A Conservation Area Design

for the Coastal Forest and Mountains of Southeast Alaska and British Columbia

Draft - November, 2003

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Round River Conservation Studies
The Nature Conservancy of Alaska
Nature Conservancy of Canada

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This document is comprised of six reports and an executive summary. The maps referred to in the individual reports are contained in the CFM Maps folder on the CFM CAD CD. The map files can be viewed on the computer using standard viewing software. The map files may also be printed. They are large format jpeg files and depending on the printer or plotter used it may be necessary to resize the files.

This document should be considered a work in progress. This document is in two formats, one with photos for viewing on the computer and a second format in a single color and without photos to facilitate printing.

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The overall effort was lead by Dr. Richard Jeo (RRCS) in collaboration with Chuck Rumsey (NCC) and Amalie Couvillion (TNC). Rick Tingey (RRCS) was the primary GIS analyst, and was responsible for compiling datasets, implementing spatial models, inputting and running the MARXAN model and also the cartography for the maps in this report. Pierre Iachetti acted as the project data manager, and collected and compiled numerous datasets from diverse sources. Jim Ferguson (TNC) was involved with the initiation of the project and provided early guidance and management. Dr. Richard Jeo (RRCS) working with Rick and Dave, led the creation of the terrestrial coarse filter classification system, the impacts analysis and helped guide creation of focal species models and interpretation of results. Anna Noson (RRCS) and Dr. Barbara Dugelby (RRCS) made significant contributions towards the impacts modeling. Dr. Kristine Ciruna (NCC) acted as the lead for the freshwater technical team and was responsible for creation of the freshwater coarse filter classification system and contributed greatly to editing the final report. Kristine also worked with Dr. Art Tautz (BC Ministry of Water, Land & Air Protection (MWLAP), Biodiversity Branch) and Dr. Blair Holtby (Department of Fisheries & Oceans Canada) to create the salmon status and trends models and analyses. Kristine also worked with Tim Curtis (Nature Conservancy of Canada), another GIS analyst on the project, to create the tailed frog focal species model and major components of the salmon analyses. Tim also assisted with many of the final SITES analyses for the CIT. David Albert (Ecotrust) also contributed GIS and analytical expertise and compiled many of Alaska datasets and implemented Tongass National Forest focal species models and early versions of the terrestrial ecosystem classification. David also developed satellite image analysis for forest condition in Southeast Alaska, necessary for evaluation of lands outside of the Tongass National Forest.

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Executive Summary

Coastal temperate rainforest is a globally rare ecosystem type, occurring on less than 1% of the earth's surface. Many native species have been extirpated from the southern portion of the region, including catastrophic reductions of many salmon stocks and the extermination of top carnivores (grizzly bears and wolves) from the coastal forests of the lower 48 United States. Some of the last remaining large contiguous areas of intact, coastal temperate rainforest are found in British Columbia and Southeast Alaska— forests that still contain a full assemblage of large carnivore species and prolific stocks of pacific salmon. Ecosystem processes in the region are also largely intact; for example, coastal forest in the region supply woody debris and other materials that are vital to river system integrity and ecological functioning and provide storage of massive amounts of carbon. The region houses a number of additional important biodiversity components including unique coastal bog complexes, unregulated river systems, intact estuaries, marine kelp and seagrass beds, seabird colonies, archipelago/fjord terrain, deep fjord and cryptodepression lakes, and intertidal flats with abundant invertebrates and resident and migratory waterbirds.

Nevertheless, despite their biological diversity and global significance, the future of the coastal temperate rainforest is still highly uncertain. The primary threat to the region is unsustainable industrial logging and its associated ecological impacts. The region has a long history of conflicts between environmentalists and the timber industry which have generated both national and international interest in both Alaska and British Columbia. Which areas should receive highest priority for conservation? How much area is enough? What types of human activities are acceptable? How should conservation policies be implemented? We sought to develop science-based tools and to assemble regional data necessary to address these sorts of questions, through the development of a Conservation Area Design (CAD) for the region. Here we present regional spatial datasets that represent a full range of biodiversity values for the coastal temperate rainforest. We also present analyses results that identify high value, irreplaceable conservation areas and identify some of the last remaining, ecologically intact and relatively undisturbed watersheds in the region.

The study area is defined by the ecosections of the Coastal Forest and Mountains ecoregion, plus the adjacent Northern Pacific Ranges and the Outer Fiordlands ecosections. The study area includes much of Southeast Alaska and the adjacent transboundary mountains, the island of Haida Gwaii, the Nass Basin and the Central and North Coast regions of British Columbia. This region has a land area of 21.4 million hectares plus an additional 11 million ha of ocean. Several primary watersheds in the region have headwaters that originate outside of the study area; inclusion of the entire extent of primary watersheds encompasses and additional 15.2 million hectares for a total study area size of 47.2 million hectares.

This report provides tools and data necessary for science-based conservation planning and a framework of how priority areas can be systematically identified. The objective of this exercise is ultimately 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. In pursuit of these goals, the Conservation Area Design for the CFM region incorporates three basic approaches to conservation planning:

- Representation of a broad spectrum of environmental variation (e.g., vegetation, terrestrial abiotic, and freshwater and marine habitat classes).

- Protection of special elements: concentrations of ecological communities; rare or at-risk ecological communities; rare physical habitats; concentrations of species; locations of at-risk species; locations of highly valued species or their critical habitats; locations of major genetic variants.

- Conservation of critical habitats of focal species, whose needs help planners address issues of habitat area, configuration, and quality. These are species that (a) need large areas or several well connected areas, or (b) are sensitive to human disturbance, and (c) for which sound habitat-suability models are available or can be constructed.

We attempted to assemble and use the best available information for this assessment. We recognize that new and more comprehensive data will continually become available and finer-scale analyses may provide more detailed information necessary for local planning and management purposes. For example, much of the data and approach we developed and applied for the entire region was also used to develop a finer-scale land-use plan for the British Columbia portions of the study area in collaboration with the B.C. Coastal Information Team and the Nature Conservancy of Canada. For such cases, finer scale analysis is often more useful for land-use and management decisions. Nevertheless, we suggest that regional analyses are important for several reasons. Regional analysis can place any landscape feature in a local, regional, or global context. A second important advantage is that species, plant communities, and other conservation targets can be considered together within an environmental framework that shaped their evolution and continues to shape their interactions. Finally, regional analysis provides a consistent, standardized framework that encourages cooperation across political boundaries and may promote implementation of conservation strategies that operate at larger geographic scales that could not be addressed at a local level.

We selected a set of conservation targets that represent a wide range of biodiversity values for the region. We included coarse filter terrestrial and freshwater ecosystem targets and a suite of focal species targets. To ensure broad representation of a wide range of these values, we stratified target selection by using the ecoregion / ecosection classification system. This system is in common use in North America (and around the world), and divides terrestrial ecosystem complexity into discrete geographical units. Ecosections describe areas of similar climate, physiography, oceanography, hydrology, vegetation, and wildlife potential (Maps 1 & 2).

The spatial distribution and relative amount of each conservation target was summarized using 1000 hectare hexagonal planning units. Representative configurations of planning units were assembled using the software program MARXAN which utilizes an algorithm called "simulated annealing with iterative improvement" as a heuristic method for efficiently selecting regionally representative sets of areas for biodiversity conservation at a minimum of cost. We used MARXAN to run a combination of 5 different goal settings (30 – 70% representation goals in 10% increments) and 3 boundary length modifiers (which influences the degree of clumping) and each run was repeated 100 times for a total of 1500 possible conservation solutions. The sum total of all runs was integrated into a single final "summed solution" which is a measure of irreplacability or conservation value for each planning unit (Map 26). Conservation value for each watershed (a more practical unit for land use designation) was calculated by taking the area-weighted mean of the planning unit conservation value.

We also assessed the ecological integrity of all watersheds in the study area based on relative levels of human impacts (Map 24). These two streams of information (conservation value and ecological integrity) were used in combination to delineate the Conservation Area Design, which includes 3 Tiers of conservation priority (Map 27). We suggest that this approach can be used to identify the highest level regional priorities, i.e. high value, relatively intact areas that serve as anchors for a comprehensive Conservation Area Design for the Coastal Temperate Rainforest. The design can also be used to identify areas in need of restoration, such as watersheds which relatively high value with moderate levels of human impacts.

Although the preponderance of evidence from the scientific literature suggests that there may be no substitute for large, strictly protected areas for meeting conservation objectives, even a designation of a set of new, large protected areas may not be enough for long-term conservation. Species will eventually decline as protected areas begin to resemble habitat islands and surrounding areas become increasingly inhospitable. Thus, identification and protection of large contiguous areas, coupled with the maintenance of favorable conditions in non-protected areas, are both equally important for long-term conservation. Despite these lessons from science, resource managers and decision makers are often tasked with meeting multiple, conflicting demands and are often forced into compromises that result in the incremental degradation of ecosystems. While developing new and innovative solutions for resolving conflicts surrounding conservation is both attractive and pragmatic, we should continue to keep in mind that a comprehensive conservation solution may require conservation of vast, unfragmented areas, and protection of this scale (no matter how innovative) may be expensive and somewhat unpopular with existing economic interests. Nevertheless, we believe that we have developed a set of usable tools and assembled necessary data for designing a comprehensive set of conservation areas in the Coastal Forest and Mountains region. However, even the best plan or design will come to naught if it is not implemented. If the extinction crisis, now underway globally, is to be tackled locally, the Conservation Area Design for the coastal temperate rainforest must be integrated into regional and local conservation and development policies and practices. The fate of this key step is in the hands of local people, environmental organizations, First Nation's and government representatives. If it fails, this unique synthesis of data and the map it provides will become not a map for hope but another postmortem for nature.

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Map	Data used	Use in CAD
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Map 3. Land Formation	50 meter DEM used to create landforms model, derive slopes/aspects	Conservation goal for each formation; physiognomic goal
Map 4. Vegetation Structure	BC Ministry of Forest 1: 20,000 Forest Cover (FIP), Tongass National Forest "TIMTYPE" and "CLU" Data, Satellite Interpreted data for areas lacking Forest Service data in AK, Baseline Thematic Mapping (BTM) for areas missing BC MoF FIP data.	Conservation goals for structural elements as a part of focal ecological systems; coarse-filter vegetation goal
Map 5. Forest Alliances	BC Ministry of Forest 1: 20,000 Forest Cover (FIP), Tongass National Forest "TIMTYPE" and "CLU" Data, Satellite Interpreted data for areas lacking Forest Service data in AK, Baseline Thematic Mapping for areas missing BC MoF FIP data.	Conservation goals for species alliances as part of focal ecological systems; coarse-filter vegetation goal
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Map 18. Mountain Goat Habitat Model	BC FIP 1:20,000 forest cover data 50 meter DEM (elevation/slope/aspect) TNF forest data, CLU vegetation associations, 50 meter DEM	Conservation Goals set based on inclusion of a percentage of habitat values

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Map 19. Marbled Murrelet Habitat Model	BC FIP 1:20,000 forest cover data 1:50,000 Watershed Atlas 50meter DEM BC 1:20,000 Forest Cover Data (stand class, height class, canopy closure class) Coastline (Distance from Saltwater)	Conservation Goals set based on inclusion of a percentage of habitat present
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Map 26. Conservation Value (Hexagon Planning Units)	MARXAN outputs: sum of the "summed solutions" from 15 separate model runs (100 repeats, 10,000,000 iterations within each run)	Conservation Value
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Freshwater Targets

Freshwater Coarse-Filter Conservation Targets of the Coastal Forest and Mountains

Freshwater ecosystems consist of a group of strongly interacting communities held together by shared physical habitat, environmental regimes, energy exchanges, and nutrient dynamics. Freshwater ecosystems are extremely dynamic in that they often change where they exist (e.g., a migrating river channel) and when they exist (e.g., seasonal ponds). Freshwater ecosystems fall into three major groups: standing-water ecosystems (e.g., lakes and ponds); flowing-water ecosystems (e.g., rivers and streams); and freshwater-dependent ecosystems that interface with the terrestrial world (e.g., wetlands and riparian areas).

The classification of freshwater ecosystems is a relatively new pursuit. This is the first attempt at a coarse-scale freshwater ecosystem classification in British Columbia. For classification purposes coarse-scale freshwater systems are defined as networks of streams, lakes, and wetlands that are distinct in geomorphological patterns, tied together by similar environmental processes and gradients, occur in the same part of the drainage network, and form a distinguishable drainage unit on a hydrography map. Coarse-scale freshwater systems are spatially nested within major river drainages and ecological drainage units (EDUs), and are spatially represented as watershed units (specifically BC Watershed Atlas third order watersheds).

The types and distributions of freshwater systems are characterized based on abiotic factors that have been shown to influence the distribution of species and the spatial extent of freshwater communities. This method aims to capture the range of variability of freshwater system types by characterizing different combinations of physical habitat and environmental regimes that potentially result in unique freshwater communities. An advantage of this approach is that data on physical and geographic features (hydrography, land use and soil types, roads and dams, topographic relief, precipitation, etc.), which influence the formation and current condition of freshwater ecosystems, are widely and consistently available.

Our freshwater ecosystem classification framework classifies environmental features of freshwater landscapes at two spatial scales: ecological drainage units that take into account regional zoogeography, climactic, and physiographic patterns; and mesoscale units that take into account dominant environmental and ecological processes occurring within a watershed. Seven abiotic variables were used to delineate coarse-scale freshwater system types: drainage area, underlying biogeoclimatic zone and geology, stream gradient, dominant lake/wetland features, glacial connectivity, and coastal connectivity. Within each drainage area class (headwaters/small coastal rivers, small rivers, intermediate rivers, large rivers), every watershed was classified according to the dominant biogeoclimatic zone it fell within, its dominant underlying geology, and its dominant stream gradient class. Each of these coarse scale freshwater system types were then further subdivided based on their characteristics of being glacially and/or coastally connected, and if dominant lake and wetland features were present.

Wetlands and Riparian Areas

We identified wetlands and riparian areas as important freshwater conservation targets. We used several datasets to define these areas. Wetlands in B.C. were taken from the TRIM wetlands and swamps; in SE Alaska, wetlands were identified using the palustrine emergent class in the National Wetlands Inventory data.

We developed a simple model to predict the occurrence of riverine riparian vegetation communities. Areas of gentle slope, adjacent to streams were classified as riparian areas (<= 7% slope, contiguous with and within 500m of a stream). Conservation targets for riparian areas and wetland features were defined in percentage of area increments from 30% to 70%.

Tailed Frog

The Tailed Frog (Ascaphus truei), is a highly localized, specialized species that lives in cool, swift, permanently flowing headwater mountain streams composed of cobble and anchored boulders that provide refuge for tadpoles and adults. In BC, the only Canadian province where it occurs, the Tailed Frog is found along the Coast Mountains, from the Lower Mainland to Portland Canal, north of Prince Rupert. Although its range in BC is quite extensive, there are concerns about the status of the Tailed Frog due to its low reproductive rate, its highly specialized habitat requirements, human activities within its range, and lack of knowledge about minimum viable population size, particularly in fragmented landscapes. Adult Tailed Frog abundance is positively correlated with the percent of old-growth forest in a watershed, most likely because these forests dampen microclimatic extremes.

Tailed Frog populations in BC have been poorly surveyed. This is the first attempt to model habitat for this species at a landscape scale. Five biophysical conditions were identified as being critically important for Tailed Frog habitat: 1) Basin area between 0.3 and 10 km2; 2) Basins where the bottom elevation < 600 m and the ratio (top elevation – 900)/(900 – bottom elevation) = between 0.0 and 2.0; 3) Watershed ruggedness between 31 and 90%; 4) Northerly aspect in Coast and Mountains region and Southerly aspect in Interior regions; and 5) Forest cover age class >= 6. These conditions were spatially modeled within the CIT study. Habitat areas meeting all five biophysical conditions stated above were classified as being optimal habitat areas for Tailed Frog. Habitat areas meeting biophysical criteria one to three were classified as being suitable habitat areas for Tailed Frog. Conservation Goals were set as a percentage of stream reach corresponding to modeled tail frog habitat.

In total, 4,466 km of suitable Tailed Frog stream habitat was identified within the CIT study area consisting of 5,155 habitat areas. Of this suitable habitat, 2,323 km of stream habitat consisting of 2,486 habitat areas were determined to be optimal habitat that meets all five biophysical parameters within the model. There was a 60% correlation between field survey data and modeled suitable habitat for the Tailed Frog.

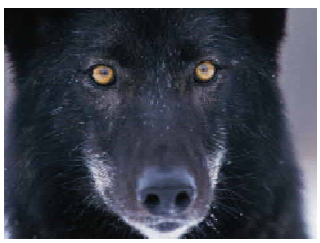
Proposed recommendations for forestry activities in Tailed Frog habitat include leaving forested buffers to maintain the structure of stream channels and provide a source of shade to keep water temperatures cool; installing sediment traps where ditches or culverts meet creeks; deactivating secondary roads to minimize the input of sediment from road surfaces into streams; keeping heavy equipment out of stream channels to prevent on-site damage and downstream silting; and felling and yarding of trees away from permanent creeks to maintain slash-free water courses.

Pacific Salmon and Steelhead

Six species of salmon were used as freshwater focal species: chinook, chum, coho, pink, and sockeye salmon, plus steelhead. They are wide-ranging, migratory species with life histories that integrate marine, freshwater, and terrestrial ecosystems. They are considered a key set of focal species not only because of their highly specialized life histories but also because they play a critical role in the integrity of BC's coastal ecosystems. They face critical threats across all life history stages and habitats. We used the FISS database in BC and the Anadromous waters catalog in SE Alaska to determine the extent of salmon habitat distribution. Buffers around streams with salmon present (200m) were calculated and conservation goals were set to include a percentage of this terrestrial and freshwater salmon habitat for all species. Salmon distribution is shown in Maps 9 - 14.

Terrestrial Targets

Terrestrial Coarse-Filter Conservation Targets of the Coastal Forest and Mountains



Summary

This report describes trans-boundary coarse-filter terrestrial ecosystem maps for the Coastal Forest and Mountains of British Columbia and Southeast Alaska. Resulting maps include Land Formations (Map 3), Vegetation Structure (Map 4), Forest Alliances (Map 5) and Focal Ecological Systems (Map 6). Taken together these maps define a suite of coarse-filter conservation targets that represent a wide range of biodiversity characteristics of the region. The following provides background information and detailed methods related to the assembly of the coarse filter ecosystem data.

Introduction

An explicit goal of any systematic, science-based approach to conservation planning and design should include representation of a full range of native ecosystem types (Noss 1991; Margules and Pressey 2000). Ecosystem classification maps, species inventory data and species distribution information have all been used to form the basis of systematic representation of a full range of native ecosystem types and species. Although terrestrial ecosystems of the coastal temperate rainforest have been extensively mapped at a variety of scales in areas of both British Columbia and in Southeast Alaska, comprehensive, cross-border ecosystem maps for the entire region did not previously exist. Here, we report the development of a digital terrestrial ecosystem map that combines best-available, cross-border spatial information in a manner suitable for coarse-filter representation analysis for the entire Coastal Forest and Mountains ecoregion plus the adjacent Northern Pacific Ranges and Outer Fiordlands ecosections. We combined physiognomic and floristic data to produce a classification system that uniformly covers the entire extent of the region. We used this approach because 1) a combination of physical and floristic data is likely to capture more variation than either class alone, as each vegetation type encompasses considerable internal heterogeneity (Kirkpatrick and Brown 1994), 2) because the best available, independently developed, data sets were based on physical (elevation), and floristic (forest and vegetation cover) data respectively and 3) because a combinatorial, coarse-filter approach can be used to represent a full range of physical and floristic variation without the need for laborious, fine-scale terrestrial plant community classification.

Coarse-filter approaches rely on identifying and protecting general features at a relatively broad scale (e.g. physical landform classes and ecological system types), rather than species or fine-scale community types, assuming that broader-scale biodiversity surrogates sufficiently represent the finer-scale aspects of biodiversity (Pressey 1994; Pressey and Logan 1994). Moreover, representing a full spectrum of physical substrates and associated vegetation, especially if done in large, contiguous ecologically intact areas, may facilitate shifts in species distributions in response to climate change (Noss 2001). However as Pressey (1994) points out, the assumed relationship between environmental classes and species distributions is unclear and seldom investigated. In addition, certain species, especially rare species confined to small patches of habitat which are not recognized as distinct coarse-filter classes, or which cross boundaries of coarse-filter classes may fall through the coarse-filter when using broad-scale classification techniques (Noss 1983; Bedward, Pressey and Keith 1992; Panzer and Schwartz 1998). To address these shortcomings, parallel techniques have been recommended, including a focal species approach combined with special elements mapping (Noss 1991).

In addition, we suggest that a coarse-filter approach can be used in combination with finer-scale species distribution and other patchy biodiversity information in a two-step approach. First, region-wide information (such as the terrestrial ecosystem coverage reported here) can be used to set initial region-wide representation goals (Margules and Pressey 2000). Although information with limited spatial coverage has limited utility for setting region-wide conservation goals because conservation area selection will be biased towards areas where information exists, spatially patchy information can be used as an integral part of representation analysis, specifically to verify that the selected conservation areas are sufficient for meeting representation goals. Therefore the second step in this process is to verify representation in selected areas using finer-scale, spatially patchy data. This two-step approach has the advantage of utilizing the best available data in a scale-appropriate manner and also utilizes all available information. This approach also has the advantage that combinations of physical and floristic information sets can be identified without the need for laborious classification into specific ecological systems and plant community types, as specific systems and communities can be verified without the development of a region-wide coverage.

We suggest that the coverage, described here, is suitable for coarse-filter, region wide representational analysis. Furthermore, we suggest that this information can be used in combination with finer-scale biodiversity and human impacts information to ensure comprehensive representation and protection of best-remaining, ecologically intact areas. This document contains descriptions of data sets and methods employed in creation of a coarse-filter terrestrial ecosystem map for the Coastal Forest and Mountains ecoregion plus the adjacent Northern Pacific Ranges and Outer Fiordlands ecosections in British Columbia and southeast Alaska.

Coastal Forest Ecosystems

Coastal British Columbia, a region characterized by moderate climates, high rainfall (192 cm or more annually), and proximity to both mountains and the Pacific Ocean (Pojar et al. 1987), contains a unique assemblage of terrestrial ecosystems, including glaciers and steep mountain systems, high elevation alpine tundra, coastal muskeg forests and woodlands, estuarine and riparian systems, intertidal and coastal habitats and old growth coastal temperate rainforests (Meidinger and Pojar 1991). This section outlines coarse-filter spatial data and methods for representation of a full range of terrestrial ecosystem components that are found in coastal British Columbia.

The coastal temperate rainforest is a globally rare ecosystem (Smith and Lee 2000) and is highly vulnerable to continued industrial activities. Therefore, identification and representation of a suite of old growth ecological systems is central to this coarse-filter conservation planning approach. In recent times, old growth coastal temperate rainforests of North America, particularly communities dominated by Sitka spruce, Douglas fir and Western Red Cedar, have seen massive changes in distribution, composition and age structure (Schoonmaker, von Hagen and Wolf 1997; Smith and Lee 2000). The reason for these anthropogenic changes is not because coastal forests are exceptionally vulnerable to human disturbance but instead, the forests themselves, particularly stands that contain a large volume of old trees, are economically valuable and have been targeted by industrial scale logging. Thus, identification and protection of the best examples of remaining old growth forests is critical to the success of long-term conservation efforts, not because forest communities are particularly sensitivity to disturbance, but rather in response to unparalleled resource exploitation in every place old growth coastal temperate rainforest was previously found.

Coastal old growth forest ecosystems are distinguished by late-successional plant communities and related structural features. Coastal old-growth characteristics and definitions have been the subject of intense scientific research and legal scrutiny and old growth has been described variably in terms of stand structures (Franklin et al. 1981), stand development processes (Oliver and Larson 1990) and a combination of perspectives including genetic, population, ecosystem and landscape levels (Spies and Franklin 1995). Old growth definitions tend to include characteristics related to the later stages of stand development, that typically differ from earlier stages based on tree size, accumulations of large, dead, woody material, canopy layers, species composition, function, and other attributes (e.g. Franklin et al. 1986). These structural characteristics often include pronounced high timber volume areas containing dramatic examples of large and old trees. We utilized structural and age class data in a manner designed to identify a range of old growth forest ecosystems. Unfortunately, many of the best examples of coastal temperate rainforest ecosystems have already been destroyed by industrial activities. Therefore, a quantitative consideration of levels of historic impacts and setting goals for inclusion of areas based on historical distribution is also an explicit component of this analysis and we describe a method to first represent intact ecosystems, followed by inclusion of impacted areas if necessary to meet representation goals. Thus, we developed two independent methods to identify and represent different coarse-filter components of terrestrial ecosystems. The first was based on largely physiognomic data sets and resulted in explicit conservation targets based on modeled landforms. This approach allowed us to determine the historic impact of various ecological systems types and set goals based on historic abundance. The second approach was based on overstory species composition combined with a range of structural characteristics with the goal of representing both the structural and functional features that are characteristic of coastal temperate rainforests.

Methods

The Nature Conservancy developed a vegetation classification system (Maybury 1999) that blends the features of many existing classification systems in a hierarchical framework. The classification system essentially represents a structured compilation of fine-scale resolution data from both floristic and physiognomic data sources. The information is integrated using a modified version of UNESCO's worldwide framework for coarse-scale classification (UNESCO 1973). We applied a modified version of this framework to delineate coarse-filter terrestrial ecosystems of the coastal temperate rainforest of the Coastal Forest and Mountains ecoregion plus the adjacent Northern Pacific Ranges and Outer Fiordlands ecosections in British Columbia and southeast Alaska. The system groups physical and floristic data into seven hierarchical levels of classification, described briefly below.

Class

Class is related to the major structural characteristics of the dominant components of land cover. Because the majority of the vegetated areas of the coastal forest and mountains region is forested, and most of our floristic data is related to forest attributes, we focused our classification on structural characteristics of forest ecosystems. Class information is embedded within the structure field of the floristics and the physiognomic grids (see appendix I for details).

Subclass

Subclass is based on plant phylogeny and/or leaf character. Because non-forest classes had little data, we omitted subclass definitions for most non-forest types, except woodland. Woodland and forest classes were subdivided into deciduous, coniferous and mixed deciduous – coniferous. This information was classified from forest cover data and embedded in the floristics and the physiognomics grids (see appendices II, II and IV).

Group

Group is defined by leaf character and broad climactic type. Because our leaf character definitions were relatively simple, we restricted group classification to climactic regime and we used Shining Mountains to define common climactic areas (http://srmwww.gov.bc.ca/rib/wis/bei/shine/index.htm). Group is embedded in the floristics and physiognomics grids.

Subgroup

Subgroup is based on human alteration. Subgroup is embedded in the structure field within the floristics and ELU grids. Subgroups are listed below.

Subgroups

Intact Forest

Clearcut Forest

Natural non-forest vegetation

Altered non-forest vegetation

Natural unvegetated

Altered unvegetated

Formation

The formation level represents vegetation types that share definite physiognomy within broadly defined physical factors including, landscape position, elevation, and physical landform. A variety of variables can be calculated from analysis of a DEM, and numerous methods have been developed to predict physical landscape characteristics based on such variables (e.g. Moore 1991; Moore 1988; Lynn et al. 1995; Iverson et al. 1997; Fels and Zobel 1995). We used a combination of 3 variables based on the DEM to develop a landform model. We combined landform model with classified slope and aspect to determine formation, which is embedded within the physiognomic and the ELU grids (note that formation has often been used interchangeably with Ecological Land Unit or ELU and represents a region-wide coverage of the physical variation of the landscape).

Each component of formation is described below.

<u>Slope</u>

Gentle	< 25 deg
Moderate	25 – 50 deg
Steep	> 50 deg

<u>Aspect</u>

Cool (North facing: 240 - 120 degrees)

Warm (South Facing: 120 – 240 deg)

Landform model

We developed a Landform model to classify distinct combinations of elevation, slope and land position. Most previous ELU classifications operate by setting somewhat arbitrary thresholds that are assumed to be associated with landform distinctions. However, in large areas with diverse terrain, the physical characteristics of different landforms often overlap. To make objective and repeatable decisions where physical characteristics overlap based on statistical probability, we employed a maximum likelihood classification model. We used Tongass National Forest Common Land Unit (CLU) to guide the maximum likelihood classification. CLU landform data was based on air photo interpretation, combined with field observations and covers a large area (the Tongass National Forest) with diverse landforms. This method is more accurate than setting exact thresholds for slope, elevation and land position, because it statistically accounts for the natural variation in physical geography that was observed in air photos and in the field. However, additional training sets for British Columbia (e.g. from TEM field data) would greatly increase the reliability of the model for landforms that are increasingly distant from the training set. Training data for sub-maritime and non-coastal (e.g. sub-boreal spruce areas in the Stikine and Taku watersheds) would also extend the landform model to additional areas. More detailed data to train the model would also result in more detailed ELU classes. For example, we eliminated the "sub-alpine" class from our landform model, but this could be added if sufficient training data was included. Mountain summits were further divided into lower, mid and upper using unsupervised classification techniques.

Components of the landform model include:

<u>Elevation</u>

Continuous elevation based on 50m DEM, combining data from BC and AK.

<u>Slope</u>

Continuous slope (in degrees) based on 50m DEM. Note that we used classified slope (and aspect) breaks in combination with the landform model to produce formations. This has the advantage of further describing the predicted landform and also illustrates the variation of slope in the predicted model.

Landscape position

The landscape position (also referred to as slope position or topographic position) is determined by location relative to the elevation of neighboring positions. Landscape position was calculated using a 100 m resolution DEM (generated by resampling the 50m DEM). Landscape position for each grid cell was modeled using a distance-weighted elevation difference neighborhood model (Fels and Zobel, 1995):

Table 1. Ecological system and alliance species groupings based on ITG

ITG	ITG_desc	Alliance	Ecological System
1	Fd	Doug Fir	Doug Fir Forest
2	FdCw	Doug Fir	Doug Fir Forest
3	FdH	Doug Fir	Doug Fir Forest
4	FdS	Doug Fir	Doug Fir Forest
5	FdPl	Doug Fir	Doug Fir Forest
6	FdPy	Doug Fir	Doug Fir Forest
7	FdL	Doug Fir	Doug Fir Forest
8	FdDecid	Mixed Doug Fir –Deciduous	Mixed Deciduous Forest
9	Cw	Cedar	Cedar Forest
10	CwFd	Cedar	Cedar Forest
11	CwH	Hemlock – Cedar	Hemlock – Cedar Forest
12	H	Hemlock	Hemlock Forest
13	HFd	Hemlock	Hemlock Forest
14	HCw	Hemlock	Hemlock Forest
15	HB	Hemlock - Silver Fir	Hemlock - Silver Fir Forest
16	HS	Hemlock – Spruce	Hemlock – Spruce Forest
17	Hdecid	Mixed Hemlock – Deciduous	Mixed Deciduous Forest
18	B	Hemlock - Silver Fir	Hemlock - Silver Fir Forest
19	BH	Hemlock - Silver Fir	Hemlock - Silver Fir Forest
20	BS	Hemlock - Silver Fir	Hemlock - Silver Fir Forest
21	S	Spruce	Spruce Forest
22	SFd	Spruce	Spruce Forest
23	SH	Hemlock – Spruce	Hemlock Spruce Forest
24	SB	Spruce	Spruce Forest
25	SPl	Spruce – Pine	Spruce – Pine Forest
26	Sdecid	Mixed Spruce – Deciduous	Mixed Deciduous Forest
27	Pw	Western White Pine	
28	Pl	Shore Pine	Lodgepole Pine Forest
29	PlFd	Shore Pine	Lodgepole Pine Forest
30	PlS	Spruce – Pine	Spruce – Pine Forest
31	PlDecid	Mixed Shore Pine - Deciduous	Mixed Deciduous Forest
32	Py	Ponderosa Pine	
33	LFd	Larch	Deciduous Forest
34	L	Larch	Deciduous Forest
35	AcConif	Mixed Cottonwood – Conifer	Riparian Forest
36	AcDecid	Cottonwood	Riparian Forest
37	DrDecid	Alder	Deciduous Forest
38	Mb	Maple	Deciduous Forest
39	E	Birch	Deciduous Forest
40	AtConif	Mixed Aspen – Conifer	Mixed Deciduous
41	AtDecid	Aspen	Deciduous Forest

Landscape position = $[\sum_{1}^{n}(E_s - E_o)/d]/n$

where

Es = elevation of surrounding cell

Eo = elevation of cell under evaluation

d = horizontal distance

n = total number of surrounding points in the evaluation

Thus, landscape position is the mean of the distance-weighted elevation differences between a given cell and all other cells within a specified search radius. We used 3000m as the maximum search radius (which represented a trade-off between identification of narrowest versus the widest river valley).

CLU Landform Associations

- lowlands
- valley floor (floodplains and alluvium)
- hills and mountain slopes
- mountain summits
- coastal

Alliance

Groups of plant associations. Alliances and Associations are shown in appendices II, III and IV. Alliances are floristic and embedded in the floristic and the ELU grids.

Association

Ideally, association would include both major overstory and understory species. Fine scale understory plant associations are mapped in some areas of Alaska (CLU plant associations) as well as areas of B.C. (TEM/PEM site series). However, because we did not have comprehensive coverage of understory plant association, we restricted our association classification to overstory tree species. Dominant overstory species associations were mapped using inventory type group (ITG) from the BC forest cover data and crosswalked AK FTYPE and CLU plant associations to match ITG codes. As such we defined 41 overstory associations (appendices II, III and IV). More specific plant associations (e.g. site series) can be predicted from combination of floristic and physical ecosystem elements. Association based on ITG is included as a separate grid coverage that matches the spatial extend of the floristic, ELU and physiognomic grids.

Ecological Systems

Terrestrial ecological systems are defined as a group of plan community types (associations or alliances) that tend to co-occur within landscapes with similar ecological processes and/or environmental gradients (Nature Serve, 2003). Ecological systems are intended to provide a "meso-scale" classification unit (about 600 ecological systems are described for North America), suitable for regional-scale conservation planning. Ecological systems have the utility of grouping together plant alliances/associations and provide more practical unit for goal setting in conservation planning. We identified a set of ecological systems based floristic information in our coarse-filter terrestrial ecosystem classification (Table 1).

To ensure representation of a full range of variation within each ecological system type, we developed a method to identify a range of characteristics within each system by combining ecological system data with vegetation structure information to produce a suite of "focal ecological systems" for which conservation goals were set. Focal ecological systems are described in table 2. At least twenty-five species of conifers and inhabit the coastal rainforest of BC and we used size class, height and volume class and age class define and delineate stands of old-growth and other forest types based on both floristic and structural characteristics. We grouped inventory type groups to identifying ecological systems. Because the same species groups from the forest cover database may signify different ecological systems in different ecosection, we stratified goal setting by ecosection. For example, high volume cedar forest in the Hecate Lowlands

Table 2. Focal ecological system structure classes

Height Class	Age Class	Structure
> 4	>7	Very High Volume Old Growth
= 3,4	>7	High Volume Old Growth
< 3	Any Intact	Low Volume Forest / Woodland

probably represent different on the ground terrestrial ecosystems than high volume red cedar forests in the Kitimat Ranges (or in any other ecosection).

This method allows us to represent a full range of ecosystem types without the need to know exactly which ecosystem or community type is present (this is a major advantage for this coarse-filter approach). We do this in order to help capture some of the structural, functional, and age characteristics of Coastal B.C. terrestrial systems, including a range of old growth forest ecosystems. Focal ecosystems were simply defined as unique combinations of structure, ecological system (as defined in Tables 1 and 2) and ecosection. Goals for focal ecosystems were varied from 30% to 70% in 10% increments.

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Appendix I.

COASTWIDE FOREST STRUCTURE 1 May 2003

Structure GRID CODES description

1) Natural, Non-forest, unvegetated (NFUNVEG)

BC: Np_cd = 1,3,7,9,15,18,25,26,64

AK: NFCON = D,F,I,L,K,O,W,C,N,X

2) Altered, Non-forest, unvegetated (NFUNVEG)

BC: Np_cd = 6,50,54

AK: NFCON = P,U

3) Natural, Non-forest, vegetated (NFVEG)

BC: Np_cd = 2,3,10,11,16,35,42,62, NF = NCBR

AK: NFCON = A,B,G,M,S,T,H,R

4) Altered, Non-forest, vegetated (NFVEG)

BC: Np_cd = 60,63 , logging

AK: none, logging

5) Low Volume Forest

BC: HTCL_PR = 1-2

AK: FPROD <> “” & VOLC 1-3

6) Medium Volume Forest

BC: HTCL_PR < 3 or AGECL_PR <= 7

AK: VOLC = 4 & FPROD = “”

7) High Volume Old Growth Forest (HPOG)

BC: HTCL_PR = 3,4 & AGECL_PR > 7

AK: VOLC = 5 & FPROD = “”

8) Very High Volume Old Growth Forest (SPOG)

BC: HTCL_PR >= 5 & AGECL_PR > 7

AK: VOLC 6,7 & FPROD = “”

CROSSWALKS

1) Southeast Forest Condition to Forest Structure (only used to patch small areas of missing data)

Southeast Forest Condition	Forest Structure
10 (commercial forest)	6 PROD
11 (commercial, low volume)	6 PROD
12 (commercial, med volume)	7 HPOG
13 (commercial, high volume)	8 SPOG
20 (clear cut & 2nd growth)	4 ANFV
30 (non commercial)	6 PROD
40 (non forested)	5 NP
50/55 (unvegetated/urban)	1/2 Nunv/Aunv
60 (ice)	1 Nunv

CROSSWALKS

2) BTM to Forest Structure (only used to patch small areas of missing data)

BTM	Forest Structure
Agriculture	4 Anfv
Alpine	3 Nnfv
Barren surfaces	1 Nunv
Estuaries	9999 NOT INCLUDED
Fresh water	1 Nunv
Glaciers and Snow	1 Nunv
Mining	2 Aunv
Old forest	7 High Volume Old Growth
Rangelands	4 Anfv
Recently burned	3 Nnfv
Recently logged	4 Anfv
Recreation activities	5 NP
Residential/agriculture mix	4 Anfv
Salt water	1 Nunv
Selectively logged	4 Anfv
Shrub	3 Nnfv
Avalanche chutes	3 Nnfv
Urban	2 Aunv
Wetlands	3 Nnfv
Young forest	6 PROD

Appendix II. ITG (association), subclass and Alliance

ITG	subclass	ITG_desc	Alliance
1	C	Fd	Doug Fir
2	C	FdCw	Doug Fir
3	C	FdH	Doug Fir
4	C	FdS	Doug Fir
5	C	FdPl	Doug Fir
6	C	FdPy	Doug Fir
7	C	FdL	Doug Fir
8	M	FdDecid	Mixed Doug Fir -Deciduous
9	C	Cw	Cedar
10	C	CwFd	Cedar
11	C	CwH	Hemlock - Cedar
12	C	H	Hemlock
13	C	HFd	Hemlock
14	C	HCw	Hemlock
15	C	HB	Hemlock - Silver Fir
16	C	HS	Hemlock - Spruce
17	M	Hdecid	Mixed Hemlock - Deciduous
18	C	B	Hemlock - Silver Fir
19	C	BH	Hemlock - Silver Fir
20	C	BS	Hemlock - Silver Fir
21	C	S	Spruce
22	C	SFd	Spruce
23	C	SH	Hemlock - Spruce
24	C	SB	Spruce
25	M	SPl	Spruce - Pine
26	M	Sdecid	Mixed Spruce - Deciduous
27	C	Pw	Western White Pine
28	C	Pl	Shore Pine
29	C	PlFd	Shore Pine
30	C	PlS	Spruce - Pine
31	M	PlDecid	Mixed Shore Pine - Deciduous
32	C	Py	Ponderosa Pine
33	C	LFd	Larch
34	C	L	Larch
35	M	AcConif	Mixed Cottonwood - Conifer
36	D	AcDecid	Cottonwood
37	D	DrDecid	Alder
38	D	Mb	Maple
39	D	E	Birch
40	M	AtConif	Mixed Aspen - Conifer
41	D	AtDecid	Aspen

Appendix III. CLU crosswalk

CLU_PA1	Subclass	ITG	Alliance	CLU species group description
100	C	15	Hemlock	Western Hemlock
110	C	15	Hemlock	Western Hemlock
120	C	15	Hemlock	Western Hemlock
130	C	15	Hemlock	Western Hemlock
140	C	15	Hemlock	Western Hemlock
170	C	15	Hemlock	Western Hemlock
180	C	15	Hemlock	Western Hemlock
190	C	15	Hemlock	Western Hemlock
200	C	11	Hemlock - Cedar	Hemlock - Yellow Cedar
210	C	11	Hemlock - Cedar	Hemlock - Yellow Cedar
220	C	11	Hemlock - Cedar	Hemlock - Yellow Cedar
300	C	21	Spruce	Sitka Spruce
310	C	21	Spruce	Sitka Spruce
320	C	21	Spruce	Sitka Spruce
330	C	21	Spruce	Sitka Spruce
335	C	21	Spruce	Sitka Spruce
340	C	21	Spruce	Sitka Spruce
350	C	21	Spruce	Sitka Spruce
360	C	21	Spruce	Sitka Spruce
370	C	21	Spruce	Sitka Spruce
400	C	23	Hemlock - Spruce	Hemlock - Spruce
410	C	23	Hemlock - Spruce	Hemlock - Spruce
420	C	23	Hemlock - Spruce	Hemlock - Spruce
430	C	23	Hemlock - Spruce	Hemlock - Spruce
450	C	23	Hemlock - Spruce	Hemlock - Spruce
460	C	23	Hemlock - Spruce	Hemlock - Spruce
480	C	23	Hemlock - Spruce	Hemlock - Spruce
490	C	23	Hemlock - Spruce	Hemlock - Spruce
500	C	12	Hemlock	Mountain Hemlock
510	C	12	Hemlock	Mountain Hemlock
520	C	12	Hemlock	Mountain Hemlock
530	C	12	Hemlock	Mountain Hemlock
540	C	12	Hemlock	Mountain Hemlock
700	C	14	Hemlock - Cedar	Hemlock - Red Cedar
710	C	14	Hemlock - Cedar	Hemlock - Red Cedar
730	C	14	Hemlock - Cedar	Hemlock - Red Cedar
750	C	14	Hemlock - Cedar	Hemlock - Red Cedar
760	C	14	Hemlock - Cedar	Hemlock - Red Cedar
800	D	35	Cottonwood	Cottonwood
840	M	36	Cottonwood	Cottonwood
BH	D	37	Alder	Alder
BR	M	38	Alder	Alder
DA	D	35	Cottonwood	Cottonwood

Appendix IV. FTYPE crosswalk

FTYPE	Subclass	ITG	Alliance
H	C	12	Hemlock
S	C	21	Spruce
X	C	23	Hemlock - Spruce
C	C	9	Cedar
L	C	30	Shore Pine
A	D	38	Alder
P	D	36	Cottonwood
Z	M	35	Mixed Cottonwood - Conifer

Appendix V. Species Codes used to generate ITG and alliance codes. Some of these were undocumented, and we used landscape position, adjacent polygons and additional data sets to determine the correct code.

Hemlock
"HW" Or "H" Or "HM"

Cedar
"CW" Or "C" Or "YC" Or "CY"

Fir
"B" Or "BA" Or "BL" Or "BG"

Deciduous
"AC" Or "AT" Or "MB" Or "E" Or "EP" Or "EA" Or "EW" Or "DR" Or "DM" Or "D" Or "ACT" OR "CT"

Spruce
"S" Or "SS" Or "SB" Or "SE" Or "SW" Or "SX"

Doug Fir
"FD" Or "FDC" Or "F"

Larch
"L" Or "LT" Or "LW" OR "LA"

Pine
"PL" Or "PA" Or "P"

Terrestrial Focal Species

Terrestrial Focal Species of the Coastal Forest and Mountains

Grizzly Bear / Brown Bear (Map 15)

Grizzly bears are found throughout coastal British Columbia, with the exception of the Georgia Depression Ecoprovince, Vancouver Island, Queen Charlotte Islands, and the Coastal Douglas-fir (CDF) biogeoclimatic zone. Grizzly (i.e. Brown) bears are found on some of the islands of SE Alaska, but are absent from several of the islands. Coastal grizzly bears are mostly solitary, intra-specifically aggressive omnivores that typically have large seasonal and annual home ranges. They require habitat that provides for their nutritional, security, thermal, reproductive and "space" needs. To meet these varied needs, bears use an array of habitats, ranging from subalpine to valley bottom, old-growth to young forest, and wetlands to dry areas. With the exception of denning areas and avalanche chutes, the prime habitat of coastal grizzlies occurs predominantly below treeline and is largely concentrated in valley-bottom ecosystems often associated with important salmon streams. Grizzly bears were chosen as focal species because they can be keystone species (transporting salmon away from spawning channels), indicators (because they are susceptible to a wide variety of human influences and have low population densities), and umbrellas (representing a number of species because of their use of such a wide variety of habitats).

The BC grizzly bear model is a developmental extension of the provincial grizzly bear estimation process commonly referred to as the Fuhr-Demarchi method. The premise behind the approach is that different ecological units vary in their ability to support grizzly bear food resources and that such variations are linked (linearly) to bear density. Instead of attempting to translate habitat effectiveness into bear density, the model used here simply reports grizzly bear habitat effectiveness across the region. The model used the following data as indicators of habitat capability and suitability: 1) Broad Ecosystem Units (BEU); 2) TRIM 1:20,000 Digital Elevation Model (DEM); 3) Salmon biomass estimates; and 4) Roads/road density. The primary model outputs are habitat effectiveness ratings for each of the watersheds in occupied grizzly bear range within the British Columbia portion of the study areas.

For SE Alaska ecosections (i.e. The Northern and Southern Alexander Archipelagos and the Transboundary Ranges ecosections), we applied the grizzly bear habitat capability model developed by the Tongass National Forest (Schoen et al. 1992). Conservation goals were set by using a percentage of the total habitat value score 10% incremental steps ranging from 30% to 70%. The Tongass The Tongass model was adapted to the transboundary terrestrial ecosystems map.

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Black Bear (Map 16)

Black bears are commonly found throughout much of British Columbia and Southeast Alaska. They are very adaptable and inhabit a wide variety of habitats, from coastal estuaries to high elevation alpine meadows. Grasses, sedges, and horsetails form the bulk of their diet, particularly in late spring and early summer. They also feed on insects, fruits, berries, fish, garbage, carrion, small mammals, and occasionally on young deer. In the late summer and fall, salmon spawning rivers and streams represent important feeding areas. Black bear habitat use is strongly influenced by intraspecific social interactions and the presence and activities of people.

The black bear model for B.C. is a modification of the Fuhr-Demarchi grizzly bear estimation process. The higher any one land area is ranked for its ability to provide black bear foods, the higher the density estimator attached to it. Black bear habitat was mapped only outside of grizzly bear range, i.e., on Haida Gwaii/QCI and along the mainland coast. Data used in creating the model included 1) BEI – ratings table; 2) TRIM 1:20,000 Digital Elevation Model (DEM); 3) Salmon biomass estimates; 4) Roads; 5) Settlements/towns/recreation user days; and 6) Shoreline – rated for seasonal habitat availability for foraging. The primary model outputs are habitat effectiveness ratings for each of the watersheds in occupied black bear range within the British Columbia portion of the study areas. For SE Alaska ecosections (i.e. The Northern and Southern Alexander Archipelagos and the Transboundary Ranges ecosections), we applied the black bear habitat capability model developed by the Tongass National Forest (Suring et al. 1992), using the transboundary terrestrial ecosystems map. Conservation goals were set by using a percentage of the total habitat value score 10% incremental steps ranging from 30% to 70%.

References

Suring, L. Degayner, E., Flynn, R. and McCarthy, T. 1992. Habitat Capability Model for Black Bears in Southeast Alaska. Version 4.1. Distributed by the U.S. Department of Agriculture. Forest Service, Alaska Region, P.O. Box 21628, Juneau, Alaska 99802-1628

Sitka Black-Tailed Deer (Map 17)

The Sitka black-tailed deer was chosen as a focal species because loss of old-growth forest cover has a high potential to negatively affect deer populations. The complex canopy structure of old-growth forests allows sufficient light to penetrate, promoting the growth of a diverse set of vascular and non-vascular plants for forage, as well as providing for interception of snow. Deer abundances also ultimately affect predator-prey relationships.

We targeted Sitka black tailed deer winter range as a key component of their habitat, which acts as a limiting factor in deer abundance. The amount and duration of snowfall an area receives strongly influences its ability to support deer. During periods of deep and prolonged snow, deer look for old, high-volume forests on gentle to moderate slopes at low elevations.

The Sitka black-tailed deer winter range model for coastal BC is based on an "old-growth, deer winter-range" model developed by the Raincoast Conservation Society. Deer winter range habitat was only modeled for the Central and North Coast portions of the study area, as black-tailed deer introduced to Haida Gwaii/QCI have experienced a population explosion due to lack of natural predators, destroying and significantly altering plant communities and ecosystems throughout the islands.

To model black-tailed deer habitat in SE Alaska ecosections (i.e. The Northern and Southern Alexander Archipelagos and the Transboundary Ranges ecosections), we implemented the Tongass National Forest Black-Tailed Deer habitat capability model developed by Suring and colleagues (1992) applied to the cross-walked terrestrial ecosystems map. Targets were set as percentage of habitat value in the model in 10% incremental steps ranging from 30% to 70%.

References

Lowell H. Suring, Eugene J. Degayner, Rodney W. Flynn, Matthew D. Kirchhoff, John W. Schoen, And Lana C. Shea. 1992. Habitat Capability Model For Sitka Black-Tailed Deer In Southeast Alaska: Winter Habitat. Version 6.5 April 1992. Distributed by the U.S. Department of Agriculture, Forest Service, Region 10, P.O. Box 21628, Juneau, Alaska 99802-1628

Raincoast Conservation Society. 2003. Sitka black-tailed deer winter range model for Coastal British Columbia.

Mountain Goat (Map 18)

The mountain goat occupies steep, rugged terrain in the mountains of northwestern North America. British Columbia is home to up to 60 percent of the continental mountain goat population. Generally, mountain goats inhabit alpine and subalpine habitats in all of the mountain ranges of the province. The characteristically rugged terrain is comprised of cliffs, ledges, projecting pinnacles, and talus slopes. The availability of winter range may be limiting. Winter habitats may be low elevation habitats where snow accumulation is low, or high elevation habitats where wind, sun or precipitous terrain adequately shed snow from foraging habitats. In coastal BC areas, mountain goats generally move to south-facing, forested areas that offer reduced snow loading and increased access to foraging. The mountain goat was selected as a focal species because of its sensitivity to direct impacts of forest cover removal from limited winter ranges, as well as the potential direct and indirect mortality associated with increased access to human activity.

In many regions of the study area, past surveys and fine-scale habitat modeling has identified present populations and associated winter habitats. These data and the modeling results were used to identify the highest priority mountain goat areas in the region. Additionally, a coarse-scale, spatially-explicit model was developed to predict potential mountain goat winter habitats in areas not included by these previous efforts, and also to predict potential future habitat potential (i.e., habitat capability). This effort builds on the foundational GIS-based modeling used to identify areas for finer-scale habitat identification. The combined models identified approximately 300,000 ha of occupied winter goat habitat in the BC portion of the study area. These habitats are not equally distributed across the study area, due to the project-specific nature of the data. The BC potential winter habitat model overlaps 65% of these occupied winter mountain goat habitats, and predicts additional potential winter habitat across the study area. To identify goat habitat for SE Alaska ecosections (i.e. The Northern and Southern Alexander Archipelagos and the Transboundary Ranges ecosections) we implemented the Tongass National Forest Habitat Capability Model for Mountain Goat Winter Habitat (Suring et al. 1992).

References

Lowell H. Suring, Rodney W. Flynn, John W. Schoen, And Lana C. Shea. 1988. Habitat Capability Model For Mountain Goats In Southeast Alaska: Winter Habitat v 4.1. Distributed by the U.S. Department of Agriculture. Forest Service, Alaska Region, P.O. Box 21628, Juneau, Alaska 99802-1628

Marbled Murrelet (Map 19)

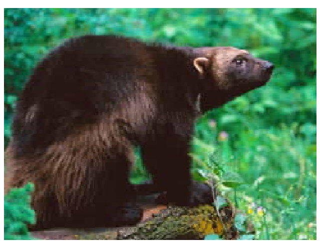
The Marbled Murrelet is a small seabird whose biology has given it an unusually important role in resource management in British Columbia. With only a few exceptions, its nests are in old-growth forest. The Marbled Murrelet was chosen as a focal species due to conservation concerns over loss of nesting habitat and increased predation risk from forestry activity. There is also increasing concern for the influences of human activity on its survival at sea.

The habitat-suitability model for this species was based on the Conservation Assessment developed for the Marbled Murrelet Recovery Team in British Columbia. Targets were set as percentage of habitat identified in the model in 10% incremental steps ranging from 30% to 70%.

The model showed a widespread distribution of murrelet habitat without any strong concentrations or significant isolated pockets. Most lowland areas and valley bottoms were included. Sites for known nests were captured in the Queen Charlotte Islands, but many of the nest sites around Mussel Inlet occurred at too high an elevation to be captured. The model indicated the presence of 216,093 hectares (ha) of the most likely habitat on the Queen Charlotte Islands. No areas were added by relaxing the criteria. There were 359,699 ha on the Central Mainland Coast and 154,736 ha on the Northern Mainland Coast that increased by 16,356 ha and 2,858 ha respectively, when the criteria were relaxed. The model provides a general picture of the distribution of murrelet habitat along the coast of BC, but provides no information about variation in quality or usage.

Ecological Integrity

Measuring Ecological Integrity for the Coastal Forest and Mountains



The biological integrity of terrestrial, near-shore marine and freshwater ecosystems depends largely on previous human alterations. Although it has been well established, through experimental and correlative studies, that ecological systems are adversely affected by human alterations, there is relatively little information about the functional relationship between ecological integrity, key ecological processes and human activities (Jungwirth et al. 2002). This lack of information hampers assessment of ecological integrity; consequently, standard methods for quantifying the relative degree of impacts and methods for utilizing impact measures to prioritize areas for conservation have not been developed. Nevertheless, a number of studies have been completed that can provide direction with setting thresholds associated with ecological integrity (Table 1).

Watersheds were utilized both as the unit of analysis and as the recommended element for management. There are multiple studies that suggest conservation action and management should take place at the scale of entire watersheds (Sullivan et al. 1987; Sheldon 1988; Williams et al. 1989; Moyle, 1991; Naiman et al. 1992; Stanford and Ward 1992; ; Naiman, Decamps and Pollock 1993; Naiman, Bilby and Bisson 2000; Pringle 2001; Baron et al. 2002). For example, many of the species and trophic systems of coastal B.C. (e.g. salmon spawning and rearing and the interactions between wildlife species and salmon) tend to be strongly linked to key ecological processes at a watershed-scale such as sedimentation control, regulation of flow regimes and nutrient cycling. Indeed, the fate of coastal ecosystems is intrinsically

TABLE 1. Reported thresholds for human impacts on biodiversity

Report	Results
Mace et al. 1996	High female Grizzly bear habitat use areas (i.e. within composite home ranges) had less than 0.6 km / 1 km^2 road density; comparable areas outside of composite home ranges had > 1 km/km^2 road density.
McGurk and Fong, 1995	Detrimental effects on aquatic ecosystems based on macro-invertebrate distribution, where roads cover >5% or more of a watershed
Mech 1989	0.6 km / km2 road density threshold for wolves
Van Dyke et al. 1986	0.6 km / km2 road density threshold for mountain lions
Forman et al. 1997	0.6 km / km2 road density threshold for grizzly bears
Findlay and Houlahan 1997	Species richness in Ontario, Canada wetlands was negatively correlated with proximity to roads at distances up to 1-2 km
Jones and Grant 1996; Jones et al. 2000	Partial logging (25% of watershed) significantly increases flood event magnitude. No measurable difference above 25% threshold (i.e. 100% logged areas had similar effects as 25%)
Schuler 1995	10% threshold for aquatic system permeability
Quarles et al. 1974; Dales and Freedman 1982	Soil contamination decreases exponentially away from roads; thresholds vary between 20m and 200m
Lyon 1983; Paquet and Callaghan 1996; Rost and Bailey 1979	Elk and other large ungulate avoidance 100 – 200m distance from road.
Forman 1995	Indirect impacts for wildlife (i.e. increased human access, mortality etc.) range from 200m – 1000 m from a road

linked to the fate of salmon populations as salmon serve as a "keystone" species (Wilson and Halupka 1999), and although not sufficient in itself, conservation of a full range of intact watersheds containing terrestrial salmon habitat is necessary for long-term coastal temperate rainforest conservation.

In addition, field studies suggest that watersheds are the appropriate scale to measure and manage cumulative human impacts. Measurable indicators tend to correlate with human activity data when measured at watershed scales, while the correlation is often absent at local scales (Karr 1991; Roth 1996; Muhar and Jungwirth 1998; Thorton 2000; Carignan et al. 2002; Pess et al. 2002). Thus, because watersheds define an appropriate ecological unit where human impacts tend to accumulate and can be measured and because of their value for key ecological processes and their global rarity, identifying and representing a range of intact watersheds should be included as a part of any credible, systematic, science-based conservation analysis.

Here we report methods for assessing relative impacts at multiple scales, using watersheds as our analysis unit, based on known linkages between human impacts and ecological processes. We report here simple evaluation criteria specifically designed to utilize surrogates for ecological integrity. We chose surrogates that 1) are likely to correlate with key ecological functions and processes found in intact ecosystems, 2) are measurable and able to be mapped and 3) have region-wide data available with relatively uniform quality and coverage. In addition, we define standard comparison units, based on systematic and repeatable criteria for defining watershed boundaries based. We suggest that these tools, in combination, can be used to assess ecological integrity multiple scales, from 3rd order watershed-scale to a regional scale and can thus provide critical information for systematic conservation planning efforts.

Methods

Watershed boundaries were defined using a systematic set of decision rules. The B.C. watershed atlas was utilized as the basis, since it provides established and documented spatial data. Additional units were based on aggregating BC watershed atlas "3rd order" (i.e. LWSD) polygons into discrete units. Primary watersheds were created by grouping all watershed polygons that share a common saltwater exit point. Although primary watersheds define drainages, their size range covers several orders of magnitude (i.e. from less than 1 ha to over 5 million hectares). Note that primary watersheds define an objective unit and can be sub-divided using any number of arbitrary methods. Therefore, to systematically classify sub-primary watersheds, two additional units were defined: intermediate river systems and large river systems. These sub-primary watersheds between 10,000 ha and 100,000 ha and 100,000 ha to 1,000,000 ha respectively, were defined using a standardized set of decision rules. This allowed assessment of impacts and other characteristics at multiple spatial scales.

Using these criteria, we applied a scheme to assess ecological integrity, based on a modified Moore (1991) methodology. Human impacted area was calculated by combining all human altered areas (clearcut, urban, agriculture) with a 200m buffer area around roads. A 200m buffer was used as a compromise between indirect impacts of roads on vertebrate species (i.e. "zone of influence") which has been reported to range from 200m to several kilometers and direct impacts of roads on adjacent habitat, which ranges from 20m to over 200m (see Table 1 for summary). Overlapping areas were treated as impacted (i.e. overlaps were only counted once), which also allowed calculation of overall percentage of development in any watershed unit. This method has several advantages including correcting for patchy data (e.g. where either logging data or road data is absent).

Table 2. Intact area definitions. Areas without vegetative cover data are omitted from this analysis.

Class	**Description**
$Intact_1$	Pristine, no industrial impact
$Intact_2$	Modified, < 2% area impacted and < 0.35 km/km^2 road density
$Intact_3$	< 10% of area impacted and < 10% of area in proximity to rivers/streams impacted and < 0.35 km/km^2 road density
$Modified_1$	< 15% of area impacted and < 0.6 km/km^2 road density
$Modified_2$	< 25% of area impacted and < 0.6 km/km^2
Developed	> 25% of area impacted or > 0.6 km/km^2 road density

Table 3. Watersheds and River systems

Primary Watersheds	Label
< 10,000 ha	Small Primary
10,000 – 100,000 ha	Medium Primary
100,000 – 1,000,000 ha	Large Primary
> 1,000,000 ha	Very Large Primary
River Systems	
10,000 – 100,000	Intermediate Watersheds
100,000 – 1,000,000	Large Watersheds
3^{rd} Order Watersheds	
LWSD polygons	LWSD systems [note that these do not occur in Alaska]

Because some areas have relatively little vegetated area and, consequently, little developable area and little productive habitat, impacted area was calculated as a percent of potential vegetated area, which was calculated as a sum of natural vegetated area, human altered vegetated area and urban area. Road density was calculated as km of road per square kilometer, by watershed.

Watersheds with more than 2% of their area affected may still be ecologically intact, depending largely on both the cumulative impact of human alteration and the spatial location of human alterations. To identify such watersheds, two additional factors were utilized for assessing the overall level of impact, 1) proximity of impacts to rivers and streams and 2) road density. This allowed separation of moderately impacted areas from those with higher levels of human impacts (Table 2).

In addition we also sought to identify relatively intact watersheds at multiple spatial scales. Small intact watersheds may be sufficient for harboring viable occurrences of some non-vagile species (e.g. rare plant communities), but larger, contiguous intact areas and characteristics present only in larger river systems are necessary to conserve viable populations of vertebrate species. We applied definitions based on Table 2 to several scales of watersheds and river systems (Table 3).

Results

Ecological Integrity assessments for three scales of watersheds are displayed in maps 23 - 25. Note that for SE Alaska, there is very little change at different scales. This is because the "3rd order" watersheds (i.e. smaller) watersheds are not defined differently from the Intermediate watersheds (i.e. there was no sub-intermediate breakdown of watersheds in SE Alaska. Additionally, few primary watersheds were larger than 100,000 ha and thus did not require further subdivision to define Intermediate scale watersheds.

Conservation Area Design

Conservation Area Design: Spatial Analysis and Synthesis for the Coastal Forest and Mountains

Spatial Optimization

Early conservation assessments depended on manual mapping to delineate sites and were often totally reliant on expert opinion and sharpie markers to delineate and prioritize conservation sites. The large number of conservation targets and the large size and diverse types of data sets describing the targets in this study required the use of a more systematic and efficient site selection procedure. We used MARXAN, software that implements a site optimization algorithm, developed by Dr Hugh Possingham, University of Queensland, and Dr Ian Ball, now at Australian Antarctic Division in Tasmania. MARXAN comes from a lineage of successful selection algorithms, beginning with SIMAN, SPEXAN, and SITES. MARXAN was developed from SPEXAN and SITES in part to aid in work on the Great Barrier Reef Marine Park In order to design an optimal reserve network, MARXAN examines each individual planning unit for the values it contains. It then selects a collection of these units to meet the conservation targets that have been assigned. The algorithm adds and removes planning units in an attempt to improve the efficiency of the reserves. What makes these algorithms different from other iterative approaches is that there is a random element programmed into them such that early on in the process the algorithm is quite irrational in what it chooses to keep or discard, often breaking the rules of what makes a good selection. This random factor allows the algorithm to choose less than optimal planning units earlier that may allow for better choices later. As the program progresses, the computer behaves more predictably -but not entirely. The process continues, with the criteria for a good selection getting progressively stricter, until finally the reserve network is built. Given a sufficiently diverse set of features, it follows that because of the random element, no two runs are likely to produce exactly the same results. Some may be much less desirable than others. Still, if enough runs are undertaken, a subset of superior solutions can be created. Furthermore, the results from all runs may be added together to discern general trends in the selection process.

MARXAN and other similar software programs (e.g. SITES, SIMAN, SPEXAN) have been or are being used as an aid for designing and analyzing alternative portfolios in a number of The Nature Conservancy ecoregional plans, including the Northern Gulf of Mexico (Beck et al. 2000), Cook Inlet, Klamath Mountains, Sierra Nevada, Middle Rocky Mountains-Blue Mountains, and Southern Rocky Mountains ecoregions. MARXAN utilizes an algorithm called "simulated annealing with iterative improvement" as a heuristic method for efficiently selecting regionally representative sets of areas for biodiversity conservation (Pressey et al. 1996, Csuti et al. 1997, Possingham et al. 1999). It is not guaranteed to find an optimal solution, which is prohibitive in computer time for large, complex data sets such as ours. Rather, the algorithm attempts to minimize portfolio "cost" while maximizing attainment of conservation goals in a compact set of sites. This set of objectives constitutes the "Objective Cost function:"

Cost = Area + Species Penalty + Boundary Length

where Cost is the objective (to be minimized), Area is the number of hectares in 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. MARXAN attempts to minimize total portfolio cost by selecting the fewest planning units and smallest overall area needed to meet as many target goals as possible, and by selecting planning units that are clustered together rather than dispersed (thus reducing boundary length). MARXAN accomplishes this task by changing the planning units selected and re-evaluating the Cost function through multiple iterations. We had MARXAN perform 1,000,000 iterative attempts to find the minimum cost solution per simulated annealing run and perform 100 such runs for each alternative conservation scenario we explored. Alternative scenarios were evaluated by varying the inputs to the Cost function. For example, the Boundary Length cost factor was increased or decreased depending on the assumed importance of a spatially compact portfolio of sites, and a range of goals were used. Varying the inputs to MARXAN in order to assess the outcome, in terms of the planning units selected, allows portfolio design to be tailored to expert opinion, while quantifying the effects of such subjective decisions.

We used numerous MARXAN runs to determine alternative portfolios which met stated goals for protection of the target groups: coarse-filter : local-scale imperiled species, bird species, aquatic species, and plant communities within the special elements track; vegetative, abiotic, and aquatic habitat types within the representation track; and high-quality habitat for the several species analyzed within the focal species track. We conducted MARXAN runs with and without existing and potential protected areas "locked in" to the portfolio, looking for differences in the location and area of selected planning units. Our ultimate objective was to find the portfolio that met stated goals for all target groups in an efficient manner, while also meeting the general criteria of reserve design (e.g., connectivity, minimal fragmentation).

Parameters

Several factors besides the number and type of targets used influence MARXAN outcomes. These include type of planning units, protection status of planning units, planning unit cost measure, penalty applied for failure to meet target goals ('species penalty factor'), penalty applied for dispersed rather than clustered planning units in results ('boundary length modifier'), the number of repeat runs of the algorithm (and number of iterations within each run) to include in summing results from several scenarios, and goal level for each target.

Planning Units

We used 1000 hectare hexagons selected from a layer that covers all the study area. This not only allows consistency with future marine analysis, but using uniform sized planning units also avoids the area-related bias that can occur in the planning unit selection process when differently-sized planning units with irregular boundaries, such as watersheds, are used.

Suitability Index

Planning units with lower levels of human impacts should be chosen over those with higher levels of impacts, when other factors are equal. This general rule should lead to selection of areas that are more likely to contain viable examples of species and ecological systems. Thus, rather than simply using the number of hectares in each planning unit for the Area component of our MARXAN analyses, we developed a suitability index (i.e. cost index based on the same human impact data used in identification of intact landscapes.

Human impacted area was calculated by combining a 200m buffer around human-altered area (clearcut, urban, agriculture) with a 200m buffer area around roads. Overlapping areas were treated as impacted (i.e. overlaps were only counted once), which also allow calculation of overall percentage of development (e.g. Moore, 1991) in any planning unit or watershed.

To account for planning units with relatively little vegetated productive areas (and consequently little developable area and little productive habitat) we used the following suitability index:

Cost Index = Planning Unit Area + Planning Unit Area * Human Impacted Area / Potential Vegetated Area

With all areas being measured in square kilometers. Potential Vegetated Area was calculated as the sum of vegetated habitat plus the sum of clearcut and urban areas. This assumes that existing development took place on formerly vegetated habitat areas. Note that this calculation omits bare rock, glacier and lake areas. With this index applied, planning units with no human impacted area were given a cost of 10 square kilometers (1000 ha), while those having all potential vegetated area impacted had a cost of 10 square kilometers and partially impacted planning units had cost greater than zero but less than 10 square kilometers. Because the MARXAN algorithm seeks to minimize total portfolio cost, it selects planning units with low cost unless higher cost planning units contain targets that cannot be found elsewhere.

Species Penalty Factor

Because we had no way to weight targets differently, we used the same penalty factor (one) for all targets.

Boundary Length Modifiers

We used boundary length modifiers of 0.0001, 0.0003, and 0.0005 to include a range of planning unit clustering in our final combined sum runs.

Repeat Runs

We made 100 repeat runs (each comprised of 1,000,000 iterations of planning unit selection) for each of 15 combinations of boundary length modifier (three levels) and goal (five different goal levels: 30%, 40%, 50%, 60%, and 70%.) for two scenarios (one with existing protected areas locked in; the other unconstrained). Thus, for each protection scenario we used a sum of 1500 sites runs 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 similar biodiversity is found many other places or where human impacts are significant.

Results

Conservation Value

A key concept in conservation planning is irreplaceability (Pressey et al. 1994, Margules and Pressey 2000, Pressey and Cowling 2001). Irreplaceability provides a quantitative measure of the relative contribution different areas make toward reaching conservation goals, thus helping planners choose among alternative sites in a portfolio. As noted by Pressey (1998), irreplaceability can be defined in two ways: 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. Given the constraints under which the site selection algorithms operate, we can expect that summed solutions will describe a range of important conservation criteria including rarity, richness, diversity and complementarity. These criteria are optimized through the selection of a minimum set of planning units to meet goals for our conservation targets. We have used these summed solutions as a broad measure of irreplaceability, which for the purposes of this report, we more simply describe as "conservation value". Conservation value however is not always a direct and absolute measure of true irreplaceability since areas with high conservation value may indeed be replaced by using larger areas of lower value sites.
In the case of terrestrial and freshwater analysis, a combination of 5 goal settings and 3 boundary length modifiers were repeated 100 times each for a total of 1500 possible conservation solutions, each of which were inte-

Table 1. Condition Matrix

		Condition		
		Intact	Modified	Developed
Value	High	1	1	2
	Medium	1	2	3
	Low	2	3	3

grated into a single final summed solutions. A conservation value score was derived directly from the frequency by which any one planning unit was selected in these 1500 repetitions, such that a unit selected in every solution received a score of 1500, while a unit never selected was scored as a zero. These scores were subsequently rolled-up for each intermediate 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 condition matrix in Table 1 and Map 27. 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.

Target Type	Description (1037 Targets)
Coarse-Filter Terrestrial	
Land Formation (Map 3)	Landform – slope – aspect combinations stratified by ecosection. Target set as percentage of historical abundance for each land formation class; target selected from unimpacted areas (217 Targets).
Focal Ecological Systems (Map 6)	Combinations of ecological systems (groups of vegetation alliances) and structural elements (volume classes), stratified by ecosection (289 Targets).
Coarse-Filter Freshwater	
Wetlands (Map 8)	Wetland features from the BC TRIM database. Goals set as a percentage of wetland area, stratified by ecosection (15 targets).
RRCS riparian model (Map 8)	Riparian areas modeled using DEM and stream features. Goals set as a percentage of modeled riparian area, stratified by ecosection (15 targets).
Freshwater systems (Map 7)	Combinations of watershed size, biogeoclimatic zone, bedrock geology, stream gradient, coastal connectivity, glacial influence and lake/wetland influence (436 targets)
Terrestrial Focal Species	
Grizzly Bear (Map 15)	BC Govt. Grizzly Bear Habitat Effectiveness Model (rated by watershed) Tongass National Forest Brown Bear Habitat Capability Model, applied to terrestrial ecosystems spatial data. Goal set as percentage of all habitat effectiveness / capability scores, stratified by ecosection (15 targets)

Black Bear (Map 16)	BC Govt. Black Bear Habitat Effectiveness Model (rated by watershed) Tongass National Forest Black Bear Habitat Capability Model, applied to terrestrial ecosystems spatial data. Goal set as percentage of all habitat effectiveness / capability scores (15 targets)
Black-Tailed Deer (Map 17)	Raincoast Conservation Society Black-Tailed Deer model, stratified by ecosection Tongass National Forest Black-Tailed Deer Habitat Capability Model, stratified by ecosection, applied to terrestrial ecosystems spatial data. Goal set as percentage of all habitat model habitat scores, stratified by ecosection, omitting ecosections of Haida Gwaii (7 Targets)
Mountain Goat (Map 18)	BC habitat model; Tongass National Forest Habitat Capability Model Goal set as percentage of all habitat effectiveness / capability scores stratified by ecosection (9 targets)
Marbled Murrelet (Map 19)	BC Murrelet Recovery Team Habitat Model Goal set as a percentage of identified habitats, stratified by 9 ecosection (9 Targets)
Freshwater Focal Species	
Tailed-Frog	BC tailed-frog habitat model
Salmon (Chinook, Chum, Coho, Pink, Sockeye and Steelhead)	BC FISS distribution and AK anadromous waters catalog Goal set as percentage of habitat within 200m of a salmon-bearing stream for each species (6 targets).

Round River is an ecologically oriented research and education organization whose goal is the formulation and carrying out of conservation strategies that preserve and restore wildness.

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The mission of The Nature Conservancy is to preserve the plants, animals and natural communities that represent the diversity of life on Earth by protecting the lands and waters they need to survive.

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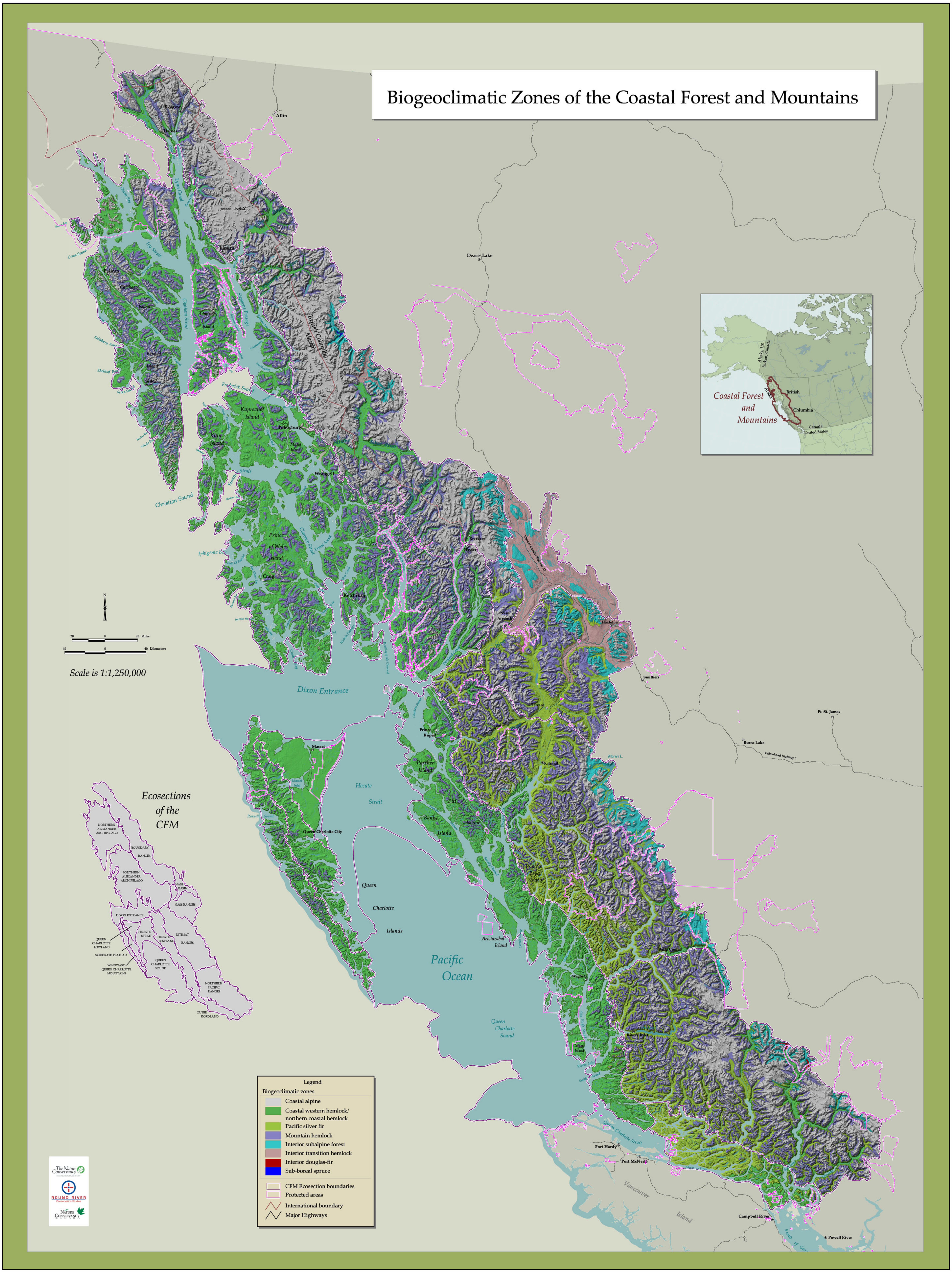
Topography of the Coastal Forest and Mountains

Biogeoclimatic Zones of the Coastal Forest and Mountains



Landscape Formations of the Coastal Forest and Mountains
Skagway
Haines
Atlin
Juneau
Pelican
Chichagof Island
Baranof Island
Sitka
Kupreanof Island
Petersburg
Kuiu Island
Wrangell
Christian Sound
Prince of Wales Island
Craig
Ketchikan
Stewart
Hyder
New Aiyansh
Hazelton
Dease Lake
British Columbia
Alaska
Coastal Forest and Mountains
British Columbia
Canada
United States
Dixon Entrance
Smithers
Ft. St. James
Burns Lake
Masset
Prince Rupert
Kitimat
Hecate Strait
Pitt Island
Banks Island
Queen Charlotte City
Queen Charlotte Islands
Aristazabal Island
Pacific Ocean
Queen Charlotte Sound
Bella Coola
Rivers Inlet
Port Hardy
Port McNeill
Vancouver Island
Campbell River
Powell River
Scale is 1:1,250,000
Kilometers
Miles
Ecosections of the CFM
NORTHERN ALEXANDER ARCHIPELAGO
BOUNDARY RANGES
SOUTHERN ALEXANDER ARCHIPELAGO
NASS BASIN
NASS RANGES
DIXON ENTRANCE
HECATE STRAIT
HECATE LOWLAND
KITIMAT RANGES
QUEEN CHARLOTTE LOWLAND
SKIDEGATE PLATEAU
WINDWARD QUEEN CHARLOTTE MOUNTAINS
QUEEN CHARLOTTE SOUND
NORTHERN PACIFIC RANGES
OUTER FIORDLAND
Legend
Landscape Formations
VALLEY FLOOR
ESTUARY
LOWLANDS
HILLS-GENTLE-COOL
HILLS-GENTLE-WARM
HILLS-MODERATE-COOL
HILLS-MODERATE-WARM
HILLS-STEEP-COOL
HILLS-STEEP-WARM
MTN SLOPES-GENTLE-COOL
MTN SLOPES-GENTLE-WARM
MTN SLOPES-MODERATE-COOL
MTN SLOPES-MODERATE-WARM
MTN SLOPES-STEEP-COOL
MTN SLOPES-STEEP-WARM
Gentle slopes <= 25 degrees
Moderate slopes 25 - 50 degrees
Steep slopes > 50 degrees
Warm aspects 120 - 240 degrees
Cool aspects 240-360, 0-120 degrees
LOWER MTN SUMMITS-GENTLE-COOL
LOWER MTN SUMMITS-GENTLE-WARM
LOWER MTN SUMMITS-MODERATE-COOL
LOWER MTN SUMMITS-MODERATE-WARM
LOWER MTN SUMMITS-STEEP-COOL
LOWER MTN SUMMITS-STEEP-WARM
MID MTN SUMMITS-GENTLE-COOL
MID MTN SUMMITS-GENTLE-WARM
MID MTN SUMMITS-MODERATE-COOL
MID MTN SUMMITS-MODERATE-WARM
MID MTN SUMMITS-STEEP-COOL
MID MTN SUMMITS-STEEP-WARM
UPPER MTN SUMMITS-GENTLE-COOL
UPPER MTN SUMMITS-GENTLE-WARM
UPPER MTN SUMMITS-MODERATE-COOL
UPPER MTN SUMMITS-MODERATE-WARM
UPPER MTN SUMMITS-STEEP-COOL
UPPER MTN SUMMITS-STEEP-WARM
VOLCANIC-GENTLE-COOL
VOLCANIC-GENTLE-WARM
VOLCANIC-MODERATE-COOL
VOLCANIC-MODERATE-WARM
Highways
Ecosection boundaries
Glaciers/snow
International boundary
The Nature Conservancy
ROUND RIVER Conservation Studies
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Vegetation Structure of the Coastal Forest and Mountains
Coastal Forest and Mountains
Alaska, US
Yukon, Canada
British
Columbia
Canada
United States
Scale is 1:1,250,000
20
0
20
Miles
40
0
40
Kilometers
Ecosections of the CFM
NORTHERN ALEXANDER ARCHIPELAGO
BOUNDARY RANGES
SOUTHERN ALEXANDER ARCHIPELAGO
NASS BASIN
NASS RANGES
DIXON ENTRANCE
HECATE STRAIT
HECATE LOWLAND
KITIMAT RANGES
QUEEN CHARLOTTE LOWLAND
SKIDEGATE PLATEAU
WINDWARD QUEEN CHARLOTTE MOUNTAINS
QUEEN CHARLOTTE SOUND
NORTHERN PACIFIC RANGES
OUTER FIORDLAND
Legend
Vegetation Structure
Clearcut forest
Very high volume forest
High volume forest
Medium volume forest
Low volume forest
Non-forest, unvegetated
Non-forest, vegetated
Protected areas
Glaciers/snow
International boundary
Major roads
Skagway
Haines
Atlin
Juneau
Pelican
Chichagof Island
Admiralty Island
Baranof Island
Sitka
Kupreanof Island
Petersburg
Kuiu Island
Wrangell
Christian Sound
Prince of Wales Island
Craig
Ketchikan
Stewart
Hyder
New Aiyansh
Hazelton
Dease Lake
British Columbia
Alaska
Dixon Entrance
Masset
Prince Rupert
Porcher Island
Terrace
Kitimat
Smithers
Ft. St. James
Burns Lake
Hecate Strait
Pitt Island
Banks Island
Queen Charlotte City
Queen Charlotte Islands
Princess Royal Island
Aristazabal Island
Pacific Ocean
Bella Coola
Wagliste
Rivers Inlet
Queen Charlotte Sound
Queen Charlotte Strait
Port Hardy
Port McNeill
Vancouver Island
Campbell River
Powell River
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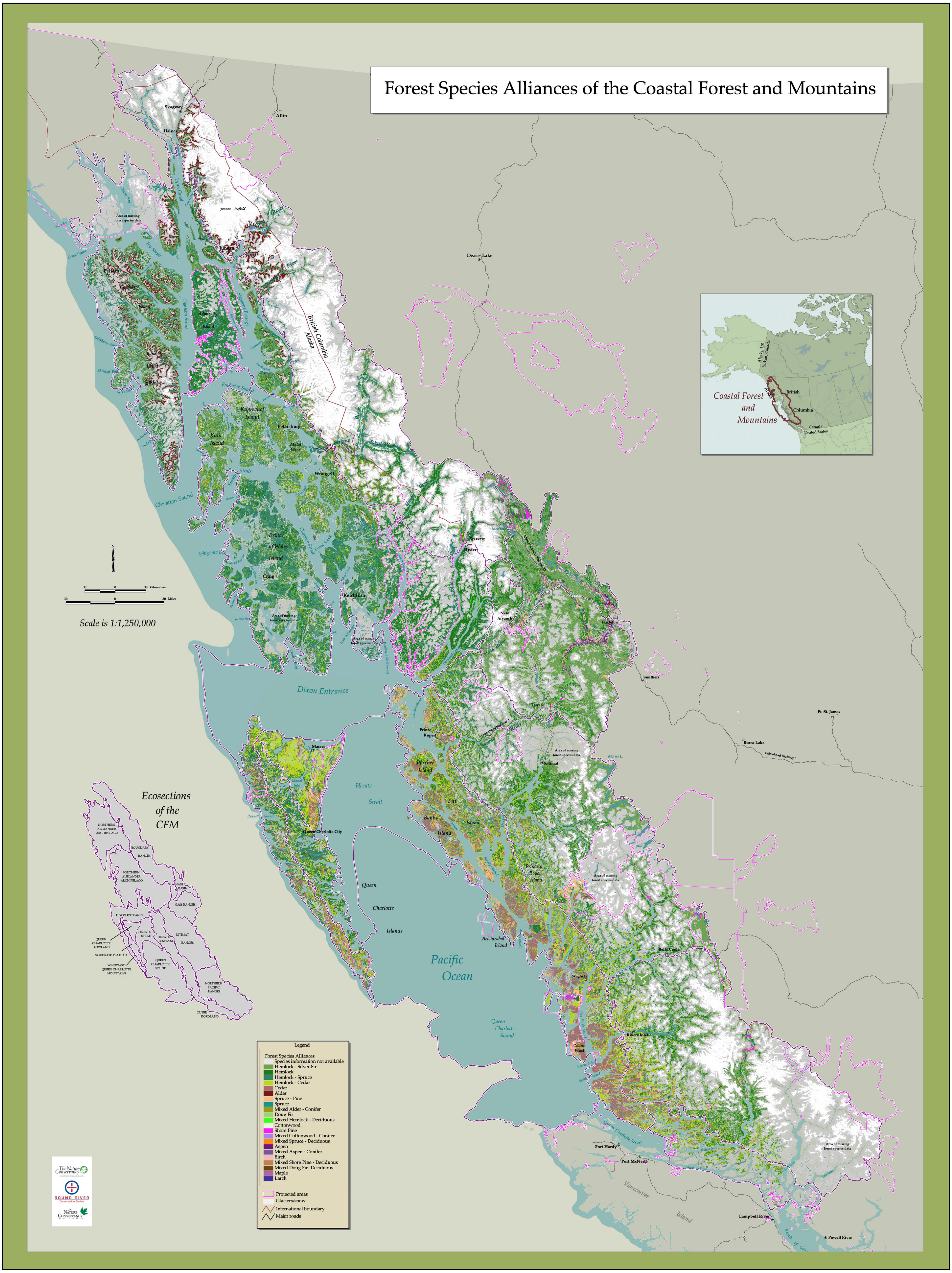
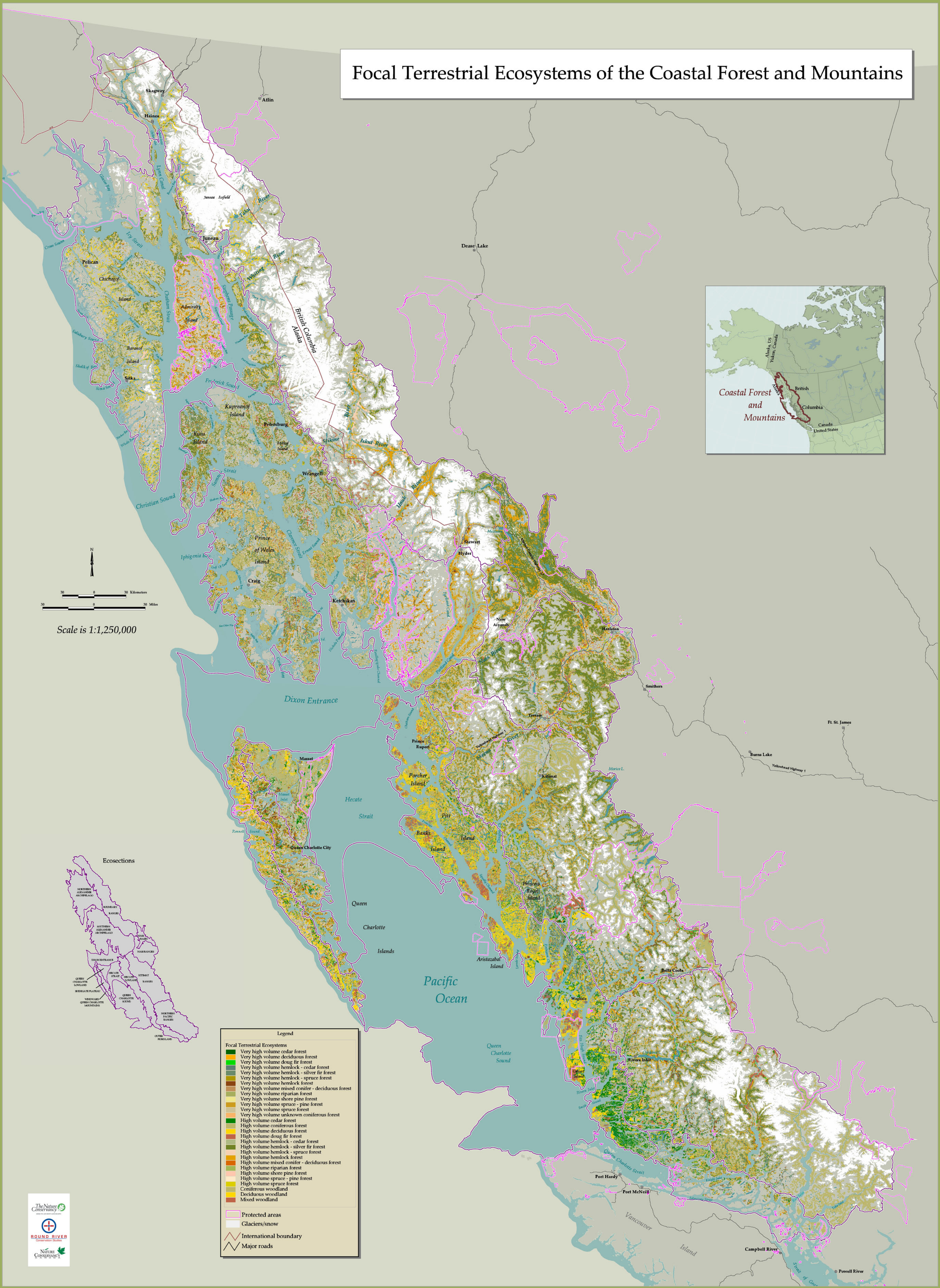
Forest Species Alliances of the Coastal Forest and Mountains



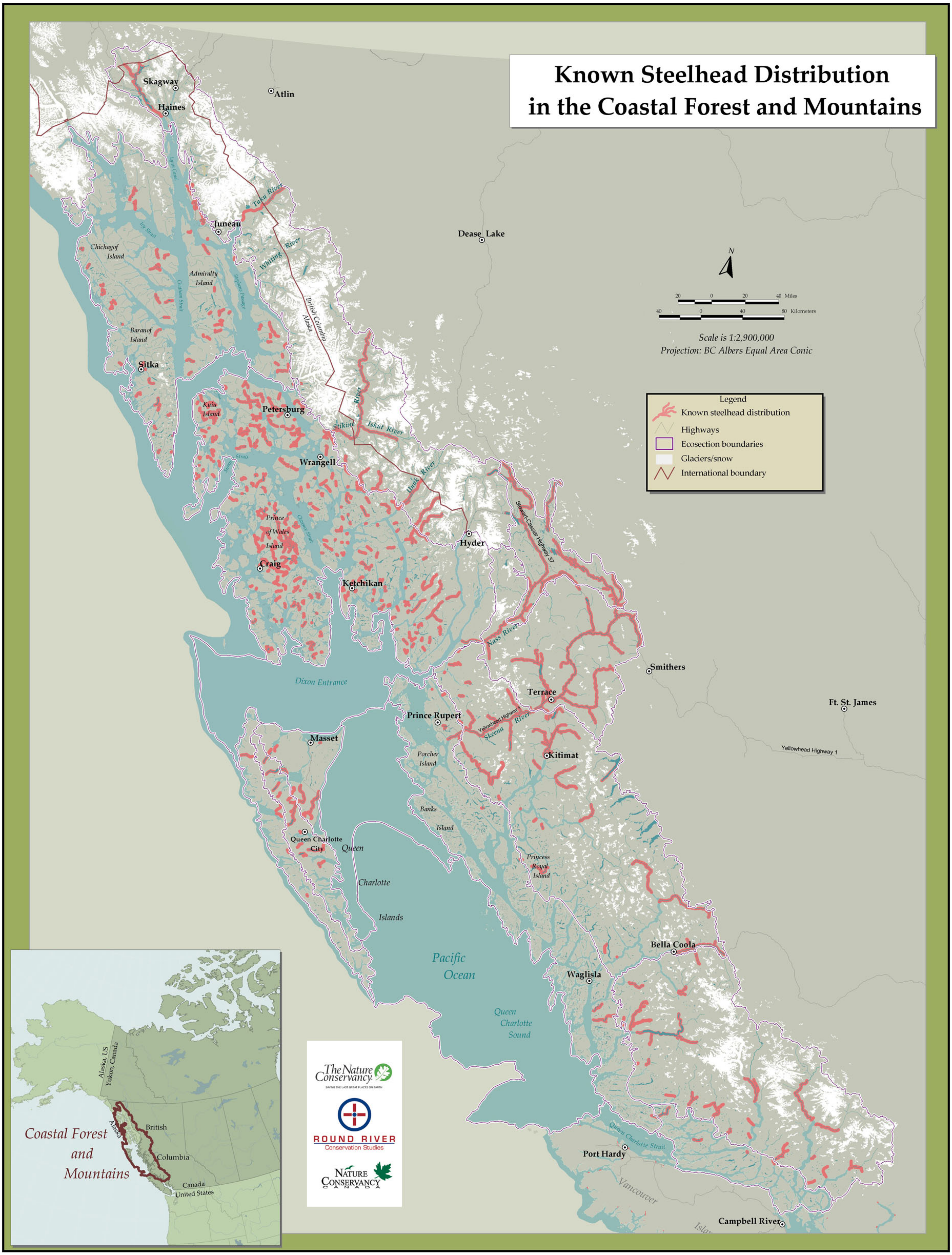
Focal Terrestrial Ecosystems of the Coastal Forest and Mountains



Freshwater Systems of the Coastal Forest and Mountains
Coastal Forest and Mountains
British Columbia
Alaska
Canada
United States
Skagway
Haines
Atlin
Juneau
Pelican
Chichagof Island
Admiralty Island
Baranof Island
Sitka
Kupreanof Island
Petersburg
Kuiu Island
Mitkof Island
Wrangell
Christian Sound
Prince of Wales Island
Craig
Ketchikan
Dease Lake
Stewart
Hyder
New Aiyansh
Hazelton
Smithers
Terrace
Prince Rupert
Kitimat
Ft. St. James
Burns Lake
Masset
Queen Charlotte City
Porcher Island
Pitt Island
Banks Island
Princess Royal Island
Aristazabal Island
Bella Coola
Waglisla
Rivers Inlet
Port Hardy
Port McNeill
Campbell River
Powell River
Vancouver Island
Dixon Entrance
Hecate Strait
Queen Charlotte Islands
Pacific Ocean
Queen Charlotte Sound
Nass River
Skeena River
Iskut River
Stikine River
Taku River
Whiting River
Lynn Canal
Icy Strait
Chatham Strait
Frederick Sound
Clarence Strait
Iphigenia Bay
Queen Charlotte Strait
Scale is 1:1,250,000
Miles
Kilometers
Ecosections of the CFM
NORTHERN ALEXANDER ARCHIPELAGO
BOUNDARY RANGES
SOUTHERN ALEXANDER ARCHIPELAGO
NASS BASIN
NASS RANGES
DIXON ENTRANCE
HECATE STRAIT
HECATE LOWLAND
KITIMAT RANGES
QUEEN CHARLOTTE LOWLAND
SKIDEGATE PLATEAU
WINDWARD QUEEN CHARLOTTE MOUNTAINS
QUEEN CHARLOTTE SOUND
NORTHERN PACIFIC RANGES
OUTER FIORDLAND
Legend
Freshwater systems
The freshwater systems displayed on this map represent 436 unique combinations of drainage system size class, predominant biogeoclimatic zone, predominant underlying geology, predominant stream gradient, glacial connectivity and lake/wetland feature information
Third order watershed boundaries
Protected areas
Glaciers/snow
International boundary
Major roads

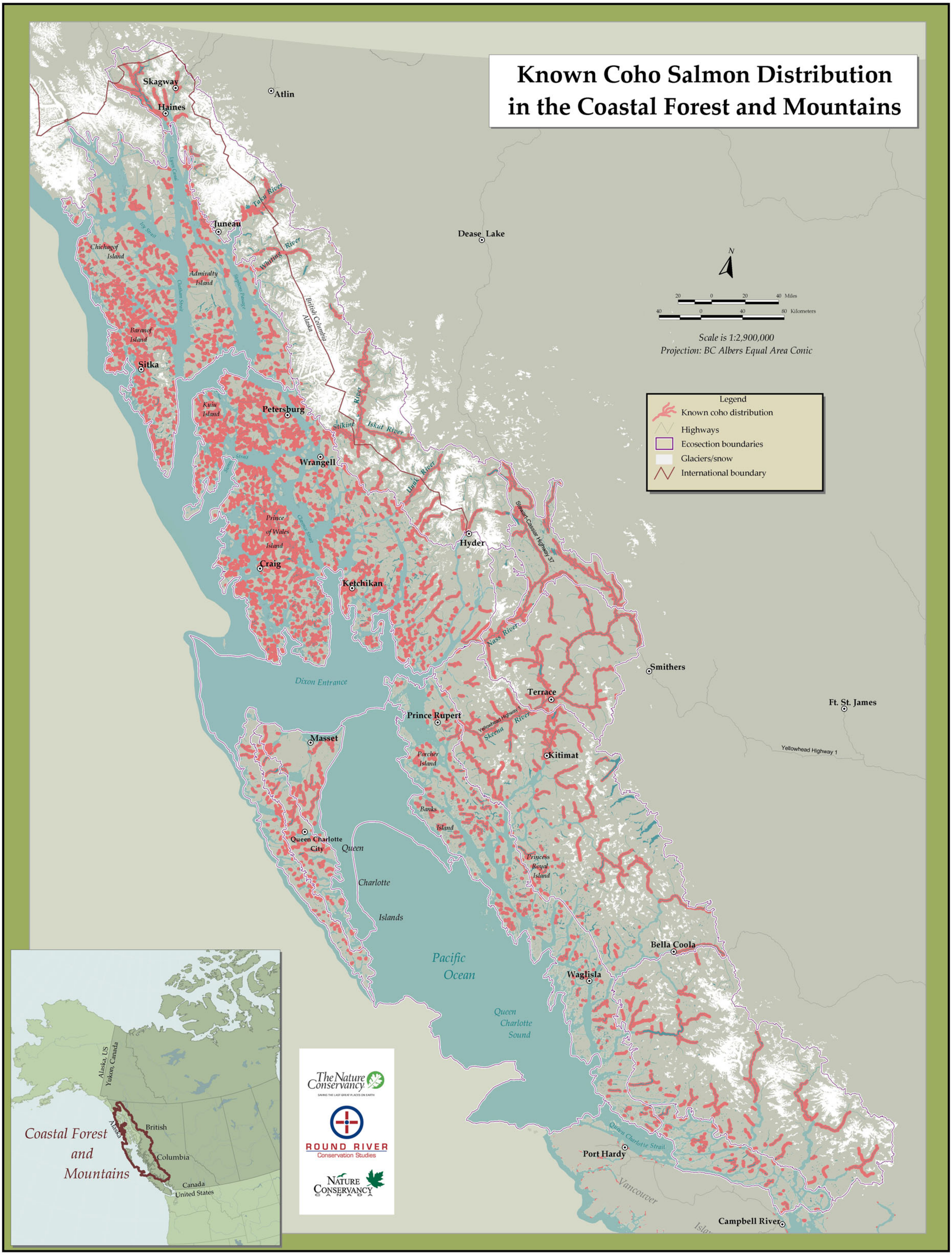
Wetlands and Modeled Riparian Areas of the Coastal Forest and Mountains

Known Steelhead Distribution in the Coastal Forest and Mountains



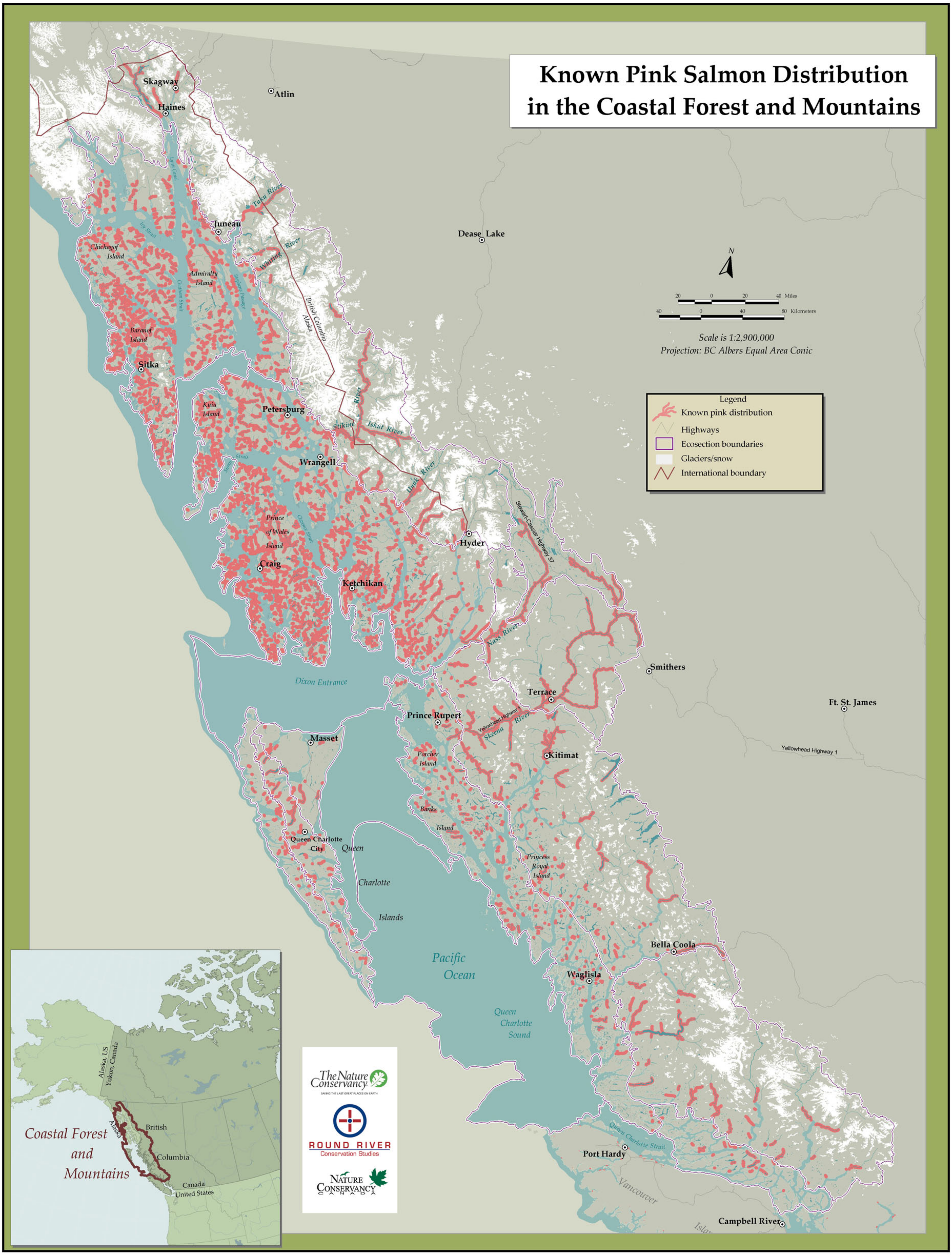
Known Chinook Salmon Distribution in the Coastal Forest and Mountains

Known Coho Salmon Distribution in the Coastal Forest and Mountains




Known Sockeye Salmon Distribution in the Coastal Forest and Mountains
N
20 0 20 40 Miles
40 0 40 80 Kilometers
Scale is 1:2,900,000
Projection: BC Albers Equal Area Conic
Legend
Known sockeye distribution
Highways
Ecosection boundaries
Glaciers/snow
International boundary
Skagway
Haines
Atlin
Juneau
Taku River
Whiting River
Dease Lake
Chichagof Island
Admiralty Island
Icy Strait
Chatham Strait
Stephens Passage
Lynn Canal
British Columbia
Alaska
Baranof Island
Sitka
Kuiu Island
Petersburg
Stikine River
Iskut River
Wrangell
Unuk River
Prince of Wales Island
Clarence Strait
Hyder
Craig
Ketchikan
Stewart-Cassiar Highway 37
Nass River
Smithers
Dixon Entrance
Terrace
Ft. St. James
Prince Rupert
Yellowhead Highway 1
Skeena River
Masset
Kitimat
Porcher Island
Banks Island
Queen Charlotte City
Queen Charlotte Islands
Princess Royal Island
Bella Coola
Pacific Ocean
Waglisla
Queen Charlotte Sound
Queen Charlotte Strait
Port Hardy
Vancouver Island
Campbell River
Alaska, US
Yukon, Canada
Coastal Forest and Mountains
British Columbia
Canada
United States
The Nature Conservancy
SAVING THE LAST GREAT PLACES ON EARTH
ROUND RIVER
Conservation Studies
NATURE CONSERVANCY CANADA

Known Chum Salmon Distribution
in the Coastal Forest and Mountains
Skagway
Haines
Atlin
Taku River
Juneau
Dease Lake
Chichagof Island
Admiralty Island
Whiting River
British Columbia
Alaska
Baranof Island
Sitka
Kuiu Island
Petersburg
Stikine River
Iskut River
Wrangell
Unuk River
Prince of Wales Island
Hyder
Stewart-Cassiar Highway 37
Craig
Ketchikan
Nass River
Dixon Entrance
Smithers
Terrace
Ft. St. James
Prince Rupert
Yellowhead Highway 1
Skeena River
Masset
Porcher Island
Kitimat
Banks Island
Queen Charlotte City
Queen
Charlotte
Islands
Princess Royal Island
Pacific Ocean
Bella Coola
Waglisla
Queen Charlotte Sound
Queen Charlotte Strait
Port Hardy
Vancouver
Campbell River
N
20 0 20 40 Miles
40 0 40 80 Kilometers
Scale is 1:2,900,000
Projection: BC Albers Equal Area Conic
Legend
Known chum distribution
Highways
Ecosection boundaries
Glaciers/snow
International boundary
Alaska, US
Yukon, Canada
Alaska
British
Columbia
Canada
United States
Coastal Forest and Mountains
The Nature Conservancy
SAVING THE LAST GREAT PLACES ON EARTH
ROUND RIVER
Conservation Studies
Nature Conservancy Canada


Known Pink Salmon Distribution in the Coastal Forest and Mountains
Skagway
Haines
Atlin
Taku River
Juneau
Dease Lake
Chichagof Island
Admiralty Island
Whiting River
British Columbia
Alaska
Baranof Island
Sitka
Kuiu Island
Petersburg
Stikine River
Iskut River
Wrangell
Unuk River
Prince of Wales Island
Craig
Ketchikan
Hyder
Stewart-Cassiar Highway 37
Nass River
Dixon Entrance
Smithers
Terrace
Prince Rupert
Yellowhead Highway 1
Skeena River
Masset
Porcher Island
Kitimat
Ft. St. James
Yellowhead Highway 1
Banks Island
Queen Charlotte City
Queen Charlotte Islands
Princess Royal Island
Pacific Ocean
Bella Coola
Waglisla
Queen Charlotte Sound
Queen Charlotte Strait
Port Hardy
Vancouver Island
Campbell River
N
20 0 20 40 Miles
40 0 40 80 Kilometers
Scale is 1:2,900,000
Projection: BC Albers Equal Area Conic
Legend
Known pink distribution
Highways
Ecosection boundaries
Glaciers/snow
International boundary
Alaska, US
Yukon, Canada
Alaska
British Columbia
Canada
United States
Coastal Forest and Mountains
The Nature Conservancy
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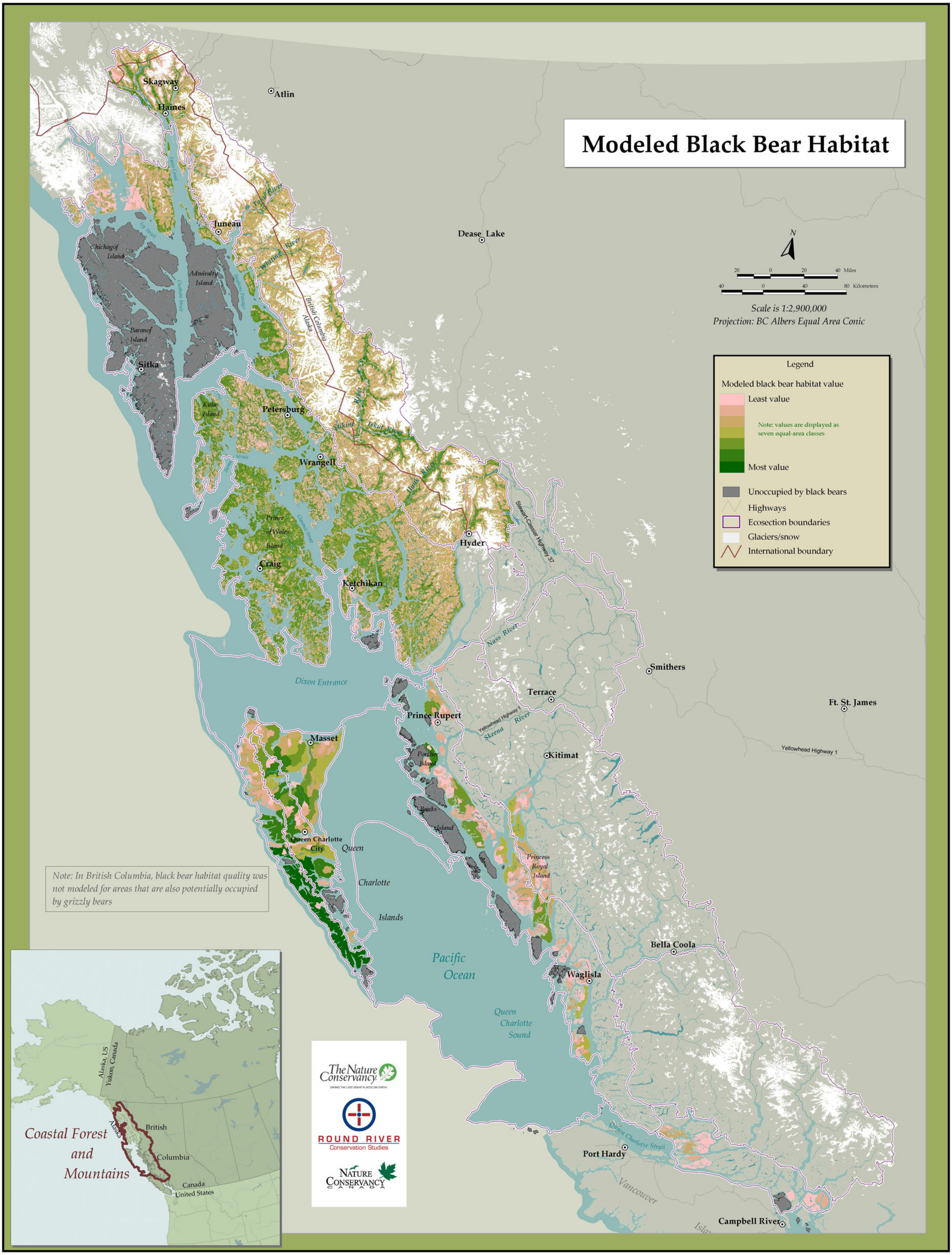
ROUND RIVER
Conservation Studies
Nature Conservancy Canada

Modeled Grizzly Bear Habitat
Scale is 1:2,900,000
Projection: BC Albers Equal Area Conic
20 0 20 40 Miles
40 0 40 80 Kilometers
N
Legend
Modeled grizzly bear habitat value
Least value
Note: values are displayed as seven equal-area classes
Most value
Unoccupied by grizzly bears
Highways
Ecosection boundaries
Glaciers/snow
International boundary
Note: Grizzly bear habitat models were restricted to areas within the known grizzly bear range
Skagway
Haines
Atlin
Juneau
Dease Lake
Chichagof Island
Admiralty Island
Baranof Island
Sitka
Kuiu Island
Petersburg
Wrangell
Prince of Wales Island
Craig
Ketchikan
Hyder
Smithers
Terrace
Ft. St. James
Prince Rupert
Masset
Kitimat
Yellowhead Highway 1
Dixon Entrance
Porcher Island
Banks Island
Princess Royal Island
Queen Charlotte City
Queen Charlotte Islands
Pacific Ocean
Bella Coola
Waglisla
Queen Charlotte Sound
Queen Charlotte Strait
Port Hardy
Vancouver
Campbell River
Coastal Forest and Mountains
Alaska, US
Yukon, Canada
Alaska
British Columbia
Canada
United States
The Nature Conservancy
ROUND RIVER
Conservation Studies
Nature Conservancy Canada

Modeled Black Bear Habitat



Modeled Black-Tailed Deer Habitat
Scale is 1:2,900,000
Projection: BC Albers Equal Area Conic
20 0 20 40 Miles
40 0 40 80 Kilometers
Legend
Deer habitat models
Alaska
Least value
Most value
In Alaska, models result in a range of habitat values
British Columbia
Modeled deer habitat
In BC, models predict where deer habitat occurs
Highways
Ecosection boundaries
Glaciers/snow
International boundary
Note: Deer habitat was not modeled for the Queen Charlotte Islands
Skagway
Haines
Atlin
Juneau
Dease Lake
Taku River
Whiting River
British Columbia
Alaska
Chichagof Island
Admiralty Island
Baranof Island
Sitka
Kuiu Island
Petersburg
Wrangell
Stikine River
Iskut River
Unuk River
Prince of Wales Island
Craig
Ketchikan
Hyder
Stewart-Cassiar Highway 37
Nass River
Dixon Entrance
Smithers
Terrace
Ft. St. James
Prince Rupert
Yellowhead Highway 1
Skeena River
Masset
Kitimat
Porcher Island
Banks Island
Queen Charlotte City
Queen Charlotte Islands
Princess Royal Island
Bella Coola
Pacific Ocean
Waglisla
Queen Charlotte Sound
Queen Charlotte Strait
Port Hardy
Campbell River
Alaska, US
Yukon, Canada
Coastal Forest and Mountains
Alaska
British Columbia
Canada
United States
The Nature Conservancy
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ROUND RIVER
Conservation Studies
Nature Conservancy Canada

Modeled Mountain Goat Habitat
Scale is 1:2,900,000
Projection: BC Albers Equal Area Conic
20 0 20 40 Miles
40 0 40 80 Kilometers
Legend
Goat habitat models
Alaska
Least value
Most value
In Alaska, models result in a range of habitat values
British Columbia
Modeled goat winter habitat
In BC, models predict where goat winter range occurs
Highways
Ecosection boundaries
Glaciers/snow
International boundary
Note: In British Columbia, goat habitat was modeled only for the Central and North Coast LRMP areas
Skagway
Haines
Atlin
Juneau
Dease Lake
Chichagof Island
Admiralty Island
Baranof Island
Sitka
Kuiu Island
Petersburg
Wrangell
Prince of Wales Island
Craig
Ketchikan
Hyder
Stewart-Cassiar Highway 37
Nass River
Dixon Entrance
Smithers
Terrace
Ft. St. James
Prince Rupert
Yellowhead Highway 1
Skeena River
Yellowhead Highway 1
Masset
Kitimat
Porcher Island
Banks Island
Queen Charlotte City
Queen Charlotte Islands
Princess Royal Island
Bella Coola
Pacific Ocean
Waglisla
Queen Charlotte Sound
Queen Charlotte Strait
Port Hardy
Campbell River
Alaska
British Columbia
Coastal Forest and Mountains
Alaska, US
Yukon, Canada
British Columbia
Canada
United States
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Modeled Marbled Murrelet Habitat


Modeled Tailed Frog Habitat
Scale is 1:2,100,000
Projection: BC Albers Equal Area Conic
10 0 10 20 Miles
30 0 30 60 Kilometers
N
Legend
Tailed frog habitat
Model predicts where tailed frog habitat occurs
Highways
Ecosection boundaries
Glaciers/snow
International boundary
Note: Tailed frog habitat was modeled only for the Central and North Coast LRMP areas
Wrangell
Sumner Strait
Unuk River
Prince of Wales Island
Clarence Strait
Craig
Ketchikan
Hyder
Stewart-Cassiar Highway 37
Nass River
Dixon Entrance
Smithers
Terrace
Ft. St. Jam
Prince Rupert
Yellowhead Highway 1
Skeena River
Masset
Porcher Island
Kitimat
Banks Island
Queen Charlotte City
Queen Charlotte Islands
Princess Royal Island
Bella Coola
Waglisla
Pacific Ocean
Queen Charlotte Sound
Queen Charlotte Strait
Port Hardy
Vancouver Island
Campbell River
Strait of Georgia
Coastal Forest and Mountains
Alaska, US
Yukon, Canada
Alaska
British Columbia
Canada
United States
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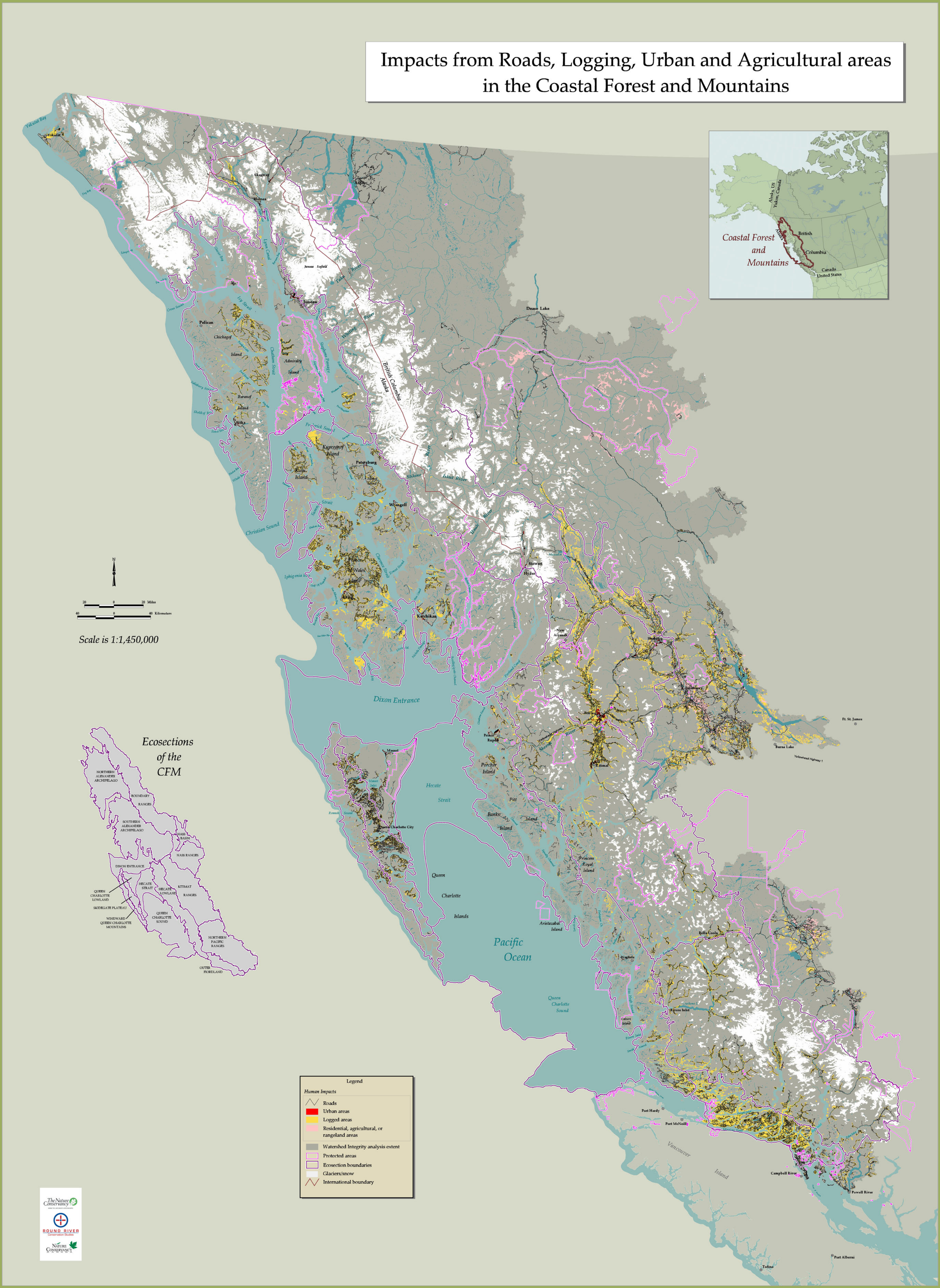
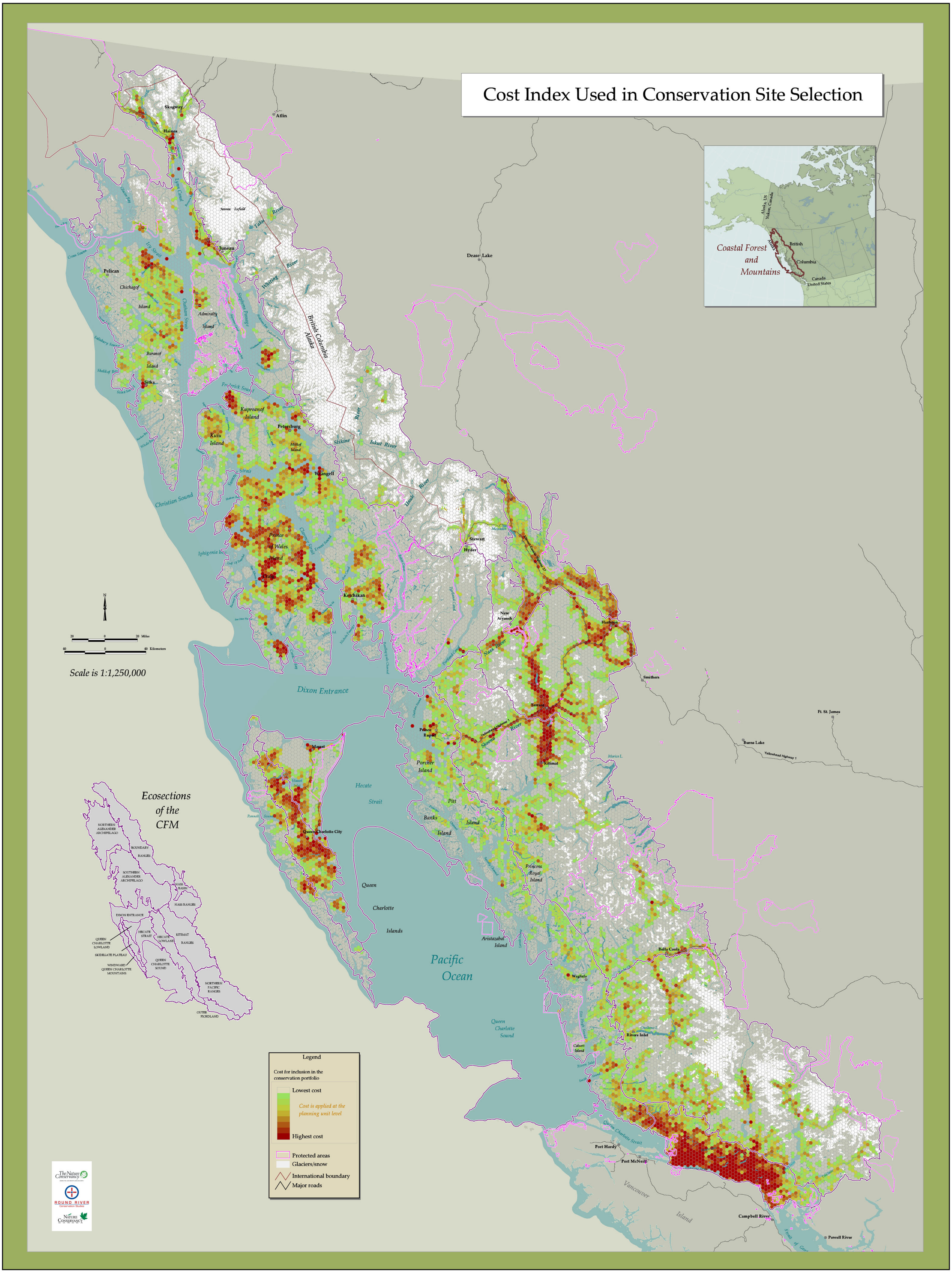
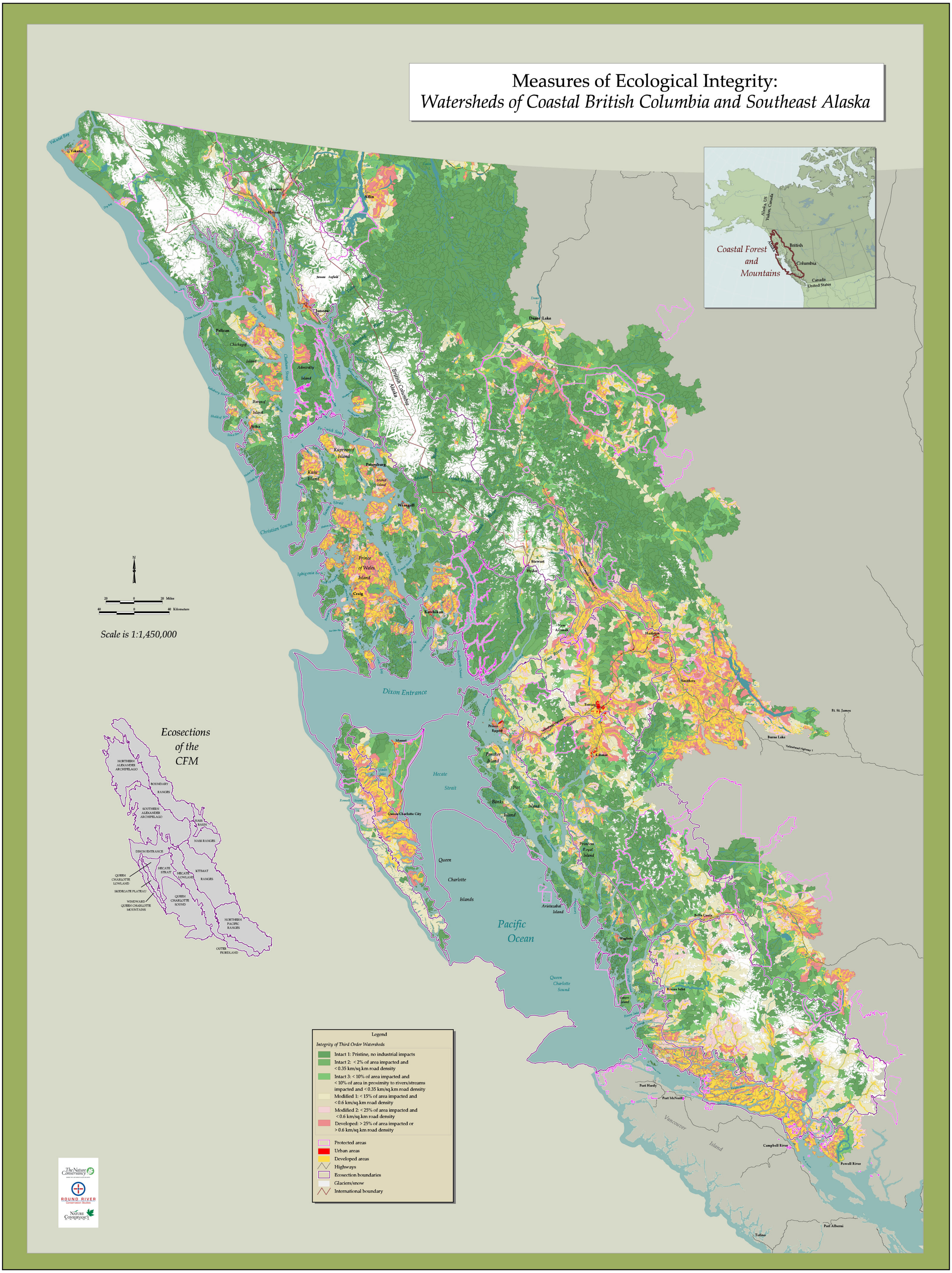
Impacts from Roads, Logging, Urban and Agricultural areas in the Coastal Forest and Mountains



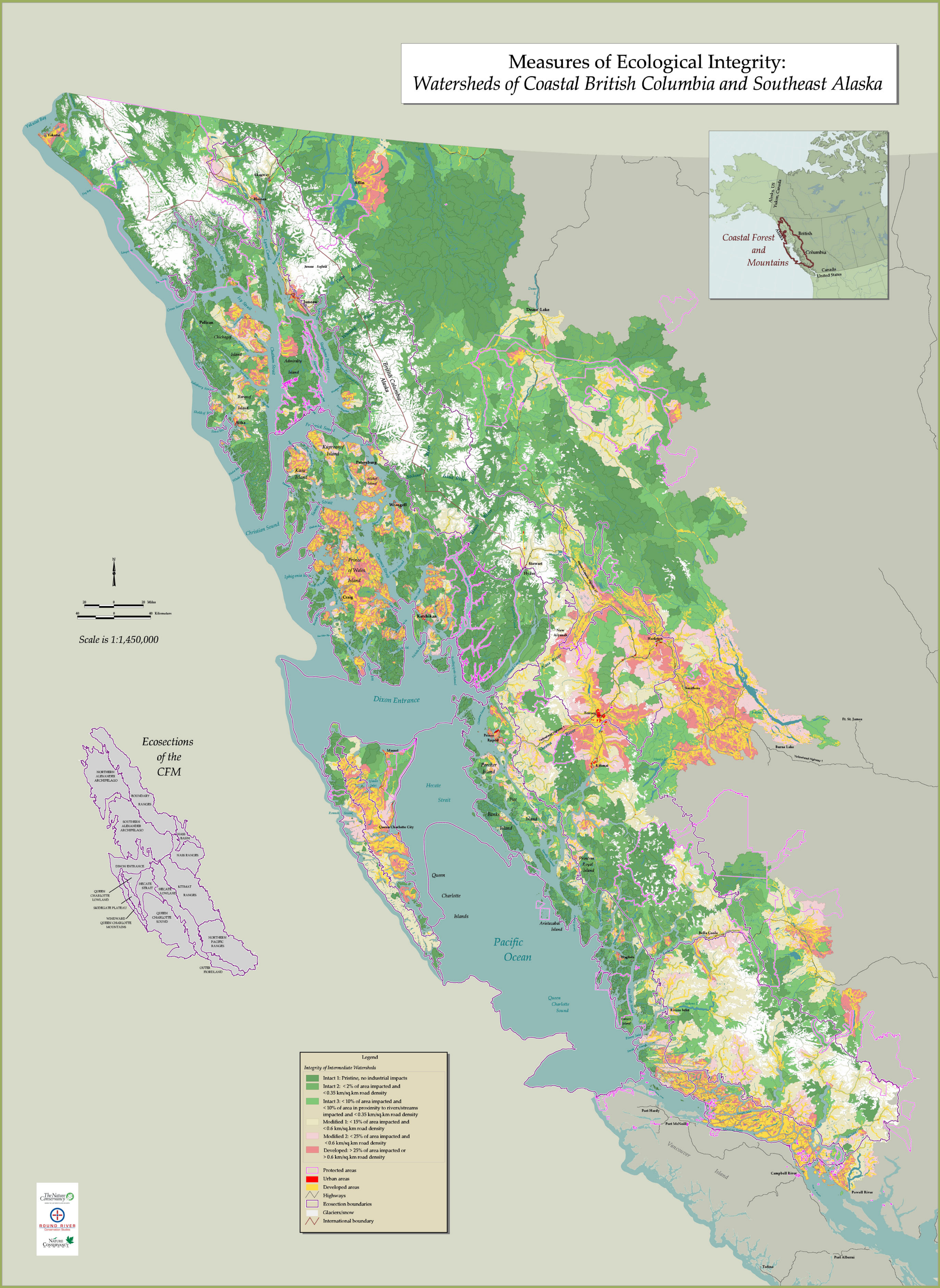
Cost Index Used in Conservation Site Selection



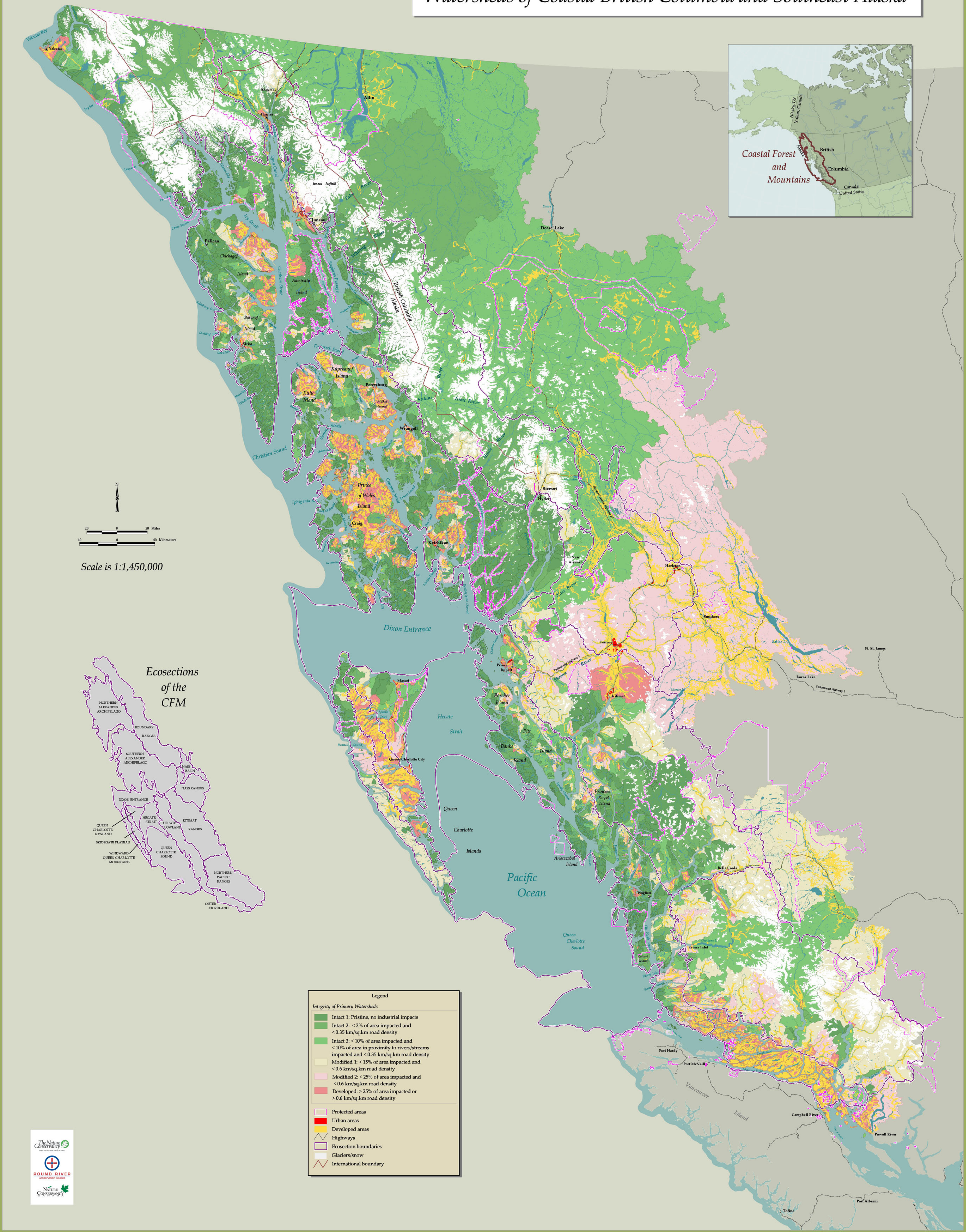
Measures of Ecological Integrity:
Watersheds of Coastal British Columbia and Southeast Alaska



Measures of Ecological Integrity:
Watersheds of Coastal British Columbia and Southeast Alaska



Measures of Ecological Integrity:
Watersheds of Coastal British Columbia and Southeast Alaska



Conservation Value by Planning Unit
Coastal Forest and Mountains
British Columbia
Alaska, US
Yukon, Canada
Canada
United States
Ecosections of the CFM
NORTHERN ALEXANDER ARCHIPELAGO
BOUNDARY RANGES
SOUTHERN ALEXANDER ARCHIPELAGO
NASS BASIN
NASS RANGES
DIXON ENTRANCE
HECATE STRAIT
HECATE LOWLAND
KITIMAT RANGES
QUEEN CHARLOTTE LOWLAND
SKIDEGATE PLATEAU
WINDWARD QUEEN CHARLOTTE MOUNTAINS
QUEEN CHARLOTTE SOUND
NORTHERN PACIFIC RANGES
OUTER FIORDLAND
Scale is 1:1,250,000
Miles
Kilometers
Legend
Number of times a planning unit was chosen as a member of the solution set over all model runs
Planning unit selected fewer times
Planning unit selected more times
1,000 hectare planning units used in Marxan analysis
Protected areas
Glaciers/snow
International boundary
Major roads
Skagway
Haines
Atlin
Juneau
Pelican
Chichagof Island
Admiralty Island
Baranof Island
Sitka
Kupreanof Island
Petersburg
Kuiu Island
Mitkof Island
Wrangell
Prince of Wales Island
Craig
Ketchikan
Chatham Strait
Frederick Sound
Christian Sound
Icy Strait
Dease Lake
British Columbia
Alaska
Stewart
Hyder
New Aiyansh
Hazelton
Smithers
Terrace
Ft. St. James
Burns Lake
Yellowhead Highway 1
Prince Rupert
Porcher Island
Kitimat
Dixon Entrance
Masset
Hecate Strait
Queen Charlotte City
Pitt Island
Banks Island
Princess Royal Island
Queen Charlotte Islands
Aristazabal Island
Pacific Ocean
Bella Coola
Wagfele
Queen Charlotte Sound
Rivers Inlet
Port Hardy
Port McNeill
Queen Charlotte Strait
Vancouver Island
Campbell River
Powell River
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A Conservation Area Design for the Coastal Forest and Mountains

Intermediate Watershed integrity	High	Medium	Low
Intact	Tier 1	Tier 1	Tier 2
Modified	Tier 1	Tier 2	Tier 3
Developed	Tier 2	Tier 3	Tier 3

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