have been extremely well done with the best available data and scientific expertise, we added new spatial analyses to address additional aspects of focal species analysis and issues of habitat connectivity that we felt to be valuable additions to the Ecoregional Plan. Our principal additions were to use focal species habitat as the primary focus of conservation value (Clark *et al*. 1996), and to explicitly include connectivity between habitat cores. This connectivity analysis is integral to our vision of a CAD for the ITR region. Connected populations have a much higher likelihood of persistence over time than do isolated populations (Noss 1991). For the connectivity analysis we embraced the wildlife connectivity analyses of Singleton *et al*. (2000, 2002, 2003) and modified them to include caribou and core habitat areas defined at a finer resolution (see Methods below). It is extremely important that areas of contiguous habitat that are sufficiently large and interconnected to maintain viable populations of focal species be identified and protected for long term persistence of those species, for maintenance of biodiversity, and for maintenance of ecosystem processes and functions. For the ITR CAD we addressed this question using the expert opinion of biologists familiar with the region to identify core areas which they felt would meet these criteria.

We then developed least-cost-path connectivity analyses for 4 of the carnivore focal species used by the RMCP for the CRM Ecoregion as focal species: gray wolf, lynx, grizzly bear, and wolverine, following the predictions of Mattson *et al*. (in press) and added the cougar and woodland caribou. These analyses serve to complement the results of the PATCH model population viability analysis runs incorporated into the CRM Ecoregional plan. Using a suite of wide-ranging mammals as focal species for ecoregional planning in the Inland Temperate Rainforest serves at least three primary conservation goals.

1. It should ensure that populations of those species have sufficient intact protected habitat to persist for perpetuity,
2. As a suite of 'umbrella species' it should provide a measure of redundancy to coarse filter (representation analysis) for the protection of diverse arrays of plants and animals which are ecologically interrelated with the focal species, and
3. It should serve as an 'umbrella' for ecological functions and processes.

In regards to the latter goal we need to recognize that our understanding of ecosystems is incomplete; the use of coarse filter representation and optimization routines to determine portfolios do not include systems-type analyses of ecosystem processes and functions. Wide-ranging mammals, especially the full suite of carnivores, can arguably be best sustained only by healthy, functioning ecosystem; and so we use their populations as an index to ecosystem intactness, and we use their habitat requirements as a guide to protecting and maintaining biodiversity; especially those components of biodiversity which we cannot identify or measure separately.

In summary, this Conservation Area Design for the ITR in Canada is based upon core-connectivity habitat models for six focal wildlife species based upon data and methods of Singleton *et al*. but modified by our planning team, a salmon priority watershed analysis, and the TNC CRM Ecoregional Plan data and analyses.

Area of Focus

The Inland Temperate Rainforest has been variously defined. In general it encompasses the lowlands comprised of interior cedar-hemlock forest as described by the Province of British Columbia Ministry of Forests (DeMarchi 1996, Ecosystems of British Columbia 1991). At higher elevations this area is comprised primarily of Engelmann spruce-subalpine fir forest and alpine tundra. The boundaries of this area include some pockets of sub-boreal spruce forest, ponderosa pine forest and montane spruce. The Inland Temperate Rainforest Working Group and the Valhalla Wilderness Society expanded the boundary to the west for this analysis to include the known range of the woodland caribou. In order to incorporate the CRM Ecoregional Plan we restricted this analysis to that portion of Inland Temperate Rainforest region which is within the CRM boundary, because equivalent datasets were not available for areas outside the TNC CRM Ecoregional Plan analysis area. Because of funding constraints we further restricted the analysis to the Canadian portion of the Inland Temperate Rainforest (Figure 1).

Methods

First Iteration Focal Species Habitat Suitability Modeling

We chose a suite of focal species that we felt met most of the criteria desired and for which there were adequate data and scientific understanding to develop habitat suitability models. (Roberge and Angelstam 2004, Carroll *et al*. 2001, 2003, Lambeck 1997). To augment the track of focal species analysis by further addressing the issue of connectivity for wildlife movement, we used the least-cost-path methodology of Singleton *et al*. (2000, 2002, 2003) to identify probable movement corridors between core areas of intact habitat within the Inland Temperate Rainforest. We used the 'cost surface' or 'friction surface' developed by Singleton *et al*. (created from the indices for the different landscape characteristics at the 90 m scale) for this area, but modified the analysis using a slightly different rating scheme derived from expert opinion.

The initial steps in developing a working conservation area design for the B.C. portion of the Inland Rainforest were to identify habitat concentration areas and to determine the least cost corridors between these core areas. The procedure followed the modeling process described in "Using Weighted Distance and Least Cost Corridor Analysis to Evaluate Regional –Scale Large Carnivore Habitat Connectivity in Washington" developed by Peter H. Singleton and John F. Lehmkuhl, USFS PNW Research Station and William Gaines, USFS Wenatchee National Forest. Comparable landscape characteristics were evaluated for the Inland Rainforest region in terms of Land Cover Class, Human Population Density, Road Density, Slope and Elevation. Relative permeabilities were assigned to six focal species (Grizzly Bear, Wolverine, Lynx, Cougar, Gray Wolf, and Mountain Caribou) for each of the classifications within the five landscape characteristic categories.

Indices of relative permeability were incorporated from the Singleton model with review and revision by Craighead and McCrory (and other members of an 'ad hoc' expert panel comprised of biologists with expertise for various species) that were specific to the ITR region. The term 'relative permeability' can be viewed as an estimate of the relative potential for animal passage across the entire landscape. The lower the index value, the more difficult the movement for the particular species or the more 'impedance' it might experience. It is important to note that this index does not necessarily identify actual animal movement but rather provide an indication of the potential barriers between core areas that might influence this movement.

A new category was developed for cougar and mountain caribou and indices created for each classification of the landscape characteristic categories. The index is a relative value assigned to the species for the particular landscape characteristic classification, ranging from 0 to 1. To facilitate the computer processing of data and conserve storage medium, values were initially based on integer values ranging from 0 to 10. These were assigned as follows in Table 1:

Table 1. Species-specific Relative Permeability Indices for landscape characteristic categories

Land cover class index						
type	Gray wolf	Lynx	Grizzly	Wolverine	Caribou	Cougar
Alpine	10	3	10	10	10	1
Forest – Old/ Young	10	10	10	10	10	10/6
Sub Alp-ava	8	8	10	8	10	5
Ice and Snow	1	1	3	8	5	1
Wetlands	3	8	4	8	7	3
Water	1	1	1	1	1	1
Bare ground	6	3	3	8	3	6
Logged (last 40 years	4	10	8	5	7	5
Agriculture	8	3	2	2	3	2
Urban	1	1	1	1	1	1
Recently Burned	4	4	4	4	4	3
Rangeland	8	2	10	6	7	6
Shrub	7	8	8	6	8	6
Population density index						
people/mi^2	Gray wolf	Lynx	Grizzly	Wolverine	Caribou	Cougar
0-10	10	10	10	10	10	10
10-25	5	7	5	5	5	8
25-50	3	3	3	3	3	5
50-100	1	1	1	1	1	1
100 +	1	1	1	1	1	1
Road Density Index						
mi/mi^2	Gray wolf	Lynx	Grizzly	Wolverine	Caribou	Cougar
0-0.01	10	10	10	10	10	10
0.01-1	10	10	10	10	10	10
1 - 2	8	10	10	8	10	10
2 -4	5	8	5	5	10	8
4 - 6	5	5	3	3	8	5
6 - 8	2	5	2	2	8	5
8 - 10	2	3	2	2	8	3
10 - 50	1	1	1	1	1	1
>50	1	1	1	1	1	1
Elevation Index						
Elevation	Gray wolf	Lynx	Grizzly	Wolverine	Caribou	Cougar
0-1000	10	10	10	6	8	10
1000-1500	10	10	10	8	10	10
1500-2000	10	10	10	10	10	5
>2000	10	10	10	10	10	1

Slope Index						
%_slope	Gray wolf	Lynx	Grizzly	Wolverine	Caribou	Cougar
0-20	10	10	10	10	10	5
20-40	8	8	10	8	8	8
> 40 (40 –60)	6	6	10	10	5	10
60-80	0	0	10	10	0	10
80-100	0	0	10	10	0	10
100-120	0	0	10	10	0	10
>120	0	0	1	1	0	1

The land cover class information for the ITR portion of BC (Basic Thematic Mapping [BTM] criteria in conjunction with biogeoclimatic classifications [BGC]) was used to co-relate the categories developed in Singleton's model. As population density information in B.C. was lacking, this required development of surrogates from existing information. Several inputs were considered and modeled including point town locations with their population estimates according to a range (0 –500, 500-1000, etc.), regional districts polygons and associated population figures, BTM data which provided urban centres as polygons as well as those for recreational, mines, and agriculture/human mixture sites. A weighted distance algorithm was considered (Merrill *et al.* 1999) where upon a value is calculated for each cell based on the population size of all surrounding towns, its averaged distance from those populated places, and a function that describes how levels of human activity decline with increasing distance from a place of residence.

After a review and running composites of the above, the most significant data emerged from considering the point source values and urban polygons. We added all the towns for which we had data with their populations (0-500, 500 – 1000, 1000 – 5000, 5000 –10,000, and 10,000 – 50,000) and determined the mean for these categories. A density (kernel) function was run on the town point centres using a radius of 10 km (to estimate the average influence/ extent of the 'town'). We converted all the "urban" polygons from the BTM to centroids and calculated a population figure based on the hectarage of the original polygons assuming that one dwelling of an average of 4 people covered 5 hectares. (hectares x 4 x 5) and again ran a density calculation using a 10 km radius.

We then added the two grids to give a composite figure to population density. We then ran a distance function on areas beyond the town core centres (an average of 5 km) in conjunction with a sinusoidal decay function with the following thresholds: 0 – 1.6 km (the beginning of the decay) and out to the 10 km for the final point of no effect. This provided a 'fall-off' effect of human population influence as one moves away from the town cores. To account for variations in the landscape complexity that might affect the influence of the population centres, a visibility function was run on the town point centres which roughly simulated the effects of sight, smell and sound proliferation from these centres. We then multiplied the population density grid, sinusoidal distance decay function grid and the 'visibility' grid to give the population density figures for the landscape (the distance decay function approximates the disturbance caused by human access into the surrounding countryside from population centers. It also approximates the influence on wildlife of the 'visibility' of nearby towns. The decay function raises the impedance / lower the permeability index… i.e. after about 10 km away from the centre of the town, the immediate influence of the town on wildlife is assumed to be minimal.

Development of Dispersal Habitat Suitability (DHS) Sublayer

Dispersal Habitat Suitability (DHS) layers were then developed for each species based upon the algorithms provided in the Singleton model which provided a 'friction' surface in terms of individual species movements across the landscape. DHS values are a composite of the impedance indices, providing a weighted value for each 'cell' on the landscape that reflects the difficulty of a particular species to move through that landscape 'cell'.

Development of Habitat Concentration Areas (HCAs)

Once the permeability indices were established for the five species for each of the landscape characteristic categories, core (habitat concentration) areas were developed according to the criteria indicated below. (When choosing shrub-sub-alpine-alpine criteria, Basic Thematic Mapping [BTM] data were used as it is more specific than the Biogeoclimatic [BGC] data.)

Grizzly:
Forest (all BGC excluding "x" and "v" subvariant classifications and Alpine Tundra protected zone- no logging) and adjoining (within 50 m) ava BTM classifications
Road density = 0
(might want to exclude >60 degree slopes)

Wolverine:
Forest (all bgc excluding "x" and "v" subvariant classifications – no lakes, no logging) alp and ava from btm
Road density = 0
Elevation > best over 1500m

Lynx:
Subalpine fir forest (ESSF – all seral- logging included –no lakes)
Road density <4 mi/mi^2 (= 2.5 km/km^2)
Elevation 1000 – 2250 m

Cougar:
Dry interior forests – all BGC dry and moist forest types (some logged, no lakes)
Road density <4 mi/mi^2 (= 2.5 km/km^2)
Elevation < 2000 m

Wolf:
Dry interior forests – all BGC dry and moist forest types (not logged, no lakes)
Elevation < 1500m

Slope <25 % (= 45/4 = 11.25 degrees)
Road density < 1mi/mi^2 (= 0.625 km/km^2)

Caribou:
Old growth ESSF bgc forest (no logging)+ICH vk and wk old growth (lichen forest- no logging)
Road density (average of 1 mi/mi^2 up to 4 mi./mi^2 as per Craighead = 2mi/mi^2) = 1.25 km/km^2
Elevation 600 – 2500 m.

Once these preliminary 'core' layers had been developed, we resampled to1 km cells and ran a summation neighborhood analysis with a 5 km circular window to provide a 'probabilistic' core habitat layer. This information will be reviewed by experts as to level of inclusion (choosing threshold values produced from the summation run) against the backdrop of individual species area (km^2) requirements and % of actual preliminary core area included in the generalized cores defined by the thresholds chosen. An arbitrary decision was made at this point (in lieu of expert review of the core areas) to include the best _ of the neighborhood analysis results (in consideration of the model's corridor development which is based on selecting the best _ of the least cost corridor analysis). These model results were visually compared with the results of the focal species resource selection function analyses developed by the Rocky Mountain Carnivore Project (Carroll *et al*. 2001a).

Habitat Concentration Areas (cores) were then used in conjunction with the friction surfaces developed for each of the 5 species to provide weighted distance layers. These surfaces indicate the cumulative impedances for animal movement between habitat concentration areas. Certain limitations to these cost distance surfaces are usually applied to these results; in the Singleton model, areas within 100 km weighted distance of modeled habitat concentration areas are referred to as "available habitat," indicating that there were not substantial landscape barriers between the evaluated area and a habitat concentration area. In addition, areas in excess of 1000 km weighted distance were considered unlikely to be accessible to individuals of the focal species moving from HCAs due to the cumulative effect of landscape barriers or filters. This completed the first phase of the CAD development for the BC portion of the Inland Rainforest.

Second Iteration Focal Species Habitat Suitability Modeling

Revision of the Grizzly Bear core habitat areas based on expert input

We digitized the polygons identifying the greatest periphery of bear core habitat as defined by our expert panel. The threshold for inclusion of cells derived from the original parameters defining the HCA (after resampling to 1000m and neighborhood analysis on summing a 5 cell (5 km) radius – see rationale above and Singleton *et al.*) was increased from 50% to ~ 90**%**. (Grizzly_core2) Values ranged from 1 to 81; all values from 6 and above were included). This produced a better correlation between the modeled HCAs and the empirical boundaries defined by our expert panel. Road buffers were then built on the

BC Terrestrial Resource Inventory Mapping (TRIM) data with the buffer distance based on a linear ratio calculation of road 'weight' and buffer distance ranging from 2 – 5 km. (buffer distance = 2 + (5 – 2)*road weight/ 40. (road weights ranged from 1 to 40). Two road buffer grids were produced: one including road classifications from "loose 1 lane" through to the maximum of "4 lane divided highway," and a second including all paved roads (paved 1 lane, bridges, tunnels up to the maximum size). Human settlements influence (population density grid as defined above) were combined with the road buffer grid and subtracted out of the revised HCAs. Both road buffer grids were examined for their overlap on the revised GB HCA grid. (Gbcore2a – all paved roads from 20–40 rating and Gb2b – with all roads rated with >3 being excluded.

Grizzly Bear Revisions according to CERI recommendations of road buffers

The HCAs were then evaluated using a modified road buffer method developed by the Craighead Environmental Research Institute. This modification was as follows: all gravel roads (loose 1 lane and up) were given a weight of 0.37 km and all paved roads (paved 1 lane and up) were given a weighted value of 0.75 km in order to not underestimate the impacts of the larger 'freeway' type disturbances. (commonly accepted average road buffers are built to 500m). Buffers were built around the roads derived from the TRIM data according to these parameters and subtracted out of the grizzly core areas described in the first revision above accepting **~90%** of the identified habitat rather than 50%). Comparing these HCAs with the polygons derived by the panel showed a much closer correlation.

Development of Caribou Habitat Concentration Areas

A somewhat different approach was used to develop HCA models for mountain caribou. We used about 9000 point locations in the GIS for mountain caribou from a variety of research projects within the province of BC to develop the HCAs. These were then converted to a 1 km grid layer with 84 cells indicating caribou 'occupancy' and used in conjunction with 6 landscape characteristics to identify potential habitat that could be used as a surrogate for core habitat identification. Logit modeling was reviewed but the data point distribution was insufficient to provide reliable results in terms of predictability. Independent parameters were also limited. More primitive cross tabulation methods provided a more reliable means to identify potential core habitat areas from the landscape characteristics. An index was calculated based upon the frequency of caribou cells for each variable class as shown in Tables 2-7:

Table 2. Frequency of Caribou Locations For Variable Class 1

Variable 1			
Landcover class	**classification #**	**# caribou cells**	**index**
Alpine	2	11	1.31
Old Forest	3	42	5.00
Young Forest	4	22	2.62
Sub – Alpine/ Avalanche	5	2	.24
Ice	6	0	0
Wetlands	7	0	0
Mine sites	8	0	0
Fresh water	9	0	0
Bare	10	1	.12
Recently logged	11	5	.60
Agriculture	12	0	0
Sustainably logged	13	0	0
Urban	14	0	0
Recent burns	15	1	.12
Recreational Sites	16	0	0
Rangeland	17	0	0
Agri- urban mix	18	0	0
Shrubland	19	0	0

Table 3. Frequency of Caribou Locations For Variable Class 2

Variable 2		
Aspect	**# caribou cells**	**index**
flat	0	0
0-90	22	2.62
90-180	15	1.79
180-270	20	2.38
270-360	27	3.21

Table 4. Frequency of Caribou Locations For Variable Class 3

Variable 3			
Elevation	**Elev class**	**# caribou cells**	**index**
0-1000	1	1	0.12
1000-1500	2	4	0.48
1500-2000	3	39	4.64
2000-2500	4	40	4.76
>2500	5	0	0.00

Table 5. Frequency of Caribou Locations For Variable Class 4

Variable 4

% slope	slope class	# caribou cells	index
0-20	1	16	1.90
20-40	2	31	3.69
40-60	3	26	3.10
60-80	4	8	0.95
80-100	5	3	0.36
>100	6	0	0.00

Table 6. Frequency of Caribou Locations For Variable Class 5

Variable 5

rd density (mi/mi^2)	density class	# caribou cells	index
0-0.01	1	62	7.38
0.01-1	2	22	2.62
1-2	3	0	0.00
2-4	4	0	0.00
4-6	5	0	0.00
6-8	6	0	0.00
8-10	7	0	0.00
10-50	8	0	0.00
>50	9	0	0.00

Table 7. Frequency of Caribou Locations For Variable Class 6

Variable 6

human density (people/mi^2)	density class	# caribou cells	index
0-10	1	84	10
10-25	2	0	0
25-50	3	0	0
50-100	4	0	0
>100	5	0	0

The index values for each HCA variable were simply calculated according to the following:

caribou cells/ 84 * 10. These values were then applied to the six variables and summed spatially to provide a composite index layer. Values ranged from 0 to ~35. The layer was queried for values >25 and to identify clusters, a neighborhood analysis was run on 5km, circular window. The highest 50% (to coincide with methods used for the other four species) was selected as potential HCA's for mountain caribou. These were then overlayed with existing herd polygon data for examination of proximity of the core areas within the herd range. Comparing these results to the original HCA model developed above, indicated a much greater correlation with the known herd ranges.

This modeling process identified core areas and connectivity habitat for caribou based upon habitat suitability and current distribution. However, mountain caribou in southern BC and Northern Idaho are a species-at-risk that are classified as endangered in the U.S. Conservation of these populations will require more than just maintaining current core habitat. For this reason, we included restoration areas for caribou as a Special Element in the CAD. These Special Element areas are added to the habitat suitability analysis to delineate the conservation priority areas for mountain caribou.

Development of Cougar Habitat Concentration Areas

We derived the following major elements of cougar habitat from the literature:

Rugged, rocky terrain surrounding major deer winter ranges
Scattered brush and trees, shrub
Semi – open forests
Mule deer as staple (consume 14 to 20 avge size/ yr)
Elk /other main prey
Prefer slopes of 5 – 60 degrees – avoid flat and >30 degrees
Avoid most areas > 10m from cover

One of the best indicators of cougar distribution is the habitat of their major prey. We assumed that a model of cougar habitat would naturally overlap their major prey species. We began with a review of the vegetation cover for the study area. First, Broad Ecosystem Inventory classifications (BEI) were used to identify semi – open forests/ scattered brush and trees and shrub that might provide suitable cougar habitat. We then compared this with a review of biogeoclimatic subzones within the ITR that provided suitable habitat for cougar, mule deer and elk. These were then cross-referenced with the BEI information to make a final determination of the specific biogeoclimatic subzone variants that provided suitable cougar habitat

These included Ponderosa Pine (PP)/Interior Douglas Fir (IDF) forests, old and mature forests in the IDF as well as young seral, south aspect DF & PP parkland and specific Bunchgrass/ Grassland subzone variants, southerly aspect, clearcuts, young seral and recent burns in the Interior Cedar Hemlock (ICH) zone, mature forests and steep southerly aspect regions in the Montane Spruce (MS) zone and old growth forested areas in the ESSF zone. These elements were selected out to provide a cougar base layer upon which to build the HCAs. This base layer was then backdropped against ungulate ranges, particularly winter ranges. Of the defined ungulate winter range as per government data Ministry of Environment data files, some 70% was captured by our cougar base layer. The winter range may be viewed as a sub-set of the overall range of both ungulates and cougar and areas of our base layer lying outside of the winter boundaries (which mainly concentrates in the lower elevation valley bottoms) would indicate a broader cougar scope in milder seasons as the ungulate populations move to higher elevations. Permeability indices for the different landscape characteristic classifications were determined by expert opinion to develop the frictional surface for this species.

Development of Wolf HCAs

The original model used to develop the wolf core areas was not considered representative when reviewed by experts. We used the resource selection function (RSF) for wolf from the CRM study to develop a more sophisticated model. Beginning with the CRM wolf layer, the values were filtered to include the highest approximation of the wolf RSF (>450). The friction surface previously developed was also filtered to identify approximately the higher _ (> 4000) of the friction values. These cells were dropped from the filtered RSF sublayer and a neighborhood analysis was then performed (1000m cells with a 5 km circular window). Although frictional surfaces were originally modeled for connectivity analysis, it stands to reason that areas of higher friction would also be areas of avoidance when viewing HCAs. In other words, these areas are not only detrimental to species movement across the landscape but also have an influence on identification of core areas. Querying for the higher _ of the neighborhood analysis grid provided a revised HCA mapping for wolf. Once again, against the backdrop of the original Singleton modeling process, the _ division was used when making subjective choices regarding the influence of the particular concern.

Development of Lynx HCAs

The CRM data included a RSF layer for lynx. An original lynx core area was developed from the parameters indicated in the HCA development above:

Lynx:
Subalpine fir forest (ESSF – all seral-logging included –no lakes)
Road density <= 2.5 km/ km^2
Elevation 1000 – 2250 m is best

We performed a cross tabulation using the core areas (1 – core, 0 – non core) derived as per these parameters against a selected set of RSF values from the CRM data. RSF values from 0 – 600 were reclassed as 0 and values from 600 – 2224 were reclassed to value 1. These were summed using a neighborhood analysis function with the highest _ being used as core cells. Similarity was vague despite a good Kappa index of agreement and Cramer's v, as the chi squared value did not support similarity to any degree of significance.

A query was performed to identify areas with values of the lower _ Same of lynx friction values in conjunction (OR operation) with areas having a RSF value >600. These results compared well with the original core determination from the above data. The original core areas were combined with the results of the above query and a patch analysis run to identify areas with an area >5000 ha. The results were used for the second version of lynx core area habitat.

Development of Wolverine HCAs

The CRM data included a RSF for wolverine. This was compared to our original core area development as per the preliminary development indicated above:

Forest (all bgc excluding "x" and "v" subvariant classifications – no lakes, no logging)
alp and ava from btm,
Road density = 0, and
Elevation >1500m is best

A preliminary cross tabulation was performed between the two layers. Similar to the lynx data this provided little correlation. A query was done to identify the areas with a friction value in the lower _ of the values (this was reduced from the lower _ due to greater sensitivity of wolverine to disturbances). Areas of RSF >600 were identified and combined with the filtered friction values. A neighbourhood sum analysis was run and the higher _ values filtered out to identify potential core areas. The results provided a reasonable mix between the CRM data and the original wolverine core areas developed above.

Second Iteration Expert Review and Core Habitat Threshold Refinement

Peer (or expert) review of model parameters and model outputs was continuous throughout the project on an opportunistic as well as a formalized basis. We define expert review as that provided by biologists working under contract on the project, and peer review as that provided by objective, disinterested experts for various species. Comments were recorded and adjustments were incorporated into model refinements at a number of scientific venues when peer reviewers were available for consultation. Initial peer review of grizzly bear core area data included Dr. Brian Horejsi -and Troy Merrill at a meeting of the Kootenay-to-Clearwater Conservation Initiative in Sandpoint, Idaho on 25 April 2003. Additional peer review input on grizzlies, wolves, and cougar was incorporated from Dr. Paul Paquet, Dr. Michael Proctor, and Dr. Sterling Miller at a Yellowstone-to-Yukon Science meeting in Calgary, Alberta on 9 May 2003.

The revised core areas for grizzly bear, gray wolf, mountain caribou, lynx, cougar and wolverine were prepared for expert review in Vancouver on the 13th of August 2003, by Dr. Lance Craighead and Wayne McCrory. The cougar and caribou core habitat polygons were adjusted according to the redrawing of portions of the appropriate polygons to better reflect 'on the ground' information. Subsequent generalizations were used to isolate major areas of core habitat for the other species by running a neighborhood analysis on the earlier grids (that used a summation over a 5 km radius) with an additional 15 km circular radius and then selecting a threshold for the summed neighborhood values that helped reduce the areas into major pockets of habitat.

This step was employed to facilitate the connectivity analysis which "identifies inter-territorial movements, long distance dispersal or exploratory movements outside of an established home range, usually associated with investigations of distant habitat areas or the establishment of new home ranges." (Singleton *et al*). The threshold value was an iterative process whereby different values were selected, the results viewed and the threshold adjusted to amalgamate areas that were close enough to be considered the same core area as well as to ensure areas were not included that were known to be highly affected by human disturbance. To run the connectivity algorithm, we had decided on a maximum of 15 cores for each species to reduce the complexity of the computations. The thresholds chosen below are based on a visual review (subjective) of the GIS maps of the preliminary core habitats that were derived as per the strict parameters indicated above (objective and generalized to a summation over 5 km)) to identify a more generalized spatial context for connectivity analysis.

Lynx:
For lynx we used the 15 km radius with a threshold of >290 for the summed values (value 1 representing core area from the previous neighborhood analysis (5 km on cell values of 1), lynx-core2 to develop lynx-core3 grid. We later revised the threshold to >250 and eliminated several of the smaller polygons to develop the lynx habitat concentration areas using expert review.

Wolverine:
For wolverine we used a threshold of >300 for the summation values on a 15 km radius on the previous wolv-core2 to get wolv-core3. We later adjusted this to a threshold of 280 and deleted some of the smaller areas to derive the wolverine habitat concentration areas using expert review.

Cougar:
For cougar we used a threshold of >210 using expert review for the summed values to derive cougar habitat concentration areas.

Wolf:
For wolves >300 was used for the summed values to derive wolf habitat concentration areas using expert review.

Grizzly:
For grizzly bear we ran a neighborhood analysis on the revised polygons, selecting a final threshold of 325 for the summed values, edited out some of the smaller polygons and adjusted some inconsistencies with the original revisions to derive grizzly habitat concentration areas using expert review.

Caribou:
Caribou core habitat was defined initially using a threshold of >80% of habitat value. This map was reviewed by expert Wayne McCrory and adjusted to incorporate additional habitat of known caribou locations derived from radio-telemetry data to derive caribou grizzly habitat concentration areas.

Least-Cost-Path Connectivity Analysis

Methods for the least-cost-path connectivity analyses are similar to those reported in Craighead *et al*. 2004 (in prep.), Craighead *et al*. 2001 (ICOET conference proceedings), Singleton *et al*. 2002 (USDAFS Pacific Northwest Research Station Research Paper PNW-RP-549) and Walker and Craighead 1997 (ESRI conference proceedings). Friction grids for each species and all core patches developed for the habitat suitability models (described above) were resampled to a resolution of 1000m. Corridor boundaries were defined between core patches with consideration of the base friction surface of the species of concern. The outer boundaries between patches were drawn with the base friction value in mind. We attempted to follow low friction paths so as to not exclude them with the idea that the species may instinctively follow these 'lesser friction' routes despite being the "longer way" around between core patches. All 'absolute' friction surfaces between the individual core patches (i.e. the sum of the cost distance grids for both patches) were saved in order to review the overall comparative 'ease' of the individual species movement across the entire landscape of the IR region. The primary corridor maps depict the relative ease of movement between pairs of core areas. A classification of "3" between one pair of cores did not necessarily reflect the same difficulty/ease as a "3" between another pair of cores. When the corridor algorithm was run, the cost distance surfaces between all pairs of cores were maintained and later added into one surface and segmented into 10 categories similar to the classification between individual pairs. This presented a better picture of cost distance over the entire surface where different areas can be compared for ease of movement on an equal basis.

Where preliminary results showed core patches were too close together (such as with the cougar model) we treated them as one core grid (putting the cells of the close patches into one grid) and ran the connectivity between these amalgamated patches and the more distant larger patch. We later ran corridor pieces between the original 'close' patches and overlaid (merged the grids with the frictions between the smaller patches having priority) the results on the corridor analysis for the amalgamated patches and the more distant larger patch. This gave credence to the possible connectivity between the smaller close patches that would not show up in the larger corridor analysis.

Development of a composite connectivity sublayer.

METHODS
Once the connectivity pieces had been run for all 6 species, a composite was developed to look at the most important landscape in terms of connectivity between species core areas. Singleton's model defines 10 categories for ease of movement, 1 being the least cost and 10 the greatest as a comparative measure between pairs of cores. Cells with values <3 (1

& 2) were selected from each species corridor layer and these were reclassified to a value of "1". These 6 reclassifications were then "added" to provide a single new grid with values between 1 and 6, 1 indicating the cell fell in the original low cost cells (1 & 2) for at least 1 species, 2 indicating for at least 2 species up to 6 indicating that the cell was originally in all 6 species categories of 1 or 2 ease of movement. This gave a graduated importance to the landscape in terms of connectivity importance that ranged over all our focal species.

We were able to run an identity function on the importance "signif-corr" grid after converting to a shape file using the subwatershed shape file as the identifier. This provided a new shape file on which was performed a summary using polygons with the same watershed code providing the sum of the importance values for each watershed. This table was then joined to the original sub-watershed layer and a new field introduced with the summation of the "signif-corr" values for each sub-watershed.

Reviewing and Incorporating the Salmon Data

A quantitative measure was created based on salmon escapement figures using an index algorithm developed by Round River Conservation Studies [RR] and a species diversity index (Shannon Diversity Index). The RR index algorithm (Sanjayan *et al*. 2000) provides a normalized mean abundance (calculated by mean abundance for each stock) by stock which accounts for both the abundance of salmon and individual stocks while the diversity index gives a relative value of variability within each system.

The final value applied to the subwatersheds was a result of adding the Round River normalized mean abundance score (as values from 1-10) with _ the diversity values (as values from 1-10). This resulted in a scale from 1 to 10 for subwatershed salmon values.

Additional Aquatics Elements Analysis

Additional data developed by Dave Mayhood for the Y2Y science program delineating areas of importance for red- and blue-listed species, and for spawning habitat for fish other than salmon, has been analyzed spatially and will be included in subsequent revisions of the CAD.

Incorporating TNC Special Elements and Representation Analyses

To address the tracks of special elements and representation analysis for the Canadian Inland Temperate Rainforest (ITR), we adapted the TNC/NCC (The Nature Conservancy and Nature Conservancy Canada) representation analysis (coarse filter) and special elements analysis (fine filter) which were used in their Canadian Rockies Ecoregional (CRM) Assessment (Rumsey *et al*. 2003). A description of this process is included in Appendix B.

A total of 4,836 watersheds were part of the final conservation portfolio for the Canadian Rockies Ecoregion totaling 13,455,793 hectares (33,249,264 acres) and equaling 49.7% of the ecoregion. The portfolio size was attributed to: 1) the types of conservation targets selected, which included matrix-forming ecological systems and wide-ranging mammals; 2) the existing natural variability and the desire to represent variability across all environmental gradients within the ecoregion; and 3) manual over-rides of the original SITES output based on additional knowledge about conservation areas. Manual overrides changed the configuration of the conservation portfolio; represented as Tier 1 and Tier 2 areas, significantly from the original optimization solution (Carroll pers. comm.). The majority of the 4,836 selected portfolio watersheds were subsequently aggregated into larger conservation units called "Conservation Landscapes," that were clusters of watersheds that were geographically connected and that shared common ecological processes.

For the Inland Temperate Rainforest CAD we utilized the CRM datasets for subwatersheds (planning units) identified in terms of a " no-locked," "locked," and Tier 1 & 2 summed solutions in a system of areas of conservation concern (see explanations in Appendix B). We then made comparisons for each of our focal species core habitat, important corridors, and priority salmon watersheds in terms of inclusion of conservation portfolios identified by these CRM methods to determine what percentage of the areas we identified as important to each focal species was included under the TNC solutions.

Additional Special Elements Analysis

As discussed under methods, mountain caribou in southern BC and Northern Idaho are a species-at-risk that are classified as endangered in the U.S. Conservation of these populations will require more than just maintaining current core habitat. For this reason, we included restoration areas for caribou as a Special Element in the CAD. These Special Element areas are added to the habitat suitability analysis to delineate the conservation priority areas for mountain caribou.

Results

Terrestrial Focal Species Cores and Connectivity

Table 8. Habitat Concentration Area (core) Totals for Focal Species.

Area of ITR (BC portion)	14,311,400 hectares total	Percent of ITR
Core Areas		
grizzly bear	5,776,579	40
wolverine	3,172,645	22
lynx	4,324,356	30
cougar	4,895,400	34
wolf	8,018,551	56
caribou	5,585,679	39
Corridors (< or = 5 cost value)		
grizzly bear	3,375,600	24
wolverine	3,511,700	25
lynx	2,668,600	19
cougar	4,223,500	30
wolf	3,447,000	24
caribou	2,962,400	21

Grizzly Bear Cores and Connectivity

The results of Grizzly Bear Focal Species analysis are presented in Figure 2. Total Habitat Concentration (core) area for grizzly bear, using the habitat thresholds described in Methods, comprises 5,776,579 ha. which is 40% of the area of the ITR.

Large areas of core habitat exist in the northern portion of the study area. In the southern portion, where there is more human development and habitat fragmentation, areas of core habitat are much smaller, requiring longer distances through less-optimal habitat to maintain connectivity.

Connectivity habitat for grizzly bears, using the thresholds described, totals 3,375,600 hectares which is 24% of the area of the ITR. Taken together, grizzly bear core and connectivity habitat, using the thresholds described, comprises 64% of the ITR; this is habitat which should be given some measure of protection in order to maintain current population status. This corresponds well with field studies of grizzly bear home ranges which record that grizzlies select from 64-86% of their home ranges within protected areas (Gilbert *et al*. 2004, Mace, etc.)

Wolverine Cores and Connectivity

The results of Wolverine Focal Species analysis are presented in Figure 3. Large areas of core habitat exist in the central, high elevation, portion of the study area. In the southern portion, where there is more human development and habitat fragmentation, areas of core habitat are much smaller, requiring longer distances through less-optimal habitat to maintain connectivity. Wolverine have not been extensively studied in the ITR and further data should improve the accuracy of this model.

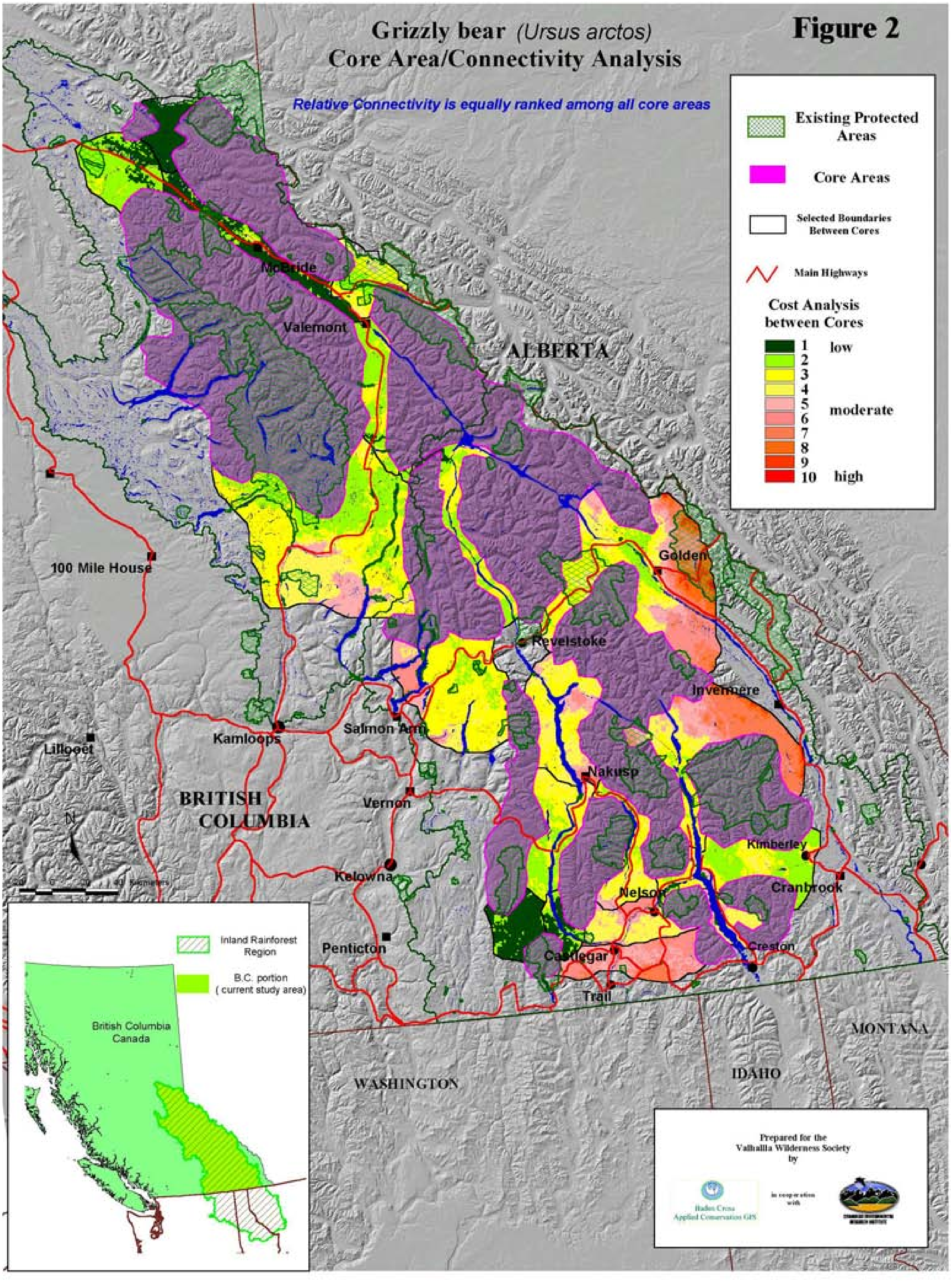
Total core area for wolverine, using the habitat thresholds described in Methods, comprises 3,172,645 ha. which is 22% of the area of the ITR.

Connectivity habitat for wolverine, using the thresholds described, totals 3,511,700 ha. which is 25% of the ITR. Taken together, wolverine core and connectivity habitat, using the thresholds described, comprises 47% of the ITR; this is habitat which should be given some measure of protection in order to maintain current population status.

Lynx Cores and Connectivity

The results of Lynx Focal Species analysis are presented in Figure 4. Large areas of core habitat exist in the northwestern portion of the study area. In the southern portion, where there is more human development and habitat fragmentation, areas of core habitat are much smaller, requiring longer distances through less-optimal habitat to maintain connectivity.

Total core area for lynx, using the habitat thresholds described in Methods, comprises 4,324,356 ha. which is 30% of the area of the ITR.



Grizzly bear (Ursus arctos)
Core Area/Connectivity Analysis
Figure 2
Relative Connectivity is equally ranked among all core areas
Existing Protected Areas
Core Areas
Selected Boundaries Between Cores
Main Highways
Cost Analysis between Cores
1 low
2
3
4
5 moderate
6
7
8
9
10 high
McBride
Valemont
ALBERTA
100 Mile House
Golden
Revelstoke
Invermere
Lillooet
Kamloops
Salmon Arm
Nakusp
BRITISH COLUMBIA
Vernon
Kimberley
Kelowna
Cranbrook
Nelson
Penticton
Creston
Castlegar
Trail
MONTANA
IDAHO
WASHINGTON
Inland Rainforest Region
B.C. portion (current study area)
British Columbia Canada
Prepared for the Valhallia Wilderness Society by
Baden Cross Applied Conservation GIS
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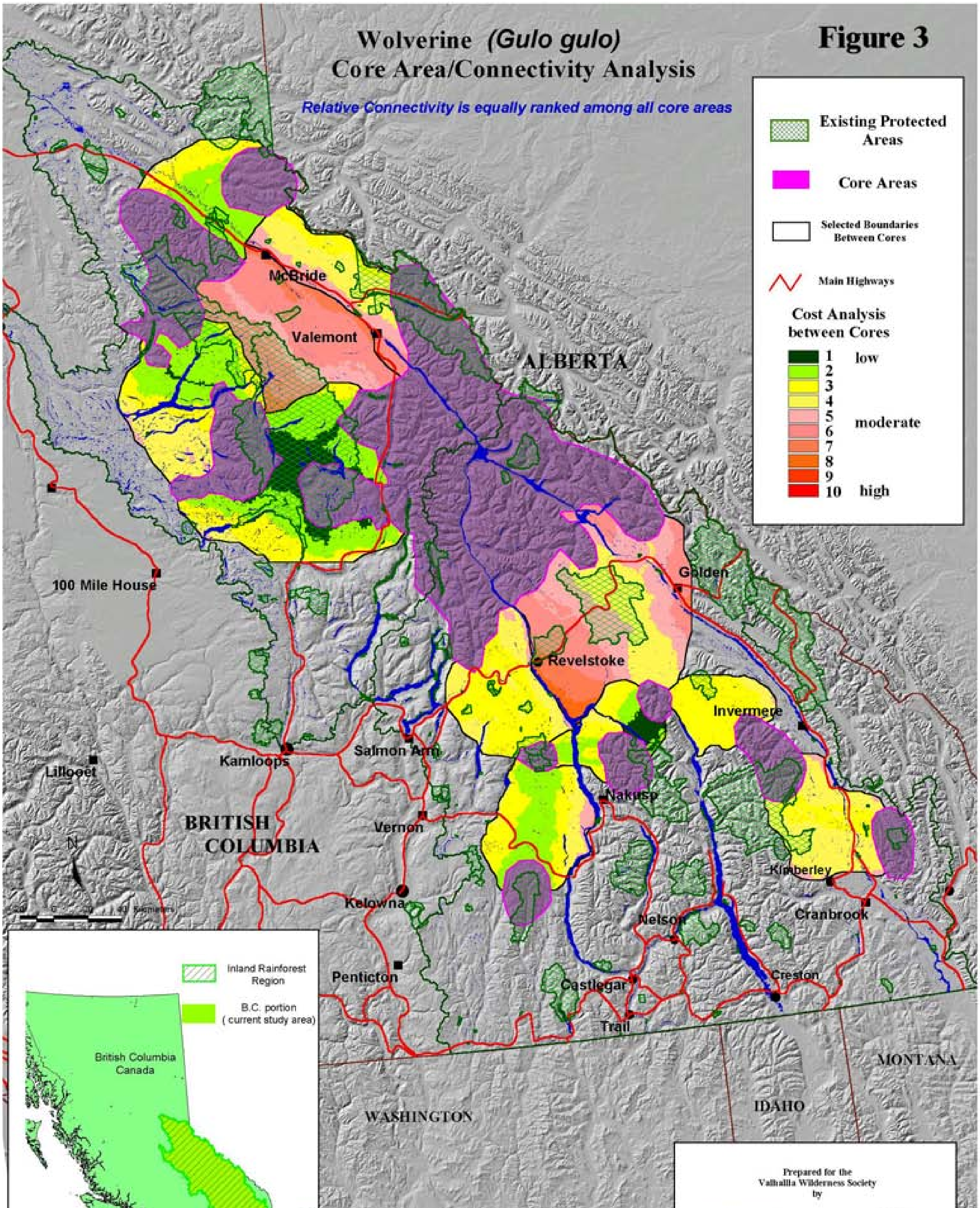
Wolverine (Gulo gulo)
Core Area/Connectivity Analysis
Figure 3
Relative Connectivity is equally ranked among all core areas
Existing Protected Areas
Core Areas
Selected Boundaries Between Cores
Main Highways
Cost Analysis between Cores
1 low
2
3
4
5 moderate
6
7
8
9
10 high
McBride
Valemont
ALBERTA
Golden
100 Mile House
Revelstoke
Invermere
Kamloops
Salmon Arm
Lillooet
Nakusp
BRITISH COLUMBIA
Vernon
Kimberley
Kelowna
Cranbrook
Nelson
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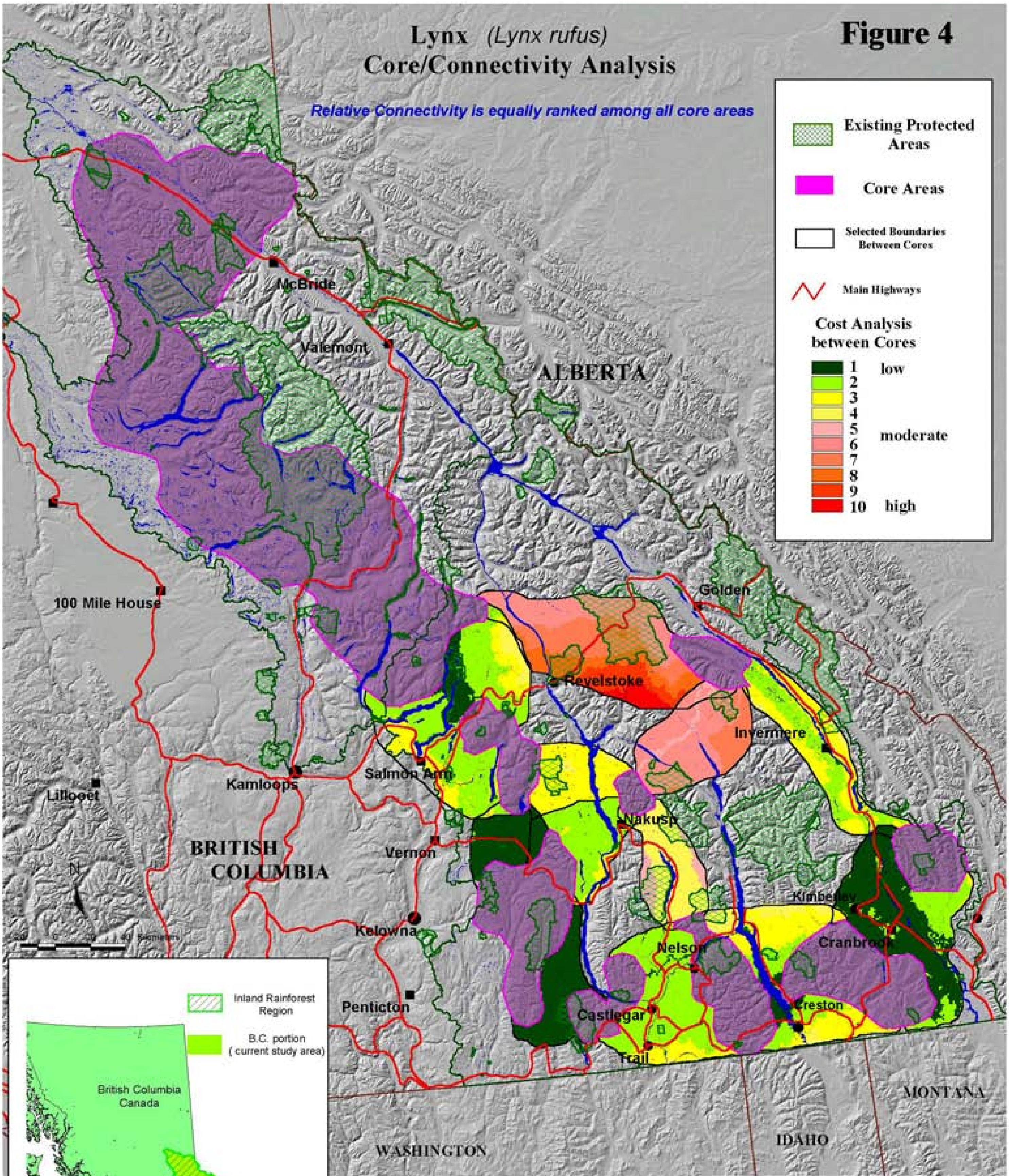

Lynx (Lynx rufus)
Core/Connectivity Analysis
Figure 4
Relative Connectivity is equally ranked among all core areas
Existing Protected Areas
Core Areas
Selected Boundaries Between Cores
Main Highways
Cost Analysis between Cores
1 low
2
3
4
5 moderate
6
7
8
9
10 high
McBride
Valemont
ALBERTA
Golden
100 Mile House
Revelstoke
Invermere
Kamloops
Salmon Arm
Lillooet
Nakusp
BRITISH COLUMBIA
Vernon
Kimberley
Kelowna
Nelson
Cranbrook
Penticton
Creston
Castlegar
Trail
Inland Rainforest Region
B.C. portion (current study area)
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in cooperation with

Connectivity habitat for lynx, using the thresholds described, totals 2,668,600 ha. which is 19% of the ITR. Taken together, lynx core and connectivity habitat, using the thresholds described, comprises 49% of the ITR; this is habitat which should be given some measure of protection in order to maintain current population status.

Cougar Cores and Connectivity

The results of Cougar Focal Species analysis are presented in Figure 5. Large areas of core habitat exist along the western and southeastern edges of the study area. In the southern portion, where there is more human development and habitat fragmentation, areas of core habitat are much smaller, requiring longer distances through less-optimal habitat to maintain connectivity. Cougar have not been well-studied in the ITR, and given their tolerance of human activities it is likely that there is much more cougar habitat, especially in the southern part of the study area where ungulate populations may be high, than the model predicts.

Total core area for cougar, using the habitat thresholds described in Methods, comprises 4,895,400 ha. which is 34% of the area of the ITR.

Connectivity habitat for cougar, using the thresholds described, totals 4,223,500 ha. which is 30% of the ITR. Taken together, cougar core and connectivity habitat, using the thresholds described, comprises 64% of the ITR; this is habitat which should be given some measure of protection in order to maintain current population status.

Wolf Cores and Connectivity

To develop the wolf model, a simple multiple regression was run using the RSF layer from CRM as the dependent variable with 4 elements: slope, elevation, road density and aspect. The results were as follows:

Regression Equation:

wolf-rsf3 = 437.3777 + 0.0010*aspect + 0.0157*elev3
- 0.3944*roads3 - 0.5307*slope3

Regression Statistics:

Apparent R = 0.390475 Apparent R square = 0.152471
Adjusted R = 0.390448 Adjusted R square = 0.152450
F (4, 119647) = 5381.135742

We then used the above regression statistics to evaluate the RSF values within the ITR region that were beyond the boundary of the CRM data. This data was then added to the CRM layer to cover our study area. The wolf RSF layer was rebuilt to the ITR boundary including the estimated values for areas beyond the CRM region. The same methodology

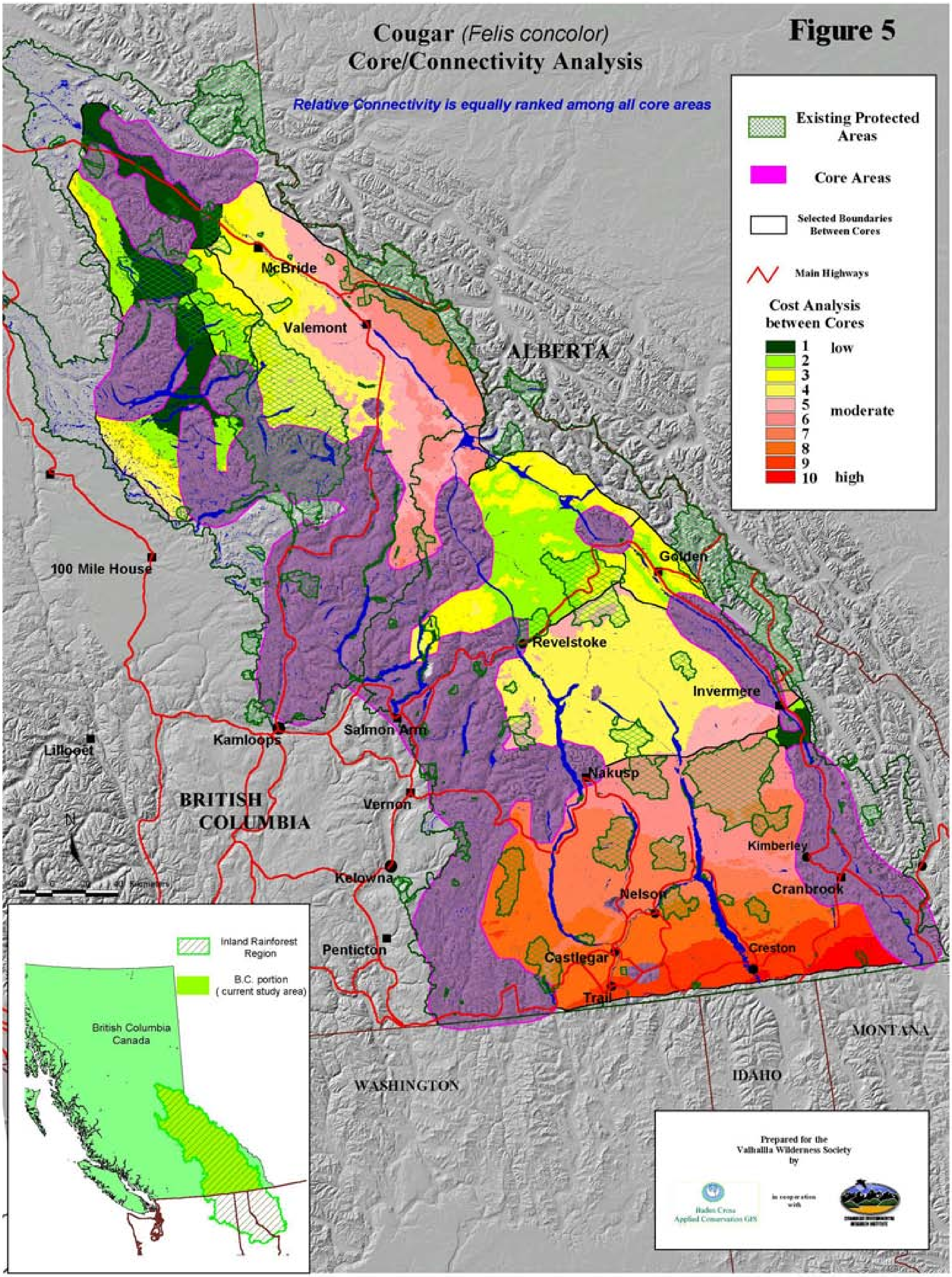

Figure 5
Cougar (Felis concolor)
Core/Connectivity Analysis
Relative Connectivity is equally ranked among all core areas
Existing Protected Areas
Core Areas
Selected Boundaries Between Cores
Main Highways
Cost Analysis between Cores
1 low
2
3
4
5 moderate
6
7
8
9
10 high
ALBERTA
BRITISH COLUMBIA
WASHINGTON
IDAHO
MONTANA
McBride
Valemont
100 Mile House
Golden
Revelstoke
Invermere
Lillooet
Kamloops
Salmon Arm
Nakusp
Vernon
Kimberley
Kelowna
Cranbrook
Nelson
Penticton
Creston
Castlegar
Trail
Inland Rainforest Region
B.C. portion (current study area)
British Columbia Canada
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as above was applied to the friction layer and the newly developed RSF layer. Core areas were estimated by using a neighborhood summation on 5 km on 1000 m cells.

The results of Wolf Focal Species analysis are presented in Figure 6. Large areas of core habitat exist in the northern portion of the study area. In the southern portion, where there is more human development and habitat fragmentation, areas of core habitat are much smaller, requiring longer distances through less-optimal habitat to maintain connectivity. Wolf also have not been well-studied in the ITR, and given their tolerance of human activities it is likely that there is more wolf habitat, especially in the southern part of the study area where ungulate populations may be high, than the model predicts.

Total core area for wolf, using the habitat thresholds described in Methods, comprises 8,018,551 ha. which is 56% of the area of the ITR.

Connectivity habitat for wolf, using the thresholds described, totals 3,447,000 ha. which is 24% of the ITR. Taken together, wolf core and connectivity habitat, using the thresholds described, comprises 80% of the ITR; this is habitat that should be given some measure of protection in order to maintain current population status.

Caribou Cores and Connectivity

The results of Caribou Focal Species analysis are presented in Figure 7. Large areas of core habitat exist in the mountainous central portions of the study area.

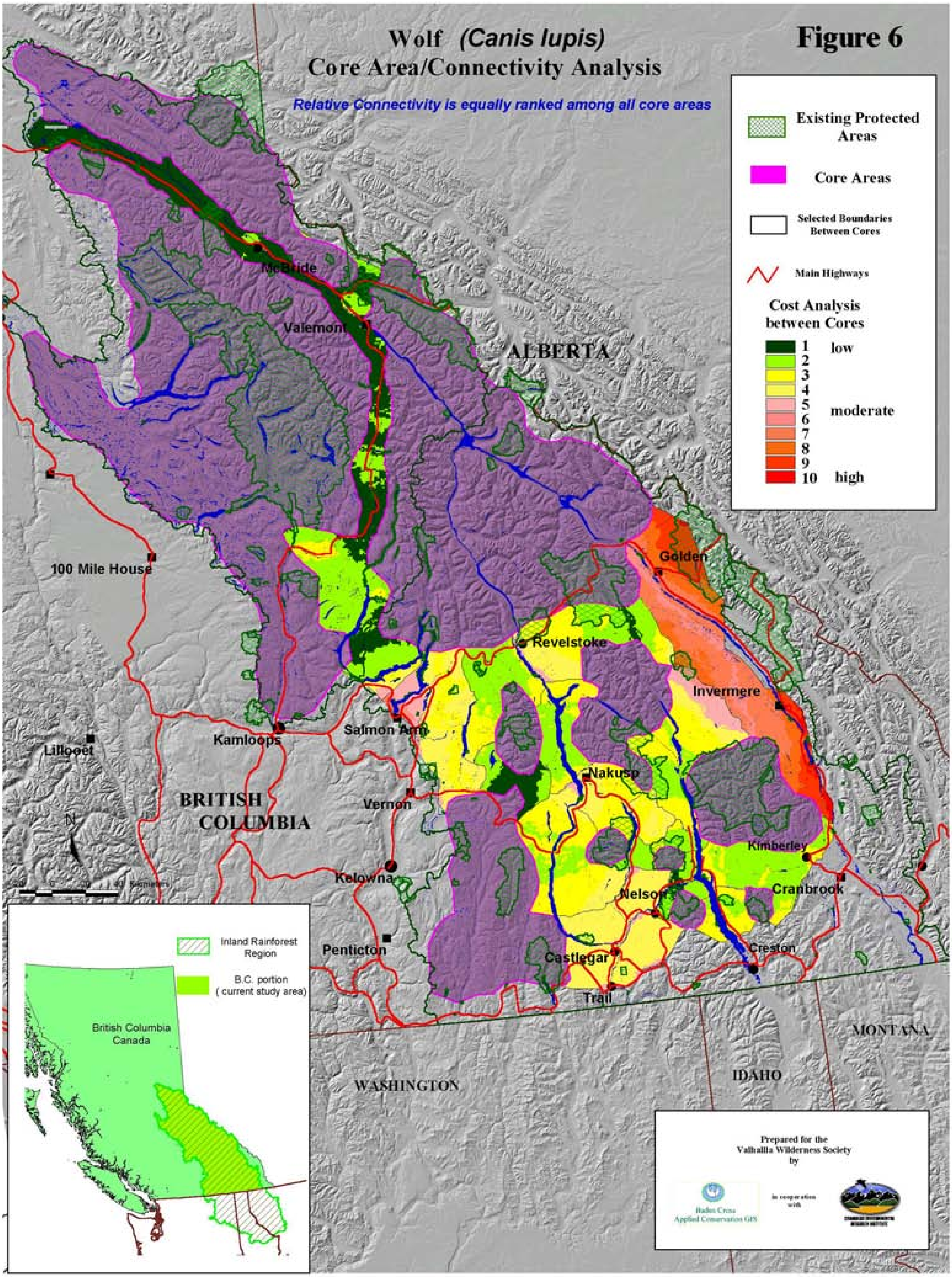
Total core area for caribou, using the habitat thresholds described in Methods, comprises 5,585,679 ha. which is 39% of the area of the ITR.

Connectivity habitat for caribou, using the thresholds described, totals 2,962,400 ha. which is 21% of the ITR. Taken together, caribou core and connectivity habitat, using the thresholds described, comprises 60% of the ITR; this is habitat which should be given some measure of protection in order to maintain current population status

The results of Caribou Focal Species analysis combined with the Caribou Special Element recovery areas are presented in Figure 8. Recovery areas would add substantially to the periphery of the core habitat along the central mountainous areas. Caribou core, connectivity, and recovery habitat, comprises a larger percentage of the ITR; this is habitat which should be given some measure of protection in order to recover a viable caribou population.

Composite Cores and Connectivity

The results of Composite Cores and Connectivity Focal Species analysis are presented in Figures 9 and 10. Composite solutions were mapped to include totals for any of the six focal species: grizzly, wolverine, lynx, cougar, wolf, and caribou. Thus, purple areas on the map in Figure 9 as 2 species contains habitat for at least two or more of the focal species. In the tables this is represented as 2,3,4,5 & 6 species. Linkage habitat (green


Wolf (Canis lupis)
Core Area/Connectivity Analysis
Figure 6
Relative Connectivity is equally ranked among all core areas
Existing Protected Areas
Core Areas
Selected Boundaries Between Cores
Main Highways
Cost Analysis between Cores
1 low
2
3
4
5 moderate
6
7
8
9
10 high
McBride
Valemont
ALBERTA
100 Mile House
Golden
Revelstoke
Invermere
Kamloops
Salmon Arm
Lillooet
Nakusp
BRITISH COLUMBIA
Vernon
Kimberley
Kelowna
Nelson
Cranbrook
Penticton
Creston
Castlegar
Trail
MONTANA
IDAHO
WASHINGTON
Inland Rainforest Region
B.C. portion (current study area)
British Columbia Canada
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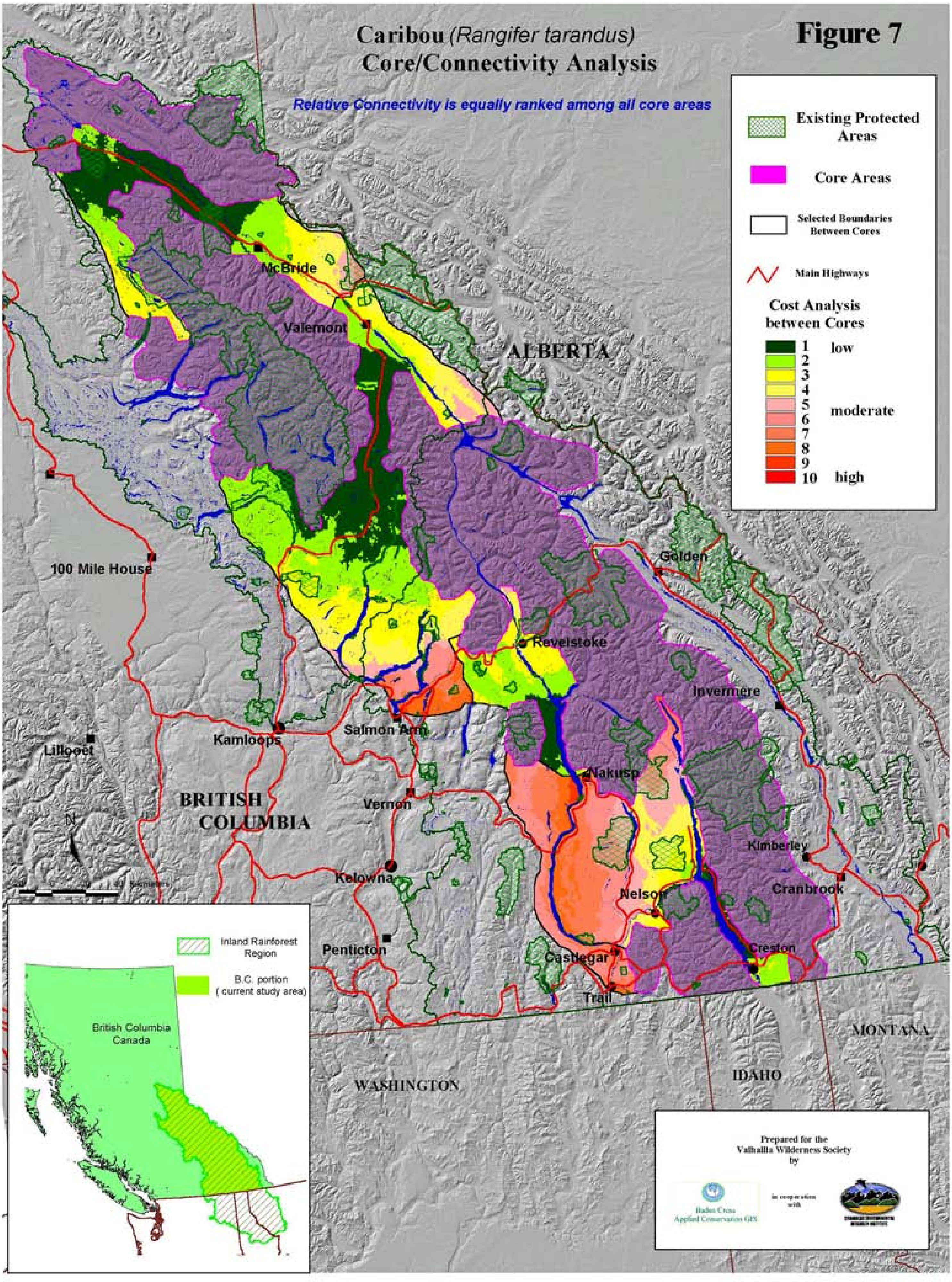

Caribou (Rangifer tarandus)
Core/Connectivity Analysis
Figure 7
Relative Connectivity is equally ranked among all core areas
Existing Protected Areas
Core Areas
Selected Boundaries Between Cores
Main Highways
Cost Analysis between Cores
1 low
2
3
4
5 moderate
6
7
8
9
10 high
McBride
Valemont
ALBERTA
100 Mile House
Golden
Revelstoke
Invermere
Salmon Arm
Kamloops
Lillooet
Nakusp
Vernon
BRITISH COLUMBIA
Kimberley
Kelowna
Cranbrook
Nelson
Penticton
Creston
Castlegar
Trail
MONTANA
IDAHO
WASHINGTON
Inland Rainforest Region
B.C. portion (current study area)
British Columbia Canada
Prepared for the
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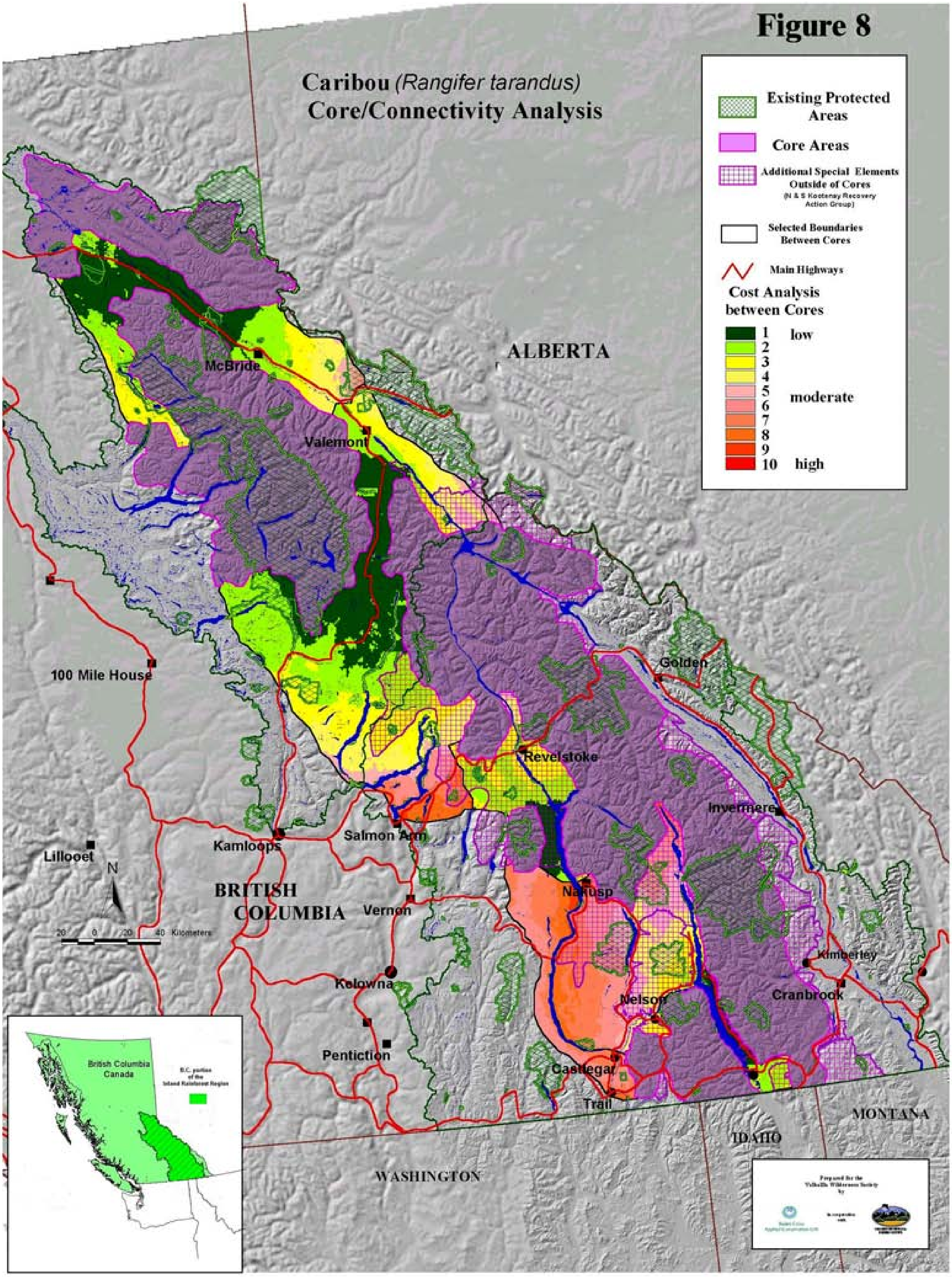

Figure 8
Caribou (Rangifer tarandus)
Core/Connectivity Analysis
Existing Protected Areas
Core Areas
Additional Special Elements Outside of Cores
(N & S Kootenay Recovery Action Group)
Selected Boundaries Between Cores
Main Highways
Cost Analysis between Cores
1 low
2
3
4
5 moderate
6
7
8
9
10 high
ALBERTA
BRITISH COLUMBIA
McBride
Valemont
100 Mile House
Golden
Revelstoke
Invermere
Kamloops
Salmon Arm
Lillooet
Nakusp
Vernon
Kimberley
Kelowna
Cranbrook
Nelson
Pentiction
Castlegar
Trail
MONTANA
IDAHO
WASHINGTON
N
20 0 20 40 Kilometers
British Columbia Canada
B.C. portion of the Inland Rainforest Region
Prepared for the Valhalla Wilderness Society by

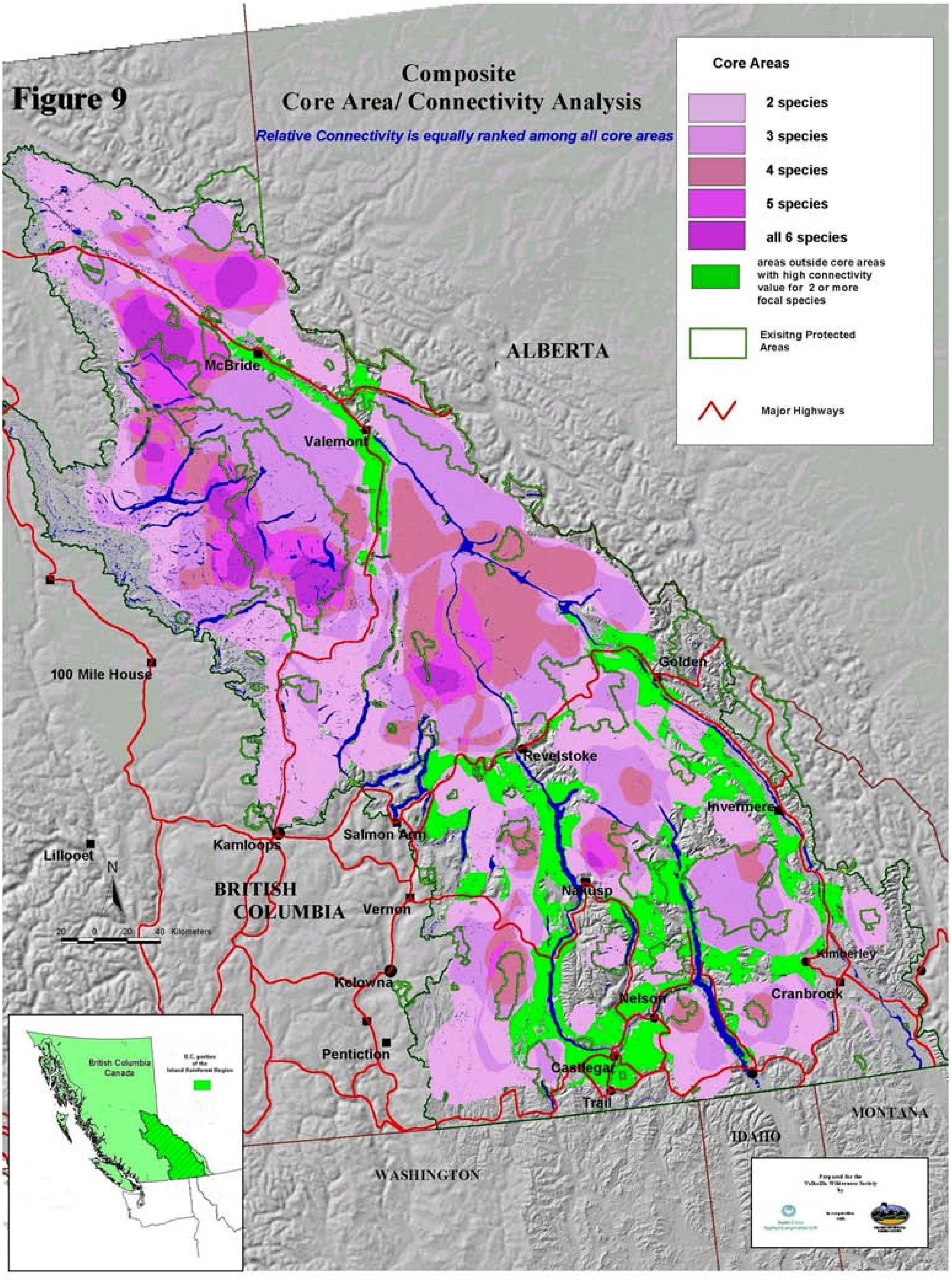

Figure 9

Composite Core Area/ Connectivity Analysis

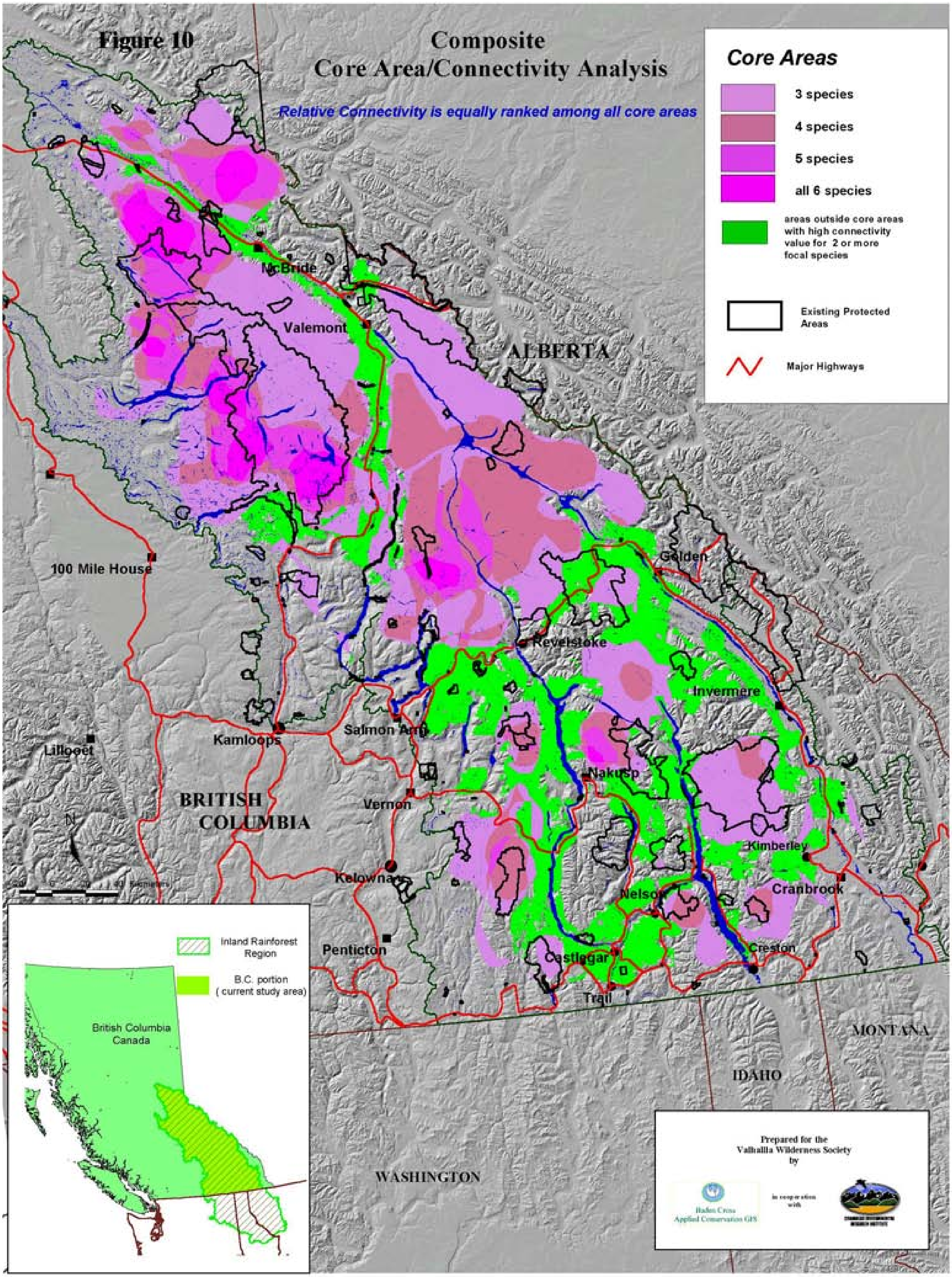
Figure 10
Composite
Core Area/Connectivity Analysis
Relative Connectivity is equally ranked among all core areas
Core Areas
3 species
4 species
5 species
all 6 species
areas outside core areas with high connectivity value for 2 or more focal species
Existing Protected Areas
Major Highways
McBride
Valemont
ALBERTA
100 Mile House
Golden
Revelstoke
Invermere
Salmon Arm
Kamloops
Lillooet
Nakusp
BRITISH COLUMBIA
Vernon
Kimberley
Kelowna
Cranbrook
Nelson
Penticton
Creston
Castlegar
Trail
MONTANA
IDAHO
WASHINGTON
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British Columbia Canada
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areas) between the cores should be managed to allow movement of individuals (and thus gene flow and demographic rescue) between core areas.

Purple areas on the map in Figure 10 show the composite habitat for 3,4,5 & 6 species (3 or more of the focal species). The fact that habitat for these 6 focal species does not overlap greatly (Figure 10 and Table below) lends credence to their value as a suite of umbrella species (Lambeck 1997, Carroll *et al*. 2001, Roberge and Angelstam 2004).

This synthesis combines the habitat cores and habitat connectivity results for all six focal species to depict areas of high conservation value for groups of focal species. The individual species are not identified in this map; it is necessary to examine the individual species maps for that information. The striking result that is displayed in this map, and supported by each of the individual species analyses, is that the best habitat is found in the northern part of the region, while the most fragmented habitat is found in the southern part. This is primarily due to the amount of roads and developments in the latter. In order to maintain viable populations of these wide-ranging species the best opportunity exists in the north. Viable populations and functioning ecosystems can still be maintained in this part of the region by protecting current habitat and limiting development.

Conserving intact rainforest habitat in the darker purple areas should maintain populations of most focal species. To maintain all core areas for all focal species requires 89% of the ITR area. To maintain key core areas that support at least 4 of the focal species requires 64% of the ITR. Population persistence is most likely in the northern portion of the study area. To maintain populations in the southern portion of the study area will require maintaining the important movement habitat identified by green. Important core habitats, and connectivity habitat extends across the boundaries of this particular study, and these results need to be considered in the larger context into the United States, and through the rest of British Columbia.

Populations in the south are at much greater risk and the conservation priority here is to restore connectivity while protecting the small core areas that remain. These results are further affirmed by the aquatic habitat analyses (next section). However, to maintain the full range of biodiversity within the region, additional areas in the southern, more diverse, part of the region need to be protected (following section).

Table 9. Habitat Concentration Area (core) Plus Linkage Habitat Totals for Focal Species.

Core areas for # of species	**hectares**	**% total BC ITR**	**Core areas + linkage habitat**	**% total BC ITR**	**% of total Grizzly Bear Core area (composite core + linkage)**
6 species	411,796	3	3,480,196	24.3	8.0
5 & 6 species	1,106,902	8	4,171,802	29.2	18.6
4,5 & 6 species	2,699,759	19	5,584,659	39.0	42.8
3,4,5&6 species	**5,736,836**	**40**	**7,910,736**	**55.3**	**80.4**
2,3,4,5&6 species	9,113,348	64	10,547,548	73.7	93.8
1,2,3,4,5&6 species	12,727,914	89	13,308,414	93.0	100.0

Including caribou recovery areas as a special element would increase the solution for **3,4,5&6 species** to 11,759,700 hectares or 82.2% of the BC ITR.

Aquatic Focal Species Analysis

Salmon stream reaches

Stream reaches supporting salmon stocks are shown in Figure 11.

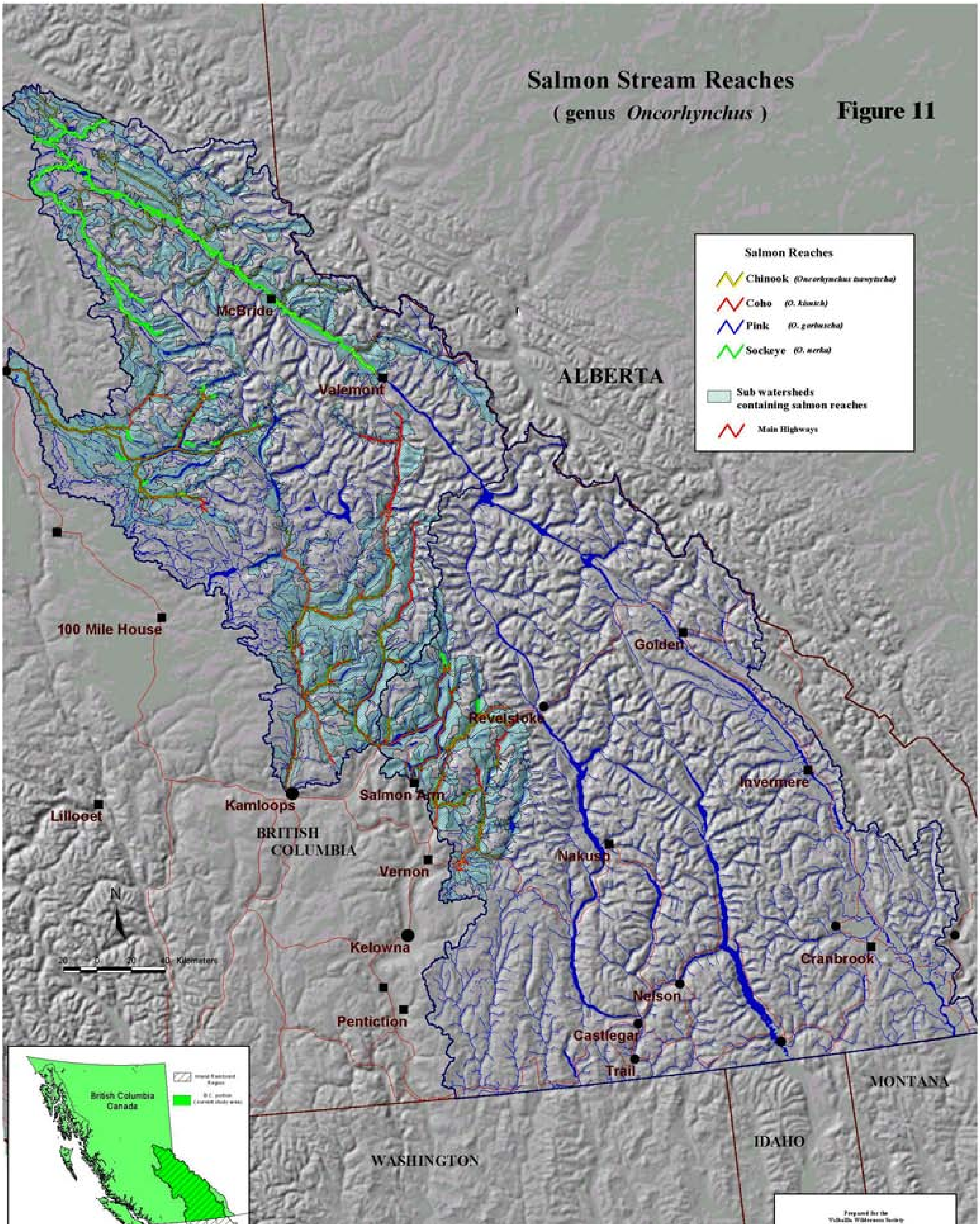
Salmon diversity

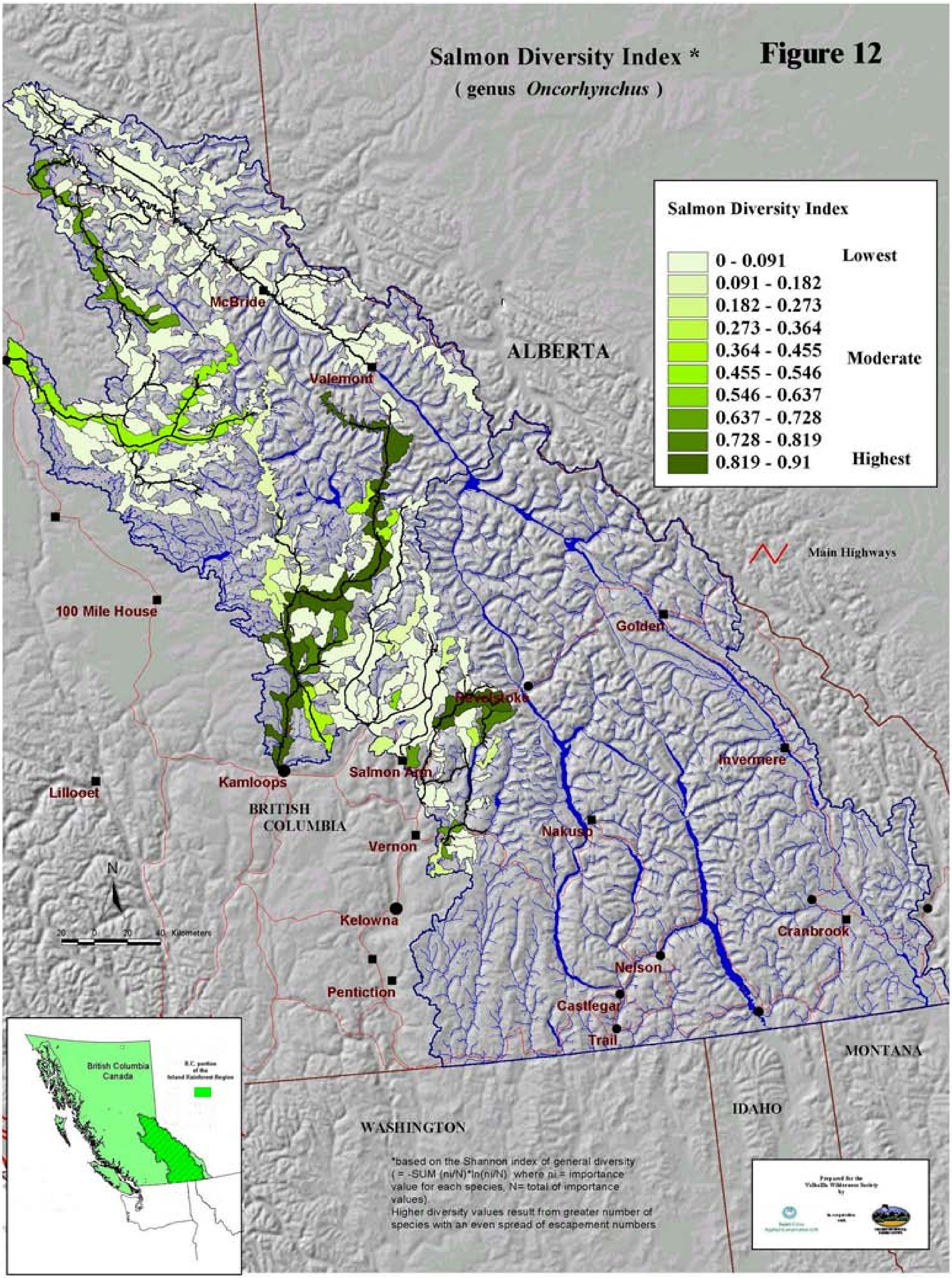
Results of the salmon diversity index, based upon number of salmon species present, is presented in Figure 12.

Stream reaches were identified using the Shannon Diversity index:

$H = - S\ (ni/N) \ln (ni/N)$ or $- S\ P_i \ln P$

where ni = importance value for each species
N = total of importance values
Pi = importance probability for each species = ni/N


Salmon Stream Reaches
(genus Oncorhynchus)
Figure 11
Salmon Reaches
Chinook
Coho
Pink
Sockeye
Sub watersheds
containing salmon reaches
Main Highways
ALBERTA
McBride
Valemont
100 Mile House
Golden
Revelstoke
Invermere
Kamloops
Salmon Arm
Lillooet
BRITISH
COLUMBIA
Nakusp
Vernon
Kelowna
Cranbrook
Nelson
Pentiction
Castlegar
Trail
MONTANA
IDAHO
WASHINGTON
N
20 0 20 40 Kilometers
British Columbia
Canada



Salmon Diversity Index *
Figure 12
(genus Oncorhynchus)
Salmon Diversity Index
0 - 0.091
0.091 - 0.182
0.182 - 0.273
0.273 - 0.364
0.364 - 0.455
0.455 - 0.546
0.546 - 0.637
0.637 - 0.728
0.728 - 0.819
0.819 - 0.91
Lowest
Moderate
Highest
Main Highways
ALBERTA
McBride
Valemont
100 Mile House
Golden
Revelstoke
Invermere
Kamloops
Salmon Arm
Lillooet
BRITISH COLUMBIA
Vernon
Nakusp
Kelowna
Cranbrook
Nelson
Pentiction
Castlegar
Trail
MONTANA
IDAHO
WASHINGTON
N
20 0 20 40 Kilometers
British Columbia
Canada
B.C. portion
of the
Inland Rainforest Region
*based on the Shannon index of general diversity
(= -SUM (ni/N)*ln(ni/N) where ni = importance
value for each species, N= total of importance
values).
Higher diversity values result from greater number of
species with an even spread of escapement numbers

Salmon abundance/escapement

Salmon abundance estimates are mapped in Figure 13. These estimates are based upon salmon escapement or numbers of salmon counted passing upstream at weirs where their passage is restricted to a narrow channel so they can be counted.

Salmon Average Abundance Index

The Salmon Average Abundance Index, using a method developed by Round River Conservation Studies (Jeo, 200x) is presented in Figure 14. This can be considered a best overall measure of relative importance of streams in terms of salmon conservation. This index was used to identify salmon priority watersheds.

Salmon Average Abundance Index: $SI_{ws} = S_1^{\,n}\ stock_{ws}^{\,n} / \max(stock_{all\ n})$

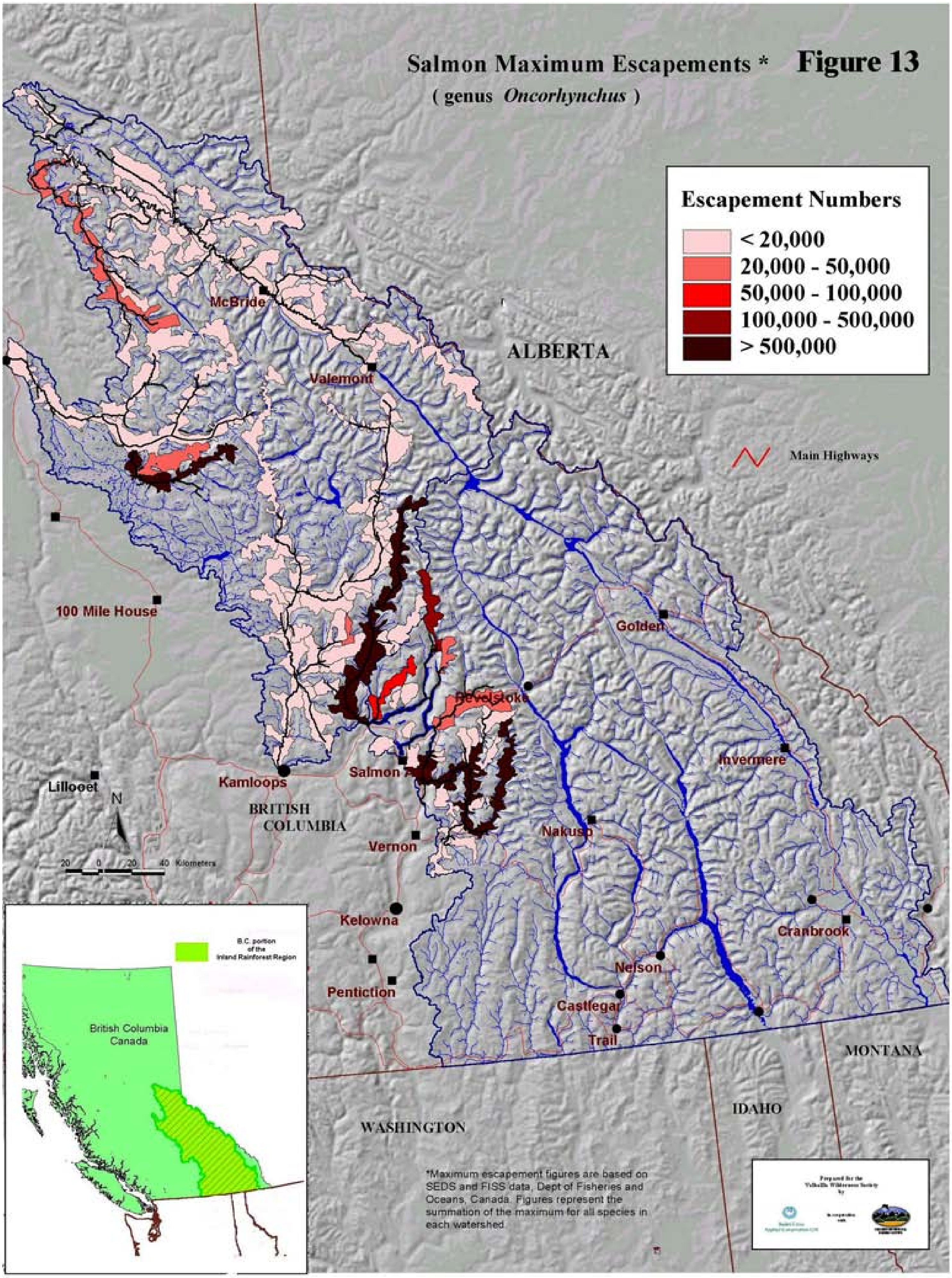
where
ws = 45 digit watershed code
n = number of stocks
stock = mean stock escapement values for the following salmon stocks:
coho, chinook, sockeye

and Shannon Diversity index:

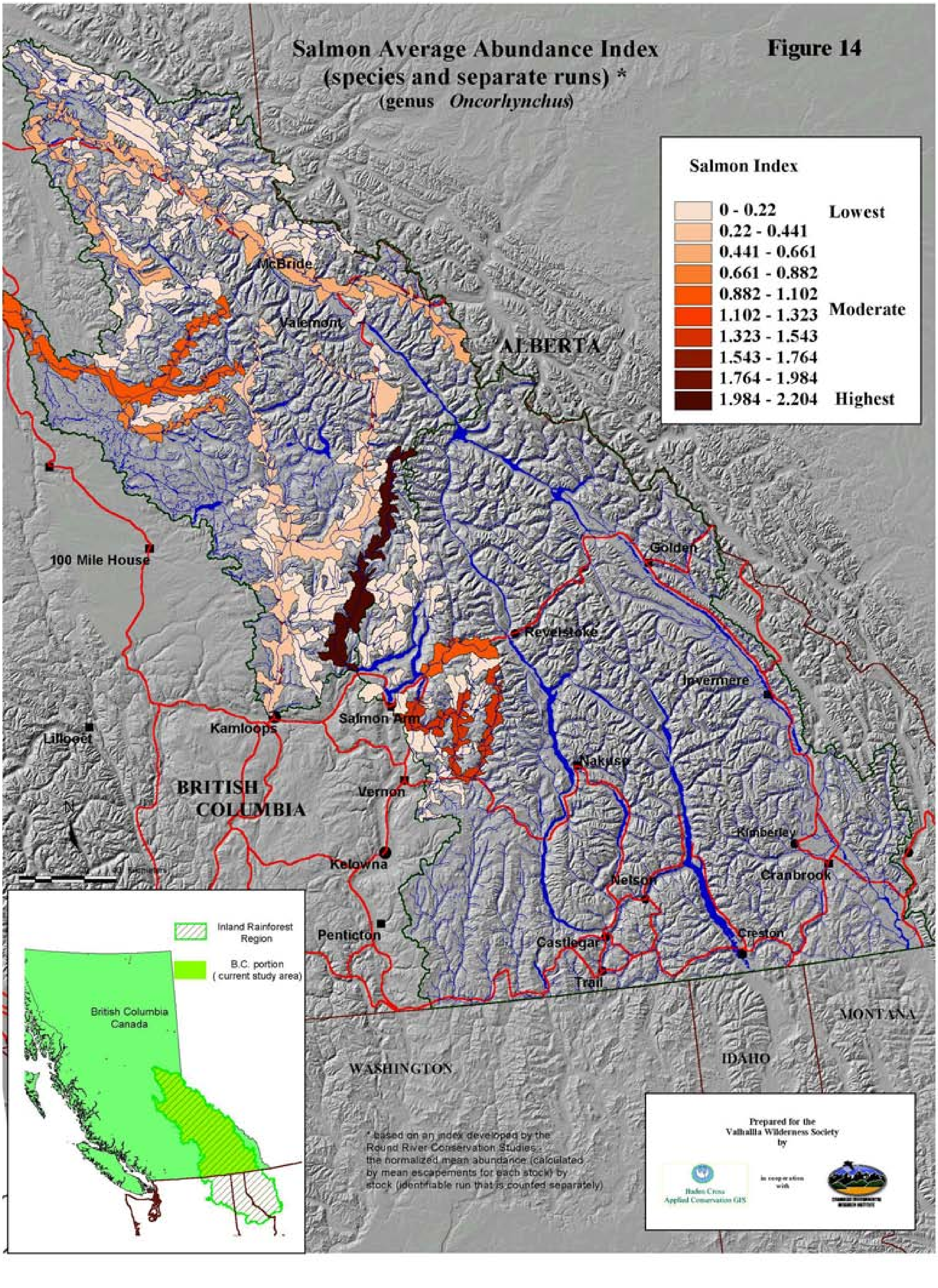
$H = -S\,(ni/N)\ln(ni/N)$ or $-S\,P_i \ln P$

where ni = importance value for each species
N = total of importance values
Pi = importance probability for each species = ni/N

The pink salmon numbers for the Fraser River from the Department of Fisheries and Oceans (DFO) database unduly affected the overall evaluation of the RR index. The pink runs occur in the lower reaches of the river system as there are no spawning reaches within the Inland Temperate Rainforest [ITR] region. These figures were deleted from our calculations.



Salmon Maximum Escapements *
Figure 13
(genus *Oncorhynchus*)
Escapement Numbers
< 20,000
20,000 - 50,000
50,000 - 100,000
100,000 - 500,000
> 500,000
Main Highways
ALBERTA
McBride
Valemont
100 Mile House
Golden
Revelstoke
Invermere
Lillooet
Kamloops
Salmon Arm
BRITISH
COLUMBIA
Nakusp
Vernon
N
20 0 20 40 Kilometers
Kelowna
Cranbrook
Nelson
Penticton
Castlegar
Trail
MONTANA
IDAHO
WASHINGTON
B.C. portion
of the
Inland Rainforest Region
British Columbia
Canada
*Maximum escapement figures are based on SEDS and FISS data, Dept of Fisheries and Oceans, Canada. Figures represent the summation of the maximum for all species in each watershed



Salmon Average Abundance Index
(species and separate runs) *
(genus Oncorhynchus)
Figure 14
Salmon Index
0 - 0.22 Lowest
0.22 - 0.441
0.441 - 0.661
0.661 - 0.882
0.882 - 1.102
1.102 - 1.323 Moderate
1.323 - 1.543
1.543 - 1.764
1.764 - 1.984
1.984 - 2.204 Highest
McBride
Valemont
ALBERTA
100 Mile House
Golden
Revelstoke
Invermere
Kamloops
Salmon Arm
Lillooet
Nakusp
BRITISH COLUMBIA
Vernon
N
Kelowna
Kimberley
Cranbrook
Nelson
Penticton
Castlegar
Creston
Trail
MONTANA
IDAHO
WASHINGTON
Inland Rainforest Region
B.C. portion (current study area)
British Columbia Canada
* based on an index developed by the Round River Conservation Studies - the normalized mean abundance (calculated by mean escapements for each stock) by stock (identifiable run that is counted separately)
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Composite Focal Species Cores and Connectivity plus Salmon Priority Watersheds

Results of the composite focal species core and connectivity analyses were overlain with the salmon priority watersheds identified by the Salmon Average Abundance Index. A map of the focal species solution for at least 2 focal species is combined with salmon priority watersheds in Figure 15. A map of the focal species solution for at least 3 focal species is combined with salmon priority watersheds in Figure 16.

To maintain core and connectivity habitat for all focal species and to maintain all priority salmon watersheds will involve conservation management of 93.9% of the ITR in Canada.

Table 10. Salmon Priority Watershed Totals Plus Habitat Concentration Area (core) Totals for Focal Species.

Core areas for # of species	ha	% total BC ITR	area of all linkage and salmon watersheds outside core combination (ha)	Total (ha)	% total BC ITR
6 species	411,796	3	5,486,900	5,898,696	41.2
5 & 6 species	1,106,902	8	5,259,800	6,366,702	44.5
4,5 & 6 species	2,699,759	19	4,894,800	7,594,559	53.1
3,4,5&6 species	5,736,836	40	3,766,900	9,503,736	66.4
2,3,4,5&6 species	9,113,348	64	2,116,800	11,230,148	78.5
1,2,3,4,5&6 species	12,727,914	89	712,600	13,440,514	93.9

The fact that habitat for the 6 terrestrial focal species does not overlap greatly (Figure 10) lends credence to their value as a suite of umbrella species (Lambeck 1997, Carroll *et al.* 2001, Roberge and Angelstam 2004). The addition of salmon as an aquatic focal species, and salmon watersheds as conservation targets (Figure 16) increases the area required and broadens the 'umbrella' effect of the focal species approach. As additional aquatic species are included some additional area will be included (according to preliminary results) but most important habitat for spawning and for red- and blue-listed species appears to be included in the focal species/salmon analysis.

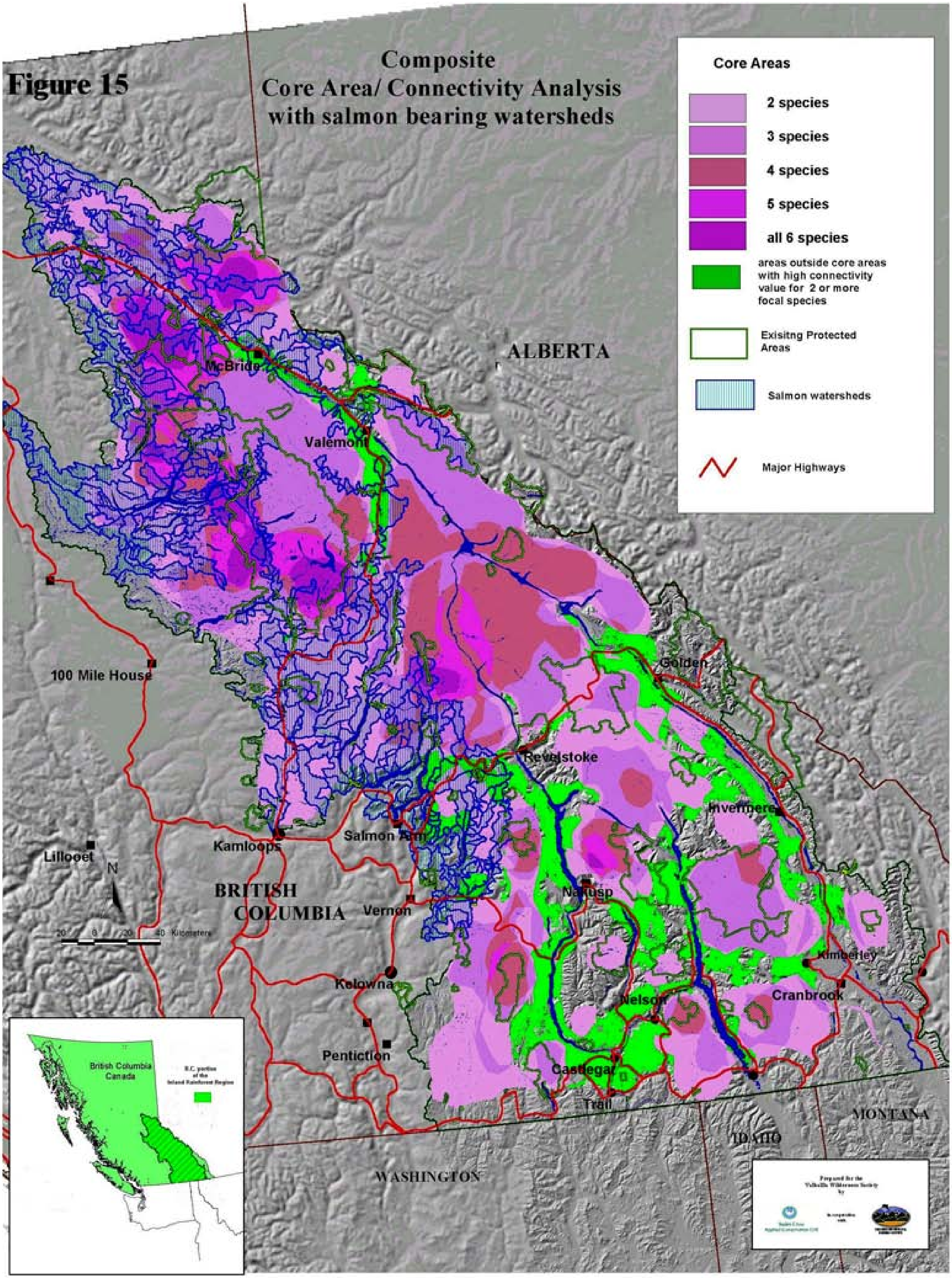
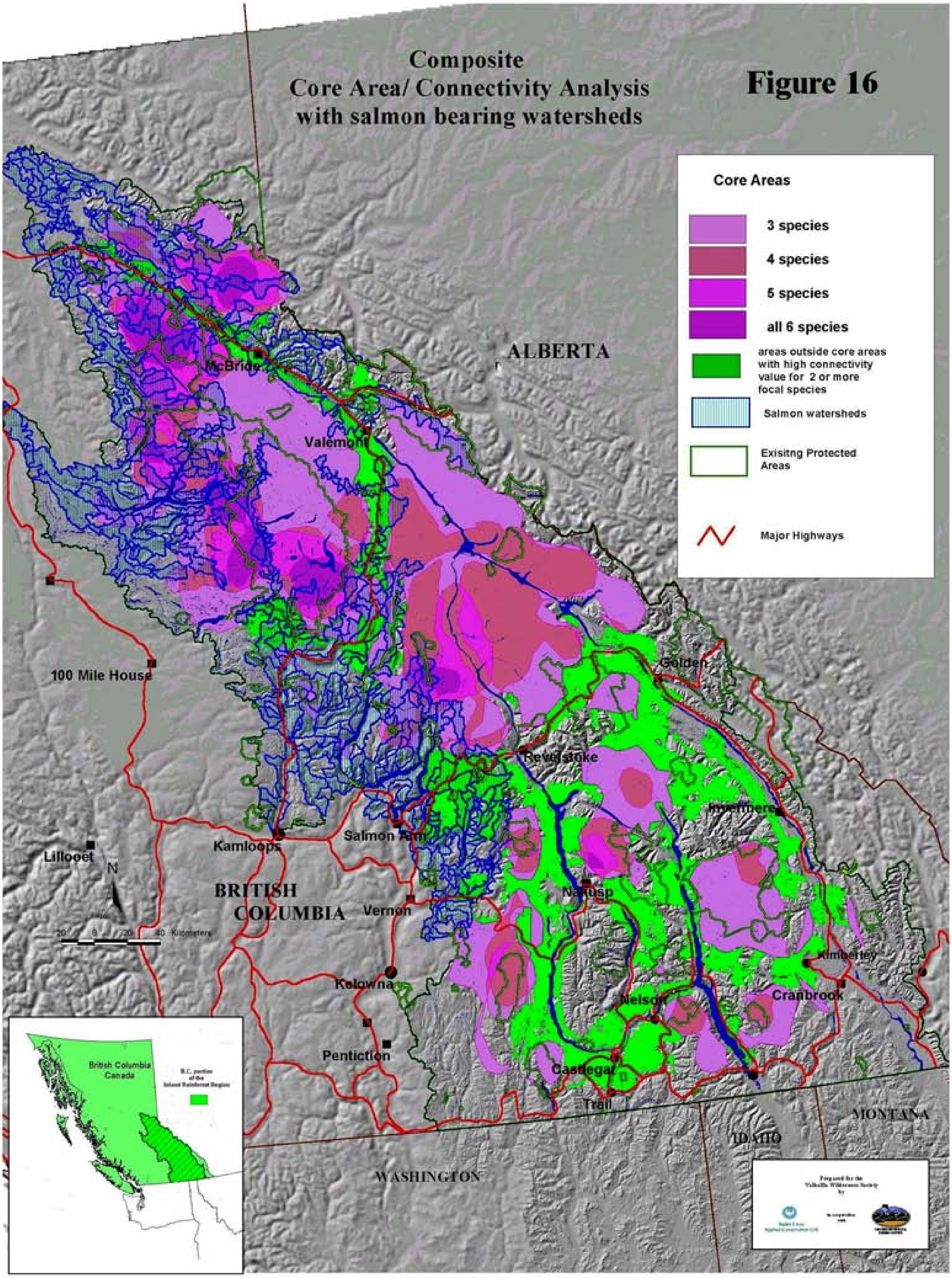


Figure 15
Composite
Core Area/ Connectivity Analysis
with salmon bearing watersheds
Core Areas
2 species
3 species
4 species
5 species
all 6 species
areas outside core areas with high connectivity value for 2 or more focal species
Exisitng Protected Areas
Salmon watersheds
Major Highways
ALBERTA
McBride
Valemont
Golden
100 Mile House
Revelstoke
Invermere
Kamloops
Salmon Arm
Lillooet
BRITISH COLUMBIA
Vernon
Nakusp
Kimberley
Kelowna
Cranbrook
Nelson
Penticton
Castlegar
Trail
MONTANA
IDAHO
WASHINGTON
British Columbia Canada
Kilometers



Composite
Core Area/ Connectivity Analysis
with salmon bearing watersheds
Figure 16
Core Areas
3 species
4 species
5 species
all 6 species
areas outside core areas with high connectivity value for 2 or more focal species
Salmon watersheds
Exisitng Protected Areas
Major Highways
ALBERTA
BRITISH COLUMBIA
WASHINGTON
IDAHO
MONTANA
McBride
Valemont
100 Mile House
Golden
Revelstoke
Invermere
Kamloops
Salmon Arm
Lillooet
Nakusp
Vernon
Kimberley
Cranbrook
Kelowna
Nelson
Penticton
Castlegar
Trail
N
20 0 20 40 Kilometers
British Columbia Canada
B.C. portion of the Inland Rainforest Region
Prepared for the Valhalla Wilderness Society

Nature Conservancy Representation Analyses

TNC 'Locked' Summed Solution

The TNC/NCC locked solution represents the best areas for biodiversity representation, according to the SITES computation, and automatically includes all areas that currently have protected status.

TNC 'No Lock' Summed Solution

The TNC/NCC no lock solution represents the best areas for biodiversity representation, according to the SITES computation, without automatically including areas that currently have protected status.

TNC Tier 1 and Tier 2 Summed Solution

The Tier 1 and Tier 2 Summed Solution comprises the priority conservation watershed identified as having the highest conservation value according to methods summarized in Appendix B.

Composite Focal Species Cores plus Salmon Watersheds plus TNC 'locked' Summed Solutions.

Results of the composite focal species core and connectivity analyses plus the salmon priority watersheds identified by the Salmon Average Abundance Index were overlain with the TNC locked summed solution for the Canadian Rockies Ecoregional plan. A map of the focal species solution for at least 2 focal species plus salmon priority watersheds plus the TNC locked summed solution is shown in Figure 17. A map of the focal species solution for at least 3 focal species plus salmon priority watersheds plus the TNC locked summed solution is shown in Figure 18.

Table 11. Salmon Priority Watershed Totals Plus Habitat Concentration Area (core) Totals for Focal Species Plus TNC 'locked' summed SITES Solutions.

Core areas for # of species	hectares	% total BC ITR	core+linkage+ salmon + TNC locked area (ha)	% BC ITR
6 species	411,796	45.9	9,965,200	69.6
5 & 6 species	1,106,902	49.2	10,142,000	70.9
4,5 & 6 species	2,699,759	57.4	10,744,600	75.1
3,4,5&6 species	5,736,836	69.4	11,542,400	80.7
2,3,4,5&6 species	9,113,348	79.8	12,690,800	88.7
1,2,3,4,5&6 species	12,727,914	94.4	14,109,700	98.6

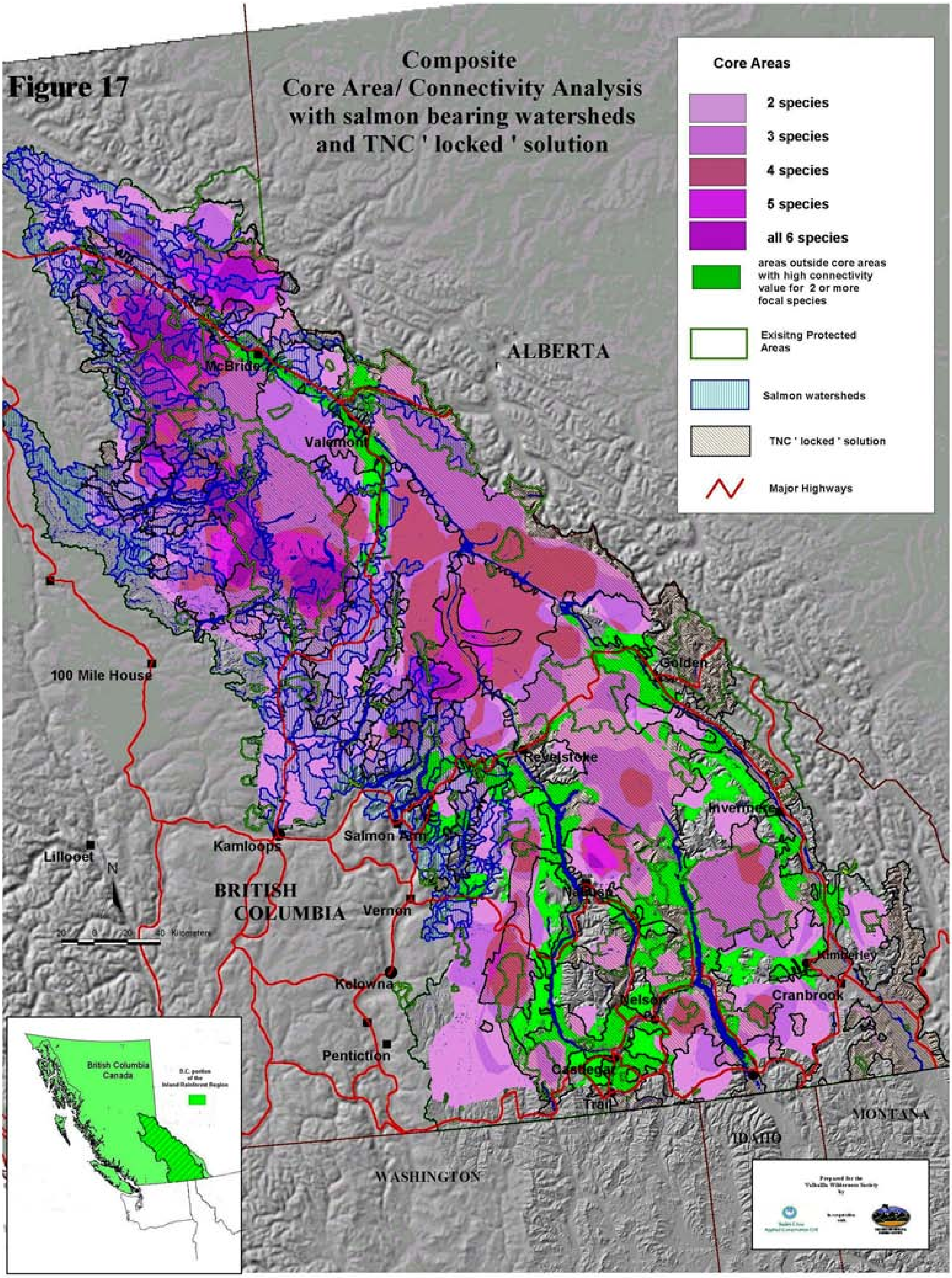


Figure 17
Composite
Core Area/ Connectivity Analysis
with salmon bearing watersheds
and TNC ' locked ' solution
Core Areas
2 species
3 species
4 species
5 species
all 6 species
areas outside core areas with high connectivity value for 2 or more focal species
Exisitng Protected Areas
Salmon watersheds
TNC ' locked ' solution
Major Highways
ALBERTA
McBride
Valemont
100 Mile House
Golden
Revelstoke
Invermere
Kamloops
Salmon Arm
Lillooet
BRITISH COLUMBIA
Vernon
Nakusp
Kimberley
Kelowna
Cranbrook
Nelson
Penticton
Castlegar
Trail
MONTANA
IDAHO
WASHINGTON
British Columbia Canada
B.C. portion of the Inland Rainforest Region
20 0 20 40 Kilometers
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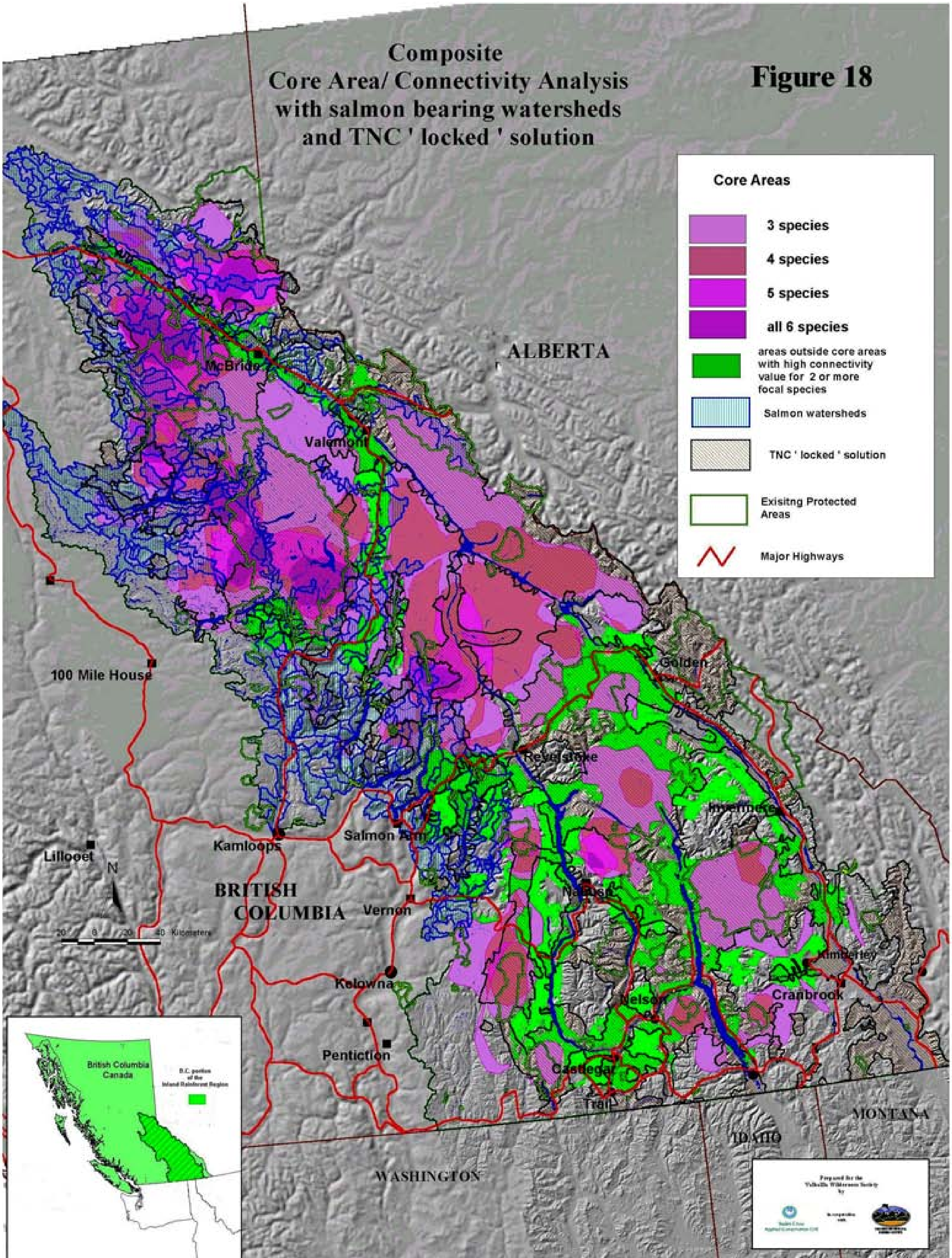

Composite
Core Area/ Connectivity Analysis
with salmon bearing watersheds
and TNC ' locked ' solution
Figure 18
Core Areas
3 species
4 species
5 species
all 6 species
areas outside core areas with high connectivity value for 2 or more focal species
Salmon watersheds
TNC ' locked ' solution
Exisitng Protected Areas
Major Highways
ALBERTA
McBride
Valemont
100 Mile House
Golden
Revelstoke
Invermere
Kamloops
Salmon Arm
Lillooet
BRITISH
COLUMBIA
Vernon
Nakusp
Kimberley
Cranbrook
Kelowna
Nelson
Penticton
Castlegar
Trail
MONTANA
IDAHO
WASHINGTON
N
20 0 20 40 Kilometers
British Columbia
Canada
B.C. portion
of the
Inland Rainforest Region

Composite Focal Species Cores plus Salmon Watersheds plus TNC 'no-lock' Summed Solutions.

Results of the composite focal species core and connectivity analyses plus the salmon priority watersheds identified by the Salmon Average Abundance Index were overlain with the TNC no-lock summed solution for the Canadian Rockies Ecoregional plan. A map of the focal species solution for at least 2 focal species plus salmon priority watersheds plus the TNC no-lock summed solution is shown in Figure 19. A map of the focal species solution for at least 3 focal species plus salmon priority watersheds plus the TNC no-lock summed solution is shown in Figure 20.

Table 12. Salmon Priority Watershed Totals Plus Habitat Concentration Area (core) Totals for Focal Species Plus TNC 'no-locked' summed SITES Solutions.

Core areas for # of species	**hectares**	**core+linkage+salmon + TNC no-locked area (ha)**	**% total BC ITR**
6 species	411,796	8,871,700	62.0
5 & 6 species	1,106,902	9,127,100	63.8
4,5 & 6 species	2,699,759	9,831,300	68.7
3,4,5&6 species	5,736,836	11,023,300	77.0
2,3,4,5&6 species	9,113,348	12,393,500	86.6
1,2,3,4,5&6 species	12,727,914	13,911,800	97.2

Composite Focal Species Cores plus Salmon Watersheds plus Tier 1 & 2 Summed Solutions.

Results of the composite focal species core and connectivity analyses plus the salmon priority watersheds identified by the Salmon Average Abundance Index were overlain with the TNC Tier 1 and Tier 2 summed solution for the Canadian Rockies Ecoregional plan.

Figure 21 represents core habitat for 2 or more focal wildlife species, (2,3,4,5 & 6 species), plus connectivity habitat between those cores, plus priority salmon watersheds, plus the TNC/NCC Tier 1 and 2 watersheds. Maintaining intact habitat in this area and managing the landscape for biodiversity would involve 84.7% of the Inland Temperate Rainforest of British Columbia. This is a more conservative alternative than that shown in Figure 22, which represents core habitat for 3 or more focal wildlife species, (3,4,5 & 6 species), plus connectivity habitat between those cores, plus priority salmon watersheds, plus the TNC/NCC Tier 1 and 2 watersheds. Maintaining intact habitat in this area and managing the landscape for biodiversity would involve 73.5% of the Inland Temperate Rainforest of British Columbia.

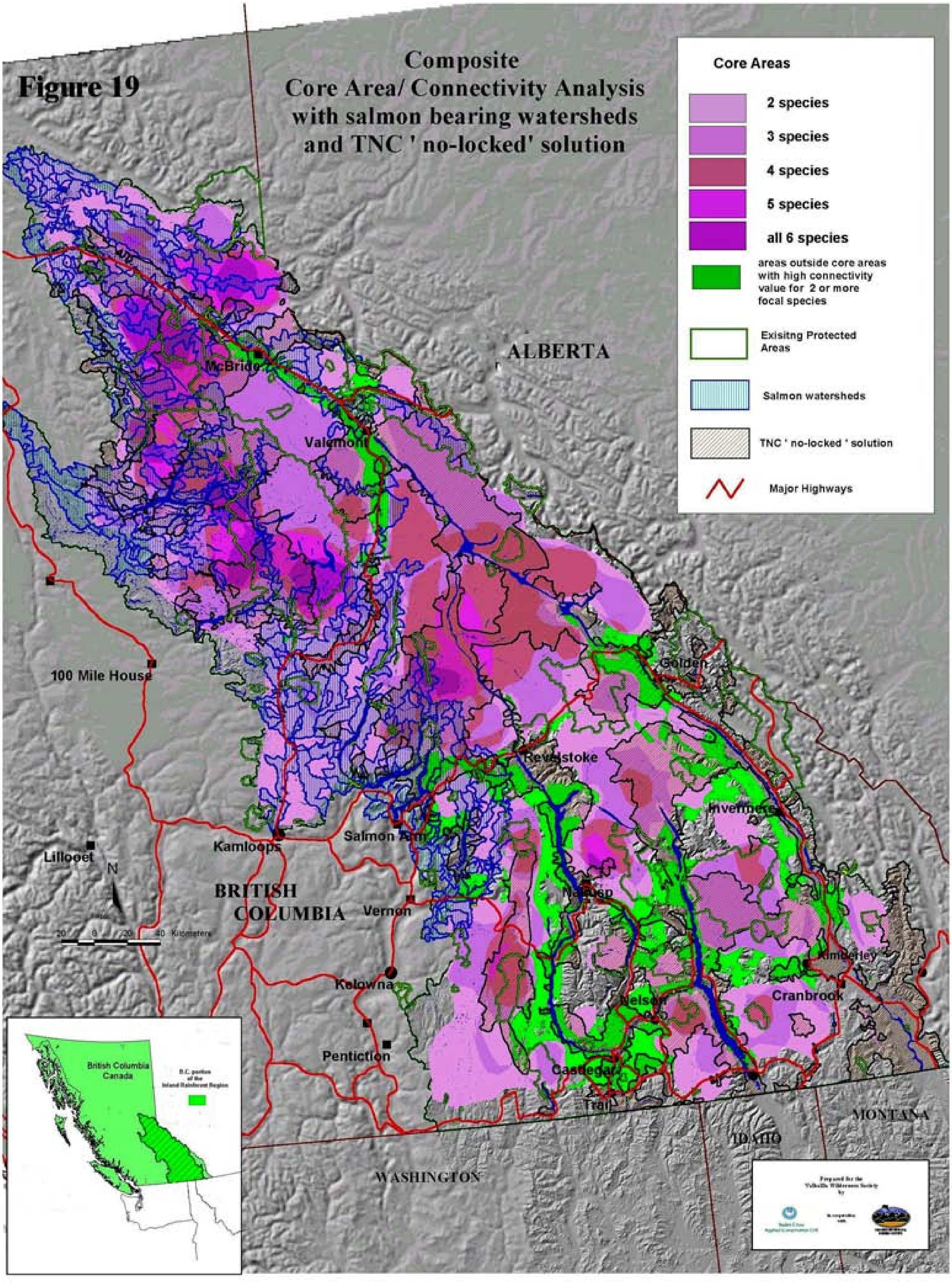
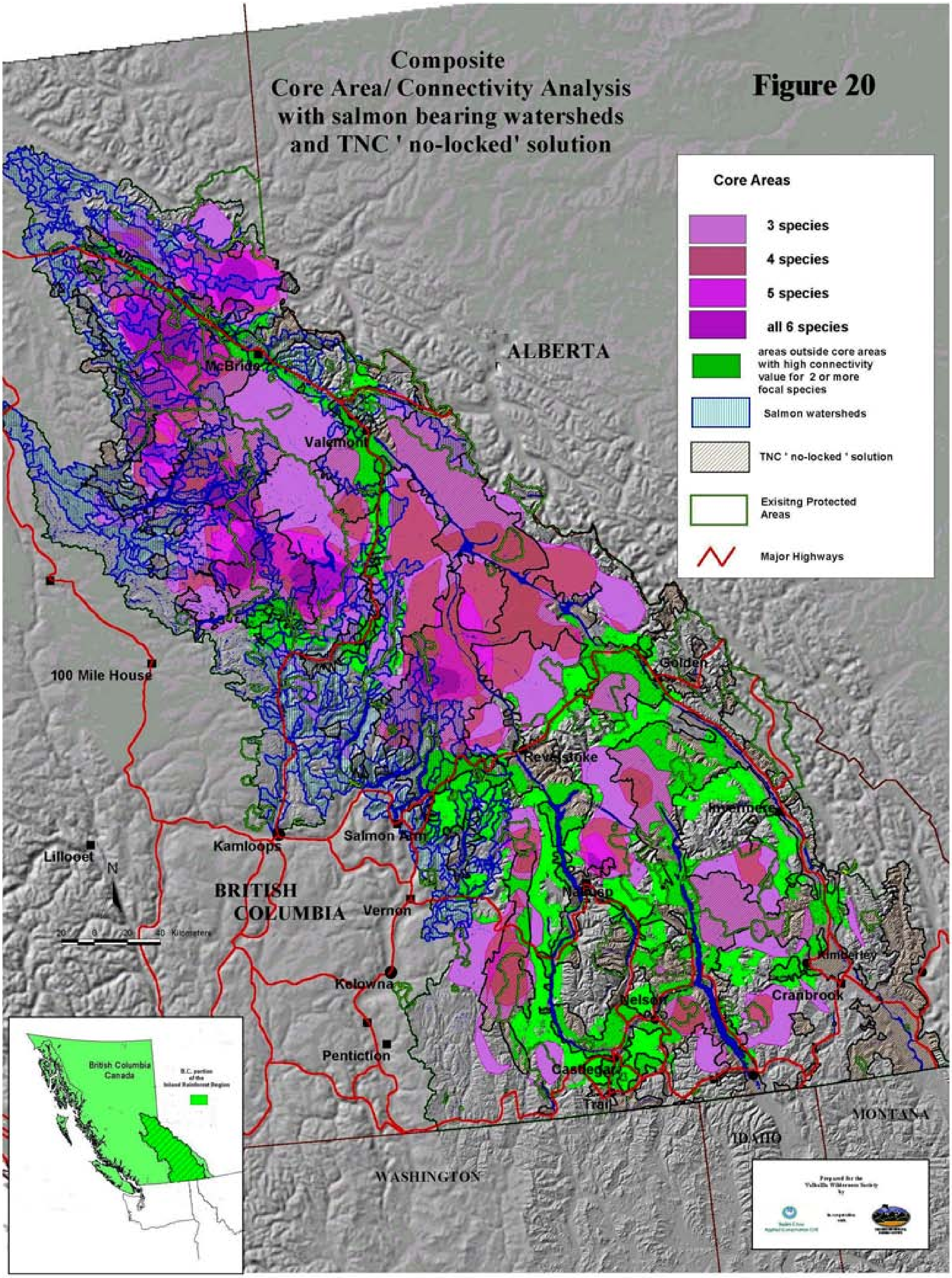


Figure 19
Composite
Core Area/ Connectivity Analysis
with salmon bearing watersheds
and TNC ' no-locked' solution
Core Areas
2 species
3 species
4 species
5 species
all 6 species
areas outside core areas with high connectivity value for 2 or more focal species
Exisitng Protected Areas
Salmon watersheds
TNC ' no-locked ' solution
Major Highways
ALBERTA
McBride
Valemont
Golden
100 Mile House
Revelstoke
Invermere
Kamloops
Salmon Arm
Lillooet
BRITISH COLUMBIA
Vernon
Kimberley
Kelowna
Cranbrook
Nelson
Pentiction
Castlegar
Trail
MONTANA
IDAHO
WASHINGTON
Kilometers
British Columbia Canada
B.C. portion of the Inland Rainforest Region



Composite
Core Area/ Connectivity Analysis
with salmon bearing watersheds
and TNC ' no-locked' solution
Figure 20
Core Areas
3 species
4 species
5 species
all 6 species
areas outside core areas
with high connectivity
value for 2 or more
focal species
Salmon watersheds
TNC ' no-locked ' solution
Exisitng Protected
Areas
Major Highways
ALBERTA
McBride
Valemount
Golden
Revelstoke
Invermere
100 Mile House
Kamloops
Salmon Arm
Lillooet
N
BRITISH
COLUMBIA
Vernon
Nakusp
Kimberley
Cranbrook
Kelowna
Nelson
Penticton
Castlegar
Trail
MONTANA
IDAHO
WASHINGTON
British Columbia
Canada
B.C. portion
of the
Inland Rainforest Region

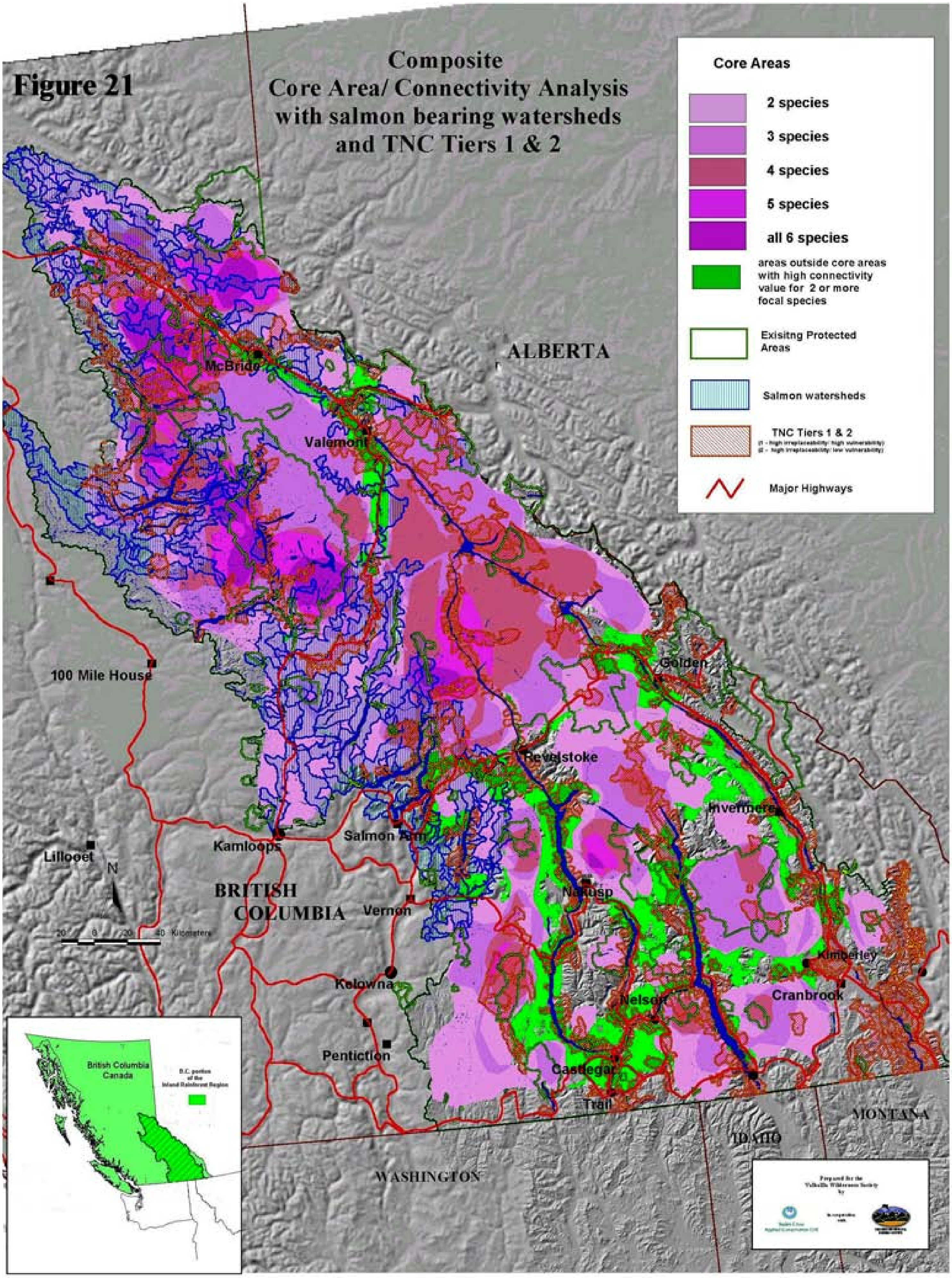


Figure 21

Composite Core Area/ Connectivity Analysis with salmon bearing watersheds and TNC Tiers 1 & 2

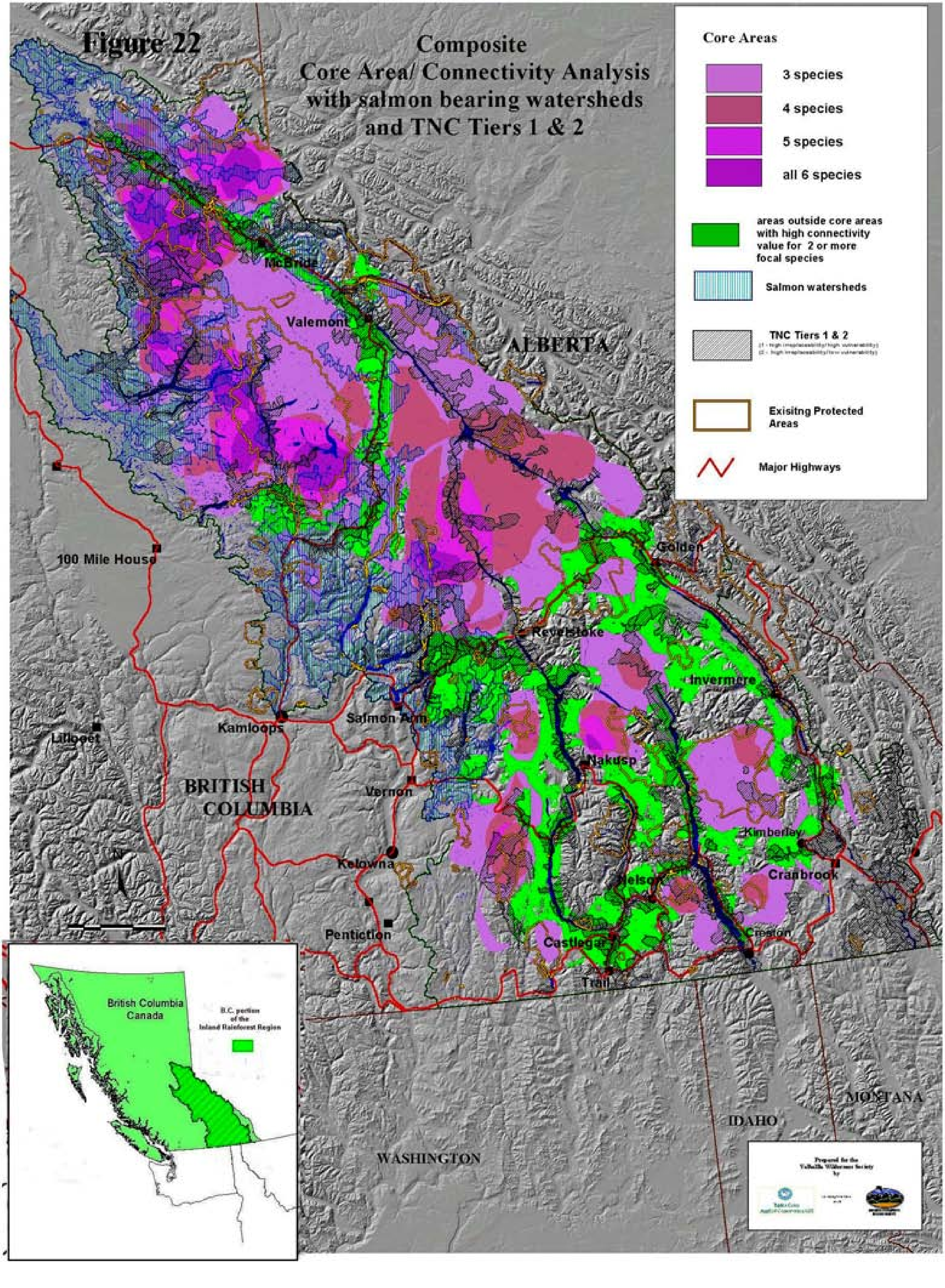


Figure 22
Composite
Core Area/ Connectivity Analysis
with salmon bearing watersheds
and TNC Tiers 1 & 2
Core Areas
3 species
4 species
5 species
all 6 species
areas outside core areas with high connectivity value for 2 or more focal species
Salmon watersheds
TNC Tiers 1 & 2
Exisitng Protected Areas
Major Highways
McBride
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British Columbia Canada
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Our analysis suggests that the alternative for at least 3 focal species would provide the best Conservation Area Design using these data. The composite for at least 3 focal species (3,4,5&6 species) captures 80.4% of grizzly habitat concentration areas (see discussion below) which is one of the few measures available for adequate habitat to maintain a population, and the TNC Tier 1 and 2 summed solution was presented as the best representation solution.

Table 13. Salmon Priority Watershed Totals Plus Habitat Concentration Area (core) Totals for Focal Species Plus TNC Tier 1 and Tier 2 summed SITES Solutions.

Core areas for # of species	**hectares**	**core+linkage+ salmon + TNC Tier1 & 2 (ha)**	**% total BC ITR**
6 species	411,796	7,526,200	52.6
5 & 6 species	1,106,902	7,921,200	55.3
4,5 & 6 species	2,699,759	8,934,000	62.4
3,4,5&6 species	5,736,836	10,573,500	73.9
2,3,4,5&6 species	9,113,348	12,117,500	84.7
1,2,3,4,5&6 species	12,727,914	13,781,400	96.3

Figure 23 represents core habitat for 3 or more focal wildlife species, (3,4,5 & 6 species), plus connectivity habitat between those cores, plus priority salmon watersheds, plus the TNC/NCC Tier 1 and 2 watersheds, plus recovery areas (Special Elements) for caribou.

The fact that habitat for the 6 terrestrial focal species does not overlap greatly (Figure 10) lends credence to their value as a suite of umbrella species (Lambeck 1997, Carroll *et al*. 2001, Roberge and Angelstam 2004). The addition of salmon as an aquatic focal species, and salmon watersheds as conservation targets (Figure 16) increases the area required and broadens the 'umbrella' effect of the focal species approach. The inclusion of the TNC/NCC representation analysis and special elements (Figures 22 and 23) increases further the area required for conservation and helps ensure that species not covered under the 'umbrella' of the terrestrial and aquatic species will be given protection.

Discussion

The final Conservation Area Design is a synthesis that includes the composite terrestrial focal species layer, the salmon average abundance layer, aquatic species-at-risk drainages, and the TNC/NCC Tier 1 and 2 areas derived from a summed solution Representation Analysis and a Special Elements analysis (Rumsey *et al*. 2003a). The aquatic and representation layers represent a prioritization of conservation choices; these are the best areas remaining according to standards of irreplaceability and vulnerability developed by The Nature Conservancy and Nature Conservancy Canada. The terrestrial focal species composite layer includes a spectrum of priorities. Choosing to conserve all areas of habitat in common to two or more species represents the best possibility of maintaining all species. Choosing habitat in common to three or more species will require less habitat, but will have less probability of maintaining long-term persistence for any single species. The same is true of connectivity habitat. Choosing habitat in common to four or more species will require even less habitat, and will have even less probability of maintaining long-term persistence for any single species, but this threshold seems to be adequate to maintain viable populations according to the few data we have to judge by (see below). The combination of all four layers: terrestrial, aquatic, representation, and special elements, represents the best choice for maintaining and restoring biodiversity in the Inland Temperate Rainforest given our current state of knowledge. This must be considered a first, rough, cut at a solution. As more knowledge becomes available, hopefully from people living on the land, better decisions can be made.

Although many current Conservation Area Designs and/or Ecoregional Plans include the three tiers of representation, special elements, and focal species analysis, few actually base the results and conservation priorities selected upon the needs of those focal species. The Canadian Rocky Mountain Ecoregional Plan probably was the most inclusive to date and included both spatial and dynamic modeling of wide-ranging carnivores as focal species. However, the conservation targets selected as Tier 1 and tier 2 priorities were not based upon focal species data as a priority for conservation other than the inclusion of their presence or absence in the representation analysis optimization using the SITES algorithm.

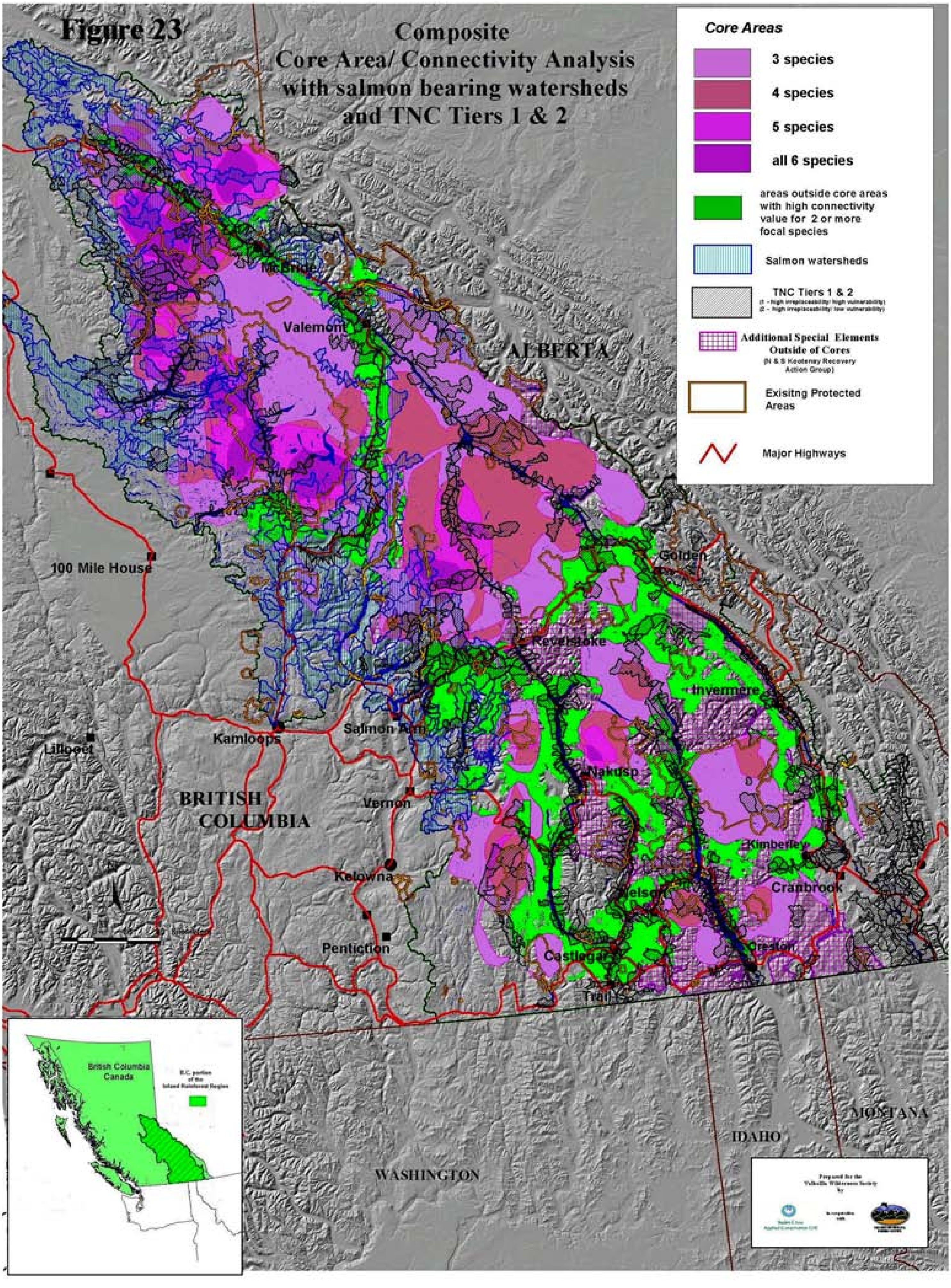

Figure 23 Composite Core Area/ Connectivity Analysis with salmon bearing watersheds and TNC Tiers 1 & 2

The Rocky Mountain Carnivore Project team developed dynamic, individual based population viability analyses, using the PATCH, for five focal species: gray wolf, wolverine, grizzly bear, lynx, and fisher as a part of the Canadian Rockies Ecoregional Plan. They then used the site-selection algorithm, SITES, to select a subset of the study region that would most efficiently choose the best habitat for all five species using the least area. As expected, the northern portion of the study region generally showed higher habitat quality for carnivores than areas further south. SITES selected intact priority areas chiefly in northern B.C. and fewer and more fragmented areas in the south. The RMC team had to compensate for the fact that SITES goals were set regionally to include maintaining well distributed and connected populations by setting both regional and subregional goals for the SITES model. A certain percentage of high-quality carnivore habitat was selected across the region, but also a minimum amount of high-quality habitat was selected within each subregion.

Carroll *et al*. (2003) compared the results of their focal species modeling with the representation analysis and found that the latter did not adequately address the needs of populations of wide-ranging carnivores. The SITES solution for the Canadian Rocky Mountains (CRM) ecoregional plan, based on representation and special element goals alone, captured only 30-34% of the total habitat value for the different carnivore species; only 33.3% of grizzly bear habitat. Current protected areas captured 25.5% of total habitat value for grizzly bears using their suitability model. Our results corroborate the findings of Carroll *et al.* The CRM 'no-lock' solution includes only 45.8% of the habitat that our model defines as the most important within the ITR portion of the Canadian Rockies Ecoregion (the very best focal species habitat: areas common to all 6 species). The CRM 'locked' solution includes 71.4%. The Tier 1 and Tier 2 solution does even worse: it captures 8.9% of area common to all 6 species, and 18.6% of habitat inclusive of any of our focal species combined. However, it must be kept in mind that these representation analyses were calculated to represent all species over a much larger area; the ITR is a subset of that area.

Our model, using the composite focal species core approach captures much more of current grizzly bear habitat than the representation analysis approach alone. The composite containing habitat and linkage for at least 4 of our focal species (4, 5 & 6 species) captures 2,470,910 ha, or 42.8% of grizzly habitat concentration areas. The composite for at least 3 focal species (3, 4, 5 & 6 species) captures 80.4% of grizzly habitat concentration areas. The composite for at least 2 focal species (2, 3, 4, 5 & 6 species) captures 93.8% of grizzly habitat concentration areas.

We use grizzlies as a comparison because more is known about their habitat needs than others of our focal species. In a recent review of the scientific criteria for the evaluation and establishment of grizzly bear management areas in British Columbia (Gilbert *et al*. 2004) a panel of grizzly bear biologists concluded that in order to meet the goals of the BC grizzly bear conservation strategy it was necessary to protect from 68%-84% of currently occupied grizzly bear habitat. In the ITR CAD, the composite cores for at least 3, and at least 2, focal species meet this criterion. The composite core solution for at least

4 focal species, plus salmon priority drainages, plus TNC Tier 1 and 2 areas, plus drainages containing aquatic species at risk also comes close to meeting this criterion and protects 3,342,951 ha, or 58.0% of grizzly habitat Concentration Areas (HCAs). Since the HCAs are smaller than the total of occupied grizzly habitat (the threshold was set to include 90% of currently occupied habitat value) other grizzly habitat, although of lesser quality is included in this CAD solution. We feel that this design will adequately protect grizzly bears as well as other focal species.

The Carroll *et al*. modeling effort identified grizzly habitat and ranked it, but did so on a pixel-by-pixel basis. We feel that our approach, where high quality habitat concentration areas (HCAs) are aggregated into contiguous cores, offers a more ecologically realistic solution, and one that may be more easily implemented. Protecting areas based upon the habitat value of small polygons would result in a fragmented and widely scattered network of smaller, high quality patches.

Because the SITES runs searched for an optimum set of landscape units over the entire Canadian Rockies Ecoregion, using a subset of those results that fall within the ITR may not truly reflect the relative conservation priorities for various areas within the ITR where the range of targets and landscape units is reduced. We were unable to conduct a series of SITES runs using a subset of data from the ITR region for this project, because of time and budget constraints. However, although the analyses we incorporated focus on the ITR region of Canada, The CAD itself must be considered within a broader context. In this sense, including the results of the SITES runs in our CAD help to ensure that our results identify conservation priorities, not just within the ITR alone, but in the context of the Canadian Rockies Ecoregion.

Conclusions and Recommendations

This Conservation Area Design (CAD) is a coarse-scale, low resolution, analysis, which is provided to determine conservation priorities on a regional scale. The CAD provides a snapshot of the best areas for conservation activities in relation to the Inland Temperate Rainforest as a whole. The CAD is presented as a tool for large-scale planning efforts. It should be seen as a rough outline of important areas to focus on-the-ground inventories, fine-scale mapping, and local conservation efforts based upon field data and local knowledge. The CAD process is ongoing; as better information becomes available the CAD can be improved. It is a starting point to help guide decisions so that biodiversity and ecosystem services can be maintained into the future.

The overall objective is to serve four well-accepted goals of conservation: 1) represent ecosystems across their natural range of variation; 2) maintain viable populations of native species; 3) sustain ecological and evolutionary processes within an acceptable range of variability; and 4) build a conservation network that is resilient to environmental change. We feel that this CAD meets those goals, and in particular provides adequate guidelines to maintain viable populations of native species. We feel that this approach meets the needs of focal species better than previous conservation plans which we have built upon. In so doing, this CAD should also adequately meet the other three goals of conservation. To adequately protect and maintain biodiversity and ecosystem function (using grizzly bears as a yardstick) we feel that it is necessary to implement a CAD that encompasses as closely as possible the areas included in our solution for at least 3 focal species (3,4,5 & 6 species), linkage, salmon, and representation or about 10,573,500 hectares (73.9%) of the total area of the ITR. This is the landscape that should be managed for biodiversity conservation. To ensure the recovery of caribou it is necessary to implement a CAD that encompasses as closely as possible the areas included in our solution for at least 3 focal species, linkage, salmon, caribou recovery areas, and representation, or about 11,759,700 hectares or 82.2% of the BC ITR.

Managing the landscape for biodiversity conservation does not mean 'locking up' 82% of the land up in protected areas. In a general sense we can say that it means ensuring that the species and populations that currently exist in the 82% of the landscape delineated by the CAD, are not extirpated either directly or indirectly. Depending on the species, some types of activity are acceptable in some parts of the landscape but not in others. Land-use decisions need to be made on a local scale while conforming to the overall conservation goals. One approach that seems promising is the Ecosystem Based Management approach used by the Coast Information Team (Rumsey *et al*. 2003b, Cardinall *et al*. 2003). The Coastal CAD process designated areas by "risk thresholds" to designate the amount of development or habitat alteration acceptable. Areas with no acceptable conservation risk (areas of high irreplaceability or conservation value) are given high priority for complete protection. Areas where some risk is acceptable were assessed at a finer scale of analysis and planning processes designate some areas for development and some areas for protection within those planning units.

Using a similar approach with the ITR CAD, we would suggest the darker purple core areas on the final map (the areas with more focal species present) are "high risk" areas and should be given more protection. To ensure viable populations of focal species, at a minimum, the areas with habitat for 4 or more focal species should be protected as parks (or the equivalent of 'designated wilderness areas' in the U.S.). The same level of protection should be given to priority aquatic habitat (priority salmon streams and species at risk) and the TNC Tier 1 & 2 areas. Adding the 4+ species cores, TNC Tier 1 & 2 areas, and salmon and aquatic species at risk areas results in a total of 7,873,543 ha or 55% of the ITR which should be 'protected'. Of this about 1,070,650 ha (7.5% of the ITR area) is already under Protected Area status, leaving 47.5%, which needs to be protected to ensure maintenance of biodiversity, focal species, and species at risk.

To reiterate, the total area, which we feel needs protection is derived from three analyses, which overlap to some degree:
1) Core habitat for terrestrial focal species (grizzly, wolf, wolverine, cougar, lynx, and caribou). These priority areas for 4+ species take up 2,699,759 ha, or 19% of the BC ITR area.
2) Aquatic priority areas (salmon priority areas and drainages supporting fish at risk). These priority areas for aquatic species take up 33% of the BC ITR area.

3) The Tier 1 and 2 results from the TNC/NCC Canadian Rocky Mountains Ecoregional Plan.
These priority areas take up 21% of the BC ITR area.
Each of these priority areas may overlap other priority areas. We feel that this combination of results adequately addresses, respectively, the conservation needs of:

1) Focal terrestrial 'umbrella' species and the prey and habitats they depend upon
2) Focal aquatic 'umbrella' species and aquatic species at risk
3) Biodiversity as captured by representation and special elements analysis

Connectivity, or movement habitat (the green 'corridor' areas on the final map), should have habitat that is 'friendly' enough for animals to travel through from one core area to another, but individuals don't necessarily need to be resident and/or reproduce in those areas. The green connectivity areas represent 2,884,900 ha or 20% of the ITR. In some places these connectivity areas overlap Tier 1 and 2 results and/or aquatic priority drainages. Some movement routes without man-made barriers should be maintained by management actions and/or habitat protection somewhere in those green corridors. The lighter purple core areas (habitat for 3 or less focal species) could be considered "medium risk" areas where ecologically sensitive development can be allowed. We would suggest an Ecosystem Based Management approach for timber harvest, mining, and other development that identifies and maintains the best wildlife habitat in those areas on a watershed scale. In both the connectivity and medium risk areas roads should be restricted as much as possible. Old growth forest should be protected and roads that are constructed should be removed quickly.

In summary, the CAD is just a broad blueprint. Concerned residents and managers need to look closely at local areas, see what species or other conservation targets exist there, and try to guide development accordingly. Similar mapping projects at a finer scale can help make those decisions, but much of the analysis needs to be done on-the-ground in the real landscape. The broad-scale CAD type of analysis should help to put local conservation values in perspective and add support for local efforts by showing that a given area is part of an important core or corridor.

The results of this CAD should constitute a defensible scientific basis for implementation of conservation planning and for campaigns to facilitate such implementation.

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APPENDIX A. Background of the CAD approach.

Basic elements of a Conservation Area Design (Sanjayan *et al*. in prep.) include the following.

- Best available knowledge
- Incorporation of credible existing conservation plans
- Strategic involvement of local partners
- Focal species analysis
- Ecological processes analysis
- Coarse scale representation analysis
- Special elements inclusion (rare species and communities)
- Limited field work to fill gaps in knowledge
- Scale dependency (spatial and temporal)
- Repeatability
- Peer review

Standards for Conservation Area Design (Wildlands Networks) have been outlined by Noss for the Wildlands Project.

I. Standard: Scientists are intimately involved throughout the planning process, from the initial formulation of goals and hypotheses to the completion of the design and, in some cases, its implementation.
II. Standards: Goals, objectives, hypotheses, and research questions are all made explicit from the start. Nothing is hidden. In addition, goals are defensible and correspond to TWP's mission.
III. Standard: The methodology includes the three tracks of special elements, representation, and focal species analysis.
IV. Standard: The methodology is rigorous and systematic, within the constraints imposed by large-scale planning, and it seeks to answer the stated questions.
V. Standard: The methodology is well documented and replicable. The studies could be repeated by others.
VI. Standard: Data analysis is as rigorous and objective as possible, with the assumptions and limitations of the approach clearly acknowledged.
VII. Standard: The interpretation and application of results are congruent with principles (i.e., empirical generalizations) of conservation biology, demonstrate a good command of the relevant literature and theory, and apply the precautionary principle.
VIII. Standard: The project is thoroughly peer-reviewed. In addition, the plan is available to the public for peer review. Peer review comments are thoughtfully considered and responded to.
IX. Standard: At least some of the results are publishable in reputable, peer-reviewed journals, as well as other outlets.
X. Standard: The entire process, from developing research methods through implementation, is iterative and adaptive. There is no "final plan," rather the plan is continually refined and improved with feedback from research, monitoring, peer review, and learning by doing.

The Conservation Area Design approach has grown out of general Reserve Design methods which were widely applied by The Nature Conservancy in developing Ecoregional Plans. As this process developed it came to incorporate the ideas of Miller, Noss, Carroll, and others, often referred to as the three-track or three-tiered approach of The Wildlands Project:

"The most unique feature of the three-track approach, which distinguishes it from most of the ecoregional plans developed by other organizations, such as The Nature Conservancy, is the rigorous modeling of habitat requirements and population viability of wildlands-associated focal species, such as large carnivores and forest mesocarnivores (Miller *et al*. 1998/99, Carroll *et al*. 2001, Noss *et al*. 2002). Focal species analysis complements the special elements and representation tracks by addressing questions concerning the size and configuration of reserves and other habitats necessary to maintain populations over time. The focal species approach can be distinguished from the species component of the special elements track, in that habitat suitability and population viability are modeled and extrapolated beyond current, known occurrences and, often, beyond the present time. In contrast, special elements mapping is a static portrayal of documented occurrences of species, usually represented as points, lines (e.g., for aquatic taxa), or polygons."

This approach has been refined over time. A recent definition was provided by Reed Noss for the Wildlands Project as:

1. Special elements selected as targets include imperiled, rare, unique, or otherwise high-value elements for which adequate data are available in the study region. Examples include G1, G2, and G3 species and plant communities, some S1 and S2 species and plant communities (i.e., refer to TNC terminology); such critical wildlife sites as bird wintering concentration and migratory staging areas; old-growth forests; watersheds important for aquatic biodiversity; and sites considered sacred by indigenous peoples.

2. Representation targets include both biotic (e.g., vegetation) and abiotic (e.g., geoclimatic) classes. If possible, vegetation types are stratified by the geoclimatic classes over which they are distributed, so as to capture samples of complete environmental gradients. Explicit representation goals are set for each combined biotic/abiotic class. If available, an aquatic habitat classification is applied, with goals set for representing each aquatic class at targeted levels.

3. Focal species include ecologically pivotal species (e.g., keystones), area-limited species, dispersal-limited species, resource-limited species, and process-limited species. The number of focal species selected will vary by region and available resources, but should be reasonably comprehensive, but not so large as to encourage superficial treatment. A set of 3-12 focal species is probably optimal in most regions.

a. Focal species modeling includes spatially-explicit resource selection functions (RSFs) which apply multiple logistic regression or other appropriate statistical techniques to link distributional data for each species to regional-scale predictor variables. If distributional data are too limited to produce a RSF for a species, spatially-explicit expert or conceptual models are applied.

b. Focal species modeling includes dynamic, spatially explicit, individual-based models (e.g., PATCH) that provide predictions of population persistence over time, identify likely source and sink areas, and illuminate the potential demographic and distributional consequences of landscape change. Landscape change scenarios are based on extrapolation of recent trends, but include scenarios of both.

Focal or target species have been an important tool for conservation area designs. Lambeck (1997) suggested that the first step in identifying focal species, which Noss and others have termed "target species" (Noss *et al*. 1997), is to identify those human-caused and environmental factors that negatively impact ecosystems by monitoring populations of native species. Like canaries in a coal mine; the decline of vulnerable species can alert us to the environmental imbalances causing the decline. Conversely, management prescriptions which result in stable or increasing populations can help to maintain biodiversity and ecosystem functions.

Several approaches have been explored to determine which focal species are appropriate for specific design projects. Using wide-ranging mammals as an "umbrella" for biodiversity and ecosystem function has been an important concept in conservation biology for many years, and it has been applied in several large-scale conservation area designs. Ideally, umbrella species are wide-ranging, ecologically well known, sensitive to human disturbances, and present in numbers sufficient to be managed for long-term population viability (Caro and O'Doherty 1999; Miller *et al*. 1999; Fleishman *et al*. 2001). It is usually recognized that a suite of focal species must be managed to provide an umbrella sufficient to protect regional biodiversity (Noss and Cooperrider 1994; Lambeck 1997).

Traditional ecoregional planning methods used by TNC in the past began using only special element and ecosystem representation approaches. As the TNC methodology evolved it struggled with the best way to integrate carnivore conservation goals with the protection of other conservation targets. To address this critical element of conservation planning for the Canadian Rocky Mountain (CRM) Ecoregion, the Ecoregional Planning Team coordinated their work with the Rocky Mountain Carnivore Project initiated by World Wildlife Fund-Canada with support from The Nature Conservancy.

Habitat suitability for a suite of five large carnivores was the basis of the World Wildlife Fund (WWF) Rocky Mountain Carnivore Project approach (Paquet and Hackman 1995). This analysis included a landscape level analysis of the Rocky Mountains biome, a review of the ecological history of the biome, determination of population goals for each large carnivore species and their associated prey species, and provisions for testing hypotheses. The basis of the WWF approach is a Carnivore Conservation Strategy (WWF 1990) that proposed to establish carnivore conservation areas (CCAs) which are large enough to ensure long-term survival of free-ranging viable populations of large carnivores. Empirical distribution models for 10 species were developed by Carroll *et al.* (1994b): grizzly bear, black bear, gray wolf, coyote, mountain lion, lynx, bobcat, wolverine, fisher, and marten. No single species was found to provide an inclusive 'umbrella' effect based upon overlap of suitable habitat or home ranges, so a suite of carnivores was selected as focal species (Carroll *et al.* 1994b). Principal component analysis revealed a contrast between species that avoid rugged terrain (wolf and lynx) and those that use it (wolverine and marten); and between species that are able to use open habitats despite some human impacts (wolf and wolverine) and those that are strongly associated with forested habitat (lynx and marten). The suite of five carnivores chosen as focal species included grizzly bear, wolf, wolverine, lynx, and mountain lion.

There were several specific challenges that the CRM Plan addressed in order to adequately consider carnivore species in the final network of conservation areas (TNC 2003):

1) How do we incorporate carnivores as conservation targets with their appropriate goal requirements within the SITES methodology?
2) How well does our portfolio of conservation areas meet the long-term survival of carnivore species?
3) How do we express the role of connectivity of habitats in the final portfolio?
4) How sensitive is the SITES analysis in assessing whether the portfolios were robust enough to complement carnivore and non-carnivore goals?

The CRM planning team incorporated static distribution and habitat models for 5 carnivore species; grizzly bear, gray wolf, lynx, wolverine, and fisher. Goals for the carnivore species were expressed as a percentage of the total habitat "value" in the region. Habitat value was measured by the output of the resource selection function (RSF) model (Carroll *et al.* 2001a). The RSF is proportional to the number of animals that can be supported in an area, thus making a goal of 30% of the RSF value might be expected to conserve 30% of the potential regional population. The RSF values for lynx, fisher, and wolverine were based on non-modeled data. Because the conservation goals for grizzly bears and wolves were based on conceptual models and not RSF values, conserving 30% of modeled habitat "value" was felt to protect more than 30% of their populations. Some additional percentage of the population will also be present on non-reserve (portfolio) lands.

Little information exists to adequately determine a threshold amount of habitat for insuring viable populations of these carnivore species. The use of SITES in prioritizing conservation decisions has several limitations, not the least of which is that there is no information on population status and trends incorporated into the choices. For the CRM Ecoregional Plan, such population viability information was developed for key carnivore species using the PATCH model. SITES runs were then done using core areas identified by PATCH to help insure that habitat sufficient to maintain viable populations would be protected.   To estimate thresholds and to try to address other population viability factors such as connectivity, the CRM team ran SITES solutions with differing levels of habitat as goals, and compared the ability of the resulting SITES porfolios to conserve viable populations, using the PATCH model (Schumaker 1998). The PATCH model takes static data (spatial data like prey availability, mortality risks) and dynamic models (non spatial data like carrying capacity) and provides an evaluation of population survival over a 25-year timetable. The evaluation was performed for two carnivore species, the grizzly bear and wolf, for which the team had the most developed and accurate PATCH models**.** It is extremely important that areas of contiguous habitat that are sufficiently large and interconnected to maintain viable populations of focal species be identified and protected for long term persistence of those species, for maintenance of biodiversity, and for maintenance of ecosystem processes and functions.

Recently, Mattson *et al*. (in press) describe a method for predicting umbrella effects and apply it to carnivores in Montana and Idaho, focusing on umbrella effects potentially imparted by species protected under state or federal policies. The method includes (1) a measure of range overlap between a putative umbrella and recipient species, expressed as numbers of annual ranges, (2) similarity of sensitivities among umbrella and recipient species to limiting ecological factors (i.e., proximal factors) and management factors (i.e., distal factors), (3) a conceptual model of relations between proximal and distal factors and a rule set for decomposing proximal effects onto distal factors, (4) a metric of area overlap weighted by proportional similarity of sensitivities to either proximal or distal factors (i.e., coverage), and (5) a standard for sufficiency based on minimal population sizes adjusted for species body mass. This method uses qualitative as well as quantitative information and accounts not only for range overlap, but also for potential similarities of responses to management actions and ecological effects. The carnivore species clustered into 5 groups based on similar sensitivities. Shared responses to road and trail access determined much of the umbrella coverage. All but wolverines were predicted to receive adequate coverage from conservation of one or more protected carnivores, although coverage was barely adequate for grizzly bears, wolves, mountain lions, and river otters. Well-distributed generalist carnivores were predicted to receive ample coverage.

APPENDIX B. Nature Conservancy Methods

The TNC/NCC (The Nature Conservancy and Nature Conservancy Canada) used representation analysis (coarse filter) and special elements analysis (fine filter) for the Canadian Rockies Ecoregional Assessment (Rumsey *et al*. 2003). For this analysis the Nature Conservancy botany technical team identified 66 vascular and 28 non-vascular plants as conservation targets in the ecoregion. The terrestrial team identified 75 rare plant associations. Seven amphibians and 11 mammals were selected as targets, 5 of the mammals are wide-ranging carnivores (grizzly bear, lynx, wolverine, fisher, gray wolf) and another, the caribou, is a wide-ranging herbivore. A total of 7 terrestrial invertebrates were selected as targets including three mountains snails. A bird target list and conservation goals for bird habitat were compiled which included species of conservation concern from the Partners in Flight (PIF) program. A total of 25 species of fish, mollusks, and insects were chosen using the criteria of high natural rarity, severe threat, and overall declining distribution. For most species or associations ("targets") each planning unit in the ecoregion was attributed with a presence/absence value for that target. Goals were then set to include a percentage of the total number of occurrences in the "portfolio" of selected planning units (see below and also Rumsey *et al*. 2003). Goals for the carnivore species were expressed as a percentage of the total habitat "value" in the region.

For carnivores, habitat value was measured by the output of the resource selection function (RSF) model (Carroll *et al*. 2001a). The RSF is assumed to be proportional to the number of animals that can be supported in an area so that selecting for 30% of the RSF value was expected to conserve 30% of the potential regional population. The SITES model was run for solutions with differing levels of habitat as goals and then the ability of the resulting SITES terrestrial portfolios to conserve viable populations was compared using the PATCH model (Schumaker 1998).

SITES uses a "simulated annealing" algorithm to efficiently select representative sets of sites (Possingham *et al*. 2000). The algorithm attempts to minimize portfolio "cost" while maximizing attainment of conservation goals in a compact set of sites. The function that SITES seeks to minimize is Cost + Species Penalty + Boundary Length, where Cost is the area of all planning units selected for the portfolio, Species Penalty is a cost imposed for failing to meet target goals, and Boundary Length is a cost determined by the total boundary length of the portfolio (Andelman *et al*. 1999).

Typically, SITES results are summed from about 100 repeat runs (each comprised of 1,000,000 iterations of planning unit selection) for each of a number of combinations of boundary length modifier (three levels) and goals (i.e.: five different goal levels: 30%, 40%, 50%, 60%, and 70%.) for two scenarios (one with existing protected areas "locked" in; the other unconstrained or "no-lock"). Thus, for each protection scenario a sum of about 1500 sites runs are used that resulted from 1,500,000,000 iterations of the simulated annealing algorithm. Hexagons chosen frequently represent places more necessary (i.e. more irreplaceable) for biodiversity conservation, while those chosen few

times represent locations where the elements of biodiversity that they contain are also found in many other places or where human impacts are significant.
A "conservation value" score is derived from the frequency by which any one planning unit is selected in the 1500 repetitions, such that a unit selected in every solution receives a score of 1500, while a unit never selected is scored as a zero.

The summed solutions describe a range of important conservation criteria including rarity, richness, diversity and complementarity, subject to the constraints applied. These criteria are optimized through the selection of a minimum set of planning units to meet goals for conservation targets. Summed solutions are often considered to be a broad measure of irreplaceability. Irreplaceability may be defined as a quantitative measure of the relative contribution different areas make toward reaching conservation goals (Pressey *et al*. 1994, Margules and Pressey 2000, Pressey and Cowling 2001). It is a measure that guides choice among alternative sites in a portfolio. Irreplaceability can be defined in two ways (Pressey *et al*. 1994): 1) the likelihood that a particular area is needed to achieve an explicit conservation goal; or 2) the extent to which the options for achieving an explicit conservation goal are narrowed if an area is not conserved. Irreplaceability is sometimes synonymous with "conservation value." Conservation value however is not always a measure of true irreplaceability since areas with high conservation value may be replaced by using larger areas of lower value.

The next step in this evaluation of conservation priorities was to calculate the mean conservation value and vulnerability scores of the planning units in each Conservation Area. These scores

For the CRM, irreplaceability was rolled into a broader measure of Conservation Value that was applied to each watershed unit of analysis. Conservation value was calculated as a composite measure, scaled between 0 and 1, based on the following four criteria:
Rarity – the degree to which rare elements are represented within the planning unit Rarity was calculated by assigning a rarity score of 1 to all G3 targets, 2 to all G2 targets and 3 to all G1 targets. Targets that did not have G-ranks were assigned rarity scores of 1 for all Limited, Disjunct and Peripheral targets and 3 for Endemic targets. The rarity scores were then summed and scaled from 0 to 1.
Richness – a measure of the overall abundance of target elements and systems within the planning unit. Richness was quantified by first calculating the total amount of each target in the planning unit (number of occurrences, hectares, stream length etc.) and expressing that as a proportion of the total amount found within the entire ecoregion. The richness score for the planning unit was then taken as the mean proportion of the total amount available in the ecoregion, for each target.
Diversity – an assessment of the variety of elements and systems within a planning unit. Diversity was scored according to the number of different target types (see Appendix 8.1) present within the planning unit.
Complementarity – a measure based upon the principle of selecting conservation areas that complement or are "most different" from sites that are already conserved. The spatial configuration of the CRM portfolio was optimized for complementarity using SITES algorithm. Subsequently, the score for planning unit complementarity was generated from

the ‘sum runs’ of portfolio SITES analysis. Sum runs is the number of times each planning unit was selected by SITES in 20 SITES runs.

Watershed planning units were then assigned a conservation value by adding all four factors together and rescaling the result from 0 to 10.

Based on available quantitative threat data (e.g., human population growth, development trends, road density, a coarse vulnerability score for each watershed planning unit was created. The next step in this evaluation of conservation priorities was to calculate the mean conservation value and vulnerability scores of the planning units in each Conservation Area. These scores were then plotted on a graph of conservation value (y-axis) versus vulnerability (x-axis) and the graph divided into four quadrants, similar to the procedure of Margules and Pressey (2000). The upper right quadrant, which includes Conservation Areas with higher conservation value and higher vulnerability, potentially comprises the highest priority sites for conservation. This top tier of Conservation Areas is followed by the upper left and lower right quadrants (Tier 2 and Tier 3, which could be ordered differently depending on needs of planners), and finally, by the lower left quadrant, Tier 4, comprising areas that are relatively replaceable and face less severe threats.

Tier 1 – Areas of Highest Conservation Value and Highest Vulnerability
Tier 2 – Areas of Highest Conservation Value but Lower Vulnerability
Tier 3 – Areas of Lower Conservation Value and Highest Vulnerability
Tier 4 – Areas of Lower Conservation Value and Low Vulnerability

As per Reed *et al*. (2003), the CRM assessment team differs from Margules and Pressey (2000) giving higher weight to the upper left quadrant (our Tier 2, their quadrant 3) over the lower right quadrant, because we feel that sites of very high and irreplaceable biological value merit conservation action even if not highly threatened today. That is, it is a good idea to protect these sites while they are still reasonably intact. In the CRM, at least, the private lands in these areas are generally less expensive to protect than more threatened sites, because they are usually in areas with lower population growth and development pressure. The conservation value vs. vulnerability prioritization resulted in 368,666 hectares (910,605 million acres) in the Higher Value/Higher Vulnerability Tier 1, Forty-three conservation areas in Tier 2 (Higher Value/Lower Vulnerability) cover 8,713,698 hectares (21,522,834 million acres); 4 conservation areas in Tier 3 (Lower Value/Higher Vulnerability) cover 61,708 hectares (152,419 million acres); and 4 conservation areas in Tier 4 (Lower Value/Lower Vulnerability cover 4,311,470 hectares (10,649,330 million acres).

The PATCH model takes static data (spatial data like prey availability, mortality risks) and dynamic models (non spatial data like carrying capacity) and provides an evaluation of population survival over a 25-year timetable. The Rocky Mountain Carnivore Project Team in conjunction with TNC/NCC conducted an evaluation for two carnivore species; the grizzly bear and wolf. PATCH links carnivore survival and fecundity to GIS data on mortality risk and habitat productivity, then tracks populations through time as individuals are born, disperse, and die. The PATCH model allowed the researchers to discriminate potential population source areas, where reproduction is expected to exceed mortality in an average year, from sink areas, where mortality is predicted to exceed reproduction. The PATCH analyses showed that the current network of protected areas were insufficient for preventing declines in carnivore populations over the next 25 years. The TNC/NCC planning team set a SITES goal of capturing 40% of habitat values for all targeted wide-ranging carnivores in the conservation portfolio based upon PATCH modeling that indicated that goal would yield a slight increase in carnivore populations over the next 25 years.

Initial test SITES runs were performed solely on terrestrial targets comparing SITES runs where protected areas were "locked in" or forced into the conservation solution versus solutions without such constraints. The locked in solution yielded a conservation portfolio that covered 48% of the ecoregion compared to 39% in SITES runs that were unconstrained by protected areas.

SITES runs for aquatic targets yielded a portfolio covering 44% of the ecoregion. When the aquatic solution was overlaid with the terrestrial solution with protected areas locked in, 66% of the ecoregion was needed for the conservation solution compared to 61% when the aquatic solution was overlain with the terrestrial solution unconstrained by the current protected areas network.

Further efficiencies were sought by combining aquatic and terrestrial targets into a single sites run. The greatest improvement came from combining aquatic and terrestrial targets in a conservation solution unconstrained by the current protected areas network (the "no-lock" solution). The total area needed for the solution dropped to just under 50% of the ecoregion.

A total of 4,836 watersheds were part of the final conservation portfolio for the Canadian Rockies Ecoregion totaling 13,455,793 hectares (33,249,264 acres) and equaling 49.7 % of the ecoregion. The portfolio size was attributed to: 1) the types of conservation targets selected, which included matrix-forming ecological systems and wide-ranging mammals; 2) the existing natural variability and the desire to represent variability across all environmental gradients within the ecoregion; and 3) manual overrides of the original SITES output based on additional knowledge about conservation areas. Manual overrides changed the final configuration of the conservation portfolio; represented as Tier 1 and Tier 2 areas, significantly from the original optimization solution (Carroll, pers. comm.). The majority of the 4,836 selected portfolio watersheds were subsequently aggregated into larger conservation units called "Conservation Landscapes," that were clusters of watersheds that were geographically connected and that shared common ecological processes.

Currently, it has been recognized that more robust SITES results are obtained using more runs with more iterations: For the Coastal Forests and Mountains (CFM) Ecoregional Plan (Rumsey *et al*. 2004) results are summed from about 100 repeat runs (each comprised of 1,000,000 iterations of planning unit selection). Conservation value scores from summed runs for the CFM Ecoregional Plan were then generalized for each watershed unit by calculating an area-weighted average score for the watershed. Scores for watersheds were then grouped into 3 classes (low, medium and high value), based on equal area thresholds. Separate thresholds were calculated for small (< 10, 000 ha) and intermediate watersheds (>=10,000 ha). The rationale for this division was twofold: 1) roll-up was biased towards smaller watersheds since an entire watershed can be encompassed by a single planning unit; and 2) comparison and prioritization of watersheds of similar scale is possible.

Conservation Area Design Area designations were determined by two factors, conservation value and ecological integrity (i.e. condition). Intermediate watersheds were clustered into 3 conservation tiers based on the conservation value and a condition matrix; watershed condition was classified as either intact, modified, or highly impacted. Under this framework, areas ranked as intact or modified that also hold high conservation value, or intact areas with medium conservation value, were ranked as Tier 1. The middle tier (Tier 2) represents those areas with high value but which are highly impacted, or areas with low value, but which are intact, or areas that fall within the mid-range of both criteria (medium value/modified condition class). Tier 3 represents those analysis units or landscapes that are developed and which have a medium or low conservation value.

APPENDIX C. Connectivity Modeling

Connectivity modeling in general, occurs at two general scales: regional (commonly 1 km^2 grids or pixels) and landscape (commonly 30-100 m^2 grids or pixels) due primarily to the constraints of remotely sensed-data. Both perspectives are critical to maintaining biodiversity and ecosystem function throughout the Rocky Mountains, and planning efforts at both scales should occur in concert. Regional connectivity models help to pinpoint areas of concern where landscape models may be most effective in a regional context. Landscape models help to pinpoint barriers to movement and fragmentation of habitat and to guide land use decisions. Ultimately, landscape models need to be adjusted by site-specific, on-the-ground biological assessments, augmented with data on animal distribution and movements if possible. Currently, all scales of connectivity modeling are based upon some type of underlying static habitat-capability-index (HCI) type models. These HCI models rank the habitat of an area for a given species (or group of species) based upon biotic features (such as vegetation or greenness), physical features (such as slope, aspect, elevation), and human disturbance features (such as roads and buildings). Connectivity models are of two types: static models based upon fixed layers of spatial data, and dynamic models which predict the choices that an animal makes to draw a probable route across a habitat surface.

Static Connectivity Models

Habitat Capability Models

Some approaches to connectivity modeling rely solely on HCI-type maps of habitat: patches of better habitat in areas of concern are assumed to be better for animal movement, and thus connectivity. This approach to identifying movement habitat was used by Servheen and Sandstrom (1993) for the US Fish and Wildlife Service. Grizzly bear habitat "linkage zones" were analyzed between some of the large blocks of public land in the Northern Rockies using 4 GIS layers: road density, human developed sites, vegetative cover, and riparian zones, to score the habitat in terms of its relative value (Servheen and Sandstrom 1993, Servheen e*t al*. 2001). Linkage zones were then subjectively drawn through high value habitat across private lands between large blocks of public land, all of which was considered to be secure grizzly habitat. Linkage zones were drawn to avoid roads and buildings, and to include riparian habitat whenever possible. A similar approach was used to determine linkage zones across Canada's highway 3 in Southeast British Columbia and Southwest Alberta (Apps 1997).

Clevenger *et al*. (2002) compared three black bear habitat models: they found that an HCI model based upon expert literature most closely approximated an empirical model based upon radio-locations of nine black bears (n=580 locations). Even with a larger sample size, the error inherent in radio locations combined with the wide range of learned behavioral responses, such as movement, in a complex omnivore such as black bear, result in an empirical model that is also just an approximation. However, the fact that two modeling approaches produced similar results, and that those results were similar to road-kill locations, lends credibility to these approaches.

Habitat Capability Models plus Cost-Distance Calculations

A more quantitative approach to modeling wildlife movement habitat uses least-cost-path algorithms in conjunction with Habitat Capability-type models to determine the least-cost-path across a habitat surface. Least-cost paths are travel routes between two given points that incur the lowest cost of transit. Originally, least-cost-paths were computed for vehicles, primarily delivery or freight vehicles, and cost was determined by distance traveled and the economics of individual vehicles (miles per gallon and maintenance costs). Because of the wide applicability of computer algorithms that could compute least-cost-paths, several of these functions were incorporated into Geographic Information System (GIS) software, such as Arc Info™ GRID. The concept behind the least-cost-path is that within a grid of cells, each cell has a cost value associated with it. The impedance, or cost of travel across the cell equals the value of the cell times one (if travel occurs parallel to a side) or times 1.414214 (if travel occurs diagonally across the cell). The cost of an entire route is the accumulated cost of all cells along the route. Most applications involve costs measured in dollars, time, or energy expended, e.g.: for emergency vehicles time is the overriding cost factor. However, these GRID functions have been useful for other analyses in which cost can be determined by other metrics.

Cost can be calculated in any terms that can be quantified. For wildlife movement modeling, cost has been generally calculated as an index of risk to the animal, or its converse; security and food. Least-cost-path models for grizzly bear movement have focused on habitat quality and human disturbance; lower costs for grizzly bears are associated with high quality habitat and low human disturbance. Higher costs for grizzly bears are associated with poor habitat and high levels of human disturbance. GIS layers of landcover and human disturbance are used to create an HCI-type model. Core areas of good habitat which offer security (little human disturbance) are selected based upon literature-based expert opinion or empirical data if available. Then a "cost surface" is derived which represents the difficulty (cost) to an animal to move through the landscape. Finally least cost paths are calculated between pairs of core areas over the cost surface. A map of probable movement habitat results; this represents the best habitat over the shortest cumulative cost-distance between cores. This can be considered one quantitative measure of relative "connectivity."

Two studies originally used this method to model movement habitat for grizzly bears in the Northern Rockies (Primm and Underwood 1996, Walker and Craighead 1997, 1998). The central approach taken in these models is the generation of a least-cost path across a value, or cost, surface. Primm and Underwood (1996) used a cost surface derived solely from human disturbance elements (roads, buildings, campsites) which were ranked according to their relative avoidance by grizzly bears.

Walker and Craighead (1997, 1998) developed an expert literature-based HCI model which followed the logic of the grizzly bear cumulative effects model or CEM (Weaver *et al*. 1986, USDA Forest Service 1990, ICE6 1994), which ranked habitat effectiveness for grizzly bears. Habitat effectiveness in the CEM was calculated by multiplying indices of habitat quality and habitat heterogeneity, and subtracting the summed indices of human disturbance and mortality risk. The cost surface for the Walker and Craighead model used indices of habitat quality and a measure of habitat heterogeneity and subtracted an index of weighted road density. Least-cost-paths were calculated between large cores of intact, relatively roadless, habitat.

Several similar least-cost-path approaches have addressed aspects of wildlife movement habitat and the barriers to movement posed by highways, generally at a finer scale. In Slovenia, a habitat suitability model was developed to model probable highway crossing points for grizzly bears using the IDRISI™ functions COSTGROW AND PATHWAY (Kobler and Adamic 1999). This HCI was based upon resource selection functions derived from observed bear locations of females with cubs. Least-cost-paths from one side of the highway to the other were created. These all crossed at one of three points, which were then further evaluated as locations for wildlife bridges or underpasses to be constructed. Other researchers that have employed least-cost techniques for the evaluation of animal movement routes include Paquet and Callaghan (1996), and Purves and Doering (1999).

A least-cost-path approach was used in Washington State (Singleton and Lehmkuhl 1999) to model movement corridors for carnivores. Broad-scale habitat models for wolf, lynx, wolverine, grizzly bear and generalized carnivores were developed using weighted distance analysis based upon land cover, human population density, road density, and slope. Cores were selected based on low road density combined with landcover. Least-cost-path analysis was then conducted between areas of core habitat. Craighead *et al*. (2001, 2004) used a least-cost-path analysis to identify probably highway crossing areas on Interstate 90 over Bozeman Pass in Montana. Road kill locations, winter track surveys, and remote cameras were used to document crossing sites within the least-cost-path movement habitat areas.

Least-cost-paths can be can be considered in one sense an optimal linkage; the shortest distance through the best habitat. They are models of habitat conditions, not animal movement. Model results need to be interpreted in terms of: 1) the assumptions made by the model, 2) the limitations of the algorithm, and 3) the scale of analysis. Firstly, most of the assumptions incorporated into the model, such as road avoidance, preference for certain habitat types, and disturbance effects of human developments, are based upon the scientific literature. Although there are many factors involved in the choices an animal makes, not all of those factors are well understood or amenable to measurement. For example, scent probably plays a very important role in grizzly bear movement across a landscape. Food sources, interactions with other bears, and avoidance of humans are all mediated greatly by scent and wind direction, but we are unable to include these parameters in the model. We can only include those data which we know are important factors and which we have previously measured. The weightings that are given to types of data, such as roads, can greatly affect the behavior of the model. It is important to understand how the model is driven by the parameters chosen, such as the relative value of different vegetation types. Simple models such as these treat all individuals of a group of species equally; a generalized forest carnivore is modeled depending upon the choices of the modeler. In reality, carnivores are highly individualistic and respond very differently to environmental stimuli depending upon their sex and age class, learning experience, and nutritional and hormonal state as well as other factors. Modelers can only choose one type of behavior as a basis for a least-cost path. In this case, secure habitat containing food sources has the highest value.

Secondly, the software constraints can cause unrealistic results in terms of animal behavior. Given starting and ending points for the path are requirements of the software. This constraint may be unrelated to some animal behavior, particularly dispersal behavior. This implies that the animal knows where it is heading. In other cases, if an animal has traveled the route before, and knows its goal and the obstacles en route, the least cost path may be more realistic. Thus, if there is not an end point (a core) on the other side of a barrier from a starting point core, there will be no least-cost-path in that direction. This precludes the mapping of any linkage habitat out towards the boundary of the study area even though there may be core habitat beyond the boundary. In summary, these software constraints can produce results that are unrealistic in terms of what we know about focal species' behavior, and they truncate habitat linkages at boundaries of the data.

Thirdly, the choice of cell size for modeling habitat affects the results; all of these models use grid cells that are 1 km^2 in area; this implies that a carnivore assesses the habitat around it to a distance of about 1 km in all directions (its perceptual distance), and then chooses the best habitat with the least disturbance. In reality, a carnivore traveling through unfamiliar territory may respond to some factors such as noise and movement, plant communities, and topography at much closer distances; respond to other factors such as scent, loud noises, and topographic relief at that distance; and may also respond to factors such as scent at much greater distances and adjust its behavior accordingly.

Detailed data on animal movements and habitat choices are difficult to obtain, but may become more available as the use of GPS collars increases. Although the Habitat Suitability models and the connectivity models currently in use may not be found to be a perfect fit with empirical data on animal use of habitat, these approaches help to better understand some of the limitations of the models, help guide our use of the models in making conservation decisions, and can produce useful and effective model-based results for key areas.