Coast Information Team

AN ECOSYSTEM SPATIAL ANALYSIS FOR HAIDA GWAII, CENTRAL COAST AND NORTH COAST BRITISH COLUMBIA

DRAFT

Chuck Rumsey, Jeff Ardron, Kristine Ciruna, Tim Curtis, Frank Doyle, Zach Ferdana, Tony Hamilton, Kim Heinemeyer, Pierre Iachetti, Richard Jeo, Gary Kaiser, Debbie Narver, Reed Noss, Dennis Sizemore, Art Tautz, Rick Tingey, Ken Vance-Borland

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CIT ESA Planning Team

The planning team brought together a diverse group of researchers from non-governmental and government agencies and the consulting field to work on the Ecosystem Spatial Analysis (ESA). The team and its advisors represent an unprecedented collective of some of the premier researchers and practitioners in the fields of conservation biology, ecology, zoology, Geographical Information Systems (GIS), and land use planning in North America. The depth and breadth of the experiences on the planning team and its advisors ensures that the ESA and its products represent the forefront of conservation biology theory and planning at the large landscape scale.

The planning team was mentored by Dr. Reed Noss (Conservation Science Inc.) who provided guidance on project design, focal species modeling, and contributed much to the final written report. The project was managed by Charles Rumsey (Nature Conservancy of Canada) who also coordinated analysis, interpreted results, and designed mapping products. Rick Tingey (Round River Conservation Studies) and Ken Vance-Borland (Conservation Science Inc.) were the primary GIS analysts responsible for compiling datasets from all of the technical teams, and inputting and running the SITES model. Dr. Richard Jeo (Round River Conservation Studies) working with Rick, 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. Dr. Kristine Ciruna (Nature Conservancy of Canada) 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.

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CIT Management Team & Secretariat

Thank you to the CIT Management Team for their ongoing support of the ESA. The Management Team is co-chaired by Ken Baker (ADM BC MSRM) representing the provincial government and Art Sterritt (Gitga'at First Nation) representing First Nations. Also on the management team are Graem Wells representing local communities and governments, Dr. Jody Holmes (Rainforest Solutions Project) representing Environmental Non-Government Organizations (ENGOs), Rick Jeffrey (Truck Loggers Association) representing the forest industry, Dallas Smith (Central Coast LRMP and Tlowitsis First Nation) representing First Nations, and Gary Reay (BC MSRM) representing the provincial government.

Thank you as well to the CIT Secretariat who provided day-to-day support and guidance with the ESA process. The Secretariat is led by Executive Director Robert Prescott-Allen (PDATA). Melissa Hadley (Cortex Consultants) is the Program Manager, Jordan Tanz (Cortex Consultants) is the alternate Program Manager, Edward Gin (Cortex Consultants) and Sheila O'Shea (Cortex Consultants) provided accounting and logistical support to the Secretariat.

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EXECUTIVE SUMMARY

Background

This report presents a comprehensive ecosystem spatial analysis for the Haida Gwaii, Central Coast, and North Coast regions of British Columbia. This region has a land area of 11 million hectares; its sea area is another 11 million hectares. Over 95% or the land area is designated crown land and is managed by the Government of British Columbia. In addition to productive, structurally-diverse old-growth ecosystems and unique bog complexes, important ecological elements in the region include unregulated rivers supporting large populations of spawning salmon and grizzly bears, estuaries, kelp beds, seabird colonies, archipelago/fjord terrain, deep fjord and cryptodepression lakes, and intertidal flats with abundant invertebrates and resident and migratory waterbirds. Haida Gwaii is an especially significant part of the region, containing an insular biota with distinctive, disjunct, and endemic taxa. The diversity of species within the CIT region is far greater than previously thought, but still incompletely known.

Two major land-use and resource-management planning processes (LRMPs) are underway in the region: the Central Coast LRMP and the North Coast LRMP. The Haida Gwaii/Queen Charlotte Islands Plan is in development (Map 1). Their purpose is to enable all parties to reach agreement on those lands and resources to be protected and those to be developed, where, and how. The Coast Information Team (CIT) was established by the Provincial Government of British Columbia, First Nations, environmental groups, and forest products companies to provide independent information on the region using the best available scientific, technical, traditional, and local knowledge. The CIT's information and analyses, which include this ecosystem spatial analysis, are intended to assist First Nations and the three ongoing subregional planning processes to make decisions that will achieve ecosystem-based management.

This study is unique in that it integrates analysis of the biological values of terrestrial, freshwater, and marine ecosystems across this vast region. The purpose of the ecosystem spatial analysis is to identify priority areas for biodiversity conservation and, 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 ESA integrates 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-suitability models are available or can be constructed.

Information obtained from this approach can be used with a computerized site-selection algorithm to create a conservation solution or "portfolio" of landscapes and seascapes, which when taken together and managed appropriately, would ensure the long-term survival of the region's biodiversity. Our team used the best available information for this assessment but recognizes that new and more comprehensive data will continually become available. Therefore, the ESA should be regarded as an initial step in an iterative assessment process.

Regional Classification

One advantage of a regional approach to planning is that it 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. The Ecoregion Classification system in common use in Canada stratifies British Columbia's terrestrial and marine ecosystem complexity into discrete geographical units at five levels: Ecodomains, Ecodivisions, Ecoprovinces, Ecoregions, and Ecosections. The lower levels in this classification describe areas of similar climate, physiography, oceanography, hydrology, vegetation, and wildlife potential.

The CIT Study area falls within the Coast and Mountains Ecoprovince of BC. This Ecoprovince extends from coastal Alaska to coastal Oregon. In British Columbia it includes the windward side of the Coast Mountains and Vancouver Island, all of the Queen Charlotte Islands, and the Continental Shelf including Dixon Entrance, Hecate Strait, Queen Charlotte Strait, and the Vancouver Island Shelf. The Coast and Mountains Ecoprovince consists of the large coastal mountains, a broad coastal trough and the associated lowlands, islands and continental shelf, as well as the insular mountains on Vancouver Island and the Queen Charlotte Islands archipelago. The study area overlaps with a total of five terrestrial based ecoregions encompassing 10 ecosections (Map 2). A sixth ecoregion is dominated by the open water marine environment and can be further divided into four marine ecosections .

In addition to using terrestrial-based classifications for stratifying the study area, we delineated broad Ecological Drainage Units (EDUs) as part of a freshwater ecosystem classification framework (Map 3). EDUs are groups of watersheds that share a common zoogeographic history and physiographic and climatic characteristics. EDUs contain sets of freshwater ecosystem types with similar patterns of drainage density, gradient, hydrologic characteristics, and connectivity. Identifying and describing EDUs allows us to stratify the study area into smaller units so we can better evaluate patterns of freshwater community diversity. Additionally, EDUs provide a means to stratify the study area to set conservation goals.

Terrestrial Targets

Terrestrial Special Elements

Special element targets were initially selected based on conservation status at various scales. The initial list of targets was then reviewed by experts and pared down on the basis of this review. Element occurrence data were collected from all known sources, with most from the BC Conservation Data Centre, which collects and maintains data on rare and endangered species and other features in the province. Data were screened based on their quality and reliability. Extinct, extirpated, and historic species occurrences were removed, as were animal occurrences older than 25 years and plant occurrences older than 40 years. The special elements database consists of 110 targets (75 vascular plants, 9 birds, 5 mammals, and 21 rare plant communities). Spatial data was obtained for 72 targets (Map 4).

The special-element dataset is small, with relatively few actual point and polygon locations. The majority of element occurrence data is on Haida Gwaii/QCI, reflecting an uneven distribution of surveying effort. Although there are concerns regarding biased survey data – i.e., surveys close to roads - special elements need to be protected where they are known to occur. To that end, instead of using these data as an input to the site selection algorithm, a post hoc analysis was conducted that simply overlaid the existing known occurrences of these elements onto the results emerging from the analysis.

Terrestrial Ecosystem Representation

Two complementary regional ecosystem classification systems exist in BC: 1) The ecoregion/ecosection classification, which describes broad regional ecosystems based on the interaction of climate and physiography. 2) The Biogeoclimatic Ecosystem Classification (BEC), which delineates ecological zones (biogeoclimatic units) by vegetation, soils, and climate. We used both systems and applied two independent classification methods to assess the representation of ecosystems in the study region.

The BEC delineates ecological zones (biogeoclimatic units) by vegetation, soils, and climate. We combined BEC information with site productivity (taken from site index in the BC forest cover data), to delineate terrestrial ecosystems, with the assumption that site productivity correlates with areas that have climax, or old growth, ecosystem characteristics (maps 5, 5a, 5b). We assumed that impacted areas of the same BEC and site index as intact areas will have similar old growth characteristics; we also assumed a relatively low level of natural disturbance. This method also allows us to preferentially identify and represent intact areas, and then represent comparable impacted areas for potential modified, only if necessary in order to meet ecosystem representation goals.

Site index was grouped into three classes (Low = 1 –14, Medium = 15 – 21 and High > 22). BEC zones were taken from the BC biogeoclimatic classification coverage. We treated separate variants and subzones as separate units because in some areas, variants were not defined. Logging data were taken from several sources; when there was a discrepancy, we considered areas logged and set age class = 1. Historical abundance of each ecosystem type was calculated as the sum of area for all seral stages.

Goals for the site-selection algorithm were set varying from 30% to 70% representation in 10% increments based on historical abundance of ecosystem type. However, for some ecosystem types, the representation goal exceeded the remaining intact forest. Representation targets were selected from areas that had both Site Index and Species information (i.e. with known vegetation information), to eliminate bare rock and ice areas. We applied the following rules for goal-setting: 1) If a representation goal can be met using intact areas (i.e. target <= remaining forest), no goal was set for logged areas; goals for remaining forest were based on historical abundance estimates. 2) If impacts equal or exceed 85%, the remaining old-growth forest and young intact forest goals were set to 100%, and the goal for logged forest was set as the difference between the overall representation target area and the remaining intact forest area using a formula: Logged forest area target (ha) = representation goal /100 * historical area (ha) – (old growth (ha) + intact young forest (ha)). 3) Where impacts were less than 85%, a 95% target was set for intact areas, with remaining representation target set using logged areas as above.

To complement the Site Productivity and BEC method for identifying ecosystems, we combined floristic and structural data to identify focal ecological systems (Map 6). At least twenty-five species of conifers and inhabit the coastal rainforest of BC; we used size class, inventory type group, and age class to define and delineate stands of old-growth and woodland areas based on both floristic and structural characteristics. We grouped inventory type groups to identify ecological systems and, because forest ecosystems differ across the region depending on the physical environment and other factors, we stratified goal setting by ecosection. This method allowed us to represent a full range of ecosystem types without the need to know exactly which ecosystem or community type is present. Focal ecosystems were defined as unique combinations of structure, ecological system, and ecosection. Goals for focal ecosystems were varied from 30% to 70% in 10% increments.

Terrestrial Focal Species

Marbled Murrelet

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. We ran two versions of the model. The first version included the habitats most likely to be preferred by the murrelets. Restrictions on elevation and distance from shore were removed in the second run and the habitat extended further inland. Only the first run with its restricted criteria was used for site selection (Map 7).

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.

Northern Goshawk

The Northern Goshawk is a broad-winged, long-tailed raptor of medium size adapted to forest habitats. It was chosen as a focal species because of its strong association with mature/old growth coniferous forests for foraging and nesting, and the possible impacts to this habitat from forestry activities. Within the CIT study area there are two subspecies of Northern Goshawk.

A goshawk breeding territory has three hierarchical components: nest area, post-fledging area, and foraging area. Habitat-suitability models for the nest area (Map 8) and foraging area (Map 9) components of a goshawk territory were developed for the three LRMP areas in the study region. The models are based on those developed for the North Coast Forest District and combined expert opinion, observed habitat characteristics at goshawk nest areas in the Coastal Western Hemlock biogeoclimatic zone, and relevant literature. Goshawks consistently select key structural attributes and forest species composition for nesting. The foraging area is the entire area used by the adults. Goshawk diets are dominated by prey associated with mature forests, which favours hunting primarily in mature/old growth forest areas with high canopy closure and a clear understory. The output of the model was a grid with habitat suitability ratings.

Sitka Black-Tailed Deer

The Sitka black-tailed deer was chosen as a focal species for the Central Coast and North Coast portions of the study area 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 is based on an "old-growth, deer winter-range" model. We applied a GIS to spatially identify deer winter range in the study area. 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.

The model identifies 688,775 ha of critical black-tailed deer winter range in the study area (517,835 ha in the Central Coast and 170,628 ha in the North Coast). Habitat was distributed evenly throughout the two LRMP areas and as expected, in areas featuring older coastal western hemlock forests including many of the islands. Modifications to the model suggested by reviewers (e.g., the inclusion of aspect, possibly exposure, and the removal of slope steepness) would more accurately reflect critical black-tailed deer winter range in the study area. However, due to time and capacity constraints, the ESA focal species team was not able to modify and rerun the model based on expert review recommendations. As a result, the model was not used as an input to the site-selection algorithm. However, a post hoc analysis comparing the site selection algorithm outputs with output from the deer winter range model shows that the site selection included [x] % of deer winter range identified by the model.

Mountain Goat

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 in 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 CIT study area. These habitats are not equally distributed across the study area, due to the project-specific nature of the data. The CIT-wide potential winter habitat model overlaps 65% of these occupied winter mountain goat habitats, and predicts additional potential winter habitat across the study area (Map 10).

Grizzly bear

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. 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 for the CIT ESA 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 CIT ESA 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 5983 modeled watersheds in occupied grizzly bear range within the study area (Map 11). A parallel coverage of target effectiveness classes was also produced. Comparison of the current effectiveness with the proposed target effectiveness can be instructive: watersheds with high correspondence between current and proposed target effectiveness may be high priorities for protection or “light touch” ecosystem-based management. Watersheds with high discrepancy between current estimates and proposed target estimates may be good candidates for modified, such as through road closures.

Black Bear

Black bears are commonly found in all biogeoclimatic zones in British Columbia. 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 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.

One of the objectives of the black bear model is to propose appropriate population targets for conservation of the species under ecosystem-based management. As for grizzly bear, comparison of the current (effectiveness) estimates and densities with the proposed target estimates and densities can be instructive for protected areas design and for management of the landscape matrix. The highest quality habitats were identified on Haida Gwaii/QCI on the west side of Moresby Island and Graham Island (Map 11).

Freshwater Targets

Freshwater Special Elements

Salmonids aside, there were little spatially explicit special element data available for freshwater species in the study area. Four freshwater fish species were selected for the target list. We were able to obtain spatial data for only the Giant black stickleback, an endemic species that is critically imperiled globally, with only two element occurrence records. Three amphibians were selected for the target list but only one had spatial data (the coastal tailed frog, also a focal species).

Freshwater Representation

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, climatic, 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.

Skeena, Nass, Haida Gwaii and North and Central Coast EDUs collectively consist of 4,476 coarse-scale freshwater ecosystems. These freshwater ecosystems were classified as follows:

- Nass EDU -755 freshwater ecosystems classified into 74 system types;
- Skeena EDU -1333 freshwater ecosystems classified into 182 system types;
- North Coast -1773 freshwater ecosystems classified into 150 system types;

- Central Coast -496 freshwater ecosystems classified into 68 system types; and
- Haida Gwaii -125 freshwater ecosystems classified into 30 system types.

Freshwater Focal Species

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 km^2; 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.

In total, 4, 466 km of suitable Tailed Frog stream habitat was identified within the CIT study area consisting of 5,155 habitat areas (Map 13). 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 occur in BC: 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.

The Department of Fisheries and Oceans (DFO) salmon escapement database was used to assess trends in salmon escapement over time and compare biomass estimates across runs. DFO enumerates salmon escapement (number of salmon returning to their natal streams to spawn) annually. The present database contains escapement estimates for Pacific salmon from the 1950s to the present. Although the database has limitations, it is unequivocally the best survey information available.

Runs with less than ten years of data were removed from the analysis and labeled as having insufficient data. Trends in escapement over time were calculated for each run. A simple classification of runs into either stable or declining escapement trend was performed. Runs with slopes greater than or equal to 0.0 were characterized as having stable escapement trends over time. Runs with slopes less than 0.0 were characterized as having declining escapement trends over time. Biomass estimates for each run were calculated using the median of ten-year running averages for each run.

Steelhead populations are managed using a different management framework from DFO. Population trends were estimated from catch information collected annually from a mail-out survey, from test fisheries in commercial fisheries with a steelhead bycatch, and from swim surveys, weir counts, and creel surveys. Population status was assigned by regional biologists using various combinations of the above methods. Results were expressed as the number of spawners divided by the estimated carrying capacity of the river. Populations were assigned to one of three categories based on how they compared to estimated carrying capacity. Salmon population units (SPUs) were derived for each of the species based on existing FISS point source data, DFO escapement data, and expert knowledge. Escapement trends and biomass estimates were summarized for each SPU (Maps 14 through 21). Biomass estimates were summed for runs within a SPU.

All Pacific salmon species showed a serious decline in escapement over time with 40% of these declines occurring in high biomass runs. Pink (even) was found to be in the best condition and Chum in the worst condition. Steelhead was found to be in stable condition across all EDUs except for Central Coast. Central Coast was in the worst condition with 80% of its salmon SPUs in decline. Haida Gwaii was a close second with 76% of its SPUs in decline. Coho appeared most stable with 53% of its SPUs containing stable runs. All summer and winter steelhead SPUs were stable. Most species SPUs were of low biomass (58%) except for sockeye in which 83% of its SPUs were high biomass runs. Nine-seven percent of summer steelhead SPUs were in decline compared to only 7% of steelhead winter SPUs. The majority of Pink (even and odd year) and Chum SPUs had high biomass runs. The majority (76%) of Pacific salmon SPUs were in decline within the Haida Gwaii EDU. The Central Coast EDU was found to be in the worst condition of all EDUs with 80% of its Pacific salmon SPUs and 48% of its steelhead (summer and winter) SPUs in decline. All salmon species were found to have greater than two-thirds of their SPUs in decline except for even year Pink (53% in decline) and steelhead (33% winter and 12% summer in decline). Chum had the highest proportion of its SPUs in decline (77%) followed by coho, sockeye, chinook, and pink (odd).

These results indicate downward trends in escapement over time for all five species of Pacific salmon throughout the entire CIT study area as well as prominent declines in winter and summer steelhead within the Central Coast. Causes of decline stem from multiple factors including climate change, changes in land use, hatcheries, and over-fishing

Nearshore Marine Targets

Introduction

We focused on the intertidal and nearshore zones in this analysis. We identified 72 conservation targets of which 59 were ecosystem targets (shoreline ecosystems) and 13 were special element targets (occurrences of marine species). This set of targets was selected to represent the full nearshore marine biodiversity of the region and to highlight elements that are threatened or declining (i.e., seabird species), or that serve as good indicators of the health of the larger ecosystem (i.e., intertidal habitats). The waters of the ecoregion were stratified into 8 sections based on British Columbia's marine ecosections (Map 22). Ecosections are characterized as unique physiographic, oceanographic, and biological assemblages that are related to water depth and habitat (pelagic versus benthic). We performed raster-based analyses to develop a human impact score for all shoreline planning units (map 23 and 23a). We also used a stratification scheme based on project regions (Map 24).

Nearshore Marine Special Elements

We included as special elements species that are imperiled or keystone species and are not likely to be protected by ecosystem representation. With this criterion we included eight marine species as targets. These forage fish and seabird targets are represented as two critical life stages, spawning aggregations and breeding colonies.

We had comprehensive coverage for herring and seabird colonies. The latter data set includes the locations of all known seabird colonies along the coast of British Columbia. Fifteen species of seabirds, (including two storm petrels, three cormorants, one gull and nine alcids) and one shorebird (Black Oystercatcher) breed on the coast of British Columbia. We selected those species that are considered imperiled or vulnerable in British Columbia (S1 - S3 status). There were seven species of seabirds selected to represent colonies along the coast of British Columbia: Thick-billed and Common Murre, Cassin's Auklet, Ancient Murrelet, Horned and Tufted Puffin, and Brandt's Cormorant. These data are represented as point locations with attributes describing their location. We used location descriptions to assign the colonies to specific shoreline segments.

Our biggest data gap concerned invertebrates. The Conservation Data Centre (CDC) does collect element occurrence data for some invertebrate species, but the data are not comprehensive throughout the study area. Without a comprehensive, continuous survey effort we were limited by the places where species were found and therefore did not have a sense of abundance across the region.

Nearshore Marine Ecosystem Representation

The ecosystem targets comprise shoreline ecosystem types derived from the shore-zone mapping system. British Columbia's shore-zone mapping system is based on shore types, which are biophysical types that describe the substrate, exposure, and vegetation across the tidal elevation, as well as the anthropogenic features. The B.C. shore-zone mapping system is built on shore types that aggregate precise community or habitat types according to their landform, substrate, and slope. There are 34 coastal classes and 17 representative types within the classification system. Wave energy classes were aggregated to five classes, which when multiplied by the 17 representative types yielded as many as 85 classes. In actuality there are only 63 shoreline categories available after compiling all six project regions of shore-zone. Four categories, three "man-made" types and one "unidentified," are not considered ecosystem targets, bringing the total number of targets down to 59.

The shore-zone mapping system also identified intertidal vegetation and habitats. "Bio-bands" are assemblages of intertidal biota, visible from the air and named for dominant species or species assemblages. With these bio-bands we identified the intertidal range biota in the nearshore, including saltmarsh, eelgrass, surfgrass, and kelp. These vegetation types form the major habitats of the nearshore zone and are the best surrogates at this scale to represent a range of habitats. We also used the "habitat observed" category from shore-zone to capture the most diverse part of the intertidal zone.

Although we included "estuaries" as targets in the analysis, we did not have complete information on all estuaries in B.C. Both the terrestrial ecological systems and the shoreline ecosystem targets identified saltmarsh communities. In both cases the definition of estuaries was associated with a vegetation type. Other estuaries were captured in the shoreline ecosystem categories as "mud flat," "sand flat," and "sand and gravel flat." The shore-zone data do not fully represent the spatial delineation of estuaries as polygons. Many estuaries are left out of the data sets because they were not identified as the dominant feature in the intertidal.

Offshore Marine Targets

Special Elements and Focal Species

The CIT offshore marine ecosystem spatial analysis includes 93 features, both biological and physical. We considered the following focal vegetation species: eelgrass, kelp, marsh grasses, surf grasses, and a general shoreline vegetation class, aggregated from the BC Shorezone classification. All major BC breeding seabird populations and colonies were considered (Map 25): Ancient Murrelet, Black Oystercatcher, Cassin's Auklet, Cormorant species, Glaucous-winged Gull, Pigeon Guillemot, Puffin species, Rhinoceros Auklet, and Storm Petrel species. In addition, very small islets, far from shore were also considered as surrogates for unsurveyed colonies. Seabirds are known to prefer certain marine waters. These we treated as "habitat capability" layers. We considered pelagic seabirds, waterfowl loons, and shorebirds. Moulting seaducks (Scoters and Harlequin Ducks) inhabit certain nearshore BC waters during summer months (Map 26). These areas were also considered separately for each species grouping.

Anadromous streams were captured using a species richness x stream magnitude ranking (Map 27). Eight of BC's nine anadromous spp were considered (eulachon, the ninth, was treated separately). About one out of 10 BC stream systems were considered likely to support significant numbers of anadromous species. Steller Sea Lion haul-outs and rookeries were ranked on a scale of 1-4 based on population density. Herring spawn shorelines were ranked on a density measure based on DFO's Spawn Habitat Index, using the latest available times series data.

We considered five special elements, on account of their rare or threatened status: Hexactinellid sponge reefs, Eulachon estuaries, Sea otter, estuaries containing red or blue listed species, and Marbled Murrelet marine habitat. We also considered areas known to harbour large habitat-forming corals, which may well be threatened or endangered, but due to a lack of surveys their status largely remains unknown.

Offshore Marine Ecosystem Representation

We included two separate indicators of distinctive habitats for ecosystem representation in the offshore marine realm: benthic topographical complexity and high current. For each of these analyses, the study area was stratified into four Ecological Regions—inlets, passages, shelf and slope—based on available substrate and depth information (maps 28 and 29). Areas of high taxonomic richness are often associated with areas of varying habitat. Complex habitats also may exhibit greater ecosystem resilience and resistance to invasive species. Benthic topographical complexity is indicated by how often the slope of the sea bottom changes in a given area. Benthic complexity considers how convoluted the bottom is, not how steep or how rough, though these both play a role. A measure of benthic complexity will often identify physical features such as sills, ledges, and other habitats that are associated as biological "hotspots" providing upwellings, mixing, and refugia. We examined benthic complexity separately within each of the four Ecological Regions (Map 30).

The high current layer was extracted from the BC Marine Ecological Classification, as well as incorporating additional local knowledge. High Current is defined as waters that regularly contain surface currents (tidal flow) greater than 3 knots (5.5 km/hr or 1.5 m/s). These are areas of known mixing and distinctive species assemblages. In addition, high current areas often represent physical "bottlenecks" to water movement and as such are important to larval transfer and nutrient exchange. The constant re-suspension of nutrients in particular is most likely responsible for the rich biota of the south Central Coast passages. Annual primary productivity in tidally mixed areas tends to be above average for coastal waters. High current areas were considered separately for each of the four Ecological Regions (Map 30).

Setting Goals

Explicit and quantitative goals are fundamental to systematic conservation planning. Establishing goals is among the most difficult - and most important - scientific questions in conservation planning (e.g., How much protected area is enough? How many discrete populations and in what spatial distribution are needed for long-term viability?). Goals for conservation targets specify the number and spatial distribution of occurrences. A broad goal is to conserve multiple examples of each target, stratified across the region in such a way that the variability of the target and its environment is captured in the site selection. Replication of occurrences of each target must be sufficient to ensure persistence in the face of environmental stochasticity and the likely effects of climate change. Strategies for focal species emphasize persistence of populations or metapopulations, whereas ecosystem-level conservation (e.g., representation) often invokes operation of ecological processes and maintenance of ecological integrity.

As biodiversity and endemism increase, so does the amount of area needed to represent all elements. Because northern temperate regions have lower biodiversity and fewer narrow endemics than found in the tropics, it is expected that less protected area is necessary to represent each biodiversity element at least once. Importantly, site selection algorithms, by themselves, do not address the more difficult and real-world questions concerning the area needed to maintain viable populations of species (i.e., as opposed to single occurrences) and overall ecological integrity. We did not have the time or funding to gather data and perform detailed, spatially-explicit population modeling for the selected focal species. Therefore, we were unable to evaluate the potential population viability of these species in alternative networks of reserves compared to the current network. Nevertheless, we can use the results of other studies to qualitatively evaluate the ability of alternate designs to sustain populations of focal species over time.

Generally, most studies and experts have concluded that some degree of protection for at least 40-60% of the terrestrial lands and fresh waters would be required to sufficiently protect biodiversity in temperate regions, assuming that the very "best" and representative areas are selected. Because individual protected areas are unlikely to be large enough to meet conservation goals, the entire landscape must be managed to maintain ecological integrity, including disturbance regimes, target species populations, and connectivity.

For the CIT ESA, initial goals were set for all of the targets based on their geographic scale, distribution, and spatial pattern. A GIS dataset was then created for input into the site selection algorithm. Given the time and resources available, we determined that the best approach to setting goals draws on the EBM framework by setting a range of goals that can be used to construct separate portfolios for several goal levels within that range. Using this approach, a series of potential conservation solutions were created for 30%, 40%, 50%, 60%, and 70% goal settings, wherein these percentage goals were applied uniformly across all ecosystem and focal species targets. These solutions were then used for purposes of prioritization, allowing the team to compare areas that were necessary to satisfy all goal scenarios including the minimal goal set, to areas only selected in larger goal sets, and to those areas never selected, regardless of the goal setting.

Threats (Human Impacts) Analysis

We developed spatial tools to summarize relative levels of human impacts, using the watershed units as our primary analytical units. Watersheds form a logical unit to summarize relative levels of human impacts because ecological linkages within watersheds tend to be stronger than linkages between watersheds. Because human impacts on ecological systems may operate at different scales, we examined relative impacts at multiple scales in order to identify intact and restorable areas.

We applied a modified classification based on Moore (1991), who classified 3rd order watersheds as follows:

- *pristine watersheds* – watersheds in which "there is virtually no evidence of past human or industrial activities. Any past small scale removal of trees - including selective logging of individual trees, small patch cutting or land clearing - is limited to less than 5 ha."
- *modified watersheds* – watersheds that have been " slightly affected by a limited amount of industrial activity, such as past or recent logging with or without roads, powerlines,

pipelines, mining, or settlements. The amount of the watershed affected is less than two percent of its area; or, in the case of watersheds greater than 10, 000 ha, is less than 250 ha."

- *developed watersheds* – watersheds with more than 2% of their area impacted by industrial activity.

We applied the Moore (1991) scheme with some modifications (Map 31). Human impacted area was calculated by combining human altered area (clearcut, urban, agriculture) with a 200 m buffer area around roads. Overlapping areas were treated as impacted. We calculated impacted area as a percent of *potential vegetated area,* which was calculated as a sum of natural vegetated area, human altered vegetated area, and urban area. Watersheds with more than 2% of their area affected may still be ecologically intact, depending on both the cumulative impact of human alteration and the spatial location of human alterations. To identify such watersheds, we used two additional factors for assessing the overall impact, 1) proximity of impacts to rivers and streams, and 2) road density. Classification thresholds for modified areas were set at levels where road density has been demonstrated to impact grizzly bear populations.

Although Moore restricted analysis to watersheds greater than 5000 ha, we also sought to identify relatively intact watersheds a multiple spatial scales. Small intact watersheds may be sufficient for harboring viable occurrences of some species and/or community types (e.g. rare plant communities), but larger, contiguous intact areas are necessary to conserve viable populations of vertebrates. Because of their value for salmon populations and global rarity, entire river systems that are relatively intact represent key areas for conservation.

Spatial Analysis

For the CIT ESA, the challenge is to take an analysis of special elements, ecosystem representation, and focal species, and create a spatially explicit assessment of where the region's biodiversity values are located and what condition they are in. To this end, we employed computerized site selection algorithms in combination with the impacts analysis described above in a GIS environment.

Terrestrial and Freshwater Analysis

For the terrestrial and freshwater analysis, we used the site selection software SITES. SITES applies an algorithm called "simulated annealing with iterative improvement" as a method for efficiently selecting sets of areas to meet conservation goals. 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 goals, and Boundary Length is a cost determined by the total boundary length of the portfolio. SITES attempts to minimize total portfolio cost by selecting the fewest planning units and smallest overall area needed to meet as many goals as possible, and by selecting planning units that are clustered together rather than dispersed.

We used 500-ha hexagons as planning units for the SITES analysis. Use of uniform-sized planning units avoids the area-related bias that can occur when differently-sized planning units, such as watersheds, are used. We applied four different protection scenarios: no protected areas "locked in" the outcome; existing protected areas locked in; existing plus candidate protected areas locked in; and existing plus candidate plus option areas locked in. Candidate and option areas were only available for the Central Coast region.

All else being equal, planning units with lower levels of human impact should be chosen over those with higher levels of impact, in order to select areas in better condition with higher chances of viability. Thus, rather than simply using the number of hectares in each planning unit for the Area component of our SITES analyses, we developed a suitability index, i.e., a cost index based on the human impact data. Human impacted area was calculated as described above. 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. Potential Vegetated Area was calculated as the sum of vegetated habitat plus the sum of clearcut and urban areas. Because the Sites algorithm seeks to minimize total portfolio cost, it selects planning units with low cost (i.e., low impact) over high-cost areas whenever possible. We used boundary-length modifiers of 0.001, 0.01, and 0.1 to include a range of planning unit clustering in our final combined runs. This range allows us to explore issues of several small clusters versus fewer large clusters.

We made 20 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 levels) for each of the four protected area scenarios. Thus, for each protection scenario we used a sum of 300 sites runs that resulted from 300,000,000 iterations of the simulated annealing algorithm. Hexagons chosen frequently represent places more necessary or irreplaceable for biodiversity conservation, while those chosen few times represent locations where similar biodiversity is found elsewhere or where human impacts are significant. We used five different goal levels: 30%, 40%, 50%, 60%, and 70%, as described above.

Nearshore Marine Analysis

For the nearshore marine analysis we used a site selection algorithm called MARXAN, which employs the same basic simulated annealing procedure as the SITES algorithm. Shoreline ecosystems were analyzed as linear segments. These units vary widely in length and extend over the entire coastline. Forage fish spawning sites and seabird colony data were attributed to the shoreline segments to represent the nearshore zone.

We included in the analysis a suitability index, or "cost index," which tends to reduce representation in places with high human impacts. Impacted areas were calculated as described above, but three cost parameters were added: aquaculture tenures, enhancement facilities, and hatcheries. We performed raster-based analyses to develop a human impact score for all shoreline planning units (Map 23). To build the cost index, we took the mean planning unit length and the sum length of human impacts within that planning unit: Cost = Mean Planning Unit Length + (Mean Planning Unit Length * Human Impact Score). We used the mean value of all shoreline planning units instead of calculating cost equal to length.

We developed a linear boundary modifier that clumped adjacent linear segments along the shoreline. The algorithm was therefore able to assemble small fragments of shoreline into more continuous stretches (i.e., select an entire islands' shoreline). We set the boundary length modifier to 0.1 for all MARXAN scenarios. We set penalty factors based on the importance of the target; a high penalty factor is assigned to a high priority target.

Our approach for building a nearshore marine portfolio combined expert input (through a technical workshop) with spatial analysis. One of the objectives from the technical workshop was to select biodiverse coastal sites based on expert knowledge. These initial seascape sites were chosen to capture relatively large, intact ecosystems that represent the region's nearshore biodiversity. Experts were asked to select areas along the B.C. coast using three criteria: 1) Large nearshore sites are important for marine biodiversity. 2) Sites must be stratified across the ecoregion. 3) There should be diversity in the types of sites chosen, i.e. good for birds, good for invertebrates, etc. The results were the identification of 18 seascape sites, which helped guide subsequent analysis.

We evaluated 12 different MARXAN scenarios to test the irreplaceability and sensitivity of the site selection. Irreplaceability analyses indicate which sites are consistently chosen. Planning units that get chosen the most often are the least replaceable. With each of the 12 scenarios run 20 times, we had a gradient from 0 to 240 solutions. Within each scenario the algorithm did 1,000,000 iterative selections per run. Two multiple goal scenarios were run: one optimizing for 10% of the entire shoreline and another for 20%. We used three stratification schemes to divide the nearshore zone: marine ecosections, project regions, and no stratification.

Offshore Marine Analysis

The offshore marine analysis applied 500-ha hexagons as planning units, as in the terrestrial/freshwater analysis, and the MARXAN site selection algorithm, as in the nearshore marine analysis.

Reporting Units

From the standpoint of reporting results of analyses, the hexagon grid that is optimal for analytic purposes leaves much to be desired in terms of reporting results and applying them to planning decisions. Several alternative units were considered for the purposes of reporting ESA results. These included Primary/intermediate watersheds developed by RRCS, and a derived landscapes/seascapes unit. While the delineation of intermediate watersheds created reporting units of more uniform size, small, coastal, primary watersheds of greatly varying size remained unclassified and a possible source of size bias in reporting. Landscapes and seascape units compensated for this effect by grouping small coastal water sheds based on the common saltwater body that they drained into. For open water reaches of the CIT study area, seascapes were based on Department of Fisheries and Oceans statistical areas. A total of 565 landscapes and seascapes were identified ranging from 10,000-99,000 ha. Islands <10,000 ha are included in seascapes (Map 32).

Options and Scenarios

In order to facilitate examination of spatially explicit conservation solutions, we made use of SITES and MARXAN to create a series of potential conservation solutions that in combination, are referred to as Options and Scenarios. At the heart of this exercise was an attempt to prioritize solution outputs according to criteria related to *conservation value*, which was based on target information and SITES/MARXAN outputs, as well as *conservation condition,* based on the evaluation of human impacts within the study area.

For the CIT ESA we used SITES and MARXAN summed solution scores (i.e., showing the number of times individual planning units were selected during runs of the model), as a broad measure of conservation value. For the terrestrial/freshwater analysis, a conservation value score was derived for analysis units based on the frequency by which any one planning unit was selected in the total of 300 SITES runs (20 repeat runs x 3 boundary length modifiers x 5 goal settings), that were performed. These scores were subsequently rolled-up for each landscape/ seascape unit as well, for comparison at a broader scale with other CIT spatial analyses.

Scores for both planning and landscape units were then grouped into five classes based on the quintile scores of the summed solutions. A planning unit selected 180 or more times in SITES fell into the top two quintiles, or top 40%, of the solution and was scored as having *high* conservation value. Analysis units with scores in the middle quintile were scored as *medium* conservation value, and those in the 4th quintile were scored as *low* conservation value. Those units with a score in the lowest quintile were not ranked.

Condition was used as a surrogate measure for target viability in the CIT ESA and was evaluated using the human impacts information described above. Impacts were assessed for both hexagonal planning units and for landscapes/seascapes. The six impact classes were simplified into the three broad condition classes--intact, modified, and developed.

Alternative Options and Scenarios for Conservation

To explore the interaction between conservation value and condition, analysis units and landscapes/seascapes were clustered into three conservation tiers based on a conservation value and condition matrix. 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. These three tiers constitute three conservation *options* that can be evaluated against various land-use scenarios.

The Central Coast LRMP tables have already proposed several potential land-use scenarios, and we wanted to evaluate each in terms of their performance against the three conservation options being generated by the ESA. To facilitate this comparison, the protected areas described by each scenario were locked into the SITES solution for terrestrial/freshwater runs. Four alternative land-use scenarios were evaluated as follows:

1. Unconstrained Analysis.

2. Base Case – existing protected areas locked into SITES.
3. Candidate Case – existing protected and CCLRMP Candidate Areas locked into SITES.
4. Option Areas Case – existing protected areas, CCLRMP Candidates, and Option Areas locked into SITES.

In order to compare between and within options and scenarios, potential solution sets from summed runs were evaluated against three goal thresholds: 30, 50, and 70%. For each scenario, performance of conservation tiers (options) was assessed both in terms of effectiveness, as measured by the proportion of targets that met or exceeded the goal threshold, and efficiency, the proportion of the study area required to meet the threshold.

Spatial Analysis Results

Terrestrial/Freshwater Spatial Analysis Results

Summed run solutions for each of the four land-use scenarios are displayed in maps 33 through 36, with Tier 1 and 2 analysis units highlighted in maps 37 thorough 40. While the pattern of conservation values differs between each land-use scenario, there are only small differences among the overall performance of the solutions. This similarity is true in regard to both the solution's efficiency, measured by the amount of area swept into each conservation option or tier, and effectiveness, measured by the conservation goals reached by those tiers.

Depending on the conservation scenario, between 44% and 50% of the highest conservation value planning units (equal to 44 to 50% of the land base of the study area), were required to satisfy the 30% goal threshold for most targets. Increases in solution area resulted in approximately proportional increases in solution effectiveness. To achieve 50% goals for most conservation targets, as much as 60 to 70% of the study area was required. After approximately 50 to 60% of the study area (50 to 60% of the highest value analysis units), has been incorporated into the solution, subsequent improvements in meeting goals required proportionally larger areas of land and water. That is, the incremental increase in goal achievement declined. This effect is much more pronounced when the 70% goal threshold is examined. In this case, inefficiencies arise to the point where the inclusion of more planning units yields only minute improvements relative to meeting goals.

Under any combination of proposed and existing protected areas we see that less than 20% of the conservation elements being targeted by the CIT ESA meet a 30% goal threshold. However, it is apparent that there are considerable conservation values within the areas that have been designated and proposed. Up to a quarter of the region's Tier 1 analysis units would be captured in a scenario that designated candidate and option areas as protected.

Summaries of conservation tiers for each land use scenerio are presented in maps 41 to 44. Tier thresholds for conservation value were based according to quintiles of the mean summed solution scores of the analysis units within each watershed.

The large size of the landscapes and seascape units prevented adequate performance measures to be calculated among conservation options. The large size of these units (10,000 to 100,000 ha) equates to a loss of spatial specificity and coarsens the SITES summed solution significantly.

When we calculated the effectiveness of Tier 1 landscapes (124 of a total 565) against a 30% conservation goal for the existing protected areas scenario, we found that just over a third of targets met or exceeded the 30% threshold. Adding Tier 2 landscapes improved effectiveness such that 82.9% of targets met the goal threshold, but well over 70% of the planning area was swept into the Tier 2 option.

From these results it is apparent that more work is needed to find appropriate thresholds among landscape/seascape units. Shortcomings related to finding thresholds among landscapes and seascapes do not, however, detract from using landscapes as a lens by which to examine the higher resolution results based on the 500 ha analysis units be overlooked. In fact, a more "hands on" approach involving stakeholders themselves to examine these data in an interactive framework may prove much more useful than basic statistical summaries of results.

Nearshore Marine Spatial Analysis Results

Sensitivity analyses were conducted by selecting thresholds in the summed solution gradient and evaluating how well nearshore targets were captured in solutions. The area required to meet goals changed as we lowered the threshold along the summed solution gradient. We set three thresholds to illustrate this: 10% (Option A), 20% (Option B), and 30% (Option C) of the entire shoreline length. The summed solution gradient from the 12 MARXAN scenarios provided the basis for setting these thresholds. Several options for displaying and interpreting these results using shoreline units are displayed in maps 44 through 48. Alternatively these options can be examined relative to landscape/seascape units as presented in maps 49, 50, and 51.

We believe it is valuable to illustrate the results of the nearshore analysis as spatially explicit shoreline sites and reporting-out landscapes. The analysis of shoreline planning units provided a high level of detail for identifying site-specific coastal areas; reporting-out to landscapes or watersheds along the coast provided a look at the integration of terrestrial and nearshore ecosystems.

Offshore Marine Spatial Analysis Results

Conservation value was ranked according to the number of times each planning unit was selected in 2,400 MARXAN solutions (displayed in Map 52). The examination of various clumping values indicates that regardless of whether reserves are many and small, or few and large, certain areas recur over the course of many runs. For example, within the Central Coast, the *larger* areas of high conservation value that emerge include hexactinellid sponge reefs, Goose Islands, Bardswell Islands and vicinity, Rivers Inlet, Scott Islands, Entrance to Queen Charlotte Strait, Broughton Archipelago, Head of Knight Inlet and Cordero Channel.

Although these areas alone would not constitute a fully representative Central Coast conservation portfolio, it is very likely that were they not included, such a portfolio would be difficult or impossible to achieve. Thus, regardless of the exact percentages chosen by planning processes, and the exact shape of the boundaries, we would expect the bright yellow areas of map 52 to be key components of most conservation planning. Larger areas of high conservation value within the North Coast include hexactinellid sponge reefs, West Aristazabal Island (and NW Price I.), Kitimat Arm, Anger Island and vicinity, SW and N Porcher Island, Kitkatla Inlet, S. Chatham Sound, and Mouth of the Nass River.

Larger areas of high conservation value within the Haida Gwaii waters include W. Dixon Entrance, Naden Hr., Masset Inlet, Skidegate Inlet (Kagan Bay), and South Moresby Island.

Areas of high conservation value alone would not constitute a fully representative conservation portfolio. The individual network solutions produced by MARXAN can be diverse. Such diversity allows for flexibility when considering external factors, such as user interests, parks, local politics, access, and enforcement.

Integrated Terrestrial, Freshwater and Marine Spatial Analysis

The separate analytical products can still be compared with one another for the purposes of identifying areas of conservation convergence between these systems. However, it is also desirable to integrate nearshore, offshore, and terrestrial/marine assessments into a single analysis for the purposes of optimizing conservation solutions between these environments. Such an integration process is currently being initiated.

Integrating CIT ESA, EGSA, and CSA Spatial Analyses

After the completion of the ESA, EGSA and CSA, the CIT hopes to take advantage of this wealth of spatially explicit information to produce a simple and readily understood set of land-use options and scenarios that minimize conflict and maximize compatibility between biodiversity conservation requirements, development potential, and places of cultural significance within the CIT study area. For instance, spatially explicit data emerging from the EGSA and CSA can be used to adjust the cost function in SITES. By running the SITES model with a cost function modified by the EGSA and CSA under a variety of different goal settings, patterns of conflict and compatibility can be uncovered and presented to planning tables in the form of a series of potential land-use options and scenarios.

If time and resources permit, these options and scenarios will be further refined by a more stakeholder accessible software tool known as QUEST, developed by the Sustainable Development Research Institute (University of British Columbia) and Envision Sustainability Tools to facilitate scenario development and assessment. QUEST integrates data and models and makes the resulting information accessible via a facilitator-controlled user interface.

1.0 INTRODUCTION

This report presents the methods and results of a comprehensive ecosystem spatial analysis for the Haida Gwaii, Central Coast, and North Coast regions of British Columbia. This study is unique in that it integrates analysis of the biological values of terrestrial, freshwater, and marine ecosystems across this vast region. To our knowledge, no previous science-based conservation assessment in this region has considered all three realms. The methodology employed in this study represents the state of the art in science-based conservation planning. It integrates geographic information system (GIS) analysis of rare species and other unique features (“special elements”); representation of terrestrial, freshwater, and marine ecosystem units; and conservation of suitable habitats for species of special interest (“focal species”). Regional Conservation Planning

Conservation planning on a regional scale has become the standard approach for organizations and agencies worldwide interested in the conservation of biodiversity and other ecological values. Whereas much of recent conservation history in North America has been dominated by actions often described as “piecemeal,” “species-by-species,” or “site-by-site,” in large part stimulated by the requirements of species-based legislation (Noss et al. 1997), conservationists today focus increasingly on ecosystems, landscapes, and ecoregions. Species are not forgotten as the spatial and temporal scale of conservation broadens; indeed, species are often the best indicators of the status of ecosystems and are essential in answering questions about how the configuration of habitats across the landscape affects ecological integrity, which includes considerations of population viability (Noss 1990, Lambeck 1997, Carroll et al. 2003). Species conservation is no longer piecemeal, however. The conservation of individual species is now interpreted within the broader context of maintaining the structure, function, and composition of ecosystems within a natural or historic range of variability (Franklin et al. 1981, Landres et al. 1999, Swetnam et al. 1999). Moreover, modern conservation seeks to conserve species and other elements of biodiversity before they become threatened or endangered and before conflicts between conservation and economic activities escalate out of control.

Regional conservation planning differs from conventional land-use planning in that regions are defined ecologically rather than politically (Noss and Cooperrider 1994). Many conservation agencies and non-profit groups, in North America and elsewhere, base their planning on the boundaries of ecoregions – large areas distinguished by similarities in climate, landform, soils, vegetation, and natural processes (Dinerstein et al. 1995, Bailey 1998, Ricketts et al. 1999, Groves 2003). Such ecoregions regularly overlap provincial and national boundaries. In 1996, The Nature Conservancy initiated its approach to ecoregional planning in the United States, drawing on experience from *ad hoc* regional conservation plans nationwide. Shortly thereafter, World Wildlife Fund, working with a number of experts, provided a conservation assessment of the ecoregions of the United States and Canada (Ricketts et al. 1999), one of many assessments the organization has undertaken worldwide. Meanwhile, since 1991, The Wildlands Project and cooperating groups have been developing regional conservation plans and reserve network designs across the United States, Mexico, and Canada, drawing on prototypes developed earlier (e.g., Noss 1987a, 1993). Today, The Nature Conservancy and the Nature Conservancy of Canada have completed or are in the process of completing ecoregional plans in over 100 ecoregions in North America and elsewhere in the world

A fundamental requirement of regional conservation planning is that it be systematic. As described by Margules and Pressey (2000), systematic conservation planning is superior in many ways to opportunistic or politically-biased planning because it: 1) requires clear choices about the features to be used as surrogates for overall biodiversity, 2) is based on explicit goals, preferably translated into quantitative, operational targets, 3) recognizes the extent to which conservation goals have been met in existing reserves, 4) uses simple, explicit methods for locating and designing new reserves to complement existing ones in achieving goals, 5) applies explicit criteria for implementing conservation action on the ground, and 6) adopts explicit objectives and mechanisms for maintaining the conditions within reserves that are required to foster the persistence of key natural features, together with an effective monitoring and adaptive management program.

Finally, regional conservation planning is precautionary. Although reserve selection algorithms, based on mathematical models that emphasize efficiency, attempt to capture the most biodiversity in the least area, the minimal area is properly interpreted as the area sufficient and essential to meet the stated conservation goals and objectives. "Sufficient" implies that the action can be fully expected to attain the stated goals; "essential" implies that, without the action, the goal or objective will not be attained. Superfluous actions, such as protecting more land than necessary to assure viability of species and ecosystems, are avoided. Nevertheless, the precautionary principle, which is becoming well accepted in many fields (Peterman 1990, Shrader-Frechette and McCoy 1993, Taylor and Gerrodette 1993, Noss et al. 1997), suggests that, in cases of uncertainty, it is better to risk protecting too much than too little. This precaution can be implemented in conservation planning by setting ambitious goals, while using the best available science to reduce uncertainty over time. Moreover, conservation measures can be implemented sequentially, starting with the sites of highest irreplaceability and vulnerability, then progressing to those where conservation values are lower or less certain.

1.1 The Planning Process

Our ecosystem spatial analysis is designed to serve four well-accepted goals of conservation (Noss & Cooperrider 1994): 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 we integrate three basic approaches to conservation planning: 1) protection of special elements; 2) representation of a broad spectrum of environmental variation; and 3) protection of critical habitats of focal species. Together, these three tracks, which will be described in more detail below, constitute a comprehensive approach to regional conservation planning (Noss et al. 1999, 2002).

1.2 Study Area and Objectives

1.2.1 Study Area

North and Central Coastal British Columbia (BC) covers the coastal waters, islands, and watersheds of the Canadian Pacific from the Alaskan border south to the Strait of Georgia and from the summits of the coastal ranges west to the continental slope. It includes Haida Gwaii/Queen Charlotte Islands (QCI) and northern Vancouver Island. The region has a land area of 11 million hectares (the size of Iceland or Guatemala) but a population of just 90,000—a third of Iceland's and less than a hundredth of Guatemala's. Its sea area is another 11 million hectares.

The region is the heart of the Northeast Pacific archipelagos coast, one of the world's three large glaciated leading edge coastal zones (the others being Norway and southern Chile). These zones are on the leading edge or collision margin of tectonic plates and have been sliced and diced by glaciations. Hence they have narrow to nonexistent coastal plains, drop sharply from mountain heights to ocean depths, and are incised by fiords, fissured by channels, and broken into islands large and small.

Biologically and culturally, the Northeast Pacific is the most diverse of the three zones. In particular, North and Central Coastal BC includes the world's largest tracts of intact temperate rain forest, once-abundant runs of Pacific salmon, and the northern or southern limits of many species. Globally unique hexactinellid sponge reefs lie in deep troughs of the continental shelf. Several endemic species of plants and animals and an endemic subspecies of black bear occur on Haida Gwaii/QCI; and an unusual white form of the black bear—the kermode or Spirit bear—lives on Princess Royal Island.

The region includes the traditional territories of 26 First Nations (aboriginal peoples) in four linguistic groups: Haida (2), Coast Tsimshian (5), Heiltsuk-Wuikala (3), Coast Salish (1), and Kwakwala (14). The total aboriginal population is about 26,000: 11,000 on reserve; 15,000 off reserve (some in the region, others in metropolitan centres in the south). Other communities in the region have a total population of about 90,000; only three with populations greater than 10,000 (Prince Rupert and Kitimat on the mainland and Campbell River on Vancouver Island).

The economy is dominated by logging, followed by the public sector, tourism, fishing, and (to much lesser degrees) aquaculture and mining. Fishing plays a major role in the subsistence economy. Economic development is hampered by limited infrastructure. Fish and marine invertebrate stocks have been reduced. Uncertainty surrounds the development of minerals, and exploitation of offshore oil and gas is barred by a moratorium. Tourism is below potential. The forest industry faces markets shrunk by the downturn in the North American economy and high import tariffs by the United States (its main market). As a result, the regional economy is in a severe recession and unemployment is high.

First Nations in the region assert their aboriginal rights and title, which are acknowledged by the Canadian constitution and federal and provincial governments but (except for the Nisga'a) have yet to be translated into treaty settlements. Pending resolution of outstanding land issues, several Nations are preparing their own land use plans, either independently or as part of interim measures agreements with the Provincial Government.

1.2.2 Haida Gwaii, Central Coast and North Coast British Columbia

Over 95% or the BC coast is designated crown land and is managed by the Government of British Columbia. Decisions regarding land-use are made via Land and Resource Management Plans (LRMPs), three of which are currently underway in the CIT region – Central Coast, North Coast, and Queen Charlotte Islands/Haida Gwaii. These three LRMPs have adopted a sectoral model with a collaborative approach to reaching decisions with a small number of people at the planning table representing larger constituencies. Representatives from the environmental community, the forest industry, tourism, recreation, labour, small business forestry, local governments, the federal government and First Nations are included.

The boundaries of the LRMP plan areas (map 1) are not ecologically based, but instead largely correspond (by default) to other administrative and/or land-use planning boundaries. For instance, in the case of the Central Coast LRMP (see below), the boundary to the east incorporates a large portion of Tweedsmuir Provincial Park and corresponds with the completed Cariboo-Chilcotin land- use plan and Lower Mainland IAMC planning boundaries. The western boundary extends offshore into Queen Charlotte Sound. This boundary is subject to change. The southwestern boundary corresponds to the Vancouver Island land- use plan boundary. The northern boundary extends beyond the Mid-Coast Forest District to encompass Princess Royal Island and the adjacent mainland to address the Spirit Bear park proposal and related timber issues

1.2.2.1 Central Coast

The Central Coast planning area encompasses 4.8 million hectares (11.8 million acres) of land, fresh water and marine area. Extending west of the Coast Mountains, it spans the mainland coast of British Columbia from Bute Inlet in the south to Douglas Channel in the north.

The region is home to over 4,400 people, mainly First Nations. Natural resource industries, including fisheries and forestry, play a primary role in the local economies and well-being of communities such as Bella Bella, Shearwater, Ocean Falls, Klemtu, Bella Coola and Oweekeno.

The Central Coast is ecologically diverse, characterized by rugged mountains, deep ocean fjords, numerous islands and alluvial valleys that reach into the interior ecosystems of the province. Coastal temperate rainforests dominate lower elevation landscapes. These forests as well as the wetlands, bogs, estuaries, and rivers found throughout the region are biologically dynamic and rich in biodiversity.

About half the area is forested, while approximately 12 per cent contains commercial forests available for timber harvesting. Currently, 10.74% of the Central Coast Plan Area is protected (excluding marine waters). This percentage includes provincial parks, recreation areas, and ecological reserves. Large protected areas in this region include Hakai and Fiordland Recreation Areas[1] and a major portion of Tweedsmuir Provincial Park. Smaller protected areas include such areas as Codville Lagoon Provincial Park, Broughton Archipelago Marine Park, and the Duke of Edinburgh Ecological Reserve. An Interim Land Use Plan for the Central Coast has created 22 new protection areas, classified as *candidate protected areas,* amounting to some one million hectares or twenty percent of the region. Another suite of areas remains under negotiation and are referred to as *option areas.* Option Areas are areas where the determination of future use (Operating Area or Protection Area or some other area) is postponed pending the development of the CIT's Ecosystem-Based Management Framework and completion of the CCLCRMP after December 2003. The purpose of Option Area Status is to maintain options while the EBM is finalized over the next 12 to 24 months (map 1).

1.2.2.2 North Coast

Covering 1.7 million hectares (4.2 million acres), the North Coast planning area lies to the north of the Central Coast and stretches to the town of Stewart.

More than 20,000 people live within the North Coast, most in the city of Prince Rupert, and the remainder in the communities of Port Edward, Metlakatla, Lax Kw'alaams, Kitkatla, and Hartley Bay. These communities all lie next to the sea and draw their wealth from marine resources, forestry, and tourism.

The North Coast includes similar ecosystems to those found in the Central Coast, offering a diversity of habitat types and ecological complexes. Approximately 38 per cent of the area is forested, and about six per cent is available for timber harvesting.

1.2.2.3 Haida Gwaii/Queen Charlotte Islands

Haida Gwaii/Queen Charlotte Islands lies about 90 kilometres west of the north coast of mainland B.C. The archipelago contains 150 islands and hundreds of islets. The total land area is just over a million hectares (2.5 million acres).

About 6,000 people live in the Queen Charlotte Islands; a third are members of the Haida Nation. Forestry, commercial fishing, and tourism contribute to the area's economy.

Almost 25 per cent of the area is protected in the Gwaii Haanas National Park Reserve (147,500 hectares encompassing the southern portion of Moresby Island) and Naikoon Provincial Park (73,800 hectares, occupying the northeast corner of Graham Island).

1.2.3 Biological Stratification

Ecoregional definitions are often used to delineate boundaries for conservation design and planning (Groves et al. 2000). The Ecoregion Classification system in common use in Canada stratifies British Columbia's terrestrial and marine ecosystem complexity into discrete geographical units at five levels. The two highest levels, Ecodomains and Ecodivisions, are very broad and place British Columbia globally. The three lowest levels, Ecoprovinces, Ecoregions, and Ecosections are progressively more detailed and narrow in scope and relate segments of the Province to one another. They describe areas of similar climate, physiography, oceanography, hydrology, vegetation and wildlife potential. Within each terrestrial ecoregion, climatic zones occur where specific soils, plant and animal communities and aquatic systems develop because of the interaction of climate with the land surface and surficial materials. These zones are best defined within the Biogeoclimatic Ecosystem Classification system:

- ***Ecodomain*** - an area of broad climatic uniformity, defined at the global level;
- ***Ecodivision*** - an area of broad climatic and physiographic uniformity, defined at the continental level;
- ***Ecoprovince*** - an area with consistent climatic processes and relief defined at the sub-continental level;

- ***Ecoregion*** - an area with major physiographic and minor macroclimatic variation defined at the regional level;
- ***Ecosection*** - an area with minor physiographic and macroclimatic variation, defined at the sub-regional level.

The CIT Study area falls within the Coast and Mountains Ecoprovince of BC. This Ecoprovince extends from coastal Alaska to coastal Oregon. In British Columbia it includes the windward side of the Coast Mountains and Vancouver Island, all of the Queen Charlotte Islands, and the Continental Shelf including Dixon Entrance, Hecate Strait, Queen Charlotte Strait, and the Vancouver Island Shelf. The Coast and Mountains Ecoprovince consists of the large coastal mountains, a broad coastal trough and the associated lowlands, islands and continental shelf, as well as the insular mountains on Vancouver Island and the Queen Charlotte Islands archipelago.

1.2.4 The ESA Study Area Boundaries

One advantage of an ecoregional approach to planning is that it 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. Of course, some species, especially wide-ranging animals such as grizzly bears and salmon, are ideally considered at much broader spatial scales. A third advantage of an ecoregional approach is that it enables an assessment of abundance and distribution of biological elements within their entire ecological extent or range thereby enabling valid assessment of diversity to be conducted. Moreover, using an ecoprovince or ecoregional boundary for the ESA sweeps a vast amount of geography into the assessment, over which the land-use decisions that this report is meant to inform have no jurisdiction. Indeed, creating an ecological assessment that is of compatible scale and geography to the Central Coast, North Coast, and QCI/Haida Gwaii LRMP boundaries is essential if the ESA is to be used by these decision-makers. In order to balance these competing (but not mutually exclusive) criteria, the ESA has taken a modified approach to delineating an ecologically-based study area boundary. Within the Coast and Mountains Ecoprovince, the finer-level stratification of ecosections is used to set study area boundaries. More specifically, within the Coast and Mountains Ecoprovince, those ecosections that intersect with the Central Coast, North Coast, and QCI/Haida Gwaii LRMP boundaries constitute the study area[1] (map2).

1.2.5 Study Area Ecoregions and Ecosections

The study area overlaps with a total of 5 terrestrial based ecoregions encompassing 10 ecosections. A sixth ecoregion is dominated by the open water marine environment and can be further divided into 4 marine ecosections. These stratifications are described as follows:

[1] Despite the fact that one of these ecosections extends into Southeast Alaska, constraints of time and data availability restrict the CIT analysis to British Columbia. However, CIT data and analysis are currently being shared with a transboundary assessment—the Coastal Forests and Mountains ecoregional plan, being performed by Round River Conservation Studies, The Nature Conservancy of Alaska, and the Nature Conservancy of Canada. This transboundary effort has an expected completion date of December 2003 and will seamlessly integrate the CIT ESA results.

- **The Coastal Gap Ecoregion** contains somewhat rounded mountains with lower relief than mountain ranges to either the north or south. Valley sides are rugged and steep. Because of their lower relief, the mountains allow considerable moisture to enter the interior of the province. The Ecoregion contains two Ecosections:
  - **The Hecate Lowland Ecosection** is an area of low relief, consisting of islands, channels, rocks, and lowlands adjacent to Hecate Strait and Queen Charlotte Sound.
  - **The Kitimat Ranges Ecosection** is an area of subdued, yet steep-sided mountains, east of the Hecate Lowlands Ecosection.
- **The Hecate Continental Shelf Ecoregion** is the shallow oceanic area offshore of the Hecate Lowlands, south of the Alaska Panhandle and north of Vancouver Island. Much of this shelf lies leeward of the Queen Charlotte Islands. It contains four Ecosections.
  - **The Dixon Entrance Ecosection** is located between northern Graham Island and Prince of Wales and Dall Islands in southeastern Alaska. This Ecosection has a strong freshwater discharge influence from the Skeena, Nass, and other rivers.
  - **The Hecate Strait Ecosection** is a broad semi-enclosed estuarine waterway located between the mainland coast, the Queen Charlotte Islands, and northern Vancouver Island. This is a very shallow strait dominated by coarse bottom sediments. It has semi-protected waters with strong tidal currents that promote "mixing."
  - **The Queen Charlotte Sound Ecosection** is a deeply dissected shelf area with several large intervening banks. This Ecosection is exposed to oceanic waves allowing for oceanic water intrusions.
  - **The Queen Charlotte Strait Ecosection** is shallow marine area that is interspersed with many islands and reefs, located between northern Vancouver Island and the Hecate Lowland. There are strong currents mixing the oceanic and freshwaters.
- **The Northern Coastal Mountains Ecoregion** is a rugged, largely ice-capped mountain range that rises abruptly from the coast. It contains three Ecosections in British Columbia.
- **Southern Alexandria Archipelago**
  - **The Alaska Panhandle Mountains Ecosection** is an area of wet rugged mountains. It is the southern, windward mountain segment of the three major units in this Ecoregion. Most of this Ecosection occurs in Alaska. In British Columbia this unit occurs in the areas of Portland and Observation inlets the lower Nass River.
  - **The Boundary Ranges Ecosection** is a large block of rugged, ice-capped, granitic mountains that are dissected by several major river valleys. It is the eastern or interior-most segment of the three major units in this Ecoregion. Most of this unit occurs in British Columbia.
- **The Pacific Ranges Ecoregion** is the southernmost mountain range of the Coast Mountains in British Columbia. It includes the coastal islands, channels, and fjords east of Queen Charlotte Sound; otherwise it lies east of the Georgia Depression Ecoprovince. The mountains

are characteristically high and rugged. It contains four Ecosections, only two of which overlap with the Study Area LRMP boundaries,

- **The Northern Pacific Ranges Ecosection** is an area of steep, rugged, often ice-capped, mountains located in the northern portion of this Ecoregion.
- **The Outer Fiordland Ecosection** is an area of rugged, low relief, consisting of inlets, sounds, islands, and peninsulas, east of Johnstone Strait and Seymour Narrows.

- **The Queen Charlotte Lowland Ecoregion** is represented by only one Ecosection.
  - **The Queen Charlotte Lowland Ecosection** is an area of low relief, poor drainage and extensive muskegs and wetlands in the northeastern part of the Queen Charlotte Islands.
- **The Queen Charlotte Ranges Ecoregion** includes the fjords and mountains of the Queen Charlotte Mountains. Precipitation is somewhat reduced here. This Ecoregion is represented by two Ecosections.
  - **The Skidegate Plateau Ecosection** is a plateau in the lee of the Queen Charlotte Mountains. Precipitation is lower here.
  - **The Windward Queen Charlotte Mountains Ecosection** is the very wet and rugged western side of the Queen Charlotte archipelago.

1.2.6 ESA Ecological Drainage Units

In addition to using terrestrial based classifications for stratifying the study area, the ESA planning team delineated broad Ecological Drainage Units (EDUs) as part of their freshwater ecosystem classification framework. EDUs are groups of watersheds that share a common zoogeographic history, physiographic and climatic characteristics. EDUs contain sets of freshwater ecosystem types with similar patterns of drainage density, gradient, hydrologic characteristics, and connectivity. Identifying and describing EDUs allows us to stratify the study area into smaller units enabling us to better evaluate patterns of freshwater ecosystem diversity. Additionally, EDUs provide a means to stratify the study area to set conservation goals. A total of five EDUs were defined within the CIT region based on Hocutt and Wiley (1986), Haas' bioregions (1998), and MacPhail and Carveth (1994) (map 3):

- Nass;
- Skeena;
- North Coast;
- Central Coast; and
- Haida Gwaii / QCI.

1.2.7 Study Area Ecological Description

The moist, cool climate, mountain and lowland physiographies, and non-random natural disturbances create patterns of ecosystems on the landscape. In the Lowlands, patches of productive forest often occur within a matrix of non-forested bog lands and stunted bog woodland. In the watersheds of the Insular and Coast Mountain ranges, the forest mosaic typically consists of large, continuous tracts of all-aged, structurally diverse old-growth coastal western hemlock forest, separated by cliffs, gullies, wetlands, and shrub-covered avalanche and landslide tracks.

Within a climatically and physiographically homogeneous sub-region, slope position and substrate influence soil moisture and nutrient regime, and consequently, productivity and species composition. The biogeoclimatic ecosystem classification system identifies and interprets forested ecosystems in the CIT region (Banner et al. 1993). Where water accumulates, the wet, cool climate has led to areas of extensive unproductive bog ecosystems. Where water drains freely, the history of infrequent, stand-replacing disturbances and wet, mild climate has led to productive forests characterised by large, old trees, and tremendous accumulations of biomass, included downed wood and snags (Pojar and MacKinnon 1994). Large trees, snags and downed wood play significant ecological roles in the CIT region, providing habitat and influencing hydroriparian processes.

On the wet, cool coast, freshwater ecosystems are particularly prevalent. In the Lowlands, wetlands (bogs, ponds and small lakes) cover 51 – 75% of the landscape (Banner et al. 1986, 1988). Small low-gradient streams are very common, draining the extensive slope/blanket bogs. There are many small, but few large, estuaries and floodplains, because watersheds are small and primarily rain-fed (McKenzie et al. 2000). Exposed marine shores, some supporting unique ecosystems, are common. The Insular and Coast Mountains contain a variety of freshwater ecosystems, including small, steep headwater streams and gullies, running down into fans and wide floodplains. Moderately-sized linear lakes head some valleys and a variety of small wetlands dot floodplains. Large estuaries, fed by rivers, rain, glaciers, and permanent snow are common (MacKenzie et al. 2000).

Marine Zonation - There is a strong estuarine gradient across study area, from the freshwater discharges into fjords, across the protected continental shelf to the outer continental shelf. Fjord zones are very common, nearly all large rivers empty into fjords, rather than directly onto the continental shelf. A nearshore zone surrounds all the islets, islands and mainland, with a strong intertidal zone as the dominant interface between land and sea. Extreme wind and wave exposure occurs on the west coast of the Queen Charlotte Islands, whereas more protected coasts occur in the Dixon Entrance, Hecate Strait, Queen Charlotte Strait and inshore areas. Most of the continental slope is dominated by mesopelagic zonation with a surface, epipelagic layer.

Fauna - Mountain goats are widespread but restricted to rugged areas in the Coast Mountains. Black bears occur throughout the region, wolves are absent from the Queen Charlotte Islands, cougars are absent from the Boundary Ranges and Queen Charlotte Islands, while grizzly bears occur only on the mainland except in the south where they have been extirpated. The sea otter was once one of the most abundant shellfish predators, and the river otter is still numerous and very widespread. Northern sea lions and harbour seals occur along the coastal areas and the killer whale is a common inhabitant. Characteristic small terrestrial mammals include the Keen's myotis, and mink. There are many distinct island races of Townsend's vole and white-footed mouse.

The Coast and Mountains Ecoprovince holds the second highest number of birds in British Columbia, supporting 79% of all species known to occur in the province and 57% of those species known to breed. Waterbirds make extensive use of the coastal wetlands as well as nearshore and offshore habitats, including islands, islets, and cliffs. The colonial breeding seabirds are of note, and many of those species breed nowhere else in Canada. Offshore habitats provide feeding sites for pelagic birds like the Black-footed Albatross, Sooty Shearwater, jaegers, Northern Fulmar, gulls, and some shorebirds. Breeding Red-throated Loons and Spotted Owls are mostly restricted to this Ecoprovince. Some resident species, including the Bald Eagle, Peregrine Falcon, and Black Oystercatcher, contain significant portions of their world populations here. In winter, the estuaries and shores support most of the world's population of Trumpeter Swans and Barrow's Goldeneyes. The coast is also an important corridor for millions of migrating birds, especially shorebirds and waterfowl. The Towsend's Warbler is a high density breeder on the Queen Charlotte Islands. The Western Flycatcher is a high density breeder on the Queen Charlotte Islands.

The centre of abundance of the northwestern garter snake occurs here. The rough-skinned newt, northwestern salamander, western red-backed salamander, ensatina, clouded salamander, and red-legged frog are amphibians whose range is mostly restricted to the Coast and Mountains Ecoprovince.

This Ecoprovince supports a wide variety of fish, from purely oceanic species such as rockfish, sole, Pacific herring, Pacific halibut and spiny dogfish, to fish that spawn in freshwater, but live as adults in marine waters, such as the Pacific salmon, steelhead, coastal cutthroat trout and eulachon, through to the species that only live in fresh water, such as Coast Range and torrent sculpin. In addition to fish the marine environment supports a wide variety of clams, barnacles, shrimp, crabs, starfish and jellyfish

1.2.8 The Coast Information Team

The Coast Information Team (CIT) has been established to provide independent information on the region using the best available scientific, technical, traditional, and local knowledge. It was set up by the Provincial Government of British Columbia, First Nations of the region, environmental groups, and forest products companies. It is led by a management committee consisting of representatives of these bodies; and is funded by the Provincial Government, the environmental groups and forest products companies, and the Federal Government of Canada. The technical team comprises nine project teams consisting of scientists, practitioners, and traditional and local experts, supported by a secretariat. The secretariat includes an executive director, a project manager, and other part-time staff.

The CIT's information and analyses are intended to assist First Nations and the three ongoing subregional planning processes to make decisions that will achieve ecosystem-based management (EBM), defined as "an adaptive approach to managing human activities that seeks to ensure the coexistence of healthy, fully functioning ecosystems and human communities". Two of the subregional processes are run by the provincial government; the other is run jointly by the province and the Haida. They involve governments (First Nations, provincial, local) and a wide range of sectors (environment, fishing, forestry, labour, mining, recreation, small business, tourism). These communities and sectors are the CIT's "stakeholders," consultations with whom are organized by the planning processes concerned.

1.2.8.1 Components of the CIT

The CIT began work in January 2002 and is due to finish by December 2003, after which it will cease to exist. Its program consists of three types of information:

1. Ecosystem-Based Management (EBM) guides

An *EBM Framework* defines EBM, sets out principles to guide its implementation, and sets out goals, objectives, and key elements of EB planning and the transition to EBM.

2. Spatial analyses

An *Ecosystem Spatial Analysis* (ESA) identifies key areas for biodiversity conservation, focusing on representation of land, freshwater, and marine ecosystem types; protection of special elements such as rare or at-risk species and places; and maintenance of the critical habitats of focal species such as grizzly bear, marbled murrelet, and salmon.

A *Cultural Spatial Analysis* identifies key areas for sustaining the cultural values of First Nations and other communities, notably sustenance, heritage, spiritual, and recreational values.

An *Economic Gain Spatial Analysis* identifies key areas for economic development, focusing on fisheries and aquaculture, minerals, nontimber forest products, timber, and tourism.

3. Integrated analyses

A *Wellbeing Assessment* measures current environmental and human conditions in each of the eight subregions that make up the CIT analysis region, to provide a context for decision making, a test of options and scenarios, and a baseline for monitoring implementation of the plans and progress toward EBM and sustainability. It also places the region in a global context and identifies features of global significance.

Options and Scenarios (CIT QUEST) will identify combinations of key areas for ecosystem protection, cultural values, and economic gain that have the highest probability of maintaining ecosystem integrity and improving human wellbeing. Planning processes will be able to use CIT Quest to explore different options and scenarios interactively.

An *Institutional Analysis* will examine institutional needs and constraints and additional actions required to achieve the goals of EBM.

1.2.9 The CIT Ecosystem Spatial Analyses

The purpose of the ESA is to identify priority areas for biodiversity conservation. The analysis is designed to serve the well-accepted goals of conservation summarized earlier. In pursuit of these goals, the ESA will integrate 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 suitability models are available or can be constructed.

For the CIT ESA, our challenge was to conduct an analysis of special elements, ecosystem representation, and focal species, and create a spatially explicit assessment of where the region's biodiversity values are located and what condition they are in. This information can then be used to create a conservation solution or "portfolio" of landscapes and seascape, which when taken together and managed appropriately, will ensure the long-term survival of the region's biodiversity. In order to perform this assessment, the three-track approach was applied to freshwater, terrestrial, and marine environments using the following process:

1. Select conservation targets (e.g., special elements, focal species and ecological systems) that will be used to characterize the biodiversity values within the study area. These targets are essentially surrogates for overall biodiversity, which cannot be measured in its entirety.

2. Collect data for special element occurrences, develop habitat suitability models for focal species, and create ecosystem classifications that can be used to map the distribution of targets within the study area.

3. Using available data and simple models, assess the potential viability of targets and map human impacts in the region

4. Set conservation goals to serve as benchmarks for identifying conservation priorities and as initial hypotheses about the level of effort and land allocation required to conserve biodiversity.

5. Integrate information for special elements, ecosystem representation, and focal species in each of freshwater, terrestrial, and marine environments to create a spatially explicit assessment of conservation values for the study area.

6. From that assessment, use goals and viability measures to develop options for creating a portfolio of conservation areas that will effectively conserve the region's biodiversity in the long term.

This type of rigorous analysis employs and integrates many thousands of pieces of detailed information. It requires location-specific information for conservation targets as well as the past, current, and potential future status of lands where they occur. Our team used the best available information for this assessment but recognizes that new and more comprehensive data will continually become available. Therefore, the ESA should be regarded as an initial step in an iterative assessment process.

2.0 CONSERVATION TARGETS

2.1 The Three Track Approach to Setting Conservation Targets and Goals

Over the last few decades, many scientific approaches have been applied to the task of identifying conservation targets and settling conservation goals. Most of these approaches fall into the three general categories or tracks noted earlier as forming the basis of the comprehensive approach applied in this ESA: 1) protection of special elements; 2) representation of environmental variation, i.e., habitats; and 3) conservation of focal species.

Each of these three approaches—or even different ways of conducting a given approach—arrives at a unique set of conservation priorities, which are often difficult to reconcile with the priorities established by other methods. Someone interested in rare plants, for instance, will arrive at different conservation priorities from someone interested in songbirds; both will differ in their conclusions from someone interested in representing examples of all plant communities in reserves or maintaining a viable population of grizzly bears. The data sought to fulfill these goals also will vary greatly in type, spatial scale and resolution, and completeness. Few previous regional conservation plans have combined all three tracks and their associated data, yet such a combination is necessary to make fully informed decisions about land and water allocation and management (see Noss et al. 2002). Moreover, applying a diversity of approaches in conservation planning spreads the risk of failure of any single approach and potentially achieves a more comprehensive set of goals (Lindenmayer et al. 2002, Noss et al. 2002).

2.1.1 Special Elements

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

The Nature Conservancy (U.S.) and the Nature Conservancy of Canada traditionally emphasized a special elements approach, often referred to as the "fine filter" (Noss 1987), although they have today expanded to an ecoregional planning strategy as summarized earlier (Groves et al. 2002, Groves 2003). In the fine filter, individual occurrences of imperiled species (which may or may not correspond to populations), communities, and other features are located, mapped, and targeted for protection. The fine-filter approach works well for plants and small-bodied animals, especially in regions where biodiversity databases (e.g., conservation data centers) are reasonably complete. It is not as well suited for large-bodied or wide-ranging animals, such as grizzly bears, salmon or northern goshawks, whose needs cannot be captured by occurrence data. In all cases, the fine filter is dependent on reasonably comprehensive, or at least well-distributed, biological surveys to be most useful. Although surveys are not comprehensive for most of Canada, to neglect areas known to be rich in biodiversity or other ecological values simply because survey data across the region in question are incomplete would be foolhardy. A precautionary approach would protect known hotspots. Hence, the fine filter remains valuable (indeed necessary, if not sufficient) even in relatively poorly surveyed regions.

2.1.2 Representation

In contrast to the fine-filter or special elements approach, the "coarse filter" is intended to protect high-quality examples of all ecosystems in a region. If applied to small, localized occurrences of imperiled natural community types, as it often has been in practice, the coarse filter is really no different from the fine filter or special elements approach. If applied on a landscape scale, however, with the notion of representing all ecosystems in a region across their natural range of variation along environmental gradients, the coarse filter is complementary to special-elements conservation (Noss 1987, Hunter et al. 1988, Hunter 1991).

The coarse filter is an example of the representation strategy, the history of which extends back to the late 19th century in Australia and the early 20th century in North America (Noss and Cooperrider 1994, Scott 1999). One of the strongest arguments for the representation strategy is that it is likely to capture species, genes, communities, and other elements of biodiversity that are poorly known or surveyed. Bacteria, fungi, bryophytes, and many invertebrate groups, for instance, would rarely be considered in the special elements track, simply because data on their distributions are not available. In a sense, the coarse filter serves as a buffer for our ignorance about biogeography (Hunter 1991).

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

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

2.1.3 Focal Species

Detailed consideration of the habitat requirements and population dynamics of individual species constitutes a third track in science-based conservation planning—focal species. Focal species analysis complements the special elements and representation tracks by addressing questions concerning the size and configuration of reserves and other habitats necessary to maintain viable populations. The focal species approach can be distinguished from the species component of the special elements track, in that habitat suitability and population viability are modeled and extrapolated beyond currently known occurrences and, usually, beyond the present time. To date, however, focal species analysis is the track most often missing from conservation plans, which often consider only special elements and/or habitat representation. Hence, many conservation plans prepared with the use of site-selection algorithms feature fragmented designs and lack the habitat area and connectivity required by certain focal species (Briers 2002, Noss et al. 2002).

It is through modeling of habitat suitability and population viability that focal species are most useful in conservation planning. Modeling approaches for focal species may be either static or dynamic; for greatest utility, both types of models should be spatially explicit and GIS-based. Static habitat suitability models, such as those employed in this study, can be either conceptual models, based on existing literature and expert opinion about species-habitat relationships, or empirical models, e.g., resource-selection functions built by associating occurrence data with potential predictor variables through multiple logistic regression or other statistical techniques (Manly et al. 1993, Boyce and McDonald 1999, Carroll et al. 2001). Data needs for empirical models include an adequate sample of point occurrences for the species in question and GIS databases on a variety of potential predictor variables, including vegetation, topography, climate, prey availability (or a surrogate thereof), metrics derived from satellite imagery, and human-impact variables such as population density and roads (Carroll et al. 2001, Noss et al. 2002, Carroll et al. in press).

Dynamic population models useful in conservation planning include the several kinds of spatially explicit population viability analyses (PVAs) (Beissinger and McCullough 2002). These models are typically more time-consuming and difficult to construct than static models, and require more information on the demographic characteristics of each focal species. Hence, our focal species models do not explicitly consider population viability. We recommend that dynamic population models for selected species be developed in the future.

2.2 Terrestrial Targets

2.2.1 Special Elements

2.2.1.1 Methods

Special element ("Fine filter") targets were selected based on global, national, and provincial conservation status within the larger ecological boundaries of the Coast and Mountains Ecoprovince (COM). [2] Also targeted were "Species of Special Concern" - species or subspecies which globally are apparently secure and/or abundant (ranked G3-G5 by BC Conservation Data

[2] For an overview and description of the Coast and Mountains Ecoprovince refer to BC MSRM webpage: http://srmwww.gov.bc.ca/ecology/ecoregions/humidtemp.html#coast

Centre), but within the COM exhibit the following characteristics: exhibit significant, long-term declines in habitat/and or numbers, are subject to a high degree of threat, or may have unique habitat or behavioural requirements that expose them to great risk; are restricted to the COM (or a small geographic area within the ecoprovince), depending entirely on the ecoprovince for survival, and therefore may be more vulnerable than species with a broader distribution; have populations that are geographically isolated from other populations; are more widely distributed in other ecoprovinces but have populations in the COM at the edge of their geographical range; are usually abundant and may or may not be declining, but some aspect of life history makes them especially vulnerable – e.g., migratory concentration or rare/endemic habitat; have spatial, compositional, and functional requirements that may encompass those of other species in the region and may help address the functionality of ecological systems; are unique, irreplaceable examples for the species that use them, or are critical to the conservation of a certain species or suite of species; are critical migratory stopover sites that contain significant numbers of migratory individuals of many species (Comer 2001, Groves et al. 2002, TNC 2000). Table 2.1. summarizes the details of target selection criteria.

2.2.1.1.1Data collection

A database was created with information on species and communities obtained from BC Conservation Data Centre (BC CDC), BC Ministry of Forests, Committee On the Status of Endangered Wildlife In Canada (COSEWIC), Partners In Flight, and NatureServe databases, a review of BC coastal land use planning documents, pertinent research (e.g. Douglas et al. 2002, Lomer and Douglas 1998, Calder and Taylor 1968, Campbell et al. 1990, Cannings and Ptolemy 1998, Cannings et al. 1999), and interviews with species and communities experts. This database was then reviewed by staff from the BC Conservation Data Centre, the BC Ministry of Water, Land and Air Protection, the BC Ministry of Sustainable Resource Management, BC Ministry of Forests, and the Royal BC Museum. As well, target lists were reviewed by planning team members.

Table 2.1 Special elements target selection criteria.

Criteria	Rank	Description
Global conservation status	G1-G3; T1-T3	1 = Critically Imperilled either because of known threats or declining trends, or because extremely restricted breeding or non-breeding range make the element vulnerable to unpredictable events, a candidate for 'endangered' status; 2 = Imperilled, a candidate for 'threatened' status; 3 = Vulnerable – usually more abundant or widespread than 1 or 2, but sensitive to threats, perhaps declining (BC CDC, NatureServe)
Subnational (provincial) conservation status	S1-S3	
National conservation status (Committee On the Status of Endangered Wildlife In Canada)	E T SC	Endangered (E) – A species facing imminent extirpation or extinction. Threatened (T) – A species likely to become endangered if limiting factors are not reversed. Special Concern (SC) – A species that is particularly sensitive to human activities or natural events but is not an endangered or threatened species (COSEWIC 2003).
Provincial listing (BC Conservation Data Centre)	Red Blue	Red – includes any indigenous species or subspecies that have, or are candidates for Extirpated, Endangered, or Threatened status in British Columbia. Extirpated taxa no longer exist in the wild in British Columbia, but do occur elsewhere. Endangered taxa are facing imminent extirpation or extinction. Threatened taxa are likely to become endangered if limiting factors are not reversed. Blue – includes any indigenous species or subspecies considered to be of Special Concern (formerly Vulnerable) in British Columbia. Taxa of Special Concern have characteristics that make them particularly sensitive or vulnerable to human activities or natural events. Blue-listed taxa are at risk, but are not Extirpated, Endangered or Threatened.
Partners In Flight Score (for Bird Conservation Region 5 – Northern Pacific Rainforest)	Sum of Vulnerability Factors. Scores for each factor range from 1 (low vulnerability) to 5 (high vulnerability).	Relative Abundance – reflects the abundance of breeding individuals of a species, within its range, relative to other species; Breeding Distribution – reflects the global distribution of breeding individuals of a species during the breeding season; Non-breeding Distribution – reflects the global distribution of a species during the non-breeding season; Threats to Breeding – reflects the effects of current and future extrinsic conditions on the ability of a species to maintain healthy populations through successful reproduction. Threats to Non-breeding – reflects the effects of current and future extrinsic conditions on the ability of a species to maintain healthy populations through successful survival over the non-breeding season; Population Trend – reflected by the direction and magnitude of changes in population size over the past 30 years; Area Importance – reflects the relative importance of an area to a species and its conservation, based on the abundance of the species in that area relative to other areas.
Special Concern	Declining Endemic Disjunct Peripheral Vulnerable Umbrella species Species aggregations	Declining - exhibit significant, long-term declines in habitat/and or numbers, are subject to a high degree of threat, or may have unique habitat or behavioural requirements that expose them to great risk; Endemic - are restricted to the COM (or a small geographic area within the ecoprovince), depending entirely on the ecoprovince for survival, and therefore may be more vulnerable than species with a broader distribution; Disjunct - have populations that are geographically isolated from other populations; Peripheral - are more widely distributed in other ecoprovinces but have populations in the COM at the edge of their geographical range; Vulnerable - are usually abundant and may or may not be declining, but some aspect of life history makes them especially vulnerable – e.g., migratory concentration or rare/endemic habitat; Umbrella species - have spatial, compositional, and functional requirements that may encompass those of other species in the region and may help address the functionality of ecological systems; Species aggregations - are unique, irreplaceable examples for the species that use them, or are critical to the conservation of a certain species or suite of species; Globally significant examples of species aggregations - are critical migratory stopover sites that contain significant numbers of migratory individuals of many species.

2.2.1.1.2Target list

The terrestrial special elements database consists of 110 targets (75 vascular plants, 9 birds, 5 mammals, and 21 rare plant communities), which met the criteria outlined previously. Spatial data was obtained for 72 targets. Table 2.2 provides a summary of the final terrestrial fine filter targets database.

Table 2.2 Summary of terrestrial fine filter targets.

Taxa	Targets with spatial data/ total # targets	# of targets ranked G1-G3; T1-T3	Endemics	# of targets ranked Red or Blue (BC CDC)	# of targets ranked Endangered, Threatened, or Special Concern (COSEWIC)	# of element occurrence records
Birds	5/9	7	8	9	1	150
Mammals	3/5	3	2	5	4	5
Vascular Plants	52/75	20	9	75		205
Rare plant communities	12/21		21	21		10
TOTAL	**72/110**	**30**	**40**	**110**	**5**	**370**

2.2.1.1.3GIS data

Spatial data was collected from all available sources. The majority came from the BC Conservation Data Centre (>90%), which collects and maintains data on rare and endangered species in the province (Map 4). The datasets were screened based on data quality. CDC element occurrence records ranked as "low quality", extinct, extirpated, or historic (BC CDC codes D, E, EI, H, X, and X?) were removed from the final GIS dataset. As well, animal occurrence data >25 years and plant occurrence data >40 years were deleted (Rumsey et al. 2003, TNC 2000). Appendix 1.3.1.1 details the complete list of special elements.

2.2.1.2 Results and Discussion

Spatially, the majority of the special elements data are located on Haida Gwaii/QCI where there are 227 element occurrence records. The North Coast contains 49 records and the Central Coast has 94 records. Most of these special element occurrences are vascular plants and rare plant communities. Calder and Taylor (1968) surveyed Haida Gwaii/QCI on several occasions where they identified 593 vascular plants. As well, the BC Conservation Data Centre conducted surveys in 1997 and 1998 to locate and document the size and condition of provincially rare native vascular plant populations where they increased the number of identified taxa to 665 (Lomer and Douglas 1998). Although the CDC and Ministry of Forests maintain a database of rare plant associations from biogeoclimatic mapping, there was very little spatial data on rare plant communities.

The special elements analysis highlights the scarcity of occurrence data on much of the BC coast. The majority of element occurrence data is on Haida Gwaii/QCI reflecting an uneven distribution of surveying effort. There is also a concern that many of the occurrence points are near roads, possibly reflecting a surveying bias. Instead of using the fine filter data as an input to the SITES runs, a post hoc analysis was conducted by overlaying the fine filter data on the SITES outputs to determine how well the analysis captured the fine filter element occurrences. Although there are concerns regarding biased survey data we still need to protect the locations of special elements where we have location data.

2.2.1.3 Recommendations

2.2.1.3.1 Initial Conservation Goals

For future iterations of this plan and other planning efforts in the region, given the state of our limited knowledge on target viability and population dynamics, we recommend establishing initial conservation goals for special elements, then refining these goals as much as possible with target-by-target information (Comer 2001).

Initial conservation goals were set for terrestrial targets based on their geographic scale, distribution and spatial pattern. Initial conservation goals are an attempt to represent the "natural" or historic range of distribution for the target. For example, if 50% of the known, natural range of the target falls within the ecoprovince, the goal for the ecoprovince should reflect roughly 50% of a range wide goal. The target's distribution, relative to the ecoprovince is used to establish numeric differentials in goal setting – i.e. higher with endemic, to lower with peripheral (Comer 2001, TNC 2000, Rumsey et al. 2003). Table 2.3 outlines the matrix used in setting initial conservation goals.

Table 2.3 Initial conservation goals for terrestrial species targets stratified by ecosection [3] (Comer 2001).

Spatial Pattern [4]	Regional Scale	Coarse Scale	Intermediate Scale	Local Scale
Distribution [5]	Case-by-case, defining core and connecting habitat components	(# of occurrences stratified by ecosection)		
Endemic		10	18	25
Limited		5	9	13
Disjunct		5	9	13
Widespread		3	5	7
Peripheral		1	2	3

2.2.1.3.2Data Gaps

The fine filter analysis was lacking in invertebrate data. No sources for location data were found. Coastal temperate rainforests are known to have very high invertebrate biodiversity (Scudder 1996). However, targeting old-growth forests in the focal ecosystems analysis, supplemented by focal-species modeling, will presumably capture the majority of rare and endangered invertebrates. There are also a number of rare and endangered lichens that were not included in the fine filter database. Although these are outlined in "The Lichens of British Columbia" by Goward (1999), we were not able to obtain or create digital files for these locations. Haida Gwaii/QCI is one of the few areas where comprehensive lichen studies have been carried out (Goward 1999).

2.2.2 Representation

2.2.2.1 Background and Rationale

Coastal British Columbia, a region characterized by moderate climates, high rainfall (192 cm or more), 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

[3] Refer to BC MSRM webpage for ecosection descriptions -- http://srmwww.gov.bc.ca/ecology/ecoregions/coast

[4] Local = typically include all/most plants, invertebrates, herps, and small mammals. They are often associated with "small patch" and "large patch" terrestrial ecosystems, and small lake/stream systems. These localized occurrences are efficiently represented on maps as points; Intermediate = include small/medium-size mammals, birds, and fish, and some herps. They are often associated with "large patch" and "linear" terrestrial ecosystems, and medium-size lake and river systems. These targets can be represented as polygons of "occupied habitat" (e.g., lines for river-dwelling fish). In some instances, point locations may suffice; Coarse = typically include medium-size mammals, birds, and fish. They are often associated with "matrix-forming" terrestrial ecosystems, large lakes and medium-large river systems. These targets are represented as polygons (or lines) of "occupied habitat."; Regional = typically include large mammals and fish associated with diverse and extensive complexes of terrestrial, aquatic, and marine ecosystems. These targets are represented as polygons (or lines) of "potentially occupied habitat" and where possible, polygons of specific habitat components.

[5] Endemic = >90% of global distribution in ecoprovince; Limited = global distribution in 2-3 ecoprovinces; Disjunct = distribution in ecoprovince quite likely reflects significant genetic differentiation from main range due to historic isolation; roughly >2 ecoprovinces separate this ecoprovince from central parts of it's range; Widespread = global distribution >3 ecoregions; Peripheral = <10% of global distribution in ecoregion.

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.

Coarse-filter approaches described here are designed to identify regional-scale or system-scale biodiversity features (e.g. biogeoclimatic and general ecological system or floristic types), rather than specific, fine-scale, vegetation community types or species, assuming that the broader-scale biodiversity surrogates sufficiently represent the finer-scale aspects of biodiversity (Pressey and Logan 1994, Pressey 1994, Williams and Humphries, 1996, Wessels et al. 1999, Fairbanks and Benn 2000, Fairbanks et al. 2000). Moreover, representing a full spectrum of abiotic types 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 et al. 1992, Panzer and Schwartz 1998). To address these shortcomings, we suggest that coarse-filter approaches can be used in combination with finer-scale species and ecosystem distribution information. However, because such fine scale information is patchy, with limited spatial coverage, such data has limited utility for initial phases of regional conservation planning efforts, such as for driving optimization portfolio models (e.g. SITES), since areas selected would be based largely on the presence or absence of data rather than representation. We suggest that such fine-scale information can be used as an integral part of representation analysis, specifically for post-optimization, verification of representation. This two-step approach has the advantage of utilizing the best available data in a scale-appropriate manner. This approach also has the advantage that combinations of physical and floristic information sets can be created without the need for laborious and groupings into specific ecological systems and plant community types.

Thus, we developed two independent methods to identify and represent different coarse-filter components of terrestrial ecosystems. The first was based on biogeoclimatic zone, subzone and variant information combined with seral stage and site productivity information. 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.

2.2.2.2 Methods

In BC, two different, but complementary regional ecosystem classification systems exist. The ecoregion/ecosection classification, developed by the B.C. Ministry of Environment, Lands and Parks, describes broad regional ecosystems based on the interaction of climate and physiography. The Biogeoclimatic Ecosystem Classification (BEC) delineates ecological zones (biogeoclimatic units) by vegetation, soils, and climate. We used both systems and applied two independent classification methods, described in the sections below.

2.2.2.2.1 Terrestrial Ecosystem Analysis Units: Biogeoclimatic, Site Productivity and Seral Stage

The Biogeoclimatic Ecosystem Classification (BEC) delineates ecological zones (biogeoclimatic units) by vegetation, soils, and climate (Pojar et al. 1987, Meidinger and Pojar 1991, Map 5a). We combined BEC information with site productivity (taken from site index in the BC forest cover data), to delineate terrestrial ecosystems, with the assumption that site productivity correlates with areas that have climax, or old growth, ecosystem characteristics (including canopy structure and understory vegetation and associated faunal community types). Because both BEC and site index rely largely on physiognomic characteristics, the relative impacts by ecosystem type can be predicted, without knowledge of the type of vegetation that was present before the areas were logged. Note that here we also assume that impacted areas of the same BEC and site index as intact areas will have similar old growth characteristics and we also assume a relatively low level of natural disturbance (e.g. infrequent fires, Morrison and Swanson 1990) in BC coastal forest ecosystems. An advantage of application of this method is the capacity to identify matched ecosystems in both intact and impacted areas, because many of the best examples of coastal temperate rainforest ecosystems were targeted for logging because of the economic value and accessibility of particular areas, and in many cases, few examples of intact ecosystems remain (see

Table 2.4). This method also allows us to preferentially identify and represent intact areas, and then represent comparable impacted areas for potential modified, only if necessary in order to meet ecosystem representation goals.

Site index was grouped into three classes (Low = 1 –14, Medium = 15 – 21 and High > 22). BEC zones were taken from the BC biogeoclimatic classification coverage. We treated separate variants and subzones as separate units because in some areas, variants were not defined (e.g. CWHvh1 and CWHvh were treated as different BEC zones, see Table 2.4). Logging data was taken from a mixture of forest cover and SSPEM, combined with Sierra Club B.C. image analysis to determine intact and impacted areas. Because our logging data was derived from multiple sources, logged areas often overlapped with defined old forest (i.e. age class > 7) areas in the database. We considered such areas as logged and set age class = 1, and considered these areas to have been logged. Thus, Seral stage is also implicit in this classification system and we defined 3 seral stages: old growth forest (age class > 7), young intact forest (age class < 8 and unlogged), and logged forest. Historical abundance of each ecosystem type was calculated as the sum of area for all seral stages (Map 5b).

Table 2.4 Biogeoclimatic zones (based on zone, subzone and variant) and logging impacts by site productivity.

Biogeoclimatic zone - subzone/variant	Area (ha)	Forested area (ha w/ known SI and ITG)	Percent Logged: Low (Site Index = 1 – 14)	Percent Logged: Med (Site Index = 15 –22)	Percent Logged: High (Site Index > 22)
AT	95,335.25	45,111.50	0.03%	0.00%	0.00%
CWHdm	65,501.00	18,830.00	71.01%	90.32%	72.67%
CWHds1	50,158.00	Unknown			
CWHds2	68,184.00	51,608.50	7.28%	57.92%	27.23%
CWHmm1	8,855.50	7,679.00	61.00%	95.09%	85.93%
CWHms1	45,382.25	Unknown			
CWHms2	112,958.75	109,917.50	11.77%	53.73%	27.62%
CWHvh1	116,426.25	103,273.00	7.50%	88.75%	45.82%
CWHvh2	1,519,127.00	1,439,084.75	0.78%	28.41%	13.25%
CWHvm1	200,350.75	130,040.75	9.59%	68.47%	37.55%
CWHvm2	807,201.50	734,927.50	1.35%	21.55%	9.37%
CWHvm3	476,753.50	419,905.25	0.89%	48.53%	6.16%
CWHvm	49,751.50	48,426.50	2.99%	35.43%	9.07%
CWHwh1	484,662.75	437,232.25	2.08%	39.31%	13.30%
CWHwh2	79,459.25	62,609.75	3.63%	67.06%	10.39%
CWHwm	126,119.75	94,017.75	0.77%	0.84%	4.40%
CWHws1	172,983.00	118,936.50	24.50%	58.99%	66.14%
CWHws2	495,181.75	318,803.25	2.83%	51.91%	23.22%
CWHxm2	49,345.00	28,792.25	92.08%	83.65%	90.10%
ESSFmc	513.00	509.50	0.25%		
ESSFmcp	165.00	164.75	0.00%		
ESSFmk	79,368.75	59,027.25	0.00%		0.00%
ESSFmkp	2,944.50	2,924.75	0.00%		
ESSFmw	43,728.25	11,804.25	0.03%	0.00%	0.00%
ESSFwv	134,902.00	132,519.50	0.65%	3.07%	38.26%
ESSFwvp	9,014.75	8,828.50	0.00%	0.00%	0.00%
ESSFxv1	5,188.50	Unknown			
ICHmc1	18,464.25	17,161.50	3.93%	30.14%	56.68%
ICHmc2	139,536.00	110,590.00	10.39%	15.41%	30.60%
IDFdw	3,497.75	Unknown			
IDFww	1.75	Unknown			
MHmm1	380,487.25	276,743.50	0.20%	7.26%	1.30%
MHmm2	393,276.50	234,213.75	0.35%	63.39%	10.25%
MHmmp	38,283.00	37,362.25	0.00%	0.00%	0.00%
MHwh1	68,487.75	62,439.25	0.10%	19.48%	1.77%

			Percent Logged		
Biogeoclimatic zone - subzone/variant	**Area (ha)**	**Forested area (ha w/ known SI and ITG)**	**Low (Site Index = 1 – 14)**	**Med (Site Index = 15 –22)**	**High (Site Index > 22)**
MHwh2	16,714.00	8,859.00	2.81%	50.39%	5.86%
MHwhp	4,835.50	4,668.00	0.00%	0.00%	0.00%
SBSdk	4.25	4.25			100.00%
SBSmc2	121.75	117.25	5.00%		2.25%

Goals for SITES were set varying from 30% to 70% representation in 10% increments based on historical abundance of ecosystem type. However, for some ecosystem types, the representation goal exceeded the remaining intact forest. For example, 88.75% of medium productivity - CWHvh1 has been impacted (see Table 2.4), so even a 30% representation goal would exceed the remaining intact forest of this type. Representation targets were selected from areas that had both Site Index and Species information (i.e. with known vegetation information), to eliminate bare rock and ice areas. We applied the following rules for goal-setting:

- If a representation goal can be met using intact areas (i.e. target ≤ remaining forest), no goal was set for logged areas; goals for remaining forest were based on historical abundance estimates.
- If impacts equal or exceed 85%, the remaining old growth forest and young intact forest goals were set to 100%, and the goal for logged forest was set as the difference between the overall representation target area and the remaining intact forest area. This can be expresses as the following formula:
  - Logged forest area target (ha) = representation goal /100 * historical area (ha) – (old growth (ha) + intact young forest (ha))
- Where impacts were less than 85%, a 95% target was set for intact areas, with remaining representation target set using logged areas as above.

2.2.2.2.2Focal Ecosystems: Floristic, Structural and Ecosection Combinations

To complement the Site Productivity and BEC method for identifying ecosystems, we combined floristic and structural data to identify focal ecological systems (Map 6). At least twenty-five species of conifers and inhabit the coastal rainforest of BC and we used size class, inventory type group and age class define and delineate stands of old-growth and woodland areas 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 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 2.5 and 2.6) and ecosection. Goals for focal ecosystems were varied from 30% to 70% in 10% increments.

Table 2.5 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	

ITG	ITG_desc	Alliance	Ecological System
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

Table 2.6 Focal ecological system structure classes.

Height Class	Age Class	Structure
> 4	>7	High Volume Old Growth
= 3,4	>7	Med Volume Old Growth
< 3	Any Intact	Woodland

2.2.3 Focal Species: Marbled Murrelet (*Brachyramphus marmoratus*) Nesting Habitat Suitability

2.2.3.1 Background and Rationale

The Marbled Murrelet (*Brachyramphus marmoratus*) is a small brown alcid whose biology has given it an unusually important role in resource management in British Columbia. Unlike other auks it occurs regularly throughout all of the nearshore waters of coastal BC. Where food is concentrated by currents or tidal rapids, it may occur in the hundreds. It is the only auk to be found in large numbers (200-700) in the coastal fiords and is often the most abundant water bird in those areas. The murrelet usually feeds on small marine fish, such as sand lance (*Ammodytes hexapterus*), juvenile Pacific herring (*Clupea harengus*), northern anchovy (*Engraulis mordax*) and immature rockfish (*Sebastes* spp.) but it will also take large zooplankton, such as euphausiids (Burger and Chatwin, 2002). Current population estimates for British Columbia are about 76,000 birds. The BC population is much larger than those in Washington, Oregon, and California combined but less than 5% of the Alaska population.

In spite of their apparent abundance and wide distribution, the murrelet is the only seabird listed by the Committee On the Status of Endangered Wildlife In Canada (COSEWIC). It is also Red-listed by the BC Conservation Data Centre, and is an Identified Wildlife Management Strategy (IWMS) species under the Forest Practices Code. That paradox between abundance and the conservation status stems from features of the murrelet's breeding biology that have only recently come to light and are still not thoroughly understood. Unlike most other alcids in BC, the Marbled Murrelet does not nest colonially in underground burrows and does not nest on small offshore islands close to richer concentrations of marine resources. It nests solitarily, in trees, on the mainland, often 20 to 30 km and up to 60 km or more from the sea. However most nests are less than 5 or 10 km from salt water. The murrelet uses energetically expensive high-speed flight to make a daily commute of as much as 100 km between its nest and preferred marine foraging areas. It depends on its ability to catch calorie-dense fish such as sand lance to ignore the costs of speed and distance. It appears to be a highly effective strategy and, unlike other alcids, it does not lose weight while making the effort to feed its young.

With only a few exceptions, the nests are always in some form of old-growth forest. Radio telemetry has located several hundred nests at high elevations and on steep slopes but the murrelet also nests in the large trees of lowland forests. High elevations may help murrelets escape the attentions of ravens, jays, and flying squirrels that would take the egg or young if the opportunity arose. However, high elevation nests are a relatively recent discovery and it was the widespread loss of big-tree lowland habitat that first brought the Marbled Murrelet to the attention of the conservation community. The proportion of the population that makes use of each of those habitats, and their relative rates of reproductive success, are unknown. Because the murrelet readily commutes long distances, there is only a coarse relationship between concentrations at sea and suitable nesting habitat on land.

Murrelets prefer to nest in areas with a relatively closed canopy that has trees with more than average structural complexity. The nests are little more than shallow depressions in moss or duff on large tree limbs. They vary in elevation and aspect but typically well within the canopy and often close to the trunk of the tree. The actual nest is often partially obscured by overhanging branches. Murrelets usually approach their nests in the dark and may select sites close to highly visible (to them) landmarks such as avalanche runs, gulleys, rocky outcrops, and other forest openings.

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 increasing concern for the influences of human activity on survival at sea (Steventon, 2002). Marbled Murrelets face a growing host of marine-related impacts such as oil pollution, fisheries by-catch, and aquaculture (Robinson 2002). Effects of a strong increase in recreational boat traffic and the subsequent spread of developments such as marinas and small harbours have not been assessed. Sport fishermen snag a significant numbers of murrelets each year.

The secretive terrestrial life of Marbled Murrelets has prevented convincing demonstration of population declines. However, populations have disappeared from the Lower Mainland and parts of the Strait of Georgia. Populations appear to be smaller in the region of Barkley and Clayoquot Sounds where large oil spills, by-catch in gill nets, and logging of old-growth forests have all had potential impact. In the CIT region, the stresses on the population of murrelets appear to have been much less intense. There is no indication of decline but the population has never been studied in detail and its scale is largely a matter of conjecture. However, there has been a recent attempt to establish a practical value for the population baseline by using radar to count birds moving into specific watersheds.

The weak link between the exploitation of natural resources and variation in murrelet populations may have contributed to the bird's long-term status as a threatened species. However, the biology of the bird does not lend itself to rigorous monitoring. It appears to produce only one egg per year and suffers a fairly high predation rate but the factors driving fluctuations in natural population, if there are any, are poorly understood. As a result, changes in population status can only be measured across decades and the accurate measurement of demographic parameters is problematic. However it is clear that the murrelet will be slow to recover from any population decline that does occur.

The Marbled Murrelet was selected as a focal species for the CIT ESA because of its apparent dependence on old-growth forest and the potential negative effects of exploitation of such forest. Our general understanding of the murrelet's terrestrial habitat requirements suggest that its regional needs could be reflected by a simple model based on forest cover and other types of large scale mapping.

2.2.3.2 Methods

The model is based on one developed by the Marbled Murrelet Recovery Team for the Conservation Assessment (Part B) and IWMS species account (Marbled Murrelet Recovery Team 2003). We ran two versions of the model with the first being the "most likely" and the second being "moderately likely" to capture suitable habitat for nesting Marbled Murrelets (see Table 2.7). The first version was considered to include the habitats most likely to be preferred by the murrelets. Restrictions on elevation and distance from shore were relaxed in the second run and the habitat extended further inland. Only the "most likely" run was used for the SITES analysis.

An amalgamated forest cover dataset (1:20,000) created by BC MSRM, Resource Information Section from data submitted by timber license holders (TFLs) and the Timber Supply Area (TSA) was used to collect information on Age Class, Height Class, and Canopy Closure Class for the murrelet nesting model. For Gwaii Haanas National Park Reserve, which was missing forest cover data, we used a GIS coverage created by the Gowgaia Institute depicting an updated logging history. The Canopy Closure Class attribute, critical for running the nesting model, was missing from the forest cover data for TFL 39 on Haida Gwaii/QCI and TFL 39 on the Central Coast. A solution that correlated Height and Age Classes to Canopy Closure Class was developed that allowed us to run the model. Elevation from sea level was calculated from the TRIM DEM. We created a coverage in 100m bands and built polygons for the ranges 100-900m and >900m. Due to the large size of the dataset, for computing efficiency we split the TRIM DEM (1:20000) into 350 separate segments, ran them, and then merged them back together to calculate Distance From Saltwater.

Table 2.7 Model Structure for Marbled Murrelet habitats in the CIT study area.

Criteria		Run 1 ("most likely")	Run 2 ("most + moderately likely")
Distance from Salt Water		0 – 30 km	0 – 50 km
Elevation	Central and North Coast	0 – 600 m	0 – 900 m
	Haida Gwaii/QCI	0 – 500 m	0 – 800 m
Stand Class		8 & 9 (>140 years)	8 & 9 (>140 years)
Stand Height Class		4 + (>28.5 m)	3 + (> 19.5 m)
Canopy Closure Class		4, 5 and 6	3 - 7

2.2.3.3 Results and Discussion

The model showed a widespread and generalized distribution of murrelet habitat without any strong concentrations or significant isolated pockets (Map 7). As might be predicted from the model criteria, there was a strong tendency to include all lowland areas and valley bottoms. 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 also suggested the presence of murrelet nesting habitat on small or low-lying islands and at various exposed localities along the coast. It is extremely unlikely that such sites are used by murrelets because of heightened levels of predation and the risk of storms destroying the nest. However, the total amount of habitat represented by such sites is insignificant. Their existence does suggest the possible inclusion of other unlikely sites further inland and the model should not be used at a finer scale than 1:20,000. There is no way of verifying that the maps produced by the model match the actual distribution of murrelet breeding activity in British Columbia. However, they are consistent with a broad band of opinion on what constitutes murrelet habitat at such a coarse scale.

The model indicated the presence of 216,093 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.

2.2.3.3.1 Model Applications and Limitations

The model provides a general picture of the distribution of murrelet habitat along the coast of BC but it does not make any statements about variations in quality or usage. It may be that murrelets are fairly evenly distributed throughout their range and numbers vary in proportion to the amount of nesting habitat available but it is not very likely. At-sea observations suggest that there are a few areas (4 or 5) with regular concentrations of very large numbers of birds. These areas are hundreds of kilometers apart and travel between them is beyond the murrelet's daily commuting distance. It seems likely that those marine concentrations could form the core of higher density nesting areas. This can only be tested by widespread comparison of radar counts and the location of nests by radio telemetry.

2.2.4 Focal Species: Northern Goshawk (Accipiter gentilis) Nesting Area and Foraging Area Habitat Suitability Models

2.2.4.1 Background and Rationale

The Northern Goshawk (*Accipiter gentilis;* goshawk) is a broad-winged, long-tailed raptor of medium size adapted to forest habitats where its quick acceleration and adept maneuverability make it a highly effective direct pursuit hunter (Mahon et al. 2003). The Northern goshawk was chosen as a focal species for the CIT ESA because of its strong association with mature/old growth coniferous forests for foraging and nesting, and the possible impacts to this habitat from forestry activities.

Goshawks are found throughout circumpolar regions, and in temperate and boreal forests (Mahon et al. 2003). Within the CIT study area there are two subspecies of Northern Goshawk - the larger *Accipiter gentilis atricapillus* which is found on the mainland, and the smaller provincially red-listed *Accipiter gentilis laingi,* found on Vancouver Island and Haida Gwaii/Queen Charlotte Islands (Campbell et al. 1990), and also possibly along the Central Coast (Cooper and Stevens 2000).

Goshawks prey on a variety of birds and small mammals - including Northwestern Crows (*Corvus caurinus*) and Marbled Murrelets (*Brachyramphus marmoratus*) on the coast.[6] Goshawks typically nest in mature/old growth coniferous stands that are even-aged and have a closed canopy and open understory (Mahon et al. 2003). Fragmented forests with excessive openings favour other raptors adapted to more open habitats, some of which are predators of the goshawk (Utzig and Gaines 1998).

The Committee on the Status of Endangered Wildlife in Canada (COSEWIC) has designated the Northern Goshawk (*Accipiter gentilis)* as "Not At Risk" and the Queen Charlotte goshawk (*Accipiter gentilis laingi*) was uplisted in November 2000 to "Threatened" status. In B.C., *Accipiter gentilis laingi* is Red-listed, and the Alaska Natural Heritage Program lists it as a "Species of Special Concern. "

2.2.4.2 Methods

A goshawk breeding territory has three hierarchical components: nest area, post-fledging area and foraging area (Reynolds et al. 1992 in Mahon et al. 2003). Habitat Suitability Index (HSI) models for the Nesting Area and Foraging Area components of a goshawk territory were developed for the 3 Land and Resource Management Planning (LRMP) areas in the CIT ESA study area (North Coast, Central Coast, Haida Gwaii/Queen Charlotte Islands). The models are based on those developed by Mahon et al. (2003) for the North Coast Forest District. Model structures were based on the Habitat Suitability Index (HSI) methodology developed by the U.S. Fish and Wildlife Service (1981). In developing their models, Mahon et al. (2003) combined expert opinion, observed habitat characteristics at goshawk nest areas in the Coastal Western Hemlock biogeoclimatic zone, and relevant literature.

Goshawks consistently select key structural attributes and forest species composition for nesting habitat (for a review of these attributes, see Mahon et al. 2003). Table 2.8 lists these attributes.

Table 2.8 Key structural attributes and forest species composition of goshawk nesting habitat (Mahon et al. 2003).

Key structural attributes	Supporting literature
Mature/old growth stand structure Relatively closed canopies with corresponding open understories.	Mahon et al. 2003, Kennedy 1988, Hayward and Escano 1989, Reynolds et al. 1992.
Forest species composition	**Supporting literature**
Dominated by Western Hemlock ≥ Age Class 8 (141 years) ≥ Height Class 4 (28.5 m) ≥ Canopy Closure Class 5 (56%)	Mahon et al. 2003, Mahon and Doyle 1999, Schaffer et al. 1999.

[6] For a details on goshawk prey, see Squires and Reynolds 1997, Roberts 1997, Ethier 1999, Doyle and Mahon 2001, Mahon and Doyle 2001, Lewis 2001, Mahon et al. 2003.

For the CIT ESA goshawk models, parameters and values for the North Coast models were taken from the Mahon et al. (2003) model which covered the same area, while those for the Central Coast and Haida Gwaii/QCI models were developed with the advice of Frank Doyle, one of the developers of the North Coast Forest District model, and Erica McClaren, a goshawk researcher with the BC Ministry of Water, Land and Air Protection. The habitat ratings resulting from these models represent relative values suitable for comparisons across the CIT ESA study area.

2.2.4.2.1Nesting Area HSI Model

The Nest Area HSI model follows a limiting factor, non-compensatory approach (Mahon et al. 2003). Table 2.9 provides a description of nesting area suitability indicators.

Table 2.9 Indicators of Nest Area Suitability (Mahon et al. 2003).

Indicator	Description
Height Class	The structural maturity of a stand, and trees within a stand, form the fundamental basis for nesting suitability for goshawks. Individual trees must have large enough branches to support the nest structure. Projected stand height class was used as a surrogate for structural stage in the model.
Canopy Closure	After the fundamental requirement of a 'mature' forest stage, canopy closure is the next most important structural variable relating to nest area suitability.
Tree Species	Suitability depends on the form and structure of the trees, the stands, and varies with site and age. Overall stand forest type suitability ratings are calculated by multiplying the species rating by its percentage composition and summing the individual species ratings for all types in the stand.
Edges	Data indicates that goshawks tend to avoid locating nests near forest edges (Mahon et al. 2003). Avoidance is strongest 0-50m from a 'hard' edge. Hard edges occur where mature forest meets non-forested or early seral habitats and the difference in height was >10m. Hard edges occur around regenerating cutblocks, roads, human settlement/ development, swamps, swamp forest, wetlands, brush patches, lakes, rivers and ocean.

The equation used to calculate the nesting area suitability ratings is:

Nest Area Suitability = Height Class Rating x Canopy Closure Rating x Tree Species Rating x Edge Rating

Parameters and values used for the suitability ratings are detailed in Appendix 1.0.1.3.1

2.2.4.2.2Foraging Area HSI Model

The foraging area is the entire area used by the adults. Numerous studies conducted in coastal B.C. and southeast Alaska found that goshawk diets are dominated by prey associated with mature forests such as red squirrels, forest grouse, and passerines.[7] This favours hunting primarily in mature/old growth forest areas with high canopy closure, and a clear understory, a habitat that allows goshawks to move freely under the canopy, allows good visibility of its prey and also provides ample perches from which it hunts (Squires and Reynolds 1997 in Mahon et al. 2003). The Foraging Area HSI model follows an additive, compensatory approach (Mahon et al. 2003).

[7] Mahon et al. (2003) refer to Doyle and Mahon 2001, Mahon and Doyle 2001, McClaren 2001, Chytyk and Dhanwant 1999, Iverson et al. 1996, Lewis 2001, Austin 1993, Doyle and Smith 1994, Beier and Drennan 1997, Squires and Reynolds 1997, Good 1998, Stephens 2001

The equation used to calculate the foraging area suitability ratings is the higher value of:

Foraging Area Suitability = Height Class Rating + Age Class Rating+ Canopy Closure Rating + Elevation Rating + Slope Rating + Shoreline Rating

Or

Foraging Area Suitability = Non-Productive/Non-Forested Habitat rating

Table 2.10 provides a description of foraging area suitability indicators. Appendix 1.0.1.3.1 provides full details of parameters and values for the suitability ratings.

Table 2.10 Indicators of Foraging Area Suitability (Mahon et al. 2003).

Indicator	Description
Height Class	Mature/old growth habitats are the primary foraging habitats for goshawks. Projected height class was used to capture this indicator.
Age Class	Projected age class was used as a correlate to structural stage. Including both age and height class, recognizes their strong correlation and the weighting they influence on the model. Similar to height class, age class is assumed to approximate structural stage.
Canopy Closure Class	Moderate to high canopy closure tends to correlate to open understories, which goshawks use as flyways while hunting.
Elevation	Empirical telemetry data from Iverson *et al.* (1996) indicates that goshawks foraged less at higher elevations.
Slope	Lower gradient slopes are given a higher rating, as these are typically richer sites producing larger trees and are associated with higher prey densities. Similar to elevation this factor is weighted lightly in the model.
Shoreline	Headlands and fiords heavily bisect the CIT study area and as a result much of the area is relatively close to the shore. Goshawks appear to use the forest edge as cover as they hunt the rich diversity of prey (northwestern crow, alcids, gulls, ducks) that are available along the shoreline, and which are common prey of goshawks in these areas (Lewis 2001). Areas < 300m from shore receive a higher habitat rating.
Non-Productive & Non-Forested Habitats	Many non-forested habitats occur in the CIT study area that may be used by goshawks to forage.

2.2.4.2.3GIS and datasets

A GIS (ESRI ArcGIS and ArcView) was used to run the algorithms and spatially display the outputs of the models. The models used a 1:20,000 TRIM DEM to calculate Distance to Shoreline, Elevation, and Slope; an amalgamated 1:20,000 forest cover dataset composed of data from Timber Farm License holders (TFLs) and Timber Supply Area (TSA) in the CIT study area, to calculate Height Class, Canopy Closure Class, Tree Species, an Edge Rating, and Non-Productive/Non-Forested Habitats Ratings. Tree species were added and ranked for the Central Coast that were not used in the North Coast or Haida Gwaii/QCI models. Also, because a portion of the study area did not have Canopy Closure Class in the forest cover dataset (TFL 39 on Haida Gwaii/QCI and TFL 39 on the Central Coast), theoretical Canopy Closure Class was calculated based on Height and Age classes. The assumption was that if a tree was a certain height and age range, this correlated with its canopy closure range.

2.2.4.3 Results and Discussion

Nesting and foraging habitats from the above models are displayed in maps 8 and 9. The result of running the algorithms and GIS data was a grid with Habitat Suitability Index ratings ranging from 1 to 3, with 1 being Low, 2 being Moderate, and 3 being High Suitability nesting and foraging habitat.

2.2.4.4 Model Applications and Limitations

The Nest Area model should provide an accurate prediction of suitability at the stand level, but cannot predict probability of use (Mahon et al. 2003). The Foraging Area model is less sensitive to behavioral isolation of habitats and represents a rough index of probability of use by goshawks. However, Mahon et al. (2003) noted that overall confidence in the Foraging model is significantly lower than for the Nest Area model for several reasons. First, the Foraging Area model is a combined, multi-species prey abundance + prey availability model + goshawk use model. Therefore, it is a very general model that provides the best components and average component ratings for several factors, but loses specificity and accuracy with respect to any individual factor. Second, no local empirical data was available to support the assumptions built into the model. Third, prey abundance, prey composition, and prey availability are known to vary considerably over time (Mahon et al. 2003).

2.2.5 Focal Species: Sitka Black-Tailed Deer (Odocoileus hemionus sitkensis) Winter Range Model

2.2.5.1 Background and Rationale

The Sitka black tailed deer (*Odocoileus hemionus sitkensis;* black tailed deer) was chosen as a focal species for the Central Coast and North Coast portions of the study area because loss of old-growth forest cover has a high potential to negatively affect deer populations (Suring et al. 1992). The value of old-growth forest ecosystems to black tailed deer is directly related to the composition, structure, and productivity of these forests (Harestad 1985). 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. Along the BC coast, black-tailed deer make up a large portion of gray wolves' diets during the summer and fall months (Darimont and Paquet 2000, McCrory et al. 2003). As researchers have noted, conservation of wolves requires the conservation of prey species and their habitats (Darimont and Paquet 2000, McCrory et al. 2003). Black-tailed deer were not used as a focal species for Haida Gwaii/QCI, where they have been introduced and are destroying plant communities and ecosystems (Sharpe et al. 2002) while their numbers flourish due to the absence of their natural predators, wolves and cougars.

We targeted Sitka black-tailed deer winter range as a key component of their habitat, which acts as a limiting factor in deer abundance (see Suring et al. 1992, Darimont et al. 2003, and McCrory et al. 2003). The amount and duration of snowfall an area receives strongly influences its ability to support deer (Suring et al. 1992). For example, Mech et al. (1971) found that snow accumulations during single and consecutive winters were directly related to fawn-doe ratios and annual changes in deer populations. Other studies have also reported a correlation between snow depth and deer mortality or population levels (Severinghaus 1947, Edwards 1956 in Suring et al. 1992). Jones and Bunnell (1984) found that on northern Vancouver Island, severe winters resulted in reduced diversity of forage available to deer, restricted mobility of deer, caused mortality of deer, and lowered recruitment rates of deer.

During periods of deep and prolonged snow, deer look for old, high-volume forests on gentle to moderate slopes at low elevations (Suring et al. 1992, McCrory et al. 2003) - likely because this forest type is most effective at intercepting snowfall (Kirchhoff and Schoen 1987). Old-growth forests also provide ample winter forage, such as nutrient-rich shrubs, lichens, and litterfall (Kirchhoff and Schoen 1987). Studies in southeast Alaska have found that with increasing snowfall, deer decrease their use of open habitats such as muskegs and young clearcuts, and increase their use of old growth forests (Kirchhoff and Schoen 1987, Schoen and Kirchhoff 1990).

2.2.5.2 Methods

The CIT ESA Sitka black tailed deer winter range model is based on an "old-growth, deer winter-range" model developed by McCrory et al. (2003). We applied a GIS to spatially identify deer winter range in the study area. 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 (Sharpe et al. 2002).

The model included the following geographic datasets: forest cover data to identify Forest Type, Age Class, and Volume Class; and a Digital Elevation Model (DEM) generated from 1:20,000 TRIM maps to calculate Elevation and Slope Steepness. Table 2.11 details the model parameters and values.

Table 2.11 Sitka black-tailed deer winter range model parameters and values (McCrory et al. 2003).

Indicator	Value
Elevation	Between sea level and 500-m
Forest Type	Western hemlock (*Tsuga heterophylla*) dominated forest types.
Age classes	121-140 years to >500 years
Volume Classes	Low (151-200 m3/ha) to High (850 m3/ha)
Slope Steepness	$<40^0$

2.2.5.3 Results and Discussion

The result of the GIS modeling is a map of winter range displayed as a binary grid; cells with a value of 1 are identified as critical winter range. The model identifies 688,775 hectares of critical black tailed deer winter range in the study area (517,835 hectares are in the Central Coast, and 170,628 hectares are in the North Coast). Habitat was distributed evenly throughout the 2 LRMP areas and as expected, in areas featuring older coastal western hemlock forests including many of the islands.

The model and maps were reviewed by experts in B.C. and southeast Alaska. Review comments were consistent in 2 key areas: (1) parameter values were too general in scope; and (2) key indicators were missing from the model that could result in the model identifying the wrong areas for deer winter range habitat.

McCrory et al. (2003) omitted aspect to "reflect a wide range of winter conditions including north slopes that might be used during mild winters" (p.50). Darimont et al. (2003) in their subsequent application of the model on the Central Coast, hypothesized that aspect was highly correlated with forest type and "in steep terrain such as the topographically complex mainland of Heiltsuk Territory, aspect may not be a good predictor of sun exposure given the low angle of winter sun at this latitude" (p.6). In both reports, elevation and characteristics of the forest canopy were identified as more important variables to include in the model. However, aspect is considered an important indicator of deer winter ranges (Brunt, pers. comm., Kirchhoff, pers. comm.). The assumption that aspect was highly correlated with forest type is questionable on the grounds that variables not measured on an interval-level scale (e.g. forest types, names) cannot be statistically correlated (M. Kirchhoff pers. comm.). From an ecological viewpoint, it is doubtful that hemlock dominated forests (CWH) occur on just one aspect (or 2 or 3). Species composition is more a function of soil characteristics than aspect. For example, cedar tends to thrive on poorly drained soils, spruce dominates on alluvial and colluvial soils, and hemlock dominates on organic soils. A more even-aged stand on wind-prone southern aspects (structural differences) might be expected, but not necessarily different species (compositional differences) (M. Kirchhoff pers. comm.).

Of the 5 model variables, including Slope Steepness has weak empirical support in the literature. For example, a steep south-facing slope that has good forest cover may have quite low-snow depths and good light penetration and understory cover (Kirchhoff pers. comm.). Another indicator that was not included in the model is exposure. Good exposure during the winter occurs on steep, south aspect sites that are unshaded by adjacent mountains (Brunt pers. comm.).

With modifications to the model (e.g. the inclusion of aspect, possibly exposure, and the removal of Slope Steepness), it would more accurately reflect critical black tailed deer winter range in the CIT study area. McCrory et al. (2003) and Darimont et al. (2003) applied this model on small portions of the CIT study area, which may be the appropriate scale and use for it. However, due to time and capacity constraints, the ESA focal species team was not able to modify and rerun the model based on expert review recommendations. As a result, the model was not used as an input to the SITES/MARXAN model. However, a post hoc analysis was conducted comparing the SITES outputs with the deer winter range model outputs.

2.2.6 Focal Species: Mountain Goat (*Oreamnos americanus)* Winter Habitat Model

2.2.6.1 Background and Rationale

The genus Oreamnos is represented by a single extant species, *O. americanus*, or the mountain goat, found only on the North American continent. The mountain goat occupies steep, rugged terrain in the mountains of northwestern North America, with native populations in British Columbia, the northern Cascades of Washington and the northern Rocky Mountains of Montana and Idaho. British Columbia is home to up to 60% of the continental mountain goat population (cited in Wigal & Coggins 1982).

Generally, mountain goats inhabit alpine and subalpine habitats in all of the mountain ranges of British Columbia. The characteristically rugged terrain is comprised of cliffs, ledges, projecting pinnacles, and talus slopes. In particular, it has been noted that the availability of winter range may be limiting for many mountain goat populations (Fox & Smith 1988; Poole & Mowat 1997; Sims 1999). 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. These winter habitats are limiting, and typically goats show high site-fidelity to these areas (Pollard 2002a). Thus, direct (e.g., timber harvest) or indirect impacts (e.g., increased disturbance or road access) to these wintering habitats have can have large impacts on the local and regional mountain goat populations (Fox et al. 1989).

Declines of mountain goat population numbers and productivity have been documented in many regions across their range. Most of these declines have been linked to the noncompensatory response of goat populations to increased hunter harvest mortality and population reduction (reviewed in Peek 2000). Recovery of mountain goat populations can often be prolonged, and is often confounded by population fluctuations in response to adverse weather conditions (Peek 2000). Increased access (e.g., roads) is linked to increased hunting pressure in many harvested species, including mountain goat, and, as resources extractive activities increase access, near-by goat populations may become increasingly susceptible to over-harvest.

The mountain goat was selected as a focal species for the CIT spatial analyses because of the sensitivity of this species to direct impacts of forest cover removal from in limited winter ranges, as well as the potential direct and indirect mortality associated with increased access. In many regions of the CIT study area, past surveys and fine-scale habitat modeling has identified present populations and associated winter habitats (see Pollard 2002b). These data and the modeling results were used to identify the highest priority mountain goat areas in the CIT ESA. 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).

2.2.6.2 Methods

2.2.6.2.1Mountain Goat Winter Habitat Identification

The characteristics of winter habitat vary across goat range, likely due to the variable conditions that may cause snow to be removed (summarized in Peek 2000, Pollard 2002b). Slopes are typically greater than 65% in most studies. The habitats used by goats for foraging are highly variable, but are typically found within 400m of security terrain, and include many types of open habitats. In coastal regions of BC and Alaska, the use of mature, closed canopy forest adjacent to security habitat provides critical forage and shelter areas for goats in the winter (Pollard 2002b; Suring et al. 1988). Mountain goats typically move between winter habitat and summer habitat areas, and, while these seasonal migrations may be up 24 km in some regions, such seasonal movements have been found to be limited to short distances in coastal regions (see review in Pollard 2002b). Thus, in coastal areas, suitable winter habitat is limited to those areas within close proximity to potential summer habitats (Pollard, pers. comm.).

2.2.6.2.2Existing Data and Winter Habitat Models

As previously mentioned, there has been substantial effort previously invested across much of the study area to identify and map existing goat populations and associated winter habitats. These data were provided by MWLAP and, for the North Coast region, by the LRMP efforts (Pollard 2002a and 2002b). All of these efforts represent a combination of GIS-based modeling of potential winter habitat subsequently modified using aerial photo interpretations and known goat locations. “Mountain goat winter range was to be identified using a two tiered approach considering known and suspected patterns in sub-regional and stand level winter habitat selection. South facing, steep slopes with elevational connectivity to summer ranges were identified at the sub-regional scale on 1:50,000 mapping. Areas with a high probability of containing winter range were then examined in detail using aerial photographs and 1:20,000 TRIM maps to identify escape terrain. Historical, anecdotal and concurrent aerial survey information was used to identify areas with known winter mountain goat use.” (Pollard 2002b, Executive Summary). The habitat attributes and assumptions used in the initial GIS habitat model are summarized in Table 2.12, and form the basis for the potential winter habitat model developed for the extent of the CIT area (described below). A complete description of the methods used in the North Coast is provided in Pollard (2002b). These methods represent approaches taken across the data sets provided by MWLAP for the CIT ESA (Tony Hamilton, pers. comm.).

Table 2.12 Landscape features and assumptions used in 1:50,000 mapping for mountain goat winter range in the North Coast region of the study area (Pollard 2002a).

Landscape Feature	Mapping Assumptions	Supporting Literature [8]
Slope	Mountain goats winter on slopes between 30° and 65°.	*1, *2, *4, *6
Aspects	Mountain goats winter on aspects between 135° and 250°.	*2, *3, *4, *5, *6, *7,
Vegetation	Mountain goats winter in or beside coniferous stands older than 60 years.	*6, *7, *8, *9, *10, *11,
Accessibility	Mountain goat population movement is limited by extensive icefields or water.	*12, *13
Adjacent Summer Range	Mountain goat winter habitat is connected elevationally to suitable summer range.	*2, *14, *15

2.2.6.2.3Potential Mountain Goat Winter Habitat Model

We have conducted additional modeling to provide predictions of potential winter goat habitat across the CIT area. This effort aims at “filling in the gaps” in the spatial extent of the existing efforts, as well as identifying potential, but unoccupied habitats. This effort builds on the foundational GIS-based modeling used by Pollard (2002b) to identify areas for finer-scale habitat identification (summarized in Table 2.12). Additionally we have drawn upon other existing goat

[8] *1 – Schoen & Kirchoff (1982); *2 – Foster (1982); *3 – Hebert & Turnbull (1977); *4 – Smith (1977); *5 – Fox (1977); *6 - Fox et al. 1989; *7 – Smith (1994); *8 – Hjeljord (1973); *9 – Schoen et al. (1980); *10 – Smith (1986); *11 – Fox & Smith (1988); *12 – Hazelwood, pers. comm.; *13 – Banfield (1974); *14 – Russell (1974); *15 – Chadwick (1977) [*as cited in Pollard 2002b].

winter habitat modeling done in other similar regions (e.g., Southeast Alaska). The potential habitats predicted by this model receive lower consideration in the CIT ESA analyses than the previous efforts that included finer-scale habitat identification based on aerial photography interpretations and existing goat survey data. We used the 50m resolution DEM to identify potential escape terrain as warm aspect, steep habitats adjacent to potential foraging habitats, as well as near potential summer habitat. See Table 2.13 for habitat attributes and assumptions.

Table 2.13 CIT area-wide mountain goat potential winter model definitions and assumptions.

Landscape Feature	Mapping Assumptions	Supporting Literature [9]
Slope (winter escape terrain)	Mountain goats winter on slopes between 30° and 100°.	See Table 2.12; *1,*2, *3, *4, *5,* 6
Aspects (winter escape terrain)	Mountain goats winter on aspects between 135° and 250°.	See Table 2.12; *3, *7
Winter forage	Forested habitat (all seral stages) within 400m of escape terrain; in regions of the study area >50km for ocean may not be limited by snowfall and so also included grassy or shrubby habitat including alpine.	See Table 2.12; *1, *2, *3, *5; reviewer comments
Elevation	600 – 1200m	Reviewer comments
Accessibility	Mountain goat habitat excludes extensive icefields or water.	See Table 2.12; reviewer comments
Adjacent Summer Range	Mountain goat winter habitat is within 3km of suitable summer range (identified as open, shrubby or grassy habitats including alpine areas)	See Table 2.12; B. Pollard, pers comm.; reviewer comments
Habitat patch size and adjacency	Removed escape terrain <1ha in size and>400m from adjacent escape terrain	B. Pollard, pers. comm.

2.2.6.2.4Input into the CIT ESA

The existing MWLAP data and fine-scale modeling on occupied or highly probably winter habitats provides the best information on current goat distribution and occupied or high quality winter habitats. These spatial data were combined with the CIT-wide modeling which provides identification of areas without previous data, as well as predictions about future potential winter habitats. The areas identified in the MWLAP and North Coast LRMP data were given a 3-fold weighting relative to the potential habitat modeling completed study area wide. This weighting reflects both the scale and the confidence in the modeling and data, while still allowing the ESA to consider those areas where there has not been efforts to map existing goats populations, as well as to consider potential future goat winter habitats across the study area.

[9] 1 Sims (1999); 2 Poole & Mowat (1997); 3 Fox et al. (1989), Lowell et al. (1988), Smith (1986); 4 Joslin (1986), as cited in Peek (2000); 5 Johnson (1983), as cited in Peek (2000); 6 Haynes (1992); 7 Adams & Bailey (2002), Gross et al. (2002).

2.2.6.3 Results and Discussion

The combined MWLAP and North Coast LRMP data and modeling identified approximately 300,000 ha of occupied winter goat habitat in the CIT study area. These habitats are not equally distributed across the study area, due to the project-specific nature of each effort that contributed these data. The CIT-wide potential winter habitat model overlaps 65% of these occupied winter mountain goat habitats, and predicts an additional approximate 1 million hectares of present or future potential winter habitat across the study area (Map 10). This represents 2.3% of the mainland portion of the study area.

As mentioned earlier, the habitats that were identified in the data and modeling provided by MWLAP and the North Coast LRMP represent finer-scale habitat identification efforts and incorporate known goat locations. The areas identified in these efforts were given three-fold higher weighting than those habitats identified in the coarser-scale CIT-wide potential habitat model. The CIT-wide model does not include the finer-scale aerial photo-interpretation, and is based primarily on the model attributes used in the North Coast winter goat habitat identification. It identifies habitats with potential values for present or future goat populations, but unknown current occupation. This weighting reflects both the scale and the confidence in the modeling and data, while still allowing the ESA to consider those areas where there has not been efforts to map existing goats populations, as well as to consider potential future goat winter habitats across the study area. Existing winter goat habitat identification, provided by MWLAP and the North Coast LRMP effort and predicted potential goat winter habitat in the CIT region are displayed in Map 10.

2.2.7 Focal Species: Grizzly bear (*Ursus arctos*) Habitat Suitability and Capability Models

2.2.7.1 Background and Rationale

Grizzly bears (*Ursus arctos*) 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 habitats range from sea-level and estuaries, up into subalpine areas. Coastal grizzly bears are mostly solitary, intra-specifically aggressive omnivores that typically have large seasonal and annual home ranges (RIC 1999).

Coastal grizzlies 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.

Coastal grizzly bears are opportunistic, feeding on early green vegetation such as sedges (*Carex spp*.) and skunk cabbage (*Lysichiton americanum*) in the estuaries and rich wetlands and swamps. As the season progresses, they often use avalanche chutes where they again feed on a variety of food sources, including Cow-parsnip (*Heracleum lanatum*). As berries ripen, they feed on floodplains and sidehills where devil's club, salmonberry, raspberry, black twinberry, elderberry, and a variety of blueberries are found. In the late summer and fall, coastal grizzlies focus on spawning salmon (*Onchorynchus spp*.) often traveling long distances to fish.

Key components of coastal grizzly bear conservation include: 1) managing motorized vehicle and aircraft access to minimize bear displacement and mortality; 2) maintaining habitat quality and quantity at multiple scales, including landscape level forage supply and critical habitats at the stand level; 3) minimizing potential for bear displacement and habituation as a result of human activities such as wildlife viewing; 4) regulation of hunting levels and providing benchmark areas where hunting of bears is not permitted; and 5) minimizing potential for bear-human interaction by promoting the use of "bear awareness".

Grizzly bears were chosen as focal species for the CIT ESA because they, like other large carnivores, can be keystones (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). Grizzly bears were a main focal species in a similar conservation assessment in the Greater Yellowstone Ecosystem (Noss et al. 2002).

The CIT ESA grizzly bear model is a developmental extension of the provincial grizzly bear estimation process commonly referred to as the Fuhr-Demarchi method (Fuhr and Demarchi 1990, Hamilton and Austin 2002). 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. The higher any one land area is ranked for its ability to provide grizzly bear foods, the higher the density estimator attached to it. Each of the 6 ranks assigned to a habitat represent a density range (minimum and maximum) from zero to a maximum of 100 bears/1000km^2. Given the potential consequences of overestimating grizzly populations, the Ministry of Water, Land and Air Protection manages populations on the basis of the minimum estimates (Hamilton and Austin 2002). Although this model was originally linked to bear density, reviewers of the draft output recommended breaking that link. Instead of attempting to translate habitat effectiveness into bear density, the model simply reports grizzly bear habitat effectiveness across the region.

The subjectivity of Fuhr-Demarchi has been reduced by applying knowledge from several British Columbia coastal grizzly bear research projects (Hamilton et al. 1986, Hamilton 1987, MacHutchon et al. 1993, Himmer and Gallagher 1996), a DNA/Hair Mark-Recapture population estimate for the Kingcome and Wakeman watersheds (Boulanger and Himmer 2001) and ongoing population monitoring in the Owikeno Lake basin (Himmer and Boulanger 2003) and along the north side of the lower Nass River (Demarchi 2003). Additional information for the Northwest part of the study area near Atlin was obtained from a small grizzly bear research project associated with the proposed Tulsequah Chief Mine and Access Road (Wellwood and Diemert, pers. comm.).

2.2.7.2 Methods

The grizzly bear model used the following data as indicators of habitat suitability:

- Broad Ecosystem Units (BEU)
- TRIM 1:20,000 Digital Elevation Model (DEM)
- Salmon biomass estimates

- Roads/road density

Data assembly and processing covered a larger area than the CIT study area to apply a broader "coastal" grizzly bear context, to ensure consistency with previous grizzly bear mapping, and to cover a larger coastal planning project area. Grizzly bears were modeled in their occupied range[10] only and results were presented for both full and partial Grizzly Bear Population Units (Hamilton and Austin 2002).

The current application of Fuhr-Demarchi is at the Ecosection/Variant/Phase level of British Columbia's Biogeoclimatic Ecosystem/Ecoregional Classification (Meidinger and Pojar 1991). The CIT ESA grizzly bear model increases a level in resolution and spatial accuracy to Broad Ecosystem Units (BEU's). BEU's subdivide Variants and Phases into a permanent area of the landscape that supports a distinct type of dominant vegetation cover, or distinct non-vegetated cover (such as lakes or rock out-crops) (RIC 2000). One of the clear advantages of using the Broad Ecosystem Inventory (BEI) for modeling is that each forested unit is defined as including potential (climax) vegetation and associated successional stages. Unit classification is further subdivided by "modifiers" (RIC 2000) that characterize topographic and soil features (e.g. coarse soils, north facing aspects). These enhancements enable a more rigorous distinction between habitat *capability* (idealized value) and habitat *suitability* (current value independent of human displacement) than under Fuhr-Demarchi (1990). Individual unique combinations of Ecosection, Biogeoclimatic Zone, Subzone, Variant, Phase, BEU, Modifier and Seral (successional) Stage were rated in the standard 6-class system for capability and suitability to support grizzly bears (RIC 1999). Care was taken to rate all Seral Stages that *could* occur, rather than just those that *do* occur in the map base, in order to ensure capability was determined correctly. Rating assumptions by unit are described in Appendix 1.0.1.3.2. Mid-seral (coniferous) stages of forested BEU's were typically ranked low because few bear forage species survive the low light conditions under closed coniferous canopies (Michelfelder 2003).

A second major difference between the Fuhr-Demarchi procedure and this model is the explicit inclusion of estimates of Pacific salmon biomass as they influence bear density. Estimates of biomass were derived from Department of Fisheries and Oceans salmon escapement records[11] linked to explicit watershed boundaries[12]. A check of this link was completed for the large river systems that have more than one watershed along their main reach lengths (e.g. Nass, Skeena, Dean, Babine) by examining the spawning area location notes in the DFO salmon escapement catalogs. Spawners were assigned to any one watershed/reach length on a majority basis. Historic maximums (by species by run) were used to establish minimum and maximum capability. A ten-year average of recent escapements from 1993-2002 was used to establish the contribution to bear suitability. The model attempts to account for bear population depression

[10] "Occupied range" is the term used by British Columbia's Grizzly Bear Conservation Strategy to describe the land area inhabitated, on an annual basis, by overlapping resident adult female grizzly bears. Occasional transient bears may be sighted outside of occupied range. Some coastal islands have periodic sightings of individual animals or, on rare occasisons, adult females with cubs. However, these ares are not considered occupied for the purpose of estimating populations or setting habitat and population objectives.

[11] Salmon escapement data were not available for rivers north of Stewart - the model likely underestimates current and potential densities in the lower reaches of the major Northwestern river valleys, e.g. Whiting, Unuk, Taku, Stikine.

[12] Department of Fisheries and Oceans escapement records are limited by inconsistent stream monitoring effort and the difficulty of estimating escapement in turbid streams. Approximately 8% of the provincial total escapement did not link to any watershed boundary and were therefore excluded Escapement records for several important northern rivers (e.g. Taku) were unavailable for this modeling exercise.

caused by recent salmon declines by incorporating these declines in the 10 year suitability average (e.g. sockeye in the Owikeno Basin and pink salmon in Knight and Loughborough Inlets). Biomass estimates were derived from literature reports of average spawning weights by species and sex and assuming a 50/50 sex ratio.

The importance of spawning salmon to coastal bear density has long been recognized (e.g. Hilderbrand et al. 1996) but no study has yet examined density contributions from salmon separately from vegetative (or other animal) food sources. A "1/3" rule was assumed for this modeling exercise. That is, two thirds of the starting capability and suitability estimates were derived from interpreted BEI, one third from the dietary contribution of salmon. Catastrophic effects on cub production and survival that may result from severe salmon declines were not modeled.

Digital Elevation Model (DEM) information on slope has also been incorporated into both capability and suitability estimates. The rugged coastal topography often restricts highly suitable grizzly bear habitats to lower slopes and valley bottoms. This model limits the capability and suitability of steep slopes to recognize this restriction. Slope was assigned into 3 classes: zero to 60%, 60 to 75%, and >75%. Steep slopes were not entirely eliminated from the density estimator because grizzly bears will use such slopes on occasion, particularly as they seek the emergent vegetation on avalanche tracks (MacHutchon et al. 1993). Instead, slopes from 60 to 75% were "stepped down" by 25% and slopes greater than 75% were stepped down by 50%. That is, for any one starting capability or suitability estimate, the model applies suitability reductions of 25% and 50% respectively for these two slope classes.

The fourth departure from the Fuhr-Demarchi procedure is the explicit modeling of the influence of roads on habitat displacement. Although a large number of kilometers of open road are found in coastal British Columbia, their displacement influence is mitigated because many of them are part of isolated road networks built for logging. Traffic levels during forest harvesting can be high on such networks, but low or nil during economic downturns, fire seasons or between logging phases or "passes" (Archibald et al. 1987). In addition, some bears may show high tolerance to moving vehicles and gradually habituate to logging traffic. Other bears may have little choice than to enter the zone of influence around the road as coastal roads are often located near important seasonal habitats in river valley bottoms to minimize gradients and reduce road construction costs.

Isolated road networks may remain open long after active harvesting has been completed. Such roads may constitute a significant mortality risk well into the future. Rather than attempt to model displacement only on "active" road networks and separately model mortality risk from connected road networks vs. isolated ones, road density was used as a combined surrogate for both potential limiting factors. All mapped roads were considered to be open and to have traffic volumes that would displace bears from the immediate vicinity around them. This recognized overestimate of displacement was a deliberate attempt to somehow recognize the mortality risk potential from open coastal roads.

Habitat suitability was further reduced for various road densities in a manner similar to the application of "step downs" for slope. The most recent coastal road coverages were assembled for road density class assignment using a "moving window" approach (Mace et al. 1999). The reference density of 0.6 km/km^2 (USFWS 1993) was reduced by 25%, 0.6 to 1.2 km/km^2 by 50% and >1.2 km/km^2 by 75%. Suitability was not reduced to zero, even for the highest road densities, because studies indicate that some grizzly bears will still use high value habitats adjacent to high levels of vehicle traffic (Gibeau et al. 2002, Yost and Wright 2001). However, studies also indicate that habituated bears are the most likely to come into conflict with humans and have an elevated mortality risk as a result (Benn 1998). Estimates resulting from this last step in the model are referred to as "effectiveness" estimates. That is, ineffective habitat may be entirely suitable, but limited in its use by the displacement influence of vehicles on roads. Effective habitat is both suitable and relatively free from any human influence.

The final major departure from Fuhr-Demarchi is the application of individual watersheds as units for summarizing and mapping estimated current effectiveness, potential capability, suitability, and effectiveness. Although the model assigns effectiveness to individual watersheds for comparative purposes, the approach is artificial. Most watersheds are smaller than average bear home ranges and actual distribution of grizzly bears varies significantly on a seasonal and annual basis. The model's greatest utility is in comparing relative grizzly bear habitat priorities at the watershed level across the study area.

2.2.7.3 Results and Discussion

The primary model outputs are the GIS coverages and associated databases of current minimum effectiveness classes for each of the 5983 modeled watersheds in occupied grizzly bear range within the study area (Map 11).

2.2.7.3.1Model applications and limitations

Caution should be exercised in applying proposed conservation targets for partial GBPUs. Ecological characteristics and human activities outside the study area boundary in partial GBPUs influence grizzly bear distribution and abundance inside the modeled study area.

No attempt was made to model the potential displacement influence of aircraft. Regardless, there is some evidence that grizzly bears are displaced from landing and takeoff areas, particularly of helicopters, at or near important seasonal habitats (refs). Nor does the model attempt to examine potentially increased mortality risk around population centres. Thirdly, this model does not attempt to account for historic human-caused mortality on current population estimates. There is considerable debate on how to model such impacts appropriately and doing so objectively is one of the key recommendations of the recent Provincial Grizzly Bear Science Panel (Peek et al. 2003).[13]

Comparison of the current effectiveness with the proposed target effectiveness can be instructive: watersheds with high correspondence between current and proposed target effectiveness may be high priorities for protection or "light touch" ecosystem based management. Watersheds with

[13] A large proportion of the coast has been closed to legal grizzly bear hunting since the moratorium of 2000. Proposed Benchmark Grizzly Bear Management Areas (GBCS 1995) at the Ahnuhati/Kwalate/Upper Kakweiken/Ahta and from the Dean, through the Kimsquit to Fjiordland and the Khutze have been kept closed to hunting pending the GBMA decisions. The area around Owikeno Lake has been kept closed because of conservation concerns related to the killing of problem bears at Owikeno village and the localized collapse of the Owikeno Lake sockeye run. The Grizzly Bear Management Area proposal for the area surrounding the Khutzeymateen Grizzly Bear Sancturary, much of it closed since 1984, has been endorsed by the Kalum Land and Resource Management Plan (LRMP), tentatively endorsed by the North Coast LRMP, and is now pending government to government discussion with First Nations.

high discrepancy between current estimates and proposed target estimates may be good candidates for the recovery of suitability through silvicultural intervention or for prescribed fire in the coast-interior transition zone. In other such situations, effectiveness might be recovered through road deactivation or other, stronger, motorized access control methods such as bridge removal.

The model has been designed to address the full spectrum of ecosystem-based management of grizzly bears in coastal and northwestern British Columbia. It can assist in the identification of an appropriate reserve network with nodes of protected areas that may buffered and linked across subregions. However, perhaps more importantly, the model can also be used to help "manage the matrix" - even areas of low current or low potential density - to ensure the widest possible natural distribution and persistence of the species.

2.2.8 Focal Species: Black Bear (*Ursus americanus*) Habitat Suitability and Capability Model

2.2.8.1 Background and Rationale

Black bears are commonly found throughout coastal British Columbia. They are very adaptable and inhabit a wide variety of habitats - ranging from coastal estuaries up to high elevation alpine meadows (RIC 1999). Beaches, open riparian areas, warm aspect avalanche tracks, slides, and clearcuts are important feeding areas. They are omnivorous and opportunistic in their feeding habits. 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, and small mammals and will occasionally prey on young/small deer. In the late summer and fall, salmon spawning rivers and streams represent important feeding areas (Reimchen 1998a and 1998b). Black bear habitat use is strongly influenced by intraspecific social interactions and the presence and activities of people. Feeding and security habitats in close proximity are assumed to be the limiting factors for black bears (RIC 1999).

In coastal British Columbia, black bears are old-growth structure dependent for denning (Davis 1996). Winter dens are located in large standing live, standing dead, or in or under large dead tree boles. Den cavities are dry and secure from predators (cougars, wolves, other bears). The Kermode bear, also called the Spirit Bear or Ghost Bear, is a rare white-phase black bear also inhabits coastal British Columbia. The white genotype occurs at varying frequencies along the Northwestern coast (Ritland et al. 2001).

Black bears are globally ranked as G5 – meaning they are demonstrably widespread, abundant, and secure, and provincially yellow-listed meaning they are apparently secure and not at risk of extinction. They are also ranked by the Committee On the Status of Endangered Wildlife in Canada (COSEWIC) as 'Not At Risk' (NAR) meaning they are a species that has been evaluated and found to be not at risk.

Black bears were chosen as focal species outside of occupied grizzly bear habitat for the CIT ESA because they also can be considered keystone, indicator and umbrella species (see grizzly bear model). In addition, the Kermode genotype is extremely rare, more appropriated examined as a focal species than a special element in the ESA. Black bears were not modeled inside occupied grizzly bear habitat because of their high overlap in habitat requirements. Site series representivity was assumed to address the concern about long term old-growth supply for denning.

2.2.8.2 Methods

The structure of the black bear model was identical to the grizzly bear model with the following exceptions:

1. Broad ecosystems (Appendix 1.0.1.3.2) were rated from the perspective of black bear habitat opportunity;

2. Black bears show higher tolerance to roads, therefore the suitability reductions for the various road categories were adjusted as follows: suitability under road densities of 0.6 to 1.2 km/km^2 was reduced by 25% and >1.2 km/km^2 by 50%.

2.2.8.3 Results and Discussion

The primary model outputs are the GIS coverages and associated databases of current minimum effectiveness classes for each of the modeled watersheds in occupied black bear range within the study area (Map 11).

2.3 Freshwater Targets

2.3.1 Special elements

Salmonids aside, there was very little spatially explicit special element data available for freshwater species in the study area. In Cannings and Ptolemy (1998), only 1 of the 38 rare freshwater fish species listed occurs within the study area –the Giant Black Stickleback (*Gasterosteus species 1*). Four freshwater fish species were selected as special elements based on the selection criteria identified in table 6.2.1 –Green Sturgeon (*Acipenser medirostris*), Threespine Stickleback (*Gasterosteus aculeatus*), Giant Black Stickleback (*Gasterosteus species 1*), and Bull Trout (*Salvelinus confluentus*). We were only able to obtain spatial data for the Giant black stickleback, a G1 endemic (2 element occurrence records). Three amphibian species were selected as special elements – Tailed Frog (*Ascaphus truei*), Western Toad (*Bufo boreas*), and Northern Red-Legged Frog (*Rana aurora*), but only the Tailed Frog (a CIT focal species) had sufficient spatial data regarding its occurrence.

2.3.2 Representation Analysis

2.3.2.1 Background and Rationale

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

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

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

Finally, all water that runs through freshwater ecosystems ends up in the ocean. There, the endless cycle of life and death in freshwater ecosystems provide a steady stream of incoming food, sediment and nutrients to estuary and nearshore marine environments. The diversity of life in the world's freshwaters and the sea are thus closely linked as well.

2.3.2.1.1 Classification of coarse-scale freshwater ecosystems

The classification of freshwater ecosystems is a relatively new pursuit and as such this is the first attempt at a coarse-scale freshwater ecosystem classification within BC. 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 (e.g., hydrologic and nutrient regimes, access to floodplains) and gradients (e.g., temperature, chemical and habitat volume), occur in the same part of the drainage network, and form a distinguishable drainage unit on a hydrography map. Coarse-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). They are defined at a spatial scale that is practical for regional planning. Freshwater systems provide a means to generalize about large scale patterns in networks of streams and lakes, and the ecological processes that link them together as opposed to fine-scale freshwater systems which capture a detailed and often quite complex picture of physical diversity at the stream reach and lake level.

2.3.2.2 Methods

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

The proposed freshwater ecosystem classification framework is based to a large extent on The Nature Conservancy's classification framework for aquatic ecosystems (Higgins et al. 2002). The framework classifies environmental features of freshwater landscapes at two spatial scales. It loosely follows the hierarchical model of Tonn (1990) and Maxwell et al. (1995). It includes ecological drainage units that take into account regional drainage (zoogeography, climatic, and physiographic) patterns, and mesoscale units (coarse-scale freshwater systems) 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 that capture the major abiotic drivers of freshwater systems: drainage area, underlying biogeoclimatic zone and geology, stream gradient, dominant lake / wetland features, glacial connectivity and coastal connectivity. Table 2.14 summarizes data sources and variable classes for each of the classification variables. These variables are widely accepted in the literature as being the dominant variables shaping coarse scale freshwater systems and their associated communities and also strongly co-varying with many other important physical processes. Changing the characteristics of any of these variables for a particular coarse-scale freshwater system type will likely result in a change in freshwater communities present. For example, a steep gradient headwater system in alpine tundra running through basalt will have a very different set of freshwater communities than the same system running through limestone.

Table 2.14 Summary of data used in coarse-scale freshwater ecosystem classification.

Variable	Data Source(s)	Variable Classes
Drainage Area	BC Watershed Atlas, 1:50,000	< 100 km^2 (headwaters) 100 – 1,000 km^2 (small rivers) 1,000 – 10,000 km^2 (medium rivers) > 10,000 km^2 (large rivers)
Biogeoclimatic Zones	BC Ministry of Forests (2002)	Coastal Douglas-fir Zone Coastal Western Hemlock Zone Mountain Hemlock Zone Bunchgrass Zone Ponderosa Pine Zone Interior Douglas-fir Zone Interior Cedar-Hemlock Zone Montane Spruce Zone Sub-Boreal Pine – Spruce Zone Sub-Boreal Spruce Zone Engelmann Spruce-Subalpine Fir Zone Boreal White and Black Spruce Zone Spruce-Willow-Birch Zone Alpine Tundra Zone
Bedrock Geology	Geology sub-classes were delineated based on the following characteristics: sediment texture; degree of weatherability / erodability; stream substrate material; and aquifer potential. BC Ministry of Energy & Mines at 1:250,000	**Bedrock Geology Class - Subclass** Sediments - Undivided • Chemical sediments • Fine clastics (shale, mudstone) • Sandstones • Coarse clastics • Carbonates • Interbedded limestone/shale Volcanics - Undivided • Intermediate to felsic / bimodal • Mafic • Mixed sediments and volcanics Intrusives - Undivided • Intermediate to felsic • Mafic / Ultramafic • Alkalic Metamorphics - Undivided • Alluvium - Till
Stream Gradient	BC Watershed Atlas, 1:50,000 & BC 25m DEM	Shallow (>=50% of mainstem reaches with gradient <0.005 Moderate (>=50% of mainstem reaches within 0.005-0.20 Steep (>=50% of mainstem reaches with gradient >0.20

Variable	Data Source(s)	Variable Classes
Lakes & Wetlands	BC Watershed Atlas, 1:50,000	Presence of dominant lake and wetland features if >=5% of drainage area encompassed by lake / wetland features.
Coastal Connectivity	BC Watershed Atlas, 1:50,000	Coastally connected Not coastally connected
Glacially Fed Rivers	BC Watershed Atlas, 1:50,000	Glacially connected (freshwater system is touching a glacier) Glacially influenced (greater than 1% of upstream headwaters consist of glacier or permanent snow) Not glacially connected

The freshwater classification was stratified by ecological drainage units in order to capture broad scale freshwater zoogeographic, physiographic and climatic patterns within each ecological drainage unit (EDU). Within each EDU, headwater, small coastal river, small river, intermediate river and large river watersheds were identified. Watersheds within each of these drainage classes were further classified according to the dominant biogeoclimatic zone they fell within, their dominant underlying geology and their 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.

2.3.2.3 Results and Discussion

Skeena, Nass, Haida Gwaii and North and Central Coast EDUs collectively consist of 4,476 coarse-scale freshwater ecosystems. Table 2.15 summarizes the classification of these freshwater ecosystems into system types within each of the EDUs. Map 12 spatially summarizes the abundance and distribution of these coarse-scale freshwater system types within each of the EDUs.

Table 2.15. Summary of coarse-scale freshwater system types by EDU.

	Nass	Skeena	North Coast	Central Coast	Haida Gwaii
Total number of freshwater ecosystems	755	1333	1773	496	125
Total number of freshwater system types	74	182	150	68	30
System types by drainage class:					
Small coastal rivers	0	0	34	15	13
Headwaters	43	109	71	33	0
Small rivers	26	62	36	17	9
Intermediate rivers	4	10	9	3	8
Large rivers	1	1	0	0	0

The resultant classification framework yields a standard reporting unit of coarse-scale freshwater system types that can be replicated across ecological drainage units. Standardizing the way coarse-scale freshwater system types are defined enables both abundance and distribution queries to be made for each freshwater system type across the Province or for a specified region. Questions related to system rarity, endemism, level of imperilment and range extent can therefore be addressed. This is helpful from a conservation planning perspective in that goals can be set differentially for different system types.

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

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

2.3.3 Focal Species: Tailed Frog (*Ascaphus truei*) Habitat Suitability Model

2.3.3.1 Background and Rationale

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. The Tailed Frog is exclusively a North American species. 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, the nature of human activities within its range and our lack of knowledge about minimum viable population size, particularly in fragmented landscapes.

The Tailed Frog retains more primitive characteristics than any other living frog and is the only member of the family Ascaphidae. With a life span of 15 to 20 years, the Tailed Frog is one of the world's longest lived frog species. It also has the longest larval (tadpole) phase and takes longer to reach sexual maturity than any other North American frog species. The Tailed Frog reaches sexual maturity at 8 or 9 years of age which is roughly twice that of other species and results in an extremely low reproductive rate.

The Tailed Frog is listed as a species of special concern by the Committee on the Status of Endangered Wildlife in Canada (Dupuis 1999) and is Blue listed (considered to be vulnerable) in BC. Stable headwater mountain systems with step pool channel morphology and low levels of bedload movement provide optimal habitat for this species (Dupuis and Friele 2003). These habitat characteristics are sensitive to land-use practices that introduce sediment into and destabilize the stream channel (Dupuis and Steventon 1999). The species may also be negatively affected by the conversion of old growth to intensively managed second growth forest (Corn and Bury 1989). Adult Tailed Frog abundance is positively correlated with the percent of old growth forest in a watershed (Dupuis and Friele 2002; Stoddard 2002; Welsh and Lind 2002), most likely because these forests dampen microclimatic extremes (Chen et al. 1993; 1995; Brosofske et al. 1997; Johnston and Frid 2002). Due to the species' potential sensitivity to logging it is listed as an Identified Wildlife Species in the Forest Practices Code of BC (BC Ministry of Forest and BC Ministry of the Environment 1999).

The Tailed Frog is at risk because it has very specialized habitat requirements, and because human activities, particular timber harvesting, are destroying its habitat. Roughly 75 percent of the watersheds in BC have been subject to some level of timber harvesting. Small headwater streams usually contain no fish, so they and their forested borders receive little or no protection from resource agencies and industry, unless they are unstable or have an impact on fish or their downstream spawning grounds and nurseries. The result can be extensive disturbance to Tailed Frog habitat, making this species vulnerable to population declines and local extirpation.

2.3.3.2 Methods

Tailed Frog populations in BC have been poorly surveyed because of the remote nature of its habitat. Therefore, little is known about the viability of Tailed Frog population's in BC. This model is a first of its kind in an attempt to model optimal and suitable habitat for this species at a landscape scale based on what is currently known about its local habitat. The model is based on research by Ascaphus Consulting (Dupuis and Friele, 2003) and Sutherland *et al*. (2001) as well as direct consultation with Pierre Friele and Linda Dupuis, renowned experts on the Tailed Frog in BC.

Five biophysical conditions were identified as being critically important for Tailed Frog habitat:

1. Basin area between 0.3 and 10 km^2
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% where ruggedness = $H/A^{1/2}$ with H = basin relief and A = basin area
4. Northerly aspect in Coast and Mountains region; Southerly aspect in Interior regions
5. Forest cover age class >= 6

These conditions were spatially modeled within the CIT study area using the following data sets: British Columbia Watershed Atlas; Small Scale Predictive Ecosystem Mapping; Digital Elevation Model; and CIT forest cover.

An area of known western range limit on the Queen Charlotte Strait was also manually excluded (Moy, pers. comm., 2003). 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.

Field count data compiled by Pierre Friele and Leo Frid; and time constrained search data from 1994 – 98 and additional data from 2002 (Dupuis and Friele, 2003) were used to verify the habitat model. These surveys were conducted in accordance with RIC Standards (BC Ministry of Environment and BC Ministry of Forests 2001).

For the purposes of assessing conservation value across the CIT study area, a conservation weight of 2 was assigned to optimal Tailed Frog habitat stream reaches and a conservation weight of 1 was assigned to suitable habitat stream reaches.

2.3.3.3 Results and Discussion

In total, 4, 466 km of suitable Tailed Frog stream habitat was found to exist 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 meet all five biophysical parameters within the model. Agreement between the existing field data and the model depended on how many model criteria were applied. When all criteria were in place there was a low correlation between field data and those stream reaches defined as optimal Tailed Frog habitat. This model may be an accurate predictor of optimal habitat, but it cannot predict probability of habitat use. It is also likely that few of the field survey sites were optimal habitat. There was a 60% correlation between survey data and suitable habitat for the Tailed Frog.

The model was reviewed by Linda Dupuis, Pierre Friele, Ken Dunsworth and members of CIT's Ecological Assessment Team. It was concluded by all reviewers that the model performed well in defining suitable and optimal Tailed Frog habitat. Map 13 represents optimal and suitable habitat defined for the Tailed Frog within the CIT study area.

This habitat suitability model is a critical step in helping us to understand the scope and scale of Tailed Frog habitat and hence where viable populations of this species may occur within BC. This information is critical for establishing Wildlife Habitat Areas for this species.

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 feeling and yarding of trees away from permanent creeks to maintain slash-free water courses (Dupuis and Friele 2003).

2.3.4 Focal Species: Pacific Salmon and Steelhead

2.3.4.1 Background and Rationale

Six species of salmon occur in BC; five species of Pacific salmon – chinook (*Oncorhynchus tshawytscha*), chum (*Oncorhynchus keta*), coho (*Oncorhynchus kisutch*), pink (*Oncorhynchus gorbuscha*) and sockeye (*Oncorhynchus nerka*) - and steelhead (*Oncorhynchus mykiss*). These species have some of the most complex life histories of any species on Earth. They are wide-ranging, migratory species with life histories that integrate marine, freshwater, and terrestrial ecosystems. They carry important genetic diversity at the population level and require connectivity between life history stages and habitats across multiple biological, geographic and temporal scales. Subsequently, they face critical threats at all scales, across all life history stages and habitats. They are considered a key set of focal species for the Ecosystem Spatial Assessment 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.

BC's coastal ecosystems evolved in conditions where nutrients were transferred from the marine environment to freshwater and terrestrial environments through the annual return of spawning salmon. The nitrogen, phosphorous and carbon delivered to rivers, estuaries and riparian zones through predation and decomposition of spawned salmon are the biochemical building blocks of these ecosystems (Cederholm et al. 1989; Kline et al. 1990; Bilby et al. 1998; Ben-David 1998; Schmidt 1998; Finney et al. 2000). Helfield and Naiman (2001) concluded that this fertilization process serves not only to enhance riparian production, but may also act as a positive feedback mechanism by which salmon borne nutrients improve spawning and rearing habitat for subsequent spawning generations, and maintain the long-term productivity of river corridors along BC's coast. Gresh et al. (2000) suggested that between 120 million and 260 million kgs of salmon biomass once returned to BC's rivers. Today, this number is estimated at 60 million kg, a 50- 75 % decline in salmon biomass and a nutrient deficit of between 2 and 6 million kg of nitrogen and phosphorous.

Salmon are also critical to coastal ecosystems because they are a desirable prey species. Their existence within coastal BC ecosystems plays a major role in the dynamics of wildlife and regional biodiversity (Wilson and Halupka 1995; Ben-David et al. 1998). The range of organisms utilizing salmon carcasses extends from microscopic invertebrates to large vertebrate carnivores. The survival of these species is often linked to the timing of the salmon runs (Cederholm et al. 2000). Spawning salmon are a major food source for grizzly and black bears along the coast of BC especially during fall preparation for winter denning when salmon consist of over 90% of coastal bears' diet (Hildebrand et al. 1996). Salmon are also the predominant prey of resident killer whales in coastal BC and adjacent waters. Over 95% of documented predation events by resident orcas are on salmon (Ford et al. 1998).

Although each of these six species of salmon share unique evolutionary characteristics within the genus *Oncorhynchus*, they each exhibit unique life history characteristics and as such should be assessed independently. Furthermore, based on the genetic distinctiveness of even and odd year Pink salmon and summer and winter run steelhead, these four species types were assessed independently.

2.3.4.2 Methods

2.3.4.2.1 Pacific Salmon

The Department of Fisheries and Oceans (DFO) salmon escapement database was used to assess trends in salmon escapement over time and compare biomass estimates across runs. DFO enumerates salmon escapement (number of salmon returning to their natal streams to spawn) annually, an enormous undertaking given the size and geography of coastal BC and the multiple species and river systems. Methods used to count fish include permanent fences, visual estimations, fish wheels, aerial counts and dive surveys. While the escapement database is important, it has its limitations. Knowledge of particular river systems and species range from extensive to none existent. The present database contains escapement estimates for Pacific salmon from the 1950s to the present. It would have been tremendously beneficial to have had a database that started prior to the industrial revolution given that activities such as commercial fishing, logging, and watershed development were already extensive by then. Adverse weather, changes in surveyor/stream walkers, and inconsistent methodology can all lead to misrepresentation of the real trends in escapement, and may mask the effects of other influences such as logging and land use, over-fishing, climatic and natural variations. Lastly, although theoretically only native individuals are enumerated upon their return to their natal streams, offspring that are the result of successful reproduction of hatchery and native stock are counted in these enumerations which may artificially increase escapement values. Regardless of its problems, it is clear that DFO's salmon escapement database is still unequivocally the best ongoing survey of the state of BC's salmon.

Runs with less than ten years of data were removed from the analysis and labeled as having insufficient data. Trends in escapement over time were calculated for each run using log (e) +1 escapement over years. A simple classification of runs into either stable or declining escapement trend was performed. (It should be noted that an in-depth statistical analysis of long and short term escapement trends for each run and verification of the data is currently underway but was not completed in time for incorporation into this study.) Runs with slopes greater than or equal to 0.0 were characterized as having stable escapement trends over time. Runs with slopes less than 0.0 were characterized as having declining escapement trends over time. Biomass estimates for each run were calculated using the median of ten year running averages for each run. Average weights for each species were determined using Gresh et al. (2000).

2.3.4.2.2Steelhead

Steelhead populations are managed by the Province of British Columbia using a different management framework from DFO. Population trends were estimated from catch information collected annually from a mail out survey, from test fisheries in commercial fisheries with a steelhead bycatch, and from swim surveys, weir counts and creel surveys. Population status was assigned by regional biologists using various combinations of the above methods. Results were expressed as the number of spawners divided by the estimated carrying capacity of the river. Populations were assigned to one of the following categories:

1. Routine Management Zone (RMZ) (> 30 % of Carrying Capacity)
2. Conservation Concern Zone (CCZ) (between 10 % and 30 % of carrying capacity)
3. Extreme Conservation Concern (ECZ) (less than 10% of carrying capacity.

For the purpose of the Ecosystem Spatial Analysis, stable populations were considered to be populations in the RMZ, while the remaining zones were considered to be equivalent to the declining populations in the Pacific salmon analysis.

Biomass calculations for steelhead were rough estimates designed to place the populations in categories of large, medium and small populations using a log10 scale based on known or estimated population sizes. Missing values were then estimated by interpolation.

2.3.4.2.3Salmon Population Units

Salmon population units (SPUs) were derived for each of the six salmon species based on existing FISS point source data, DFO escapement data, and experts knowledge of runs sharing similar genetics and habitat preferences. Escapement trends and biomass estimates were summarized for each SPU by synthesizing run data where appropriate. Biomass estimates were summed for runs within a SPU. A SPU was characterized as containing high biomass runs if accumulative runs were >= 2.0 on a log(10) scale and low biomass if they were less than 2.0 on a log(10) scale.

Trends in escapement over time were examined across all runs within a SPU. If a stable or declining trend across runs was not apparent, then biomass was examined in conjunction with slope trend and the slope trend for the run(s) with the highest biomass were selected as being representative of the SPU. It should be noted that for the majority of the SPUs, trends in escapement over time were very obvious and biomass estimates did not need to be factored into the determination of slope trends.

2.3.4.2.4Goal Setting

From a biodiversity standpoint all salmon SPUs are important and equally valued. However, for the purpose of priority setting for conservation, the following weightings were used to set conservation goals: stable SPUs with high biomass were given three times the conservation weight than declining SPUs with low biomass as well as stocks with insufficient data. Stable SPUs with low biomass and declining SPUs with high biomass were given a conservation weighting of two (Table 2.16). These conservation goals for each salmon species were stratified by ecological drainage units (EDUs) and used in SITES algorithm as input files for determining areas of high conservation value across the CIT study area.

Table 2.16 Summary of weightings used to set conservation goals for all salmon SPUs.

		Slope Trend	
		Stable	Declining
Biomass	High	3	2
	Low	2	1

2.3.4.3 Results and Discussion

All Pacific salmon species showed a serious decline in escapement over time with 40% of these declines occurring in high biomass runs. Pink (even) was found to be in the best condition and Chum in the worst condition. Steelhead was found to be in stable condition across all EDUs except for Central Coast. Of all EDUs within the CIT region, Central Coast was found to in the worst condition with 80% of its salmon SPUs in decline. Haida Gwaii was a close second with 76% of its SPUs in decline. Maps 14 to 21 summarize the spatial trends in escapement and biomass for each of the six salmon species across the CIT study area. For a detailed summary of escapement and biomass trends by EDU, please refer to Tables 2.17 to 2.22. For a detailed summary of combined escapement and biomass trends for each species, please refer to Figures 2.1 to 2.9. The following sections highlight general findings of trends across EDUs as well as species trends.

2.3.4.3.1 Trends across Ecological Drainage Units (EDUs)

Salmon in the Skeena River EDU were generally in the best condition of all EDUs within the study area with 40% of its Pacific salmon SPUs containing stable runs and 100% of its steelhead SPUs containing stable runs. The majority (69%) of all SPUs in the Skeena EDU were of low biomass except for sockeye which had 64% of its SPUs composed of high biomass runs.

Sixty-three percent of Pacific salmon SPUs within the Nass EDU were in decline. Coho appeared most stable with 53% of its SPUs containing stable runs. All summer and winter steelhead SPUs were stable. Majority of all species SPUs were of low biomass (58%) except for sockeye in which 83% of its SPUs were high biomass runs.

The majority (67%) of Pacific salmon SPUs were in decline within North Coast EDU. Nine-seven percent of summer steelhead SPUs were in decline compared to only 7% of steelhead winter SPUs. The majority of Pink (even and odd year) and Chum SPUs had high biomass runs.

The majority (76%) of Pacific salmon SPUs were in decline within the Haida Gwaii EDU. There was only one chinook population within Haida Gwaii that was located in the Yakoun River. It had a stable population with a high biomass run. All summer and winter steelhead SPUs were stable. The majority (52%) of all species' SPUs had high biomass runs except for Pink (odd) and steelhead (summer and winter) with 85% and 100% respectively of their SPUs scoring as low biomass.

The Central Coast EDU was found to be in the worst condition of all EDUs with 80% of its Pacific salmon SPUs and 48% of its steelhead (summer and winter) SPUs in decline. The exception was pink (even) which had 71% of its SPUs in stable condition within this EDU. The majority (66%) of all species' SPUs had low biomass runs except for Pinks (even) with 54% of their SPUs scoring as high biomass runs.

2.3.4.3.2Species Trends

All salmon species were found to have greater than two-thirds of their SPUs in decline except for even year Pink (53% in decline) and steelhead (33% winter and 12% summer in decline). Chum had the highest proportion of its SPUs in decline (77%) followed closely by coho, sockeye, chinook, and pink (odd). Pink (even) had the highest proportion of its SPUs composed of high biomass runs (72%) followed by sockeye (55%). The remaining species had the majority of their SPUs composed of low biomass runs. The following is a summary of each salmon species by EDU.

Sockeye SPUs were found to be in the best condition in Skeena (54% of its SPUs with stable escapement trends) and Nass (84% of its SPUs with stable escapement trends). However, 74% of all sockeye SPUs within the CIT region were found to be in decline with the majority of these being high biomass runs

Pink (even year) were found to be in the best condition of all Pacific salmon species with 47% of its SPUs in stable condition. Central Coast (71%), and Skeena (54%) EDUs were found to contain the highest proportion of pink (even year) SPUs in stable condition. For the 53% of pink (even year) SPUs that were in decline within the CIT region, the majority of them were composed of high biomass runs.

Pink (odd year) were found to be in the second best condition of all Pacific salmon species with 31% of its SPUs in stable condition. Central Coast (92%) and Haida Gwaii (96%) were found to contain the highest proportion of pink (odd year) SPUs in stable condition. For the 69% of the Pink (odd year) runs that were found to be in decline within the CIT region, the majority of them were low biomass runs.

Sixty-nine percent of all chinook SPUs and 76% of all coho SPUs were found to be in decline within the CIT region. Of these chinook and coho SPUs, the majority were composed of low biomass runs. Chinook expressed a decline in escapement trends across all EDUs except for Skeena where just over half of its SPUs (52%) were found to be in stable condition. Coho expressed a decline in escapement trends across all EDUs except for Nass where just over half of its SPUs (53%) were found to be in stable condition.

Seventy-seven percent of all chum SPUs were found to be in decline within the CIT region. Of these chum SPUs, the majority were composed of low biomass runs. This decline in escapement trend was prominent across all EDUs. These results indicate that chum may be in the worst shape of all six salmon species analyzed in this study.

Summer and winter run steelhead were found to be in the best condition of all six salmon species. One hundred percent of their SPUs were stable in the Nass, Skeena, and Haida Gwaii EDUs. They were in greatest decline in the Central Coast EDU with 100% of summer run SPUs and 45% of winter run SPUs in decline. Summer and winter run steelhead had consistently low biomass runs across all EDUs except for summer run steelhead in the Nass (31%) and Skeena (42%) EDUs.

Table 2.17 CIT regional summary of salmon status.

Analysis		**Pink (Even)**	**Pink (Odd)**	**Chum**	**Chinook**	**Coho**	**Sockeye**	**Winter Steelhead**	**Summer Steelhead**
Total Salmon Conservation Units		384	384	309	139	488	217	664	112
Salmon Conservation Units with Sufficient Data		232 (60%)	356 (93%)	216 (70%)	81 (58%)	260 (53%)	99 (46%)	664 (100%)	112 (100%)
Trends Based on Sufficient Data									
Escape-ment Trends	% Stable	47	31	23	31	24	28	67	88
	% Declining	53	69	77	69	76	74	33	12
Biomass Trends	% High Biomass	72	43	48	24	30	55	19	2
	% Low Biomass	28	57	52	76	70	45	81	98

Table 2.18 Summary of salmon status for Nass River EDU.

Analysis		Pink (Even)	Pink (Odd)	Chum	Chinook	Coho	Sockeye	Winter Steelhead	Summer Steelhead
Total Salmon Conservation Units with Sufficient Data		10	21	6	11	17	6	30	13
Escapement Trends	% Stable	40	38	0	27	53	33	100	100
	% Declining	60	62	100	73	47	67	0	0
Biomass Trends	% High Biomass	50	43	17	36	35	83	10	31
	% Low Biomass	50	57	83	64	65	17	90	69

Table 2.19 Summary of salmon status for Skeena River EU.

Analysis		Pink (Even)	Pink (Odd)	Chum	Chinook	Coho	Sockeye	Winter Steelhead	Summer Steelhead
Total Salmon Conservation Units with Sufficient Data		28	74	17	31	58	28	48	33
Escapement Trends	% Stable	54	27	35	52	40	54	100	100
	% Declining	46	73	65	18	60	46	0	0
Biomass Trends	% High Biomass	36	35	12	19	21	64	7	42
	% Low Biomass	64	65	88	81	79	36	93	58

Table 2.20 Summary of salmon status for North Coast EDU.

Analysis		Pink (Even)	Pink (Odd)	Chum	Chinook	Coho	Sockeye	Winter Steelhead	Winter Steelhead
Total Salmon Conservation Units with Sufficient Data		127	146	120	24	103	39	452	34
Escapement Trends	% Stable	48	51	23	21	13	15	93	3
	% Declining	52	49	77	79	87	85	7	97
Biomass Trends	% High Biomass	81	64	56	21	34	46	2	9
	% Low Biomass	19	36	44	79	66	54	98	91

Table 2.21 Summary of salmon status for Central Coast EDU.

Analysis		Pink (Even)	Pink (Odd)	Chum	Chinook	Coho	Sockeye	Winter Steelhead	Summer Steelhead
Total Salmon Conservation Units with Sufficient Data		24	49	38	10	38	10	95	4
Escapement Trends	% Stable	71	8	13	0	16	10	54	0
	% Declining	29	92	87	100	84	90	45	100
Biomass Trends	% High Biomass	54	26	45	20	26	30	2	0
	% Low Biomass	46	74	55	80	74	70	98	100

Table 2.22 Summary of salmon status for Haida Gwaii EDU.

Analysis		Pink (Even)	Pink (Odd)	Chum	Chinook	Coho	Sockeye	Winter Steelhead	Summer Steelhead
Total Salmon Conservation Units with Sufficient Data		31	45	23	1	27	12	39	28
Escapement Trends	% Stable	36	4	35	100	33	17	100	100
	% Declining	64	96	65	0	67	83	0	0
Biomass Trends	% High Biomass	90	16	65	100	48	67	0	0
	% Low Biomass	10	84	35	0	52	33	100	100

2.3.4.4 Conclusion

Even though there is a large amount of uncertainty surrounding DFO's salmon escapement database, the results of this study indicate robust downward trends in escapement over time for all five species of Pacific salmon throughout the entire CIT study area as well as prominent declines in winter and summer steelhead within the Central Coast. This is a serious cause for concern regarding the long-term health of BC's salmon. Causes of decline in salmon populations over time stem from multiple factors including climate change, changes in landuse, hatcheries and over-fishing. To keep these salmon populations from extinction, we will need to implement more conservative harvest and hatchery's management and habitat protection strategies. Landuse planning tables need to consider the long-term protection of critical salmon habitat as a high priority if we have any hope of saving these salmon populations from extinction.

Figures

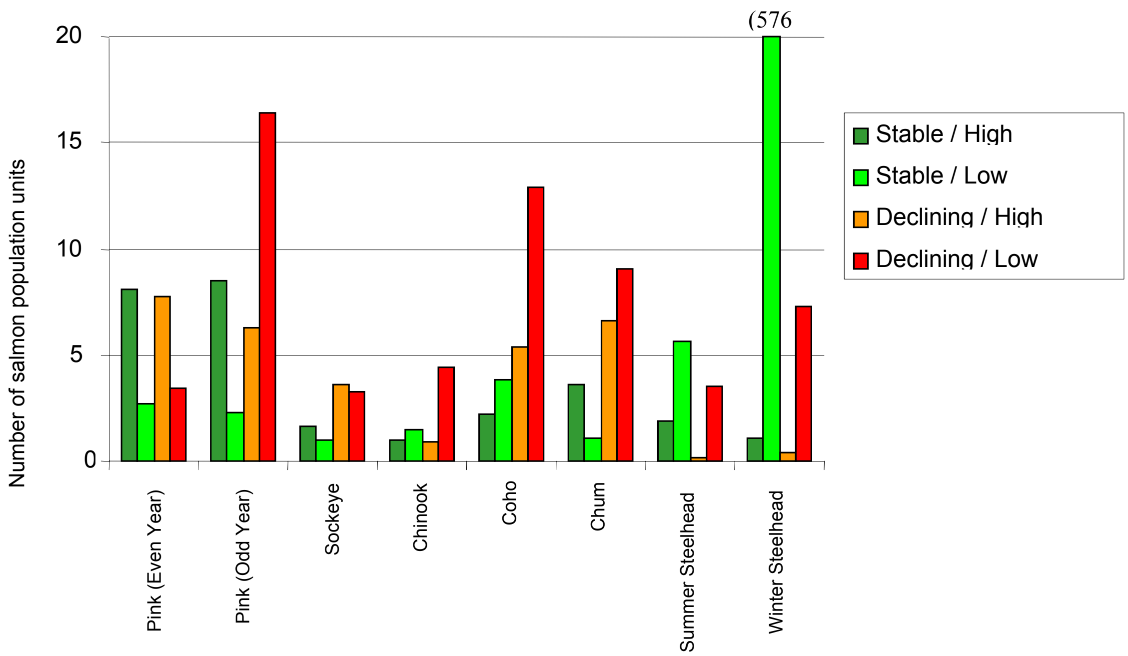


Figure 2.1 Summary of salmon species condition within CIT study area.

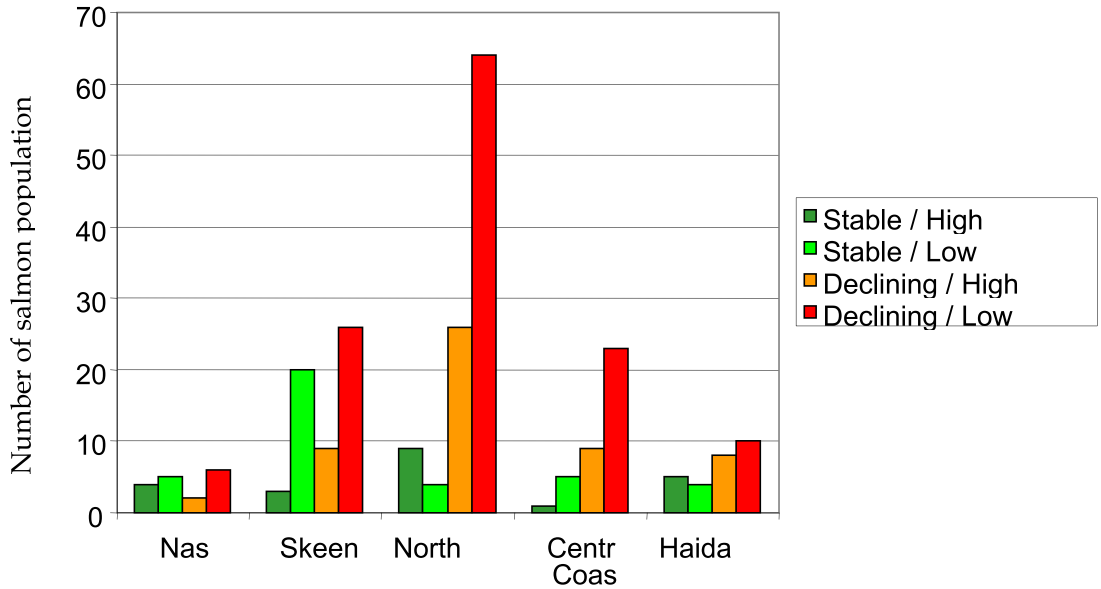


Figure 2.2 Summary of Coho condition by EDU.

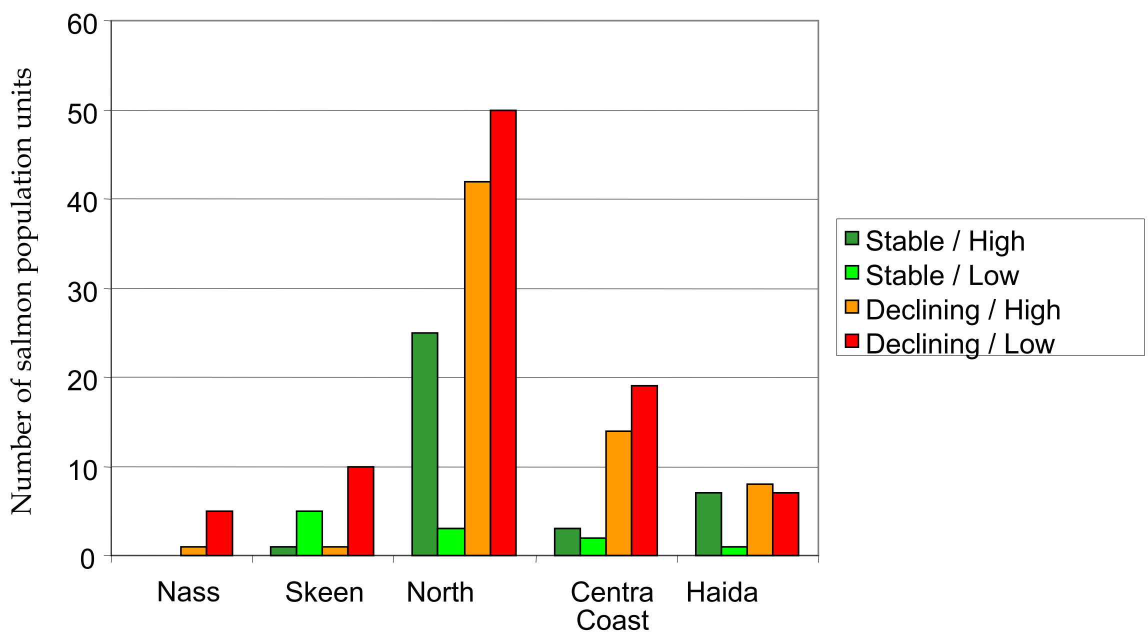


Figure 2.3. Summary of Chum condition by EDU.

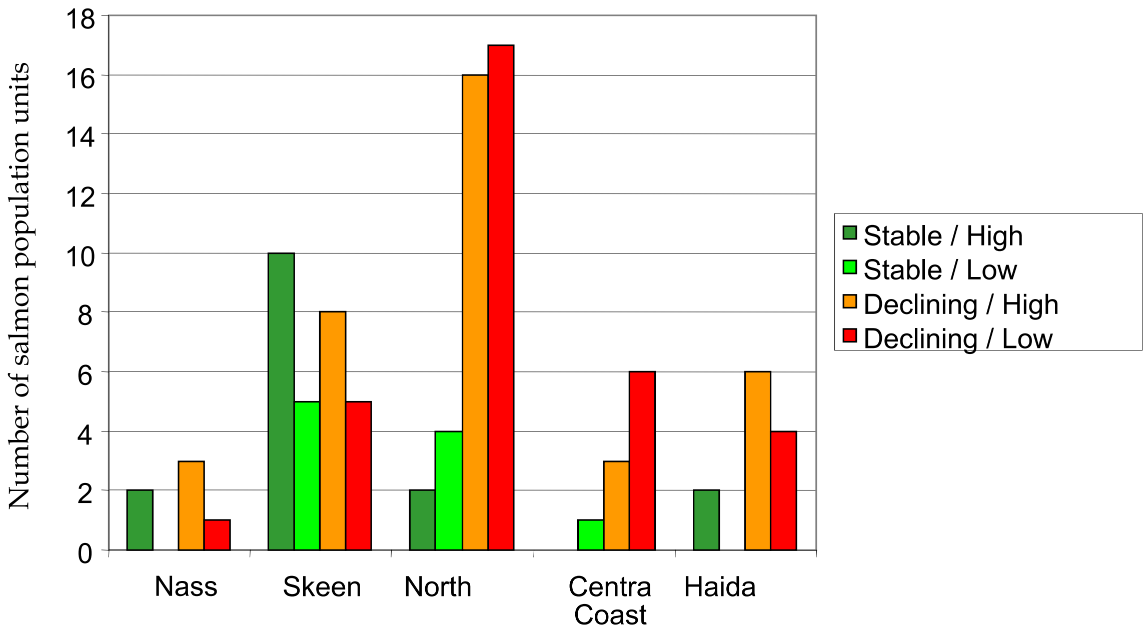


Figure 2.4. Summary of Sockeye condition by EDU.

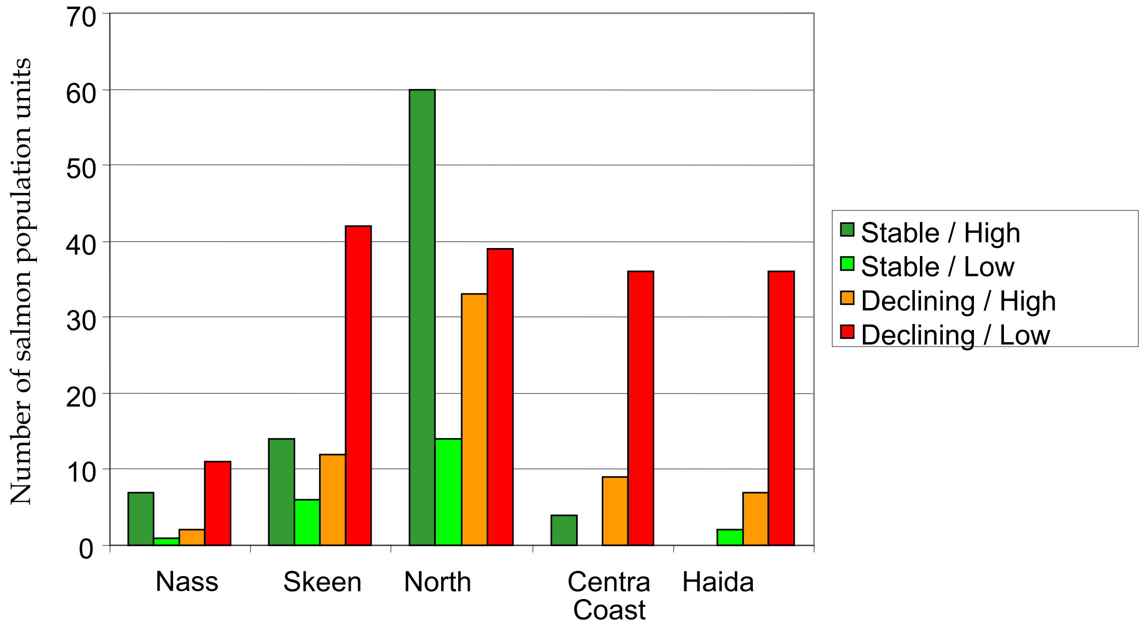


Figure 2.5. Summary of Odd Year Pink condition by EDU.

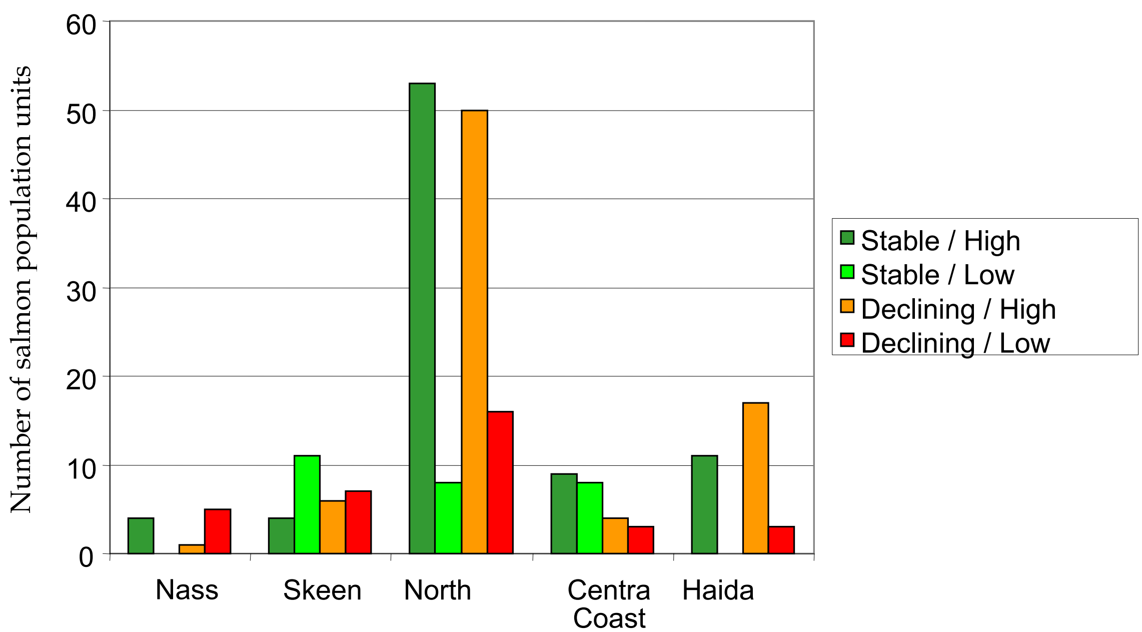


Figure 2.6. Summary of Even Year Pink condition by EDU.

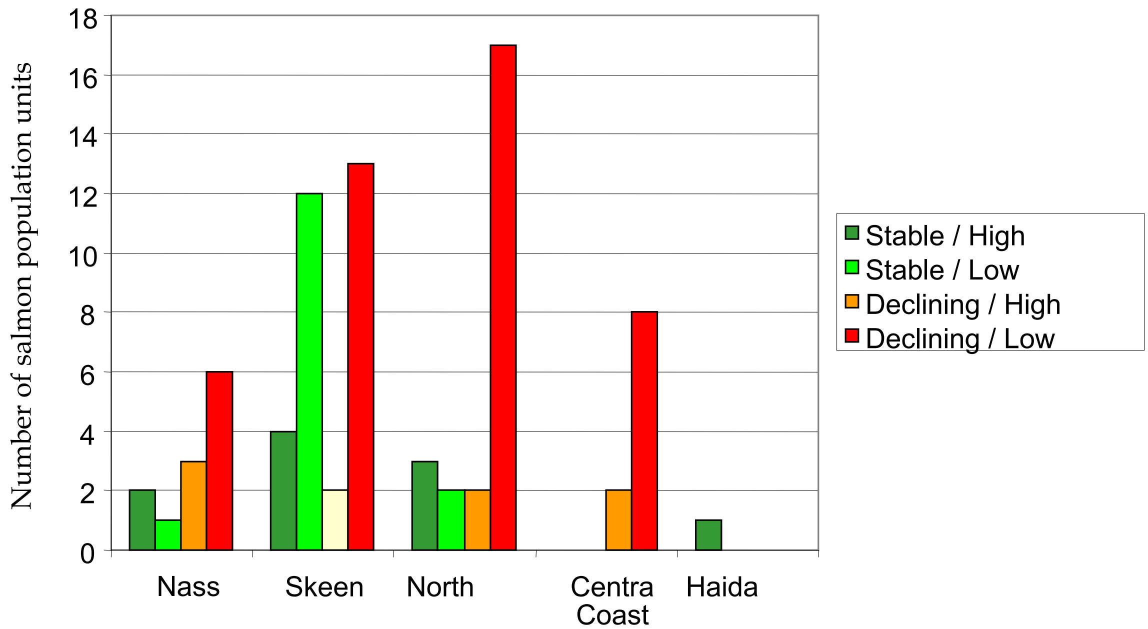


Figure 2.7. Summary of Chinook condition by EDU.

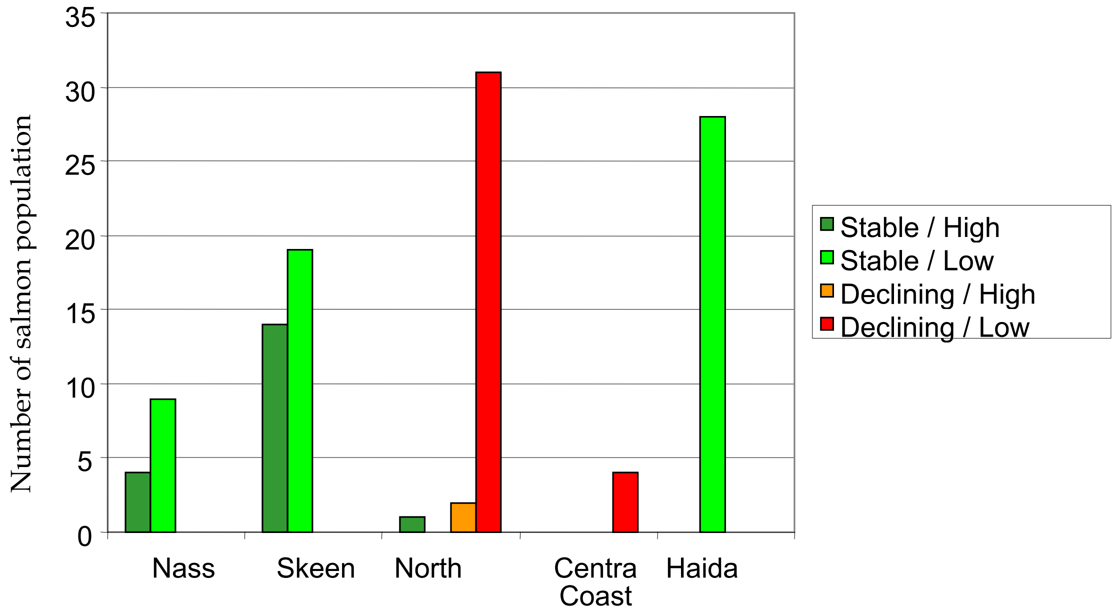


Figure 2.8. Summary of Summer Steelhead condition by EDU.

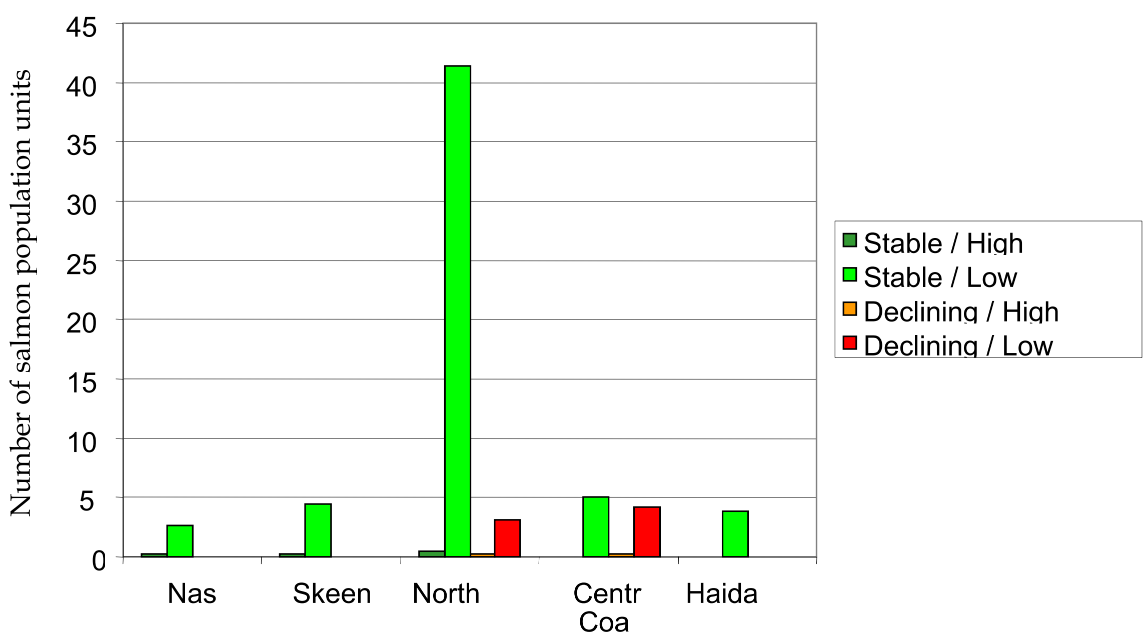


Figure 2.9. Summary of Winter Steelhead condition by EDU.

2.4 Marine Targets

2.4.1 Nearshore Marine

2.4.1.1 Background and Rationale

This section provides assessment information about the nearshore marine ecological systems and species in Queen Charlotte Island, Gwaii Haanas, and the North and Central Coasts of British Columbia. The objective of the nearshore marine component was to identify a set of conservation areas (i.e., an ecoregional portfolio) that, if conserved, will protect a representative subset of the nearshore marine biodiversity of those waters. A technical workshop set the stage for a nearshore assessment to identify specific conservation targets in the form of marine species, shoreline types, and nearshore marine ecosystems. The workshop also identified key areas in the coastal zone known for their diverse species assemblage or high abundance of certain species. Refer to Appendix 1.0.3 for full details of the workshop. We set conservation goals for each marine species and ecosystem target, and ran the site selection algorithm MARXAN to compare these known significant areas and add spatially explicit information to them. The next step of this process is to conduct a thorough review of the analytical output and compare it to key areas identified in the workshop.

The Nature Conservancy's ecoregional planning process identifies and plans for the protection of species and ecosystems. Their identification in this process leads to a thorough data collection effort, which then becomes the core ingredients for analysis. It is therefore necessary to clearly define the species and ecosystems in the marine environment that are being targeted, and the data that exist to back up these definitions.

2.4.1.2 Methods

We identified the intertidal and nearshore zone as the part of the marine environment to target and plan for protection. This zone roughly spans the supratidal area above the ordinary or mean high water line (i.e. the top of a bluff or the extent of a saltmarsh in the upper intertidal) to the subtidal area. The subtidal begins at approximately the mean lower low water line (zero feet elevation) down to the -20 meter isobath. The limit on the lower extent was defined by the shore-zone mapping system (see Berry et. al. 2001). This was the definition of the nearshore zone that was adopted for the regional analysis. Therefore when the following text refers to the "shoreline," it specifically means the analysis conducted using the shore-zone data, and when the text refers to "nearshore," it means the entire nearshore zone including intertidal vegetation and habitats, forage fish spawning sites, and seabird colonies.

We identified 72 conservation targets of which 59 were coarse filter targets (shoreline ecosystems) and 13 were fine filter targets (specific occurrences of marine species). This set of targets was selected to represent the full nearshore marine biodiversity of the region, and to highlight elements that are threatened or declining (i.e., seabird species), or that serve as good indicators of the health of the larger ecosystem (i.e., intertidal habitats).

The waters of the ecoregion were divided, or stratified, into 8 sections based on British Columbia's marine "ecosections" (Harper 1993). Ecosections are characterized as unique physiographic, oceanographic, and biological assemblages that are related to water depth and habitat (pelagic versus benthic). There are several implicit ecological factors of significance to ecosections, the most detailed level of classification after "ecozones," "ecoprovinces," "ecoregions," and "ecodistricts." Ecosections are an indicator of major community differences between benthic and pelagic biota (i.e., solid versus fluid). They are an indirect indicator of primary productivity where shallow areas in the euphotic zone have higher productivity. They are also a direct indicator of oceanic stratification and associated biological assemblages. We used this fifth order subdivision to stratify the coastal zone (Map 22**)**.

In addition to dividing the coastal zone by marine ecosection, we also used a stratification scheme based on project regions. The Ministry of Sustainable Resource Management (MSRM) has contracted with several consulting firms to inventory the shoreline using the shore-zone mapping system (see next section, "Coarse Filter Targets"). Six separate project regions (Map 24) define the CIT region, with varying methodologies adopted for inventorying and interpreting the flight surveys from one region to another. As such, we attempted to account for this discrepancy by ensuring coastal representation across these regions in addition to the more ecological stratification. A third scenario was to not stratify the region at all, but run the site selection algorithm on the 72 conservation targets across the entire CIT region.

2.4.1.3 Special Elements

In selecting these targets, we had to decipher what species were not being adequately represented by the coarse filter targets. In general, we included species that are considered imperiled, keystone (Power et al. 1996), or an ecosystem engineer that has a major impact on the structure and function of communities. Consideration was given to whether the species met the criteria across the study region, or only within a portion of it. The latter case often occurred where a species was imperiled or listed within a certain jurisdiction, and yet the population was thriving in another section of the CIT region. When this occurred it was not appropriate to include the species in the regional analysis.

With this criteria we included 8 marine species as targets. These forage fish and seabird targets are represented as 2 critical life stages, spawning aggregations and breeding colonies.

2.4.1.3.1Forage Fish (Spawning sites)

Pacific herring spawning sites were collected from MSRM. We had comprehensive coverage for herring in the study area, assembled as linear features that coincide spatially with the shore-zone mapping system. Attribute data indicate the Relative Importance (RI) of the feature per location. The values are only comparable within project regions (i.e., Queen Charlotte Islands); this is currently being changed so that these values will be comparable across British Columbia. Nonetheless, we selected values between 3 and 5 (medium to very high) for the analysis. This information was attributed to the shoreline segments.

2.4.1.3.2Seabird Colonies

The Canadian Wildlife Service, who compiled the data for distribution in 2001, provided seabird colony information. The majority of the data are the results of a comprehensive inventory of colonial nesting seabirds along the British Columbia coastline conducted between 1980 and 1989 by the Canadian Wildlife Service of Environment Canada. This data set includes the locations of all known seabird colonies along the coast of British Columbia, and provides a compilation of the most recent (up to 1989) population estimates of seabirds breeding at those colonies (Map 25).

Fifteen species of seabirds, (including two storm petrels, three cormorants, one gull and nine alcids) and one shorebird (Black Oystercatcher) breed on the coast of British Columbia. We selected those species that are considered imperiled or vulnerable in British Columbia (S1 - S3 status). The source of this information was from NatureServe. [14] There were 7 species of seabirds selected to represent colonies along the coast of British Columbia. These include Thick-billed and Common Murre, Cassin's Auklet, Ancient Murrelet, Horned and Tufted Puffin, and Brandt's Cormorant. These data are represented as point locations with attributes describing their location. We used location descriptions to assign the colonies to specific shoreline segments.

2.4.1.4 Representation

The coarse filter targets comprise shoreline ecosystem types derived from a single classification developed in British Columbia, the shore-zone mapping system. The Province of British Columbia developed its physical and biological shore-zone mapping system based on shore types after Howes, et al. (1994) and Searing and Frith (1995). Shore types are biophysical types that describe the substrate, exposure, and vegetation across the tidal elevation, as well as the anthropogenic features. The B.C. shore-zone mapping system is built on shore types that aggregate precise community or habitat types according to their landform, substrate, and slope (Berry et al. 2001). There are 34 coastal classes and 17 representative types within the classification system Table 2.23. See Berry et al. (2001) for the rationale and definitions of the 34 coastal classes. The definitions of the 17 representative types are listed in Appendix 1.0.1.2.

We examined the 17 representative types within the classification and added the "bio-exposure" field in the data sets to form our shoreline ecosystem conservation targets. Bio-exposure is defined as a summary classification of indicator species and intertidal vegetation observed in each shoreline segment (Morris et al. 2001). Species present in turn indicated the wave exposure energy for that segment. Biologists surveying the coastline had the highest level of confidence in assigning wave energy to places where intertidal vegetation was visible. Not all project regions contained the bio-exposure field, however, but instead contained an observation of exposure interpreted from a geologist. Given substrate and exposure information one can then assume the biological assemblages. This exposure observation was deemed of medium confidence in the shore-zone system, used only when bio-exposure was not available. There were 6 wave energy classes assigned to shoreline segments, ranging from very protected to very exposed. There was an additional category that did not identify wave energy.

[14] NatureServe Explorer: An online encyclopedia of life [web application]. 2002. Version 1.6. Arlington, Virginia, USA: NatureServe. Available: http://www.natureserve.org/explorer

Table 2.23 BC Coastal classes and representative types.

Coastal Class	Description	Representative Type
0	Undefined	Undefined
1	Rock ramp, wide	Rock Platform
2	Rock platform, wide	Rock Platform
3	Rock cliff, narrow	Rock Cliff
4	Rock ramp, narrow	Rock Cliff
5	Rock platform, narrow	Rock Platform
6	Ramp with gravel beach, wide	Rock with Gravel Beach
7	Platform with gravel beach, wide	Rock with Gravel Beach
8	Cliff with gravel beach	Rock with Gravel Beach
9	Ramp with gravel beach, narrow	Rock with Gravel Beach
10	Platform with gravel beach, narrow	Rock with Gravel Beach
11	Ramp with gravel and sand beach, wide	Rock with Sand & Gravel Beach
12	Platform with gravel and sand beach, wide	Rock with Sand & Gravel Beach
13	Cliff with gravel and sand beach	Rock with Sand & Gravel Beach
14	Ramp with gravel and sand beach, narrow	Rock with Sand & Gravel Beach
15	Platform with gravel and sand beach, narrow	Rock with Sand & Gravel Beach
16	Ramp with sand beach, wide	Rock with Sand Beach
17	Platform with sand beach, wide	Rock with Sand Beach
18	Cliff with sand beach	Rock with Sand Beach
19	Ramp with sand beach, narrow	Rock with Sand Beach
20	Platform with sand beach, narrow	Rock with Sand Beach
21	Gravel flat, wide	Gravel Flats
22	Gravel beach, narrow	Gravel Beach
23	Gravel flat or fan	Gravel Beach
24	Sand and gravel flat or fan	Sand & Gravel Flat
25	Sand and gravel beach, narrow	Sand & Gravel Beach
26	Sand and gravel flat or fan, narrow	Sand & Gravel Flat
27	Sand beach	Sand Beach
28	Sand flat	Sand Flat
29	Mud flat	Mud Flat
30	Sand beach, narrow	Sand Beach
31	Organics/fines	Estuary Wetland
32	Man-made, permeable	Man-made
33	Man-made, impermeable	Man-made
34	Channel	Channel

2.4.1.4.1Shoreline Ecosystem Targets

The 17 representative types and 7 wave energy classes (very protected, protected, semi-protected, semi-exposed, exposed, very exposed, plus an unidentified category) yielded 119 potential shoreline targets. We decided that having too many classes implied a level of detail that was unnecessary at the scale of the CIT region. Therefore the wave energy classes were aggregated down to 5 classes, where semi-protected was combined with the protected class, and semi-exposed was combined with exposed. We felt that this generalized the shoreline ecosystems into discernable coastal communities for planning purposes at this regional scale. This yielded as many as 85 classes depending on which wave energy classes were possible for each representative shoreline type.

In actuality there are only 63 shoreline categories available after compiling all 6 project regions of shore-zone (Table 2.24**)**. There are 62,441 distinct shoreline segments that cover the entire CIT region. The total shoreline length is 28,145 kilometers compiled from data sets at scales ranging from 1:40,000 to 1:50,000. Four categories, 3 “man-made” types and 1 “unidentified,” are not considered ecosystem targets, bring the total number of targets down to 59. Man-made types consist of 320 shoreline segments (120 kilometers), and unidentified shorelines consist of 1,026 segments (663 kilometers). Removing these categories left 61,094 shoreline segments with targets, or 27,340 kilometers.

These coarse filter shoreline types range from 8 to 21,132 meters in length, with a mean of 450 meters. Short shoreline segments tend to be tiny islands either within estuaries or off the coast. The minimum mapping unit (the smallest measurement that can be delineated on a map as a shape with boundaries) of the actual shoreline classification segments is estimated at 25 meters when mapping is conducted using 1:50,000 hardcopy maps. There are 42 individual shoreline segments (828 meters) under 25 meters in the study area. Shorter segments therefore require further evaluation as to their positional accuracy. It should be noted here that the CIT was given draft shore-zone data from MSRM. Although we were given access to these data in order to complete the coastal/nearshore analysis, there have been changes to the data sets since we acquired it. Therefore the shoreline classes and statistics associated with the data have changed since the completion of this analysis and report.

Table 2.24 Shoreline ecosystem targets.

Target	Target_ID	Shore Units	Total Length (m)
Channel	1001	3	1,548.5
ChannelE	1002	9	2,690.1
ChannelP	1003	73	38,751.9
Estuary Wetland	1004	40	43,949.0
Estuary WetlandE	1005	13	9,942.3
Estuary WetlandP	1006	1134	1,046,811.2
Estuary WetlandVE	1007	9	9,323.4
Estuary WetlandVP	1008	47	46,032.7
Gravel Beach	1009	215	78,725.4
Gravel BeachE	1010	333	93,229.1

Target	Target_ID	Shore Units	Total Length (m)
Gravel BeachP	1011	2983	941,273.4
Gravel BeachVP	1012	12	4,336.2
Gravel Flats	1013	28	15,052.7
Gravel FlatsE	1014	56	19,683.4
Gravel FlatsP	1015	148	76,247.2
Gravel FlatsVE	1016	9	3,599.3
High Tide Lagoon	1017	50	85,740.2
High Tide LagoonE	1018	10	4,254.7
High Tide LagoonP	1019	210	236,286.4
High Tide LagoonVP	1020	60	80,393.8
Man-made (not a target)	1021	13	5,253.3
Man-madeE (not a target)	1022	5	1,262.8
Man-madeP (not a target)	1023	302	135,230.8
Mud Flat	1024	7	4,985.3
Mud FlatP	1025	156	107,010.0
Rock Cliff	1026	1396	703,588.4
Rock CliffE	1027	4314	1,768,132.6
Rock CliffP	1028	11822	5,833,450.0
Rock CliffVE	1029	218	125,300.5
Rock CliffVP	1030	68	31,122.4
Rock Platform	1031	124	33,573.1
Rock PlatformE	1032	1774	661,917.3
Rock PlatformP	1033	447	128,569.6
Rock PlatformVE	1034	345	162,097.7
Rock with Gravel Beach	1035	710	287,587.8
Rock with Gravel BeachE	1036	3374	1,394,014.4
Rock with Gravel BeachP	1037	9679	4,406,751.8
Rock with Gravel BeachVE	1038	123	40,373.1
Rock with Gravel BeachVP	1039	74	35,028.4
Rock with Sand & Gravel Beach	1040	173	57,913.7
Rock with Sand & Gravel BeachE	1041	2333	876,653.2
Rock with Sand & Gravel BeachP	1042	7600	2,843,714.0
Rock with Sand & Gravel BeachVE	1043	12	11,238.0
Rock with Sand & Gravel BeachVP	1044	39	15,471.3
Rock with Sand Beach	1045	19	4,346.8
Rock with Sand BeachE	1046	363	124,830.9
Rock with Sand BeachP	1047	544	182,404.5

Target	Target_ID	Shore Units	Total Length (m)
Sand & Gravel Beach	1048	173	59,406.9
Sand & Gravel BeachE	1049	198	53,307.5
Sand & Gravel BeachP	1050	3600	1,339,292.9
Sand & Gravel BeachVP	1051	29	8,876.9
Sand & Gravel Flat	1052	96	38,497.7
Sand & Gravel FlatE	1053	176	99,267.0
Sand & Gravel FlatP	1054	2689	1,298,001.0
Sand & Gravel FlatVP	1055	29	12,829.3
Sand Beach	1056	19	10,393.3
Sand BeachE	1057	242	187,660.8
Sand BeachP	1058	298	124,058.7
Sand Flat	1059	42	23,653.5
Sand FlatE	1060	129	78,238.5
Sand FlatP	1061	2179	1,306,395.7
Sand FlatVP	1062	40	22,440.9
Undefined (not a target)	9999	1026	662,992.3
59 Targets		**61,095**	**27,340,266.0**

Total shoreline contains 62,441 units with a 28,145,005.1 meters

E = EXPOSED

P = PROTECTED

VE = VERY EXPOSED

VP = VERY PROTECTED

Note: No exposure class indicates that the exposure was not defined

2.4.1.4.2Intertidal Vegetation and Habitat Targets

The shore-zone mapping system also identified intertidal vegetation and habitats. "Bio-bands" are assemblages of intertidal biota, visible from the air and named for dominant species or species assemblages. With these bio-bands we identified the intertidal range biota in the nearshore, including saltmarsh, eelgrass, surfgrass, and kelp. Saltmarsh consists of grasses, herbs, and *Salicornia* associated with protected estuaries in the high intertidal zone. Eelgrass consists of *Zostera* species found in protected environments of the shallow subtidal. Surfgrass, or *Phyllospadix,* is another seagrass found in more exposed coastlines also in the shallow subtidal. Kelps consist of both *Macrocystis* and *Nereocystis* species, where *Macrocystis* is found in protected areas and *Nereocystis* is found on more exposed rocky shores. These kelps are found in the subtidal zone. We found that these vegetation types form the major habitats of the nearshore zone, and although these types alone do not represent that most diverse intertidal habitats, they are extremely biologically productive and the most sensitive to human alteration. Further, these categories are recognized ecologically, are protected by policy, and are the best surrogates at this scale to represent a range of habitats.

We also used the "habitat observed" category from shore-zone to capture the most diverse part of the intertidal zone. Habitat observed is the summary classification of the segment's bio-exposure – from indictor species and bio-bands – in combination with the classification of the segment's substrate and morphology. There are 10 different habitat categories in the data set. We used the Habitat 3 category as additional target to represent the semi-exposed, immobile bedrocks and blocks (coastal classes 1 – 23, see 4.4.1.4a) in the lower intertidal. Indictor species include rich red algae, *Hedophyllum, Egregia, Phyllospadix, L. setchellii,* and *Eisenia.* Indicator bio-bands include mussels-barnacles, chocolate brown algae, surfgrass, urchin, and *Nereocystis* kelp. This category represents the highest diversity of biota in the intertidal. (Mary Morris, personal communication 2003).

2.4.1.5 Data Gaps

In conducting the CIT nearshore analysis, there are bound to be data limitations and inconsistencies across jurisdictional boundaries. In general, marine data are less developed than terrestrial counterparts. This is especially true for presence/absence data on marine algae and sessile invertebrates who define ecosystems in much the way plants do on land.

2.4.1.5.1 Fine Filter Data Gaps

Marine species data are either very coarse in scale (i.e., depicting a species' distribution over a large area) or collected on a very fine scale of resolution (i.e., detailed survey transects a specific site, but the coverage across a wide area is highly discontinuous and methods vary tremendously). Including this type of information in explicit site selection analysis is problematic; therefore we screened data for inclusion in the regional analysis. We assessed all available data sets to include in the regional analysis, and set different parameters during the site selection analysis (see section 7.2.4)

Our biggest data gap in B.C. was data regarding invertebrates. The Conservation Data Centre (CDC) does collect element occurrence data for some invertebrate species, but the data is not comprehensive throughout the study area. Without a comprehensive, continuous survey effort we were limited by the places where species were found and therefore did not have a sense of abundance across the region. Although this is a systemic problem for all spatial analyses, it is particularly problematic for sessile invertebrates that may utilize large areas of benthic habitat types. The sparse data reflects neither the best nor the only sites where these species occur.

In B.C. we had no fishery-independent survey information on rockfish species, lingcod, surf smelt, or sand lance. Only Pacific Herring spawning data allowed for a comprehensive analysis across the region.

We had good representative data for seabird colonies, though there is some debate over what constitute as a seabird target. Depending on the source being used, different planning teams have selected different species to include in the analysis (i.e., nearshore and offshore analyses). Without a definitive study or source for selecting seabirds as conservation targets, there will continue to be debate over what species meet conservation target criteria. Although not a data "gap," this inconsistency in the selection process have made the integration of nearshore and offshore analyses more difficult (where the nearshore has selected specific seabirds as colony habitats, the offshore analysis focused on a different list of target species and their foraging areas.)

2.4.1.5.2 Coarse Filter Data Gaps

Although we included "estuaries" as targets in the analysis, we did not have complete information on all estuaries in B.C. Further, we were limited by the treatment of estuaries as they were defined spatially. Therefore we did not feel that we analyzed or prioritized estuaries well for the CIT region.

Estuaries were treated in this portfolio several ways. Both the terrestrial ecological systems and the shoreline ecosystem targets identified saltmarsh communities. In both cases the definition of estuaries was associated with a vegetation type. Other estuaries were captured in the shoreline ecosystem categories as "mud flat," "sand flat," and "sand and gravel flat." Here the definition was associated with gently sloping flats near river mouths represented as linear features.

The shore-zone data does not fully represent the spatial delineation of estuaries as polygons. Although the data does delineate some of the estuaries in the study region, many estuaries are left out of the data sets because they were not identified as the dominant feature in the intertidal. The strength of the shore-zone estuaries is their identification of substrate and vegetation attributes, not the spatial delineation.

The Canadian Wildlife Service and Environment Canada's Pacific Estuary Conservation Program (PECP) delineated estuaries as polygons but with limited attribute information. This mapping made use of existing information (primarily TRIM, the 1:50,000 Watershed Atlas and the Marine Charts) and detailed specifications to direct the identification and digitizing of the intertidal zone and supratidal/upstream zone of each estuary. Aerial photographic interpretation and field work were not part of the methodology. The result is a comprehensive and standardized map of BC's estuaries depicted as polygons. These data do not yet include the Fraser, Skeena, or Nass river estuaries since the methodology to delineate these large estuaries is still under development. The outer extent of each estuary (the intertidal zone) was delineated using the lowest normal tide line (zero chart contour line) from the Marine Charts. The inner extent (supratidal/upstream zone) was delineated by the TRIM coastline and 500 m upstream. Currently they are seeking data on the maximum upstream detection of surface salinity on these systems as an indicator of the upstream boundary of the estuary. Since these data focus on the delineation of estuaries and not the benthic and vegetation information within them, we did not use them in the nearshore anlaysis.

We therefore did not feel that the analysis strictly optimized for high priority estuaries as a coarse filter target. Until we have compiled comprehensive spatial and attribute information on estuaries, they will continue to be under-represented in site selection algorithms. As a result, estuaries and their importance were not emphasized enough in building the nearshore portfolio.

2.4.2 Offshore Marine Analysis

2.4.2.1 Overview

The CIT marine ecosystem spatial analysis (ESA) consists of 93 features, both biological and physical; considering representivity, distinctiveness, focal species, and rare or threatened species.

Data were compiled from Fisheries and Oceans Canada (DFO), BC Ministry of Sustainable Resource Management (MSRM), Canadian Wildlife Service (CWS), Natural Resources Canada (NRCan), private researchers, and local knowledge (Table 2.2.5).

Table 2.25 Summary of data layers by type.

"Filter"	Feature Category	Feature Sub-Category	No. of Layers
Coarse Filter	Regional Representation	Data Regions	6
Coarse Filter	Ecosystem Representation	Ecosections	8
Coarse Filter	Ecosystem Representation	Ecosystem Regions	3 regions + 3 sub-regions
Coarse Filter	Ecosystem Representation	Enduring Features & Processes	7 exposure + 21 substrate/depth
Fine Filter	Focal Species	Flora	13
Fine Filter	Focal Species	Seabirds	15
Fine Filter	Focal Species	Anadromous Spp. Richness x Stream Magnitudes	1
Fine Filter	Focal Species	Mammals	1
Fine Filter	Focal Species	Fish	1
Fine Filter	Special Elements	Rarity	6
Fine Filter	Special Elements	Distinctive Features	4 complexity + 4 current
TOTAL	**48 Coarse Filter +**	**45 Fine Filter**	**93**

In the following sections, each of these feature categories is discussed. For a more detailed table of the features, please refer to Appendix 2.1.1.

2.4.2.2 Focal Species & Special Elements

2.4.2.2.1 Focal Species

Focal species have received a lot of attention in terrestrial conservation (e.g., Noss 1991, Lambeck 1997), but have received less attention in marine conservation (e.g., Day & Roff 2000, Zacharias & Roff 2001, Roberts et al 2003). Different categories of focal species exist, such as indicators, keystone, umbrella, and flagship species (for a complete discussion, see Zacharias and Roff 2001). A common concept in terrestrial conservation is that of the umbrella species, whose conservation is believed to also spatially protect other species' habitat. Unfortunately, umbrella species are not as widely applicable in the marine environment, though they can prove valuable at more local scales (Zacharias and Roff 2001). One problem with the applicability of this concept to marine systems is that many candidate umbrella species, fitting the typical (terrestrial) apex predator profile, such as killer whales (*Orcinus orca*), exhibit massive migrations and utilise areas too large to be useful as marine umbrella species at most planning scales.

On the other hand, marine focal species can still be identified that are useful in conservation. Zacharias and Roff (2001) note that composition indicators, or species who's presence indicates other species or are used to characterize a particular habitat or community are particularly useful. They feel that sea birds, sea grasses, macroalgae, and benthic invertebrates are good candidates for focal species. We feel that sea birds may be also be seen at least partially as umbrella species, since protecting their foraging habitats will afford some protection to their prey species. Likewise, kelp beds (*Nereocystis luetkeana* and *Macrocystis intergrifolia*) were treated as local-scale umbrellas for the many species associated with them, as were eelgrass beds (*Zostera* sp.). Herring (*Clupea pallasii*) spawn were treated as a keystone species, since so many other species are attracted to, and rely upon, these areas to feed on the eggs (Hay and McCarter 2000).

Flora

For the CIT marine ESA, we considered the following focal vegetation species: Eelgrass, kelp, marsh grasses (*Salicornia* sp.), surf grasses (*Phyllospadix* sp), and a general shoreline vegetation class, aggregated from the BC Shorezone classification that includes *Fucus, Ulva,* halosaccion layers, "reds," "soft browns," and "chocolate browns." (For a more detailed shoreline vegetation analysis, we deferred to the nearshore ESA team –see Section 2.4.1).

Seabirds

All major BC breeding seabird populations and colonies were considered: Ancient Murrelet, Black Oystercatcher, Cassin's Auklet, Cormorant sp., Glaucous-winged Gull, Pigeon Guillemot, Puffin sp., Rhinoceros Auklet, and Storm Petrel sp. (data provided by Canadian Wildlife Service). In addition, very small islets, far from shore were also considered as surrogates for unsurveyed colonies (G. Kaiser pers. comm., Map 25).

Seabirds are known to prefer certain marine waters. These we treated as "habitat capability" layers. We considered pelagic seabirds (shearwaters, fulmars, albatross, some gulls, and terns); waterfowl (ducks, swans, geese, grebes, and loons); and shorebirds (oystercatchers, sandpipers, plovers, and turnstones). Data were provided by Decision Support Services, Sustainable Resource Management, based on known distributions and expert opinion.

Moulting seaducks (Scoter sp. and Harlequin Ducks) inhabit certain nearshore BC waters during summer months. Because they are unable to fly, they are particularly susceptible to stressors such as oil spills (Savard 1988). These areas were also considered –separately for each species grouping (data from CWS Coastal Waterbird Inventory; and from Savard 1988, digitized by J. Booth, Map 25).

Anadromous Streams

BC's anadromous streams were captured using a species richness x stream magnitude ranking. Eight of BC's nine anadromous spp were considered (eulachon, the ninth, was treated separately). These include all *Oncorhynchus* spp and Dolly Varden (*Salvelinus malma*). About 1 out of 10 BC stream systems were considered *likely* to support significant numbers of anadromous species. Of those, about half were assigned a low score (1-4 out of a possible 24), meaning that they are small streams supporting only a few species. Only the Fraser River (outside the CIT study area) received a top score (24), with the Nass and Skeena rivers tied in second place (20). For a full description of this layer, please refer to Appendix 2.2.2 Stream Richness x Magnitude (Map27).

Steller Sea Lion

Steller Sea Lion (*Eumetopias jubatus*) haul-outs and rookeries were ranked on a scale of 1-4 based on population density.

Herring spawn

Herring spawn (*Clupea pallasii*) shorelines were ranked on a density measure based on DFO's Spawn Habitat Index (Hay & McCarter, 2001), using the latest available times series data (DFO 2002). Data were cube root transformed and standardized to shoreline length per hexagonal planning unit.

2.4.2.2.2Rare and Threatened Species

Rare, threatened and endangered species are generally given a lot of conservation attention. However, the inaccessible nature of the sea makes it much harder to survey and therefore know most of what is rare. Declining populations may go unnoticed through to their extirpation (Thorne-Miller 1999). In the marine ESA, we consider five Special Elements, on account of their rare or threatened status: Hexactinellid sponge reefs, Eulachon estuaries, Sea otter (not WCVI), estuaries containing red or blue listed species, and Marbled Murrelet marine habitat.

Hexactinellid Sponge Reefs

Hexactinellid sponge reefs are unique to the BC coast and are important in terms of their ecology and their similarity to extinct Mesozoic sponge reefs. There is already evidence that they have been damaged by bottom trawling (Krautter et al 2001, Conway et al 2001, Conway 1999). In the spring of 2002, while setting a mooring to monitor one of the last undisturbed mounds, researchers discovered that it had been trawled since the previous visit (K. Conway pers comm. July 2002). We strongly support the recommendations of Conway (1999), Krautter et al (2001), and Jamieson & Chew (2002), all who suggest that these sponge reefs be permanently protected from trawling. Since the summer of 2002 they have been given some protection in the form of a fishing closure, however closures can be lifted at any time at the discretion of fisheries managers. There are only four such reefs known to exist in the world, all of which are in the CIT study area.

Eulachon Estuaries

Eulachon (*Thaleichthys pacificus*) are an ecologically and culturally important fish species (Hart 1973). Eulachon spawning areas in the Central Coast are limited (McCarter and Hay 1999). Although larval eulachon spend very little time (hours) in their natal streams, the associated estuary or inlet is important juvenile habitat. Eulachon streams and estuaries should therefore be considered for protection.

Eulachon are heavily preyed upon during spawning migrations by spiny dogfish, sturgeon, Pacific halibut, whales, sea lions, and birds. In the ocean, it is also preyed on by salmon and other large predatory fishes (Fishbase 2001, Pacific States Marine Fisheries Commission 1996).

Data were downloaded from DFO Habitat and Enhancement Branch's public web site (DFO 2003), and were compared to FISS data, and published literature (McCarter and Hay 1999). Points were snapped to the BC Watershed Atlas when appropriate.

Sea Otter

Sea otters (*Enhydra lutris)* were once abundant throughout the Northeast Pacific but were hunted to near extinction from the mid-1700's to early 1900's. Apocryphally, the last known sea otter in British Columbia was accidentally shot in 1929. Between 1969 and 1972 eighty-nine sea otters were reintroduced to Checleset Bay off northwest Vancouver Island and the population has been increasing at a rate of 17 percent per year (Estes 1990; Watson unpublished). Sea otters are important predators of invertebrates such as sea urchins and have been shown to play an important ecological roll as a keystone predator (Estes 1990).

Unlike other marine mammals, sea otters do not have a blubber layer. They rely on their fur to keep warm and are therefore particularly vulnerable to oil spills, even minor ones. Several thousand (approx. 5000) sea otters died in the 1989 Exxon oil spill in Valdez, Alaska (Marine Mammal Center 2000).

While the WCVI population appears to be increasing, the only known established colony in the CIT study area is in the Goose Islands.

Red-Blue Estuaries

Estuaries in the North Coast and QCI harbouring provincially red (rare) or blue (threatened) listed species, mainly birds, were identified by Remington (1993), and digitized by Living Oceans Society for the CIT.

Marbled Murrelet Marine Habitat Capability

Marbled murrelets, in the auk family, are on the provincial “Blue” list of vulnerable species. They may be moved to the “Red” list of endangered species in the near future since the marbled murrelet population has suffered an estimated 40% drop in the past decade alone (Cannings and Cannings 1996). Both natural and human-related factors may be contributing to the species' decline; potential causes include the loss of suitable nesting habitat, accidental death in gill-nets, oil pollution, increases in predator populations, and declines in food supplies due to recent El Nino events (SEI 1999).

Marbled murrelets lay a single egg on wide, mossy branch of old growth conifer trees (Cannings and Cannings 1996). Therefore, during breeding season, murrelets can be found foraging just offshore of old growth forests. Concentrations of foraging murrelets are sometimes found associated with tidal rips, high current areas, or river plumes. Researchers have identified a marbled murrelet juvenile nursery area in a semi-protected Nereocystis bed in Alaska (Kuletz and Piatt 1999). Although no similar areas have been identified in the Central Coast of BC, kelp beds and high current areas have also been considered in the marine ESA.

Marbled Murrelets are known to prefer certain marine waters. These we treated as a “habitat capability” layer. Data were provided by Decision Support Services, Sustainable Resource Management, based on known distributions and expert opinion.

Habitat-Forming Corals

We considered areas known to harbour large habitat-forming corals, which may well be threatened or endangered, but due to a lack of surveys their status largely remains unknown. Coral outcrops and “forests” are important habitat for adult fishes, crustaceans, sea stars, sea anemones and sponges because they provide protection from these currents and from predators. Some commercially important fish species are found in association with these reefs, such as Atka mackerel, *Pleurogrammus monopterygius,* and shortspine thornyhead, *Sebastolobus alascanus,* in Alaska. Rockfish are associated with *Primnoa* corals in the Gulf of Alaska (Etnoyer & Morgan 2003).

2.4.2.2.3 Distinctive Features

One shortcoming of a representative areas approach is that it requires examining and possibly setting aside very large areas. Pragmatically, there may not be the political will or management capability to fully realize this approach. Furthermore, smaller but ecologically valuable areas may be passed over. Roff & Evans (2002 unpublished) argue that such smaller "distinct" areas are by definition different from their representative surroundings and may harbour higher (or lower) species diversity, richness, and abundance. These, they suggest, must also be considered in reserve design. Distinctive areas may also be thought of as representative of a certain type of habitat, but at a finer scale than the nominal scale of the study (John Roff, pers. comm.). In the marine CIT ESA, we included two separate indicators of distinctive habitats: Benthic topographical complexity, and high current.

Benthic Complexity

Areas of high taxonomic richness are often associated with areas of varying habitat. The more kinds of niches available in which organisms can live will usually lead to a wider variety of organisms taking up residence. Furthermore, the complexity of habitat can interrupt predator-prey relationships that in a simpler habitat might lead to the clear dominance or near extirpation of certain species (e.g., Eklov 1997). Thus, in complex habitats species may co-exist in greater diversity where elsewhere they might not. Likewise, a greater variety of life stages may also be supported. Thus, complex habitats may exhibit greater ecosystem resilience (e.g., Peterson et al 1998, Risser 1995). Furthermore, if complex habitats do encourage biodiversity, as is being suggested, then it follows that they likely also offer greater resistance to invasive species (Kennedy et al 2002).

Benthic topographical complexity is indicated by how often the slope of the sea bottom changes in a given area; that is, the density of the slope of slope of the depth. Note that this is not the same as relief, which looks at the maximum change in depth. Benthic complexity considers how convoluted the bottom is, not how steep or how rough, though these both play a role. Complexity is similar but not the same as "rugosity" as is sometimes used in underwater transect surveys, whereby a chain is laid down over the terrain and its length is divided by the straight-line distance. Rugosity can be strongly influenced by a single large change in depth, however, whereas complexity is less so, since all changes are treated more equally (Ardron 2002).

We used this analysis because we felt it captured biologically and physically meaningful features that the other measures missed. For example, archipelagos and rocky reefs are invariably picked out as areas of higher benthic complexity. Both are associated with several marine values. While "obvious" to the casual observer, they had hitherto no simple quantitative definition that could be used to identify them using a GIS. Benthic complexity will often also identify physical features such as sills, ledges, and other distinctive habitats that are associated as biological "hotspots" providing upwellings, mixing, and refugia (Ardron 2002, Map29).

In the marine ESA, benthic complexity was examined separately within each of the four Ecological Regions (inlets, passages, shelf, slope).

High Current

This layer was extracted from the BC Marine Ecological Classification, version 2 (LUCO 1997, Axys 2001), as well as incorporating additional local knowledge. High Current is defined as waters that regularly contain surface currents (tidal flow) greater than 3 knots (5.5 km/hr or 1.5

m/s). These are areas of known mixing and distinctive species assemblages. In addition, high current areas often represent physical "bottlenecks" to water movement and as such are important to larval transfer and nutrient exchange.

The strong currents of the southern half of the Central Coast, particularly in Johnstone Strait and Discovery Passage, are probably the most influential oceanographic variable of that region. They mix the water column so that nutrients, oxygen, temperature and salinity levels are almost uniform throughout (Thomson 1981). The constant re-suspension of nutrients in particular is most likely responsible for the rich biota of the south Central Coast passages. Mann and Lazier (1996) explain that tidally-induced mixing in relatively shallow coastal waters prevents stratification of the water column, but the potentially adverse effects on phytoplankton are more than compensated for by the increased nutrient flux to the water column from the sediments. Annual primary productivity in tidally mixed areas tends to be above average for coastal waters (Mann and Lazier 1996). Highly productive and biologically diverse areas, such as the world-renowned dive site, Browning Passage (Queen Charlotte Strait), result from these nutrient-rich, mixed waters.

Because high current areas are always well mixed subsets of whatever larger mixing regime may exist, we have classified them as distinctive areas. They were considered separately for each of the four Ecological Regions (inlets, passages, shelf, slope).

3.0 SETTING GOALS

3.1 Background

Explicit and quantitative goals are fundamental to systematic conservation planning (Margules and Pressey 2000). Goals represent the end toward which conservation efforts are directed for targeted species, communities, and ecosystems. Goals provide the quantitative basis for identifying and prioritizing areas that contribute to a network of conservation areas. Moreover, tracking progress toward goals provides an evaluation of the performance of a conservation program, from the scale of individual projects up to province-wide, national, and ultimately global programs. Establishing goals is among the most difficult - and most important - scientific questions in conservation planning (e.g., How much protected area is enough? How many discrete populations and in what spatial distribution are needed for long-term viability?). As some have pointed out (e.g. Noss 1996, Soule & Sanjayan 1998), questions such as these cannot be answered satisfactorily by theory, but require an empirical approach, target-by-target, and a commitment to monitoring and continual re-evaluation over the long-term.

Goals for conservation targets specify the number and spatial distribution of on-the-ground occurrences. As a general rule, a broad goal is to conserve multiple examples of each target, stratified across its geographic range in such a way that we capture the variability of the target and its environment. Replication of occurrences of each target must be sufficient to ensure persistence in the face of environmental stochasticity and the likely effects of climate change.

Although we were not able to rigorously analyze population viability of our focal species in this study, we have considered the conditions that contribute to viability in a general way. Conservation goals should support the evolutionary pathway of species in continually changing ecosystems, looking into the future at least 100 years or 10 generations. While that concept of viability could be said to apply to all targets, in practice we use several closely related, though distinct, groups of targets. Strategies for focal species emphasize recovery and evolutionary adaptation of individual species. In addition to species viability, coarse-filter strategies emphasize the conservation of ecosystem services (e.g. air, water, nutrient cycling, etc.), perhaps better characterized as **ecological integrity** at a regional scale (Pimentel, Westra, & Noss 2000). While conservation goals for species correctly emphasize potential genetic fitness and the functional roles of species in ecosystems, coarse-filter goals focus on representation of ecological variability and environmental gradients.

3.1.1 How much is enough: Level of landscape protection (Representation Analysis)

Early work with mathematical site-selection algorithms concentrated on determining the "minimum set" conservation network, often defined as the area needed to protect *at least one example* (e.g., a individual plant, 1 occurrence of a mammal species or, in some cases, an entire population) of all selected elements of biodiversity (Church et al. 2000; Reyers et al. 2000; Rodrigues & Gaston 2001; Rodrigues et al. 1999). Most algorithms minimize the amount of area needed through complementary selections, or selecting areas based on the number of unique elements contained. This work has shown that, as biodiversity and endemism increase, so does the amount of area needed to represent all elements. In the regions with the highest biodiversity and many species with narrow distributions (i.e., tropical regions), Rodrigues and Gaston (2001) predicted that as much as 93% of the area would be needed to represent at least a single example of each biodiversity element, and that globally, 74% of global land area would need to be protected to conserve global biodiversity. Because northern temperate regions have lower biodiversity and fewer narrow endemics than found in the tropics, it is expected that less protected area is necessary to represent single occurrences of biodiversity elements. Nevertheless, Cumming et al. (1996) found that any reduction in total area of boreal forest resulted in the loss of forest structural diversity across the landscape, and that forest structure is critically important for supporting biodiversity in boreal forests. Importantly, site selection algorithms, by themselves, do *not* address the more difficult and real-world questions concerning the area needed to *maintain viable populations* of species and the persistence of biodiversity. Undoubtedly, maintaining viable populations requires vastly more area than representing single elements, particularly if those single elements are defined as single occurrences of individuals.

An intended application of conservation science is to assist in answering these more difficult questions, through explicitly defining the area and configuration of habitats needed for the long-term persistence of biodiversity. Many studies have proposed minimum targets for biodiversity conservation, either generally or for specific regions. In some cases these figures are based on estimates by experts of the area necessary to maintain viable populations, ecosystem services, or the persistence of biodiversity generally; in other cases they are based on the empirical results of studies employing site-selection algorithms and/or population viability analyses (Table X). The implicit objective of these recommendations is to reduce extinction rates to near-background levels, maintaining the integrity of all ecosystems, and to sustain natural ecological flows and processes on a regional scale. Generally, most experts have reported that some degree of protection for at least 40-60% of the terrestrial lands and fresh waters would be required to sufficiently protect biodiversity, assuming that the very "best" and representative areas are selected. When existing protected areas – which generally were not selected on the basis of biological criteria -- are included in designs, the results are less efficient, and more land (e.g., 70% of the Greater Yellowstone Ecosystem, where 27% of the landscape is already protected; Noss et al. 2002) is needed to meet similar conservation goals. Using spatially-explicit population models linked to site selection procedures, Carroll and collegues (2003) determined that at least 37% of their US-Canadian Rocky Mountain study area would need to be protected to meet population viability criteria for large carnivores (grizzly bear and wolf). Their modeling procedures preferentially selected the most productive (e.g., source) habitats, based on estimated fecundity, mortality and connectivity parameters. In other planning efforts, without spatially explicit population modeling, it may be impossible to select, *a priori,* similar critical (i.e., irreplaceable) sites in optimal configuration, and the precautionary principle dictates that higher levels of targets should be set.

3.1.2 How much is enough: Individual conservation area size (Representation Analysis)

The required size of individual conservation areas can be considered relative to the natural disturbance regime. Pickett and Thompson (1978) defined a "minimum dynamic area" as the smallest area that contains patches unaffected by the largest expected disturbances. This large size is required to allow recolonization from undisturbed patches within the reserve. Shugart and West (1981) estimated that in order to maintain a landscape's dynamic ecological processes in equilibrium, a reserve ought to be 50- 100 times larger than a typical large disturbance. However, calculations at this scale are unrealistic to conservation planners and agency decision makers. Moreover, the assumption that a landscape should be in equilibrium with a disturbance regime is questionable, especially in ecosystems characterized by large, catastrophic disturbances (Baker 1989). For example, the 1988 fires in and around Yellowstone National Park in the US were larger in size than the park itself, suggesting that the park should be much larger. However, the fires both inside and outside park boundaries were highly heterogeneous, with abundant refugia for native plants and animals. Indeed, recovery after the fires was more rapid than ecologists expected.

In reality, because individual protected areas are unlikely to be large enough to meet conservation goals, the entire landscape must be managed to maintain ecological integrity, including disturbance regimes, target species populations, and connectivity. It has been shown in several recent studies on protected areas in North America, Canada, and East Africa, that single protected areas or parks become island-like within a landscape inhospitable to biodiversity and natural processes. Parks and protected areas that are effectively isolated inevitably lose key species, particularly wide-ranging mammalian species. In 14 western North American park assemblages, only the very largest park *complexes* did not lose any mammals (Newmark 1995) and a similar pattern was observed in East African parks (Newmark 1996). The parks or park complexes that escaped the loss of mammal species over time were exceptionally large, over 1000 km^2 and usually around 10,000 km^2. The smaller the park, the greater the losses. For mammals in the Alleghenian-Illinoian mammal province of eastern North America, the estimated minimum area requirement is 5037 km^2 (Gurd et al. 2001). Canadian parks smaller than this have lost species (Glenn and Nudds 1989, Gurd and Nudds 1999).

These studies do not, however, include measurements of differences in human activities surrounding protected areas. In fact, while size of protected areas remains an important consideration to guard against deleterious effects of habitat fragmentation (Noss and Csuti 1997, Debinski and Holt 2000), loss of species is also tightly linked to human pressures in the surrounding matrix lands (e.g., urbanization, Parks & Harcourt 2002), as well as human pressures inside (i.e., hunting, Brashares et al. 2001) the protected areas. Depending on long-term land uses, formally protected status may not be required across the entire landscape, if management there is environmentally sensitive and emphasizes the maintenance of native biodiversity and ecological processes. Within these mosaic landscapes, protected or conservation areas serve as insurance that the most sensitive components of biodiversity receive sufficient security, whereas management of the surrounding matrix determines whether or not ecological processes remain viable across the region and long-term conservation goals are met.

3.1.3 Goals for Focal Species

Large carnivores are often selected as focal species, given their often low demographic productivity, large area requirements, low density, and potential sensitivity to landscape change (Noss et al. 1996). In many areas of western Canada and northwestern US, large predators, such as the grizzly bear, wolf, or wolverine, are used as surrogates for biodiversity in the development of conservation areas or protected area designs. These species require large contiguous or linked areas of high-quality habitats to ensure viable populations.

For such species, population viability should be assessed to determine how many individuals are necessary to insure a high probability of long-term survival. While estimating population viability has been proposed as a major objective of conservation science, the necessary data required to accurately determine the viability of populations are usually absent (Boyce 1992; Morris & Doak 2002; Shaffer 1981). These data include vital demographic rates (e.g. age-specific mortality rates, mean litter size, sex ratio, inter-birth intervals, etc.) that influence population growth and decline, as well as the natural level of variance in all vital rates. Determining vital rates is costly and time consuming, and can take years of intensive study. Consequently, most attempts to assess population viability and subsequently determine "how much is enough" often result in a correct and responsible conclusion of uncertainty, especially when natural environmental fluctuations are also factored into predictive estimates. Even when vital rates are known (or estimated), the exact linkages between habitat area/habitat quality requirements and vital demographic rates are often not well enough understood to draw conclusions with any confidence regarding "how much is enough".

3.1.4 Conclusions

In this study, we did not have the time or funding to gather the necessary data and perform detailed, spatially-explicit population modeling for the selected focal species. Therefore, we were unable to evaluate the potential population viability of these species in alternative networks of reserves compared to the current network of protected areas. Nevertheless, we are able to use the results of other studies, such as those reviewed above, to qualitatively evaluate the ability of alternate designs to sustain populations of focal species over time. We recommend that further studies be conducted to gain a more detailed understanding of how much area, and in what configuration and type of management, is needed for persistence of focal species over time.

Although it is difficult to directly transform the knowledge available from other studies into specific management prescriptions for our study region, the research reviewed above does provide insight into the question of "how much is enough”. There appears to be a general consensus that at least 40-60% of a region should receive biodiversity protection, with some scientists and studies suggesting substantially higher levels and a few suggesting lower levels (see Table 3.1). It is important to recognize that the amount of land needed to meet identical goals will vary considerably by region, depending on the physical and biological heterogeneity of the region, habitat quality, human land uses, and many other factors (Noss and Cooperrider 1994). The proportion of the landscape provided with protection, and the form and function of that protection also will vary across regions, depending upon social, political, and economic constraints. It appears that 40% might be the lower responsible limit, based on data and recommendations from previous studies, and given the existing degree of uncertainty. Higher proportions of the landscape devoted to protection could certainly be argued for, particularly given the sparse data on the ecological dynamics and requirements to maintain focal species and natural processes. Indeed, the precautionary principle dictates higher levels of protection to buffer against these uncertainties.

For coastal regions of BC, the grizzly bear has been identified as a key focal species, and represents an umbrella species with the most impressive spatial requirements. For grizzly bears, recent research provides several relevant insights (see discussion above for citations). First, maintenance of a single population of grizzly bears with a relatively low risk of extinction over the short term (20 years) would require a starting population of at least 250 bears and, although exact population density is not known, this would probably require somewhere between 3,000

km^2 and 10,000 km^2 of contiguous area. Furthermore, in order to minimize edge effects, necessary buffers around these areas increase area requirements to between 10,000 km^2 and 40,000 km^2. Second, these benchmark populations can not be expected to be viable in isolation, and should be protected within a matrix of landscapes that supports a larger, connected population or metapopulation. Third, because edge-effects are critical and the ratio of population sinks to sources should be minimized, the shape and configuration of areas is also important. Ideally, several clusters of primary watersheds would be protected as single contiguous units. For island populations, either one large block of habitat with sufficient area, or several smaller blocks in close proximity (perhaps less than 5 km apart) should be protected. Fourth, it would be consistent with a precautionary approach to provide protection for several (e.g. >3) benchmark populations. These populations should be distributed across the region and connected through linkage zones.

Table 3.1 Percentage of land recommended for protection in a number of regions, based either on general estimates of viability requirements or on empirical results of goal-driven site-selection algorithms or other quantitative studies.

Source	Region	Goal
Odum (1970)	Georgia	Optimize ecosystem services and quality of life in a self-sustaining ecosystem
Odum and Odum (1972)	South Florida	Optimize ecosystem services and economic and cultural well-being
Margules et al. (1988)	Australian river valleys	Represent all plant species and wetland types at least once
Ryti (1992)	San Diego Canyons	Represent all bird, mammal, and plant species at least once
Ryti (1992)	Islands in Gulf of California	Represent all bird, mammal, reptile, and plant species at least once
Metzgar and Bader (1992)	Northern Rocky Mountains of U.S.	Maintain an effective population of 500 grizzly bears (total pop. = 2000)
Noss (1993)	Oregon Coast Range	Protect all clusters of rare species and community occurrences and all primary forest; provide for carnivore recovery
Cox et al. (1994)	Florida	Protect rare species and natural communities
Noss (1996)	General Estimate	Meet well accepted conservation goals in various regions
Noss et al. (1999)	Klamath-Siskiyou Ecoregion	Protect roadless areas that meet all special elements, representation, and focal species goals
Hoctor et al. (2000)	Florida	Capture biological priority areas and provide connectivity statewide
Rodrigues & Gaston (2001)	Review of 21 studies worldwide	Represent each species at least once
Rodrigues & Gaston (2001)	Tropical rain forests	Represent each plant (and vertebrate) species at least once
Noss et al. (2002)	Greater Yellowstone Ecosystem	Protect megasites that meet all special elements, representation, and focal species goals
Carroll et al. (2003)	US-Canada Rocky Mountains	Protect highest-quality habitat and source areas to maintain viable populations of carnivores

3.2 CIT ESA Terrestrial/Freshwater Goal Setting

Given the time and resources available to the ESA, the most advisable approach to setting goals draws on the EBM framework by setting a range of goals that can be used to construct separate portfolios for several goal levels within that range. Using this approach, a series of potential conservation solutions were created for 30%, 40%, 50%, 60%, and 70% goal settings, wherein these percentage goals were applied uniformly across all ecosystem and focal species targets. These solutions were then used for purposes of prioritization, allowing the team to compare areas that were necessary to satisfy all goal scenarios including the minimal goal set, to areas only selected in larger goal sets, to those areas never selected, regardless of the goal setting.

3.3 Goals for the Marine Nearshore Environment

The marine team set goals for each shoreline ecosystem and species target, with some additional advice from regional experts. We set general guidelines for establishing goals for marine targets, expressed as percentages of the "amount" of the target data (i.e., 30% of all spatially delineated herring spawn sites represented as lineal meters) throughout the ecoregion. The purpose of these guidelines was to set conservation goals that address the rarity of the target, the number of occurrences, and its distribution across the ecoregion.

There was no mechanism for us to consistently assess viability for fine and coarse filter marine targets. Since we couldn't rely on the marine data sets to provide information about the relative viability of individual occurrences, we set conservative (low) goals that would help drive the algorithm to assemble an efficient portfolio around the sites most important to multiple targets. We therefore attempted to answer the question 'where do we start?' in conserving places for nearshore biodiversity, as opposed to 'how much (area) is enough?'. We based the goals on importance of the targets, co-occurrence of habitat types and species, least cost (or the most suitable places), and our confidence in individual data sets.

3.3.1 Representation (Coarse Filter) Goals

The shore-zone data were the most uniform across the ecoregion and provided us with the best data for describing a portfolio that is representative of nearshore marine biodiversity. We experimented with two different goal scenarios and compiled the results from the "summed solution" outputs (the number of times a planning unit is chosen out of the total number of iterative runs in a scenario) to a single gradient. Goals for individual shoreline ecosystem targets were 10% and 20% (Table 3.2). Lacking further ecological justification to determine the relative importance of individual shoreline ecosystems, we set goal for all ecosystems the same. In the same light, coarse filter intertidal vegetation and habitat targets were run at goals of 15% and 30%, respectively (Table 3.3).

We acknowledge that 10% and 20% of the existing extent of those ecosystems is not the same as 10% or 20% of historic composition, but we currently lack data to consistently define the historic extent of shoreline and estuary ecosystems throughout the study area.

Table 3.2 Shoreline ecosystem goals.

Target	Target_ID	Shore Units	Total Length (m)	10% Goal	10% Goal Amount	20% Goal	20% Goal Amount
Channel	1001	3	1,548.5	0.1	154.9	0.2	309.7
ChannelE	1002	9	2,690.1	0.1	269.0	0.2	538.0
ChannelP	1003	73	38,751.9	0.1	3,875.2	0.2	7,750.4
Estuary Wetland	1004	40	43,949.0	0.1	4,394.9	0.2	8,789.8
Estuary WetlandE	1005	13	9,942.3	0.1	994.2	0.2	1,988.5
Estuary WetlandP	1006	1134	1,046,811.2	0.1	104,681.1	0.2	209,362.2
Estuary WetlandVE	1007	9	9,323.4	0.1	932.3	0.2	1,864.7
Estuary WetlandVP	1008	47	46,032.7	0.1	4,603.3	0.2	9,206.5
Gravel Beach	1009	215	78,725.4	0.1	7,872.5	0.2	15,745.1
Gravel BeachE	1010	333	93,229.1	0.1	9,322.9	0.2	18,645.8
Gravel BeachP	1011	2983	941,273.4	0.1	94,127.3	0.2	188,254.7
Gravel BeachVP	1012	12	4,336.2	0.1	433.6	0.2	867.2
Gravel Flats	1013	28	15,052.7	0.1	1,505.3	0.2	3,010.5
Gravel FlatsE	1014	56	19,683.4	0.1	1,968.3	0.2	3,936.7
Gravel FlatsP	1015	148	76,247.2	0.1	7,624.7	0.2	15,249.4
Gravel FlatsVE	1016	9	3,599.3	0.1	359.9	0.2	719.9
High Tide Lagoon	1017	50	85,740.2	0.1	8,574.0	0.2	17,148.0
High Tide LagoonE	1018	10	4,254.7	0.1	425.5	0.2	850.9
High Tide LagoonP	1019	210	236,286.4	0.1	23,628.6	0.2	47,257.3
High Tide LagoonVP	1020	60	80,393.8	0.1	8,039.4	0.2	16,078.8
Man-made (not a target)	1021	13	5,253.3	0	0.0	0	0.0
Man-madeE (not a target)	1022	5	1,262.8	0	0.0	0	0.0
Man-madeP (not a target)	1023	302	135,230.8	0	0.0	0	0.0
Mud Flat	1024	7	4,985.3	0.1	498.5	0.2	997.1
Mud FlatP	1025	156	107,010.0	0.1	10,701.0	0.2	21,402.0

Target	Target_ID	Shore Units	Total Length (m)	10% Goal	10% Goal Amount	20% Goal	20% Goal Amount
Rock Cliff	1026	1396	703,588.4	0.1	70,358.8	0.2	140,717.7
Rock CliffE	1027	4314	1,768,132.6	0.1	176,813.3	0.2	353,626.5
Rock CliffP	1028	11822	5,833,450.0	0.1	583,345.0	0.2	1,166,690.0
Rock CliffVE	1029	218	125,300.5	0.1	12,530.1	0.2	25,060.1
Rock CliffVP	1030	68	31,122.4	0.1	3,112.2	0.2	6,224.5
Rock Platform	1031	124	33,573.1	0.1	3,357.3	0.2	6,714.6
Rock PlatformE	1032	1774	661,917.3	0.1	66,191.7	0.2	132,383.5
Rock PlatformP	1033	447	128,569.6	0.1	12,857.0	0.2	25,713.9
Rock PlatformVE	1034	345	162,097.7	0.1	16,209.8	0.2	32,419.5
Rock with Gravel Beach	1035	710	287,587.8	0.1	28,758.8	0.2	57,517.6
Rock with Gravel BeachE	1036	3374	1,394,014.4	0.1	139,401.4	0.2	278,802.9
Rock with Gravel BeachP	1037	9679	4,406,751.8	0.1	440,675.2	0.2	881,350.4
Rock with Gravel BeachVE	1038	123	40,373.1	0.1	4,037.3	0.2	8,074.6
Rock with Gravel BeachVP	1039	74	35,028.4	0.1	3,502.8	0.2	7,005.7
Rock with Sand & Gravel Beach	1040	173	57,913.7	0.1	5,791.4	0.2	11,582.7
Rock with Sand & Gravel BeachE	1041	2333	876,653.2	0.1	87,665.3	0.2	175,330.6
Rock with Sand & Gravel BeachP	1042	7600	2,843,714.0	0.1	284,371.4	0.2	568,742.8
Rock with Sand & Gravel BeachVE	1043	12	11,238.0	0.1	1,123.8	0.2	2,247.6
Rock with Sand & Gravel BeachVP	1044	39	15,471.3	0.1	1,547.1	0.2	3,094.3
Rock with Sand Beach	1045	19	4,346.8	0.1	434.7	0.2	869.4
Rock with Sand BeachE	1046	363	124,830.9	0.1	12,483.1	0.2	24,966.2
Rock with Sand BeachP	1047	544	182,404.5	0.1	18,240.5	0.2	36,480.9
Sand & Gravel Beach	1048	173	59,406.9	0.1	5,940.7	0.2	11,881.4
Sand & Gravel BeachE	1049	198	53,307.5	0.1	5,330.7	0.2	10,661.5
Sand & Gravel BeachP	1050	3600	1,339,292.9	0.1	133,929.3	0.2	267,858.6
Sand & Gravel BeachVP	1051	29	8,876.9	0.1	887.7	0.2	1,775.4
Sand & Gravel Flat	1052	96	38,497.7	0.1	3,849.8	0.2	7,699.5

Target	Target_ID	Shore Units	Total Length (m)	10% Goal	10% Goal Amount	20% Goal	20% Goal Amount
Sand & Gravel FlatE	1053	176	99,267.0	0.1	9,926.7	0.2	19,853.4
Sand & Gravel FlatP	1054	2689	1,298,001.0	0.1	129,800.1	0.2	259,600.2
Sand & Gravel FlatVP	1055	29	12,829.3	0.1	1,282.9	0.2	2,565.9
Sand Beach	1056	19	10,393.3	0.1	1,039.3	0.2	2,078.7
Sand BeachE	1057	242	187,660.8	0.1	18,766.1	0.2	37,532.2
Sand BeachP	1058	298	124,058.7	0.1	12,405.9	0.2	24,811.7
Sand Flat	1059	42	23,653.5	0.1	2,365.4	0.2	4,730.7
Sand FlatE	1060	129	78,238.5	0.1	7,823.8	0.2	15,647.7
Sand FlatP	1061	2179	1,306,395.7	0.1	130,639.6	0.2	261,279.1
Sand FlatVP	1062	40	22,440.9	0.1	2,244.1	0.2	4,488.2
Undefined (not a target)	9999	1026	662,992.3	0	0.0	0	0.0
59 TARGETS		61,095	27,340,266.0	10%	2,734,026.6	20%	5,468,053.2

Total shoreline contains 62,441 units with a 28,145,005.1 meters

E = EXPOSED

P = PROTECTED

VE = VERY EXPOSED

VP = VERY PROTECTED

Note: No exposure class indicates that the exposure was not defined

Table 3.3 Vegetation and fine filter goals

Target	Target_ID	Total Length (m)	15% Goal	15% Goal Amount (m)	30% Goal	30% Goal Amount (m)
Habitat 3	1063	3,674,186.6	0.15	551,128.0	0.3	1,102,256.0
Eelgrass	1064	2,780,418.1	0.15	417,062.7	0.3	834,125.4
Surfgrass	1065	2,092,980.4	0.15	313,947.1	0.3	627,894.1
Saltmarsh	1066	2,669,922.6	0.15	400,488.4	0.3	800,976.8
Kelp	1067	5,134,530.6	0.15	770,179.6	0.3	1,540,359.2
Herring Spawning	1068	418,717.1	0.15	62,807.6	0.3	125,615.1
Thick-billed Murre seabird colony	1075	8,654.3	0.15	1,298.1	0.3	2,596.3
Cassin's Auklet seabird colony	1074	322,925.4	0.15	48,438.8	0.3	96,877.6
Common Murre seabird colony	1073	18,896.5	0.15	2,834.5	0.3	5,669.0
Ancient Murrelet seabired colony	1072	251,716.0	0.15	37,757.4	0.3	75,514.8
Brandt's Cormorant seabird colony	1071	5,296.6	0.15	794.5	0.3	1,589.0
Horned Puffin seabird colony	1070	15,476.0	0.15	2,321.4	0.3	4,642.8
Tufted Puffin seabird colony	1069	99,504.6	0.15	14,925.7	0.3	29,851.4
All Vegetation and Fine Filter targets		**17,493,224.8**	**0.15**	**2,623,983.7**	**0.3**	**5,247,967.4**

3.4 Goals for Offshore Marine

Halpern (2003) reviewed 89 studies of no-take marine reserves and found that regardless of size, marine reserves lead to increases in density, biomass, individual size, and diversity in all functional groups. However, larger reserves did produce larger increases. Halpern goes on to caution "…that to supply fisheries adequately and to sustain viable populations of diverse groups of organisms, it is likely that at least some large reserves will be needed." (ibid pp129-130)

A variety of Marine reserve sizes ranging from 10% to 50% have been suggested as being efficacious as a conservation and/or fisheries management tool (MRWG 2001, NRC 2000, Roberts & Hawkins 2000, Ballantine 1997, Carr & Reed 1993), with an emphasis on larger reserves coming from the more recent literature. Furthermore, it has been found that larger reserves often have beneficial effects disproportionate to their size (Halpern 2003). In the marine CIT ecosystem spatial analysis, we explored a variety of conservation goals (also know as "targets" in the literature) that produced overall areas ranging from 5% – 50% of the study area. Specifically, we looked at Marxan solutions that comprised 5, 10, 20, 30, 40, and 50 percent of the study area. However, this does not imply that equal amounts of each of our 93 feature elements were represented. Rather, as explained below, each feature was assigned a goal based on a range of six relative rankings.

Before choosing actual percentages per feature as a goal, we examined each dataset and assigned to it a relative term, where "moderate" was taken as the common baseline or average value. The five terms used were: *low, moderate-low, moderate, moderate-high, high,* and *very-high*. In general, we assigned lower rankings such as *low* or *moderate-low* to features that were common (i.e. plentiful), and higher rankings features that were more unusual or rare. Umbrella and keystone species were generally assigned a *moderate-high* ranking. By using these six simple qualitative rankings, we were able to class the features relative to each other. Once that was completed, we could then implement a range of actual numerical targets and observe the effects. Such a strategy (though not in the context of MARXAN) has been suggested by Levings and Jamieson (1999) as "dimensionless scores," to be used to meet various criteria such as distinctiveness, and naturalness. The addition of the computer software allows for quick feedback to compare scenarios. Table 3.4 displays the actual percentages attached to each qualitative ranking. Columns display each conservation scenario, while the rows display the rankings. Appendix 2.2.1 lists all 93 features in the marine ESA, and their assigned relative goals.

Table 3.4

Relative Ranking	Conservation Goals (%)					
Low	2	4	8	12	16	20
Mod-Low	4	8	16	24	32	40
Moderate	6	12	24	36	48	60
Mod-High	8	16	32	48	64	80
High	10	20	40	60	80	100
V. High	12	24	48	72	96	120*
Overall Size	**5**	**10**	**20**	**30**	**40**	**50**

*Goals greater than 100% cannot be met, but do serve to give these features a higher emphasis.

4.0 HUMAN IMPACTS

4.1 Background and Rationale

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 4.1).

Watersheds defined both the unit of analysis and recommended 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 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 mappable and 3) have region-wide data available with relatively uniform quality and coverage. In addition, we define standard comparison units, based on a 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.

4.2 Methods

We used a systematic set of decision rules to define watershed boundaries. We used the B.C. watershed atlas as the basis, since it provides established and documented spatial data. We defined additional units 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, we also defined two units: large river systems and intermediate river systems. These are sub-primary watersheds that are between 10,000 ha and 100,000 ha and 100,000 ha to 1,000,000 ha respectively, and defined using a standardized set of decision rules (see APPENDIX X for details). This allows 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. We used a 200m buffer 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 4.1 for summary). Overlapping areas were treated as impacted (i.e. overlaps were only counted once), which also allow 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). Because some areas have relatively little vegetated areas and, consequently, little developable area and little productive habitat, we calculated impacted area 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, also using potential vegetated area.

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, we used two additional factors 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 4.2).

In addition we also sought to identify relatively intact watersheds a 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 4.2 to several scales of watersheds and river systems (Table 4.3).

4.3 Results

Map 31 summarizes the impacts assessment for the study area according to the three broad classes of intact, modified, and developed.

Table 4.1 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

Table 4.2 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 > 0.6km/km^2 road density

Table 4.3 Watersheds and River systems

Classification	**Label**
Primary Watersheds	
< 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 River Systems
100,000 – 1,000,000	Large River Systems
3rd Order Watersheds	
LWSD polygons	LWSD systems [note that these do not occur in Alaska]

5.0 SPATIAL ANALYSIS: METHODS

5.1 Background

Our ecosystem spatial analysis is designed to serve four well-accepted goals of conservation (Noss & Cooperrider 1994): 1) represent ecosystems across their natural range of variation; 2) maintain viable populations of native species; 3) sustain ecological and evolutionary processes; and 4) build a conservation network that is resilient to environmental change. In pursuit of these goals we integrate three basic approaches to conservation planning: 1) protection of special elements, including imperiled species, natural communities, and genetic variants; 2) representation of a broad spectrum of environmental variation (e.g., vegetation, geoclimatic, and aquatic classes); and 3) protection of critical habitats of focal species (Lambeck 1997; Miller et al. 1998/99), whose needs help planners address issues of habitat area, configuration, and quality. Together, these three tracks constitute a comprehensive approach to conservation planning (Noss et al.1999).

5.2 Spatial Analysis: Design Process and Tools

5.2.1 Steps of Spatial Analysis

For the CIT ESA, the challenge is to take an analysis of special elements, ecosystem representation, and focal species, and create a spatially explicit assessment of where the region's biodiversity values are located and what condition they are in. This information can then be used to create a conservation solution or "portfolio" of landscapes and seascapes that taken together, and managed appropriately, would ensure the long-term survival of the region's biodiversity. In order to perform this assessment, the three-track approach is applied to freshwater, terrestrial, and marine environments via the following key steps:

1. Select conservation targets (e.g., special elements, focal species and ecological systems) that will be used to characterize the biodiversity values within the study area.

2. Collect data for special element occurrences, develop focal species habitat models, and create ecosystem classifications that can be used to map the distribution of targets within the study area.

3. Using available data and models, assess viability of targets.

4. Set conservation goals to serve as benchmarks for identifying conservation priorities and as an initial hypothesis about the level of effort required to conserve biodiversity.

5. Integrate information for special elements, ecosystem representation, and focal species in each of freshwater, terrestrial and marine environments to create a spatially explicit assessment of conservation values for the study area

6. From that assessment, use goals and viability measures to develop options for creating a portfolio of conservation areas that will effectively conserve the region's biodiversity in the long term.

This type of rigorous analysis employs thousands of pieces of detailed information. It requires location-specific information for conservation targets as well as the past, current, and potential future status of lands where they occur. The team used the best available information for this assessment but recognizes that new and more comprehensive data will continually become available and that ultimately, the ESA must be regarded as being a first step in an iterative assessment process.

5.2.2 Automated Site Selection Algorithms

5.2.2.1 SITES

Early conservation assessments and reserve designs depended on manual mapping to delineate sites and on simple scoring procedures to compare and prioritize 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 the site selection software SITES (v1.0), developed at the University of California, Santa Barbara under contract to TNC, as an aid to portfolio assembly. SITES operates within ArcView GIS as “an analytical toolbox for designing ecoregional conservation portfolios” (Andelman et al. 1999). SITES has been or is being used as an aid for designing and analyzing alternative portfolios in a number of TNC 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.

SITES 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.

SITES 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). SITES accomplishes this task by changing the planning units selected and re-evaluating the Cost function through multiple iterations. We had SITES perform 1,000,000 iterative attempts to find the minimum cost solution per simulated annealing run and perform 20 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 SITES 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 SITES runs to determine alternative portfolios which met stated goals for protection of the target groups: 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 made SITES 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).

5.2.2.2 MARXAN

Evolving out of SITES, MARXAN is a site optimization algorithm that has been used in several of the CIT ESA's. It was 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 Authority's re-evaluation of their park designations. MARXAN brings with it several features that make it easier to experiment with different conservation targets and costs of various features. This can be valuable in sorting out what values lead to certain reserve shapes. Furthermore, Marxan can handle larger numbers of planning units than can SITES. It still requires, however, that the user be technically fluent. There are several parameters that can be adjusted as noted in both the nearshore and offshore marine analyses described below.

In order to design an optimal reserve network, both MARXAN and SITES examine each individual planning unit for the values it contains. They then select a collection of these units to meet the conservation targets that have been assigned. The algorithm will add and remove 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.

5.2.3 Terrestrial and Freshwater Spatial Analysis

5.2.3.1 SITES Parameters

Several factors besides the number and type of targets used influence Sites 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.

5.2.3.2 Planning Units

We used 500 hectare hexagons selected from a layer that covers all the CIT and CFM planning areas. This not only allows consistency with the marine analysis, but using uniform sized planning units also avoids the area-related bias that can occur in the Sites planning unit selection process when differently-sized planning units, such as watersheds, are used.

5.2.3.2.1Planning unit status

We used four different protected areas scenarios for the planning units: no protected areas 'locked in' the outcome, existing protected areas locked in, existing plus candidate protected areas locked in, and existing plus candidate plus option areas locked in. Candidate and option areas were only available for the Central Coast region.

5.2.3.2.2Suitability 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 SITES 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 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 measured in hectares. 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 500ha, while those having all potential vegetated area impacted had a cost of 1000ha and partially impacted planning units had cost between 500 and 1000ha. Because the Sites 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.

5.2.3.2.3Species Penalty Factor

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

5.2.3.2.4Boundary Length Modifiers

We used boundary length modifiers of 0.001, 0.01, and 0.1 to include a range of planning unit clustering in our final combined sum runs. Our boundary length modifier sensitivity analysis indicated that with a blm of 0.001 there would be approximately 700 clusters of hexagons; with blm 0.01, approximately 500 clusters; and with blm 0.1 approximately 200 clusters. This range of blms allows us to explore issues of several small clusters versus fewer large clusters.

5.2.3.2.5Repeat Runs

We made 20 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 levels) for each of the four protected area scenarios. Thus, for each protection scenario we used a sum of 300 sites runs that resulted from 300,000,000 iterations of the simulated annealing algorithm. Hexagons chosen frequently represent places more necessary for biodiversity conservation, while those chosen few times represent locations where similar biodiversity is found many other places or where human impacts are significant.

5.2.3.2.6Goal Settings

We used five different goal levels: 30%, 40%, 50%, 60%, and 70%, as described in section 6.2.

5.2.4 Nearshore Marine Spatial Analysis

5.2.4.1 MARXAN Parameters

For the analysis we used a site selection algorithm called MARXAN, written and developed by Ian Ball and Hugh Possingham. We set specific MARXAN parameters to increase efficiencies and optimization during site selection (see Possingham et al 2000, Leslie et al. 2002, and Pressey et al. 1996 for more information on the marine reserve selection algorithms). Shoreline ecosystems were analyzed within their native spatial format, linear segments determined by landform and slope. These units vary widely in length and extend over the entire coastline, providing a "natural" unit for analysis (Longley et al. 2001) as opposed to a unit of fixed length. Forage fish spawning sites and seabird colony data were attributed to the shoreline segments to represent the nearshore zone.

We developed a framework for nearshore marine analysis using this linear spatial format. This analysis is coupled with expert review from the initial technical workshop in April 2003, and will be used for subsequent expert review workshops.

5.2.4.1.1Planning Units

We initially considered incorporating all the nearshore information in to hexagon planning units, but we found that MARAN favored those hexagons with more shoreline and not necessarily "more efficient" shoreline toward meeting conservation goals. Hexagons arbitrarily fragment and aggregate shoreline units, leaving some hexagons with slivers of shoreline and others with large amounts (i.e. bays, inlets). In addition, the hexagon size lacks ecological justification and straddles narrow water bodies, therefore further aggregating shoreline units associated with different land masses. Shoreline planning units tend to be more spatially explicit, easier for experts to review, and more intuitive in designing a conservation portfolio site.

5.2.4.1.2Suitability Index

To select priority conservation areas we included in the analysis a suitability index, or "cost index" as its referred to in MARXAN, which tends to reduce representation in places where human uses or modifications restrict conservation and modified options. The index was developed in order to calculate both the total cost of choosing a network of sites, and the relative cost of each planning unit.

Costs are usually referred to as impacts to the environment, making particular places less suitable for conservation. There are also jurisdictional costs where assumptions are made for different lands and waters holding a specific political status. These jurisdictional costs can be seen as more (i.e. lands already in conservation status) or less (i.e. lands devoted to resource extraction) suitable.

The index developed for the nearshore analysis consists of impact cost parameters only. We used the human impacted area information developed by Round River (See section 6 for a compete discussion of the terrestrial cost parameters), which combined human altered areas (clearcuts, urban areas, agricultural lands) with a 200m buffer around roads. We added three other cost parameters to this impact calculation: aquaculture tenures, enhancement facilities, and hatcheries.

The aquaculture tenures were spatially delineated as polygons, and were incorporated into the human altered areas. For enhancements and hatcheries, we buffered the point data by 100 meters (the approximate minimum mapping unit diameter to convert points to polygons at a 1:250,000 scale). These were also included in the altered areas. All human impacted areas were given a score of 1; aquaculture tenures, enhancements and hatcheries were given a 2 (Map 23).

Next we had to develop a human impact score for all shoreline planning units. To do this we performed raster-based analyses. A raster is a rectangular array of equally spaced cells, which taken as a whole represent thematic, spectral, or picture data (Zeiler 1999). All impact data was transformed into raster data, allowing us to calculate the human impact score for each planning unit. We first chose a focal mean function to assign a cost value to all shoreline cells. Focal functions compute an output cell value from those input cells that are within a "neighborhood" centered on the output cell. The neighborhood is defined as all cells within a given radius; all shoreline cells calculate a mean value from the surrounding upland and nearshore neighborhood. Once each shoreline cell has a mean value, we summarized all values per shoreline planning unit. This mean value across all shoreline cells gave us the human impact score from 0 to2 (Map 23a).

To build the cost index, we simply took the mean planning unit length and the sum length of human impacts within that planning unit:

Cost = Mean Planning Unit Length + (Mean Planning Unit Length * Human Impact Score)

The mean planning unit length was 450 meters. This represented the base value for all planning units; the maximum cost value was 1,190. We decided to take the mean value of all shoreline planning units instead of simply calculating cost equal to length. There is an assumption that larger areas have more impacts to them and therefore should have higher cost values. We do not believe this is true in the marine realm, where long stretches of coastline can be relatively pristine, while shorter lengths may be associated with high impacts. Each ecologically-based planning unit that does not have equal areas (i.e., watersheds and shorelines) may need to be treated differently. For shorelines, giving all planning units equal value as a base assumes they have equal impacts to them; alone by multiplying the human impact score with the mean length do some planning units get a higher cost.

5.2.4.1.3Boundary Length Modifiers

A boundary modifier determines the amount of clumping between individual planning units. This is usually done with polygons, but we customized the data inputs here to utilize the linear spatial format.

We developed a linear boundary modifier that clumped, or attached adjacent linear segments (arcs) along the shoreline. The algorithm was therefore able to assemble small fragments of shoreline into more continuous stretches (i.e., select an entire islands' shoreline). We also felt that this helped us visualize more distinct sites across the shoreline ecosystem representation. We set the boundary length modifier to 0.1 for all MARXAN scenarios.

5.2.4.1.4Species Penalty Factors

Setting the species penalty factor, or the conservation penalty factor (CFPF) as it is referred to in MARXAN, determines the priority with which the algorithm meets an individual target goal. The CFPF is a multiplicative factor which can be unique to each conservation feature. It is primarily based on the relative worth of that conservation feature but it includes a measure of how important it is to get it fully represented. We set this factor based on the importance of the target; a high penalty factor is assigned to a high priority target to make the algorithm choose sites in potentially "high cost" areas in order to meet its goals.

All coarse filter shoreline ecosystem targets had a CFPF of 2. All coarse filter intertidal vegetation and community targets also had a factor of 2; fine filter seabird colony targets had a factor of 3. Man-made and undefined shoreline categories contained a factor of 1, with goals set to 0 to ensure they were not selected by the algorithm.

5.2.4.2 Nearshore Marine Portfolio Assembly

The purpose of our efforts was to develop a conservation portfolio that, if conserved and properly managed, will protect a representative subset of the existing nearshore marine biodiversity in the coastal zone of the Coast Information Team study area. This representative subset encompasses the intertidal zone and shallow subtidal zone.

We made the choice early on in the planning process to run separate analyses for the offshore, nearshore and terrestrial environments. This limited our ability to analytically test the relationship between nearshore and terrestrial ecosystems, and therefore have to rely on experts to review the separate outputs in delineating and integrating sites across ecosystem types.

The approach for building a nearshore marine portfolio combined expert input with spatial analysis. This systematic approach of using expert input at the beginning, and throughout, the planning process was used to test preliminary analytical results while refining the portfolio.

5.2.4.3 Initial Seascape Sites

One of the objectives from the technical workshop was to select biodiverse coastal sites based on expert knowledge. These initial seascape sites were chosen to capture relatively large, intact ecosystems that represent the region's nearshore biodiversity. The experts were asked to select areas along the B.C. coast using the following three criteria:

1. Large nearshore sites are important for marine biodiversity
2. Sites must be stratified[15] across the ecoregion
3. There should be diversity in the types of sites chosen, i.e. good for birds, good for invertebrates, etc.

The results were the identification of 18 seascape sites:

1. Mouth of Skeena River
2. Mouth of Nass River
3. Dundas Island
4. Langara Island
5. Forrester Island
6. Bowie Shoal
7. Dogfish Bank
8. Waikoon Park
9. Gwaii Hanas
10. Clao Bay
11. Princess Royal Island
12. Goose Group
13. Hakai Pass
14. North Queen Charlotte Strait

[15] Stratification is a process of creating subsections within the ecoregion for the purpose of spreading the site selection and review process across the entire water body. The delineation of subsections also serves as a surrogate for oceanographic processes including salinity, current, and temperature.

15. Scott Island
16. Broughton Archipelago
17. Johnstone Strait
18. Redonda Island/Oyster Inlet

The identification of these seascapes helped to guide subsequent analysis. The intention is that these areas will be tested and refined using more spatially explicit data and the analysis described here.

5.2.4.4 Spatial Analysis

The purpose of the spatial analysis was to implement and evaluate 12 different MARXAN scenarios to test the irreplaceability and sensitivity of the site selection.

Irreplaceability analyses indicate which sites are consistently chosen. Planning units that get chosen the most often are the least replaceable. These analyses can be evaluated through the "summed solution" output which is the result of the number of times an individual planning unit get chosen within a scenario. The output from all 12 scenarios was combined to form the sum of summed solutions, or the summed solution gradient. With each of the 12 scenarios run 20 times, we had a gradient from 0 to 240 solutions. Within each scenario the algorithm did 1,000,000 iterative selections per run.

Two multiple goal scenarios were run: one optimizing for 10% of the entire shoreline, and another optimizing for 20%. When shoreline ecosystem targets were set to 10%, intertidal vegetation, communities, and fine filter targets were set to 15%. When shoreline ecosystem targets were set to 20%, intertidal vegetation, communities, and fine filter targets were set to 30%. These were applied to all stratification schemes and cost/no cost scenarios. We used three stratification schemes to divide the nearshore zone: marine ecosections, project regions, and no stratification. Marine ecosections provided a stratification scheme based on oceanic and coastal processes. Project regions divided the nearshore by surveying and data collection efforts; and a third scheme was to run the algorithm with no stratification. We also ran the algorithm with and without the cost index (without the cost index means that all planning units were given a cost of 1).

The 12 scenarios are described as follows:

1. 10% shoreline, marine ecosections, cost
2. 10% shoreline, marine ecosections, no cost
3. 20% shoreline, marine ecosections, cost
4. 20% shoreline, marine ecosections, no cost
5. 10% shoreline, project regions, cost
6. 10% shoreline, project regions, no cost
7. 20% shoreline, project regions, cost

8. 20% shoreline, project regions, no cost
9. 10% shoreline, no stratification, cost
10. 10% shoreline, no stratification, no cost
11. 20% shoreline, no stratification, cost
12. 20% shoreline, no stratification, no cost

Sensitivity analyses are conducted by selecting thresholds in the summed solution gradient and evaluating how much representation of the nearshore targets are captured. The area required to meet goals changes as we lower the threshold along the summed solution gradient. Sometimes the area required changes very little as we lower the threshold; sometimes it increases drastically. In evaluating sensitivity, it helps to know the shape of this curve. The summed solution gradient from the 12 MARXAN scenarios provided the base for performing the sensitivity analysis.

There are several ways we are reporting on the results of the analysis:

Display the summed solution gradient as the raw output of the nearshore analysis. Compare this gradient with results from the technical workshop.

Choose the most optimized "best" run from the 12 scenarios. This will be used to represent the full array of coarse and fine filter targets and an overarching shoreline length captured. Compare this run with results from the technical workshop.

Find thresholds along the gradient that capture the multiple goal levels set for shoreline ecosystem, intertidal vegetation and communities, and fine filter targets.

What representation do we capture when we set a threshold of the upper 10% of the entire shoreline length? This equates to the "High Conservation Risk Option," or the high priority nearshore sites.

What representation do we capture when we set a threshold of the upper 20% of the entire shoreline length? This equates to the "Medium Conservation Risk Option," or the medium priority nearshore sites.

What representation do we capture when we set a threshold of the upper 30% of the entire shoreline length? This equates to the "Low Conservation Risk Option," or the low priority nearshore sites.

Take the established thresholds in item 3 and buffer the selected shoreline segments to create a "nearshore reporting-out unit." This adds more spatial explicit prioritization within the high, medium and low conservation risk options. Buffering selected shoreline segments by 1 kilometer (the relative distance from the mean high water line that encompasses the nearshore zone down to 20 meters depth) incorporates non-selected segments.

Calculate the total length of selected shoreline in each nearshore reporting-out unit. This gives priority to the longer segments.

Calculate the density of selected shoreline by the total length within each nearshore reporting-out unit. This gives more equal priority to shorter and longer segments.

Calculate the mean weighted average by scoring each shoreline planning unit and multiplying it by the total length in the nearshore reporting-out unit. This lowers the priority of longer segments, and heightens priority to shorter ones.

Use the "seascape reporting-out units" devised by the well-being assessment to calculate the amount of selected shoreline captured in these units. Calculations will be similar to those mentioned in items 4.a., 4.b., and 4.c.

5.2.4.5 Expert Review

We have not formally presented the preliminary results of the analysis for expert review. We hope to do this in the coming months. We plan to reconvene experts from the technical workshop and others to review and verify preliminary results of the analysis, and make suggestions for next steps. However, we have output from the spatial analysis to compare with the 18 initial seascape sites. That comparison is described in the next section, "Results."

5.2.4.6 Integration with Terrestrial Analysis

After the nearshore marine, offshore marine, and terrestrial analyses were done, we began a process of integration across land and seascapes. This integration is especially critical between upland and coastal ecosystems, where known uninhibited ecological processes play an important role in the health of both environments. Although we did not model ecological processes across ecosystems, we hope to use the site selection output as a surrogate where high priority terrestrial and nearshore sites align. See section 6.4 for a discussion on integration via reporting-out landscape and seascape units.

5.2.5 Marine Deep-water Spatial Analysis

5.2.5.1 Marxan Parameters

Marxan consists of 8 main variables to direct the optimization algorithm:

1. **Conservation Targets (Goals)**: How much of a feature is aimed for in the MPA network.
2. **Penalty Values**: How much cost is accrued for not attaining the conservation target.
3. **Boundary Length Modifier**: The relative cost of a reserve's perimeter
4. **Minimum Separation Distance**: The minimum distance that distinct groupings of a feature should be from one another.
5. **Separation Number**: The number of distinct groupings of a feature required (i.e. replication).
6. **Minimum Clump Size**: The minimum number of planning units (hexagons) needed to count as a valid grouping of the feature.
7. **Planning Unit Cost**: A relative value applied to planning units such that some may be more difficult or "expensive" to set aside than others.
8. **Boundary Cost**: The relative cost of the planning units' shared boarders.

Of these, the first three are the most important. The first parameter, conservation goals, has been discussed above (section 3), and is equivalent to stating how much of a feature is enough to meet one's conservation objectives. In the marine ESA, we explored a wide variety of goals so as to provide planning tables with a range of possibilities, from low to high conservation objectives.

5.2.5.2 Planning Units

The Marine ESA planning units are a regular grid of 500 hectare hexagons. There are about 32 thousand of these hexagons in the analysis which covered the entire CIT marine study area, and down the west coast of Vancouver Island.

To get an accurate picture of how abundant a feature is within a planning unit (hexagon) we considered two factors:

1. How much of it is there
2. How much of it could there be there (i.e., its possible maximum). In our analysis this often equals the amount of seawater contained in the hexagon, but for shoreline features would be a total measure of shoreline per hexagon.

Considering just the summation of a feature's presence (point #1) would unfairly penalize hexagons that had full 100% presence of the feature, but not 100% water. This situation might prove to be important when, for example, the nearshore component plays a critical role, such as in estuaries. In this situation, a planning unit is very unlikely to contain but a fraction of its area as water, and yet may play a far more important functional role than an offshore planning unit with the same amount of the feature, but surrounded by water.

In our model we make allowances for how much water is available per planning unit, accounting for feature density, as well as occurrence**.**

Presence / Absence Areal Data

For presence / absence data, the formula we generally used is:

$$HexScore_{f(presence)} = \sqrt{(\Sigma f)^2 / (2\,N_f)} \qquad \ldots\ldots 1$$

Where f is the feature occurrence (presence = 1, absence = 0); thus Σf is the sum of all feature cells;

And N_f is the total number of possible feature cells –which is usually the same as the total number of water cells.

Another way to state this is:

$$HexScore_{f(presence)} = \sqrt{(\Sigma f * f_{mean})/2} \qquad \ldots\ldots 2$$

Where f_{mean} is the mean value of that feature, wherever there is water. For presence data, this is the same as density as discussed above.

For presence / absence features, the scores can range from 0 to 16 per hexagon. This compression of values was found to be robust to random grid shifts and variations in base shorelines used by different datasets.

For weighted ("Relative Importance" –RI–) features, the above formula is multiplied by the mean of the feature cell weightings:

$HexScore_{f(RI)} = HexScore_{f(presence)} * RI_{mean}$ ……3

Where, $RI_{mean} = \sum f_{(RI)} / N_{f(presence)}$;

And $\sum f_{(RI)}$ is the sum of all the RI feature cells

And $N_{f(presence)}$ is the total number of presence feature cells.

5.2.5.2.1 Line and Point Features

The above formulae were used for most of our two-dimensional areal features (GIS "polygons"). For line features, we used the same formulae, except that N_f represents the total number of possible shoreline cells, instead of water.

Point features were all given buffers to convert them into appropriate areas, and then were treated as above.

5.2.5.3 Penalty Values

Assigning a penalty to a feature is in effect saying how much it matters if this feature's goal (target) is *not* met. That is, for features that do not meet their goals, penalties are assigned (on a sliding scale based on how closely the goal was achieved); and in turn it is these penalties that will "direct" the algorithm in its search for features. Thus, features with higher penalties are generally met first (if they can be met) than similarly distributed features with lower penalties. Generally, we used the penalty value as a relative factor to reflect the relative importance of a feature, and sometimes to also reflect the relative confidence in that dataset or its spatial completeness, as compared to others. We assigned lower penalties to those datasets in which we had lower confidence. We did not want these datasets driving the analysis. We assigned higher penalties to rare, threatened, & endangered species, as well as to features that play important ecological roles (such herring spawn).

As with goals (targets), penalties were first given a relative ranking. From those, weightings were assigned as follows:

Relative Penalty	Marxan Weighting
Low	0.25
Mod-Low	0.50
Moderate	1.00
Mod-High	2.00
High	4.00
V. High	8.00

Appendix 2.2.1 lists all 93 features in the marine ESA, and their assigned relative penalties.

5.2.5.4 Boundary Length Modifier (Clumping)

Boundary Length Modifier (BLM): The relative cost of a reserve's perimeter. Higher costs will force larger (but fewer) reserves, whereas a low cost will allow for several small ones. We have explored a wide range of this parameter (BLM= 0.004, 0.008, 0.016,… 8.000) but have focused on four to cover the range from fragmented to moderately clumped (BLM= 0.0625, 0.250, 1.000, 4.000) This is an arbitrary parameter that must be arrived at through experimentation. While we found that solutions using a BLM near 1.0 offered good efficiency with realistic manageability, we also discovered that the more fragmented solutions (which more truly represented the densities of conservation values) were valuable when summed together to show trends or "hotspots."

As solutions progressed from scattered to clumped, they behaved predictably, shedding smaller reserves and aggregating onto the larger ones. This would indicate that the data populate the planning units in a consistent fashion and that the planning units themselves are consistent.

5.2.5.5 Other Parameters

The other Marxan Parameters were handled as follows:

- **Minimum Separation Distance**: Not used. This parameter greatly increases processing requirements. For such a large number of planning units (32,000) and features (93), its use was impractical.
- **Separation Number**: Not used. (As above.)
- **Minimum Clump Size**: Not used. We felt the 500 hectare hexagons were already sufficiently large. In practice, the hexagons naturally clump together.
- **Planning Unit Cost**: All planning units treated the same. Cost set to 1. As that the objective of this exercise was to explore just conservation values, we did not consider whether some planning units might in practice be more difficult to protect than others.
- **Boundary Cost**: This parameter was used to fine-tune the relative clumping of hexagons in the four Ecological Regions (inlets, passages, shelf, slope). To determine this value we looked at the edge to area ratio of each of these regions and then created an appropriate scalar. The non-dimensional measure we used was: $\sqrt{(P^2/A}$ where P = total perimeter of region, and A = total area ~~of the~~ region. By altering the boundary costs per region, we allowed for more fragmented solutions in areas constrained by geography, such as inlets, but encouraged more clumped solutions in open waters, such as over the continental slope. The resulting boundary costs were as follows:

Region	Boundary Cost
Continental Slope	1.54
Continental Shelf	1.00
Passages	0.34
Inlets	0.21

5.3 Reporting Units

From a technical standpoint, a hexagon grid is desirable for analyzing ESA data using the SITES algorithm. As a reporting unit the 500 Ha hexes also allow for conservation results to be described at a fine scale and allow for a more spatially explicit set of solutions. However, the strengths of a good analysis unit—namely uniform size and shape and arbitrary placement on the landscape, can in fact be drawbacks when it comes to producing results that are meaningful to, and easily understood by, decision-makers living and working within the study area. While approximate uniform size (i.e. within the same order of magnitude) is still an important attribute to creating summary reporting units, having the extent of each unit match the known geography of the study area is desirable. In order to address this issue several alternative units were considered for the purposes of reporting ESA results.

5.3.1 Intermediate Watersheds

As described in section 4, a systematic method for classifying sub-primary watersheds was developed for the purposes of summarizing human impacts information in the study area. These intermediate watershed units also provided a scalable method for summarizing SITES outputs for the terrestrial and freshwater spatial analysis.

5.3.2 Landscapes and Seascapes

While the delineation of intermediate watersheds created reporting units of more uniform size, small, coastal, primary watersheds of greatly varying size remained unclassified and a possible source of size bias in reporting. To compensate for this, another reporting unit was developed specific to all of the CIT spatial analyses.

Making use of the intermediate watersheds developed by RRCS, the CIT created an integrated Landscape and Seascape layer that straddled terrestrial and marine environments. Inland, landscapes were based on the already delineated intermediate watersheds. On the coast however, several adjustments were made to group intermediate watersheds and third order watersheds that drained into a common salt water body such as an inlet or fjord. For the open water reaches of the CIT study area, seascapes were based on Department of Fisheries and Oceans statistical areas. Landscapes and seascapes range from 10,000-99,000 ha. Islands <10,000 ha are included in seascapes.

Landscapes and seascapes have been given a numerical code of up to three parts. The first part identifies the subregion. The second part identifies a primary seascape or landscape. The third part identifies a constituent landscape. A total of 565 landscape/seascape units were created (Map 32)

5.4 Options and Scenarios

5.4.1 Background

The use of site selection algorithms such as SITES and MARXAN brings a degree of flexibility to the spatial analysis process. Multiple settings for goals, “locking in” selected areas, adjustments to “clumping,” and the use of a cost function that incorporates human impact information, are all tools that build choice into the analytical process. Decision-makers and stakeholders, as well as planners, can explore these choices, and the subsequent implications. In order to facilitate examination of spatially explicit conservation solutions, we made use of SITES and MARXAN to create a series of potential conservation solutions that in combination, are referred to as Options and Scenarios. At the heart of this exercise was an attempt to prioritize solution outputs based on criteria related to *conservation value*, based on target information and SITES/MARXAN outputs, and *conservation condition,* based upon of the evaluation of human impacts within the study area.

5.4.2 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 complimentarity. These criteria are optimized through the selection of a minimum set of planning units to meet goals for our conservation targets. For the CIT ESA, 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" (note: the CIT offshore analysis also uses the term "conservation utility" to describe this parameter). 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 20 times each for a total of 300 possible conservation solutions, each of which were integrated 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 300 repetitions, such that a unit selected in every solution received a score of 300, while a unit never selected was scored as a zero. These scores were subsequently rolled-up for each landscape/ seascape unit as well, for a further comparison at a broader scale with other CIT spatial analyses.

Scores for both analysis and landscape units were then grouped into 5 classes based on the quintile scores of the summed solutions (see Table 5.1). A planning unit selected 180 or more times in SITES fell into the top 2 quintiles, or top 40%, of the solution and was scored as having *high* conservation value. Analysis units with scores in the middle quintile were scored as *medium* conservation value, and those in the 4th quintile were scored as *low* conservation value. Those units with a score in the lowest quintile were not ranked.

Table 5.1 CIT ESA Conservation Value ratings based on SITES summed solution scores.

Summed Solution Score	Quintile	Conservation Value Rating
> 180	Top 2/5	High
< 179, > 120	3/5	Medium
< 119, > 60	4/5	Low
< 60	5/5	Not Ranked

5.4.3 Condition

Condition was used as a surrogate measure for target viability in the CIT ESA and was evaluated using the human impacts information described in Section 4. Impacts were assessed for both hexagonal analysis units and for Landscapes/seascapes. The six impact classes described in Table 6.2 were simplified into the three broad condition classes--intact, modified and developed (see Table 5.2).

5.4.4 Alternative Options for Conservation

To explore the interaction between conservation value and condition, analysis units and landscapes/seascapes were clustered into 3 conservation tiers based on the conservation value and condition matrix in Table 5.2. 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.

Table 5.2 Conservation Tiers for the CIT ESA analysis units and landscape/seascape units.

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

5.4.5 Alternative Scenarios Analysis

The Central Coast LRMP tables have already proposed several potential land use scenarios, and we wanted to evaluate each in terms of their performance against the three conservation options being generated by the ESA. To facilitate this comparison, the protected areas described by each scenario were locked into the SITES solution for Terrestrial/freshwater runs. Four alternative land-use scenarios were evaluated as follows:

1. Unconstrained Analysis

2. Base Case – existing protected areas locked into SITES.

3. Candidate Case – existing protected and CCLRMP Candidate Areas locked into SITES.

4. Option Areas Case – existing protected areas, CCLRMP Candidates, and Option Areas locked into SITES.

5.4.6 Comparing Options and Scenarios

In order to compare between and within options and scenarios, potential solution sets from summed runs were evaluated against three goal thresholds, 30,50 and 70%. For each scenario, performance of conservation tiers (options) was assessed both in terms of effectiveness, as measured by the proportion of targets that met or exceeded the goal threshold, and efficiency, the proportion of the study area required to meet the threshold.

6.0 SPATIAL ANALYSIS: RESULTS AND DISCUSSION

6.1 Terrestrial/Freshwater Spatial Analysis Results

6.1.1 Options and Scenarios measured by Hexagonal Analysis Unit

Summed run solutions for each of the four land-use scenarios are displayed in maps 33 through 36 and priority conservation tiers are shown in maps 37 through 40. While the pattern of conservation values differs between each scenario, there are only small differences between the overall performances of the solutions. Performance measures included both the solution's efficiency, measured by the amount of area swept into each conservation option or tier, and effectiveness, measured by the conservation goals reached by those tiers (see Figure 6.1 and Table 6.1).

Table 6.1 Comparison among Option and Scenario combinations for CIT ESA analysis units

Option*/Scenario**	Proportion of targets meeting identified goal threshold			% of study area in solution	% of solution protected
	30%	50%	70%		
1.A	0.77	0.56	0.20	40.1	13.6[1]
1.B	0.76	0.53	0.18	42.0	26.3
1.C	0.77	0.52	0.18	41.7	33.9
1.D	0.76	0.52	0.18	41.9	43.0
2.A	0.99	0.91	0.70	61.9	12.5[1]
2.B	0.99	0.92	0.67	61.9	17.8
2.C	0.99	0.92	0.66	61.3	23.0
2.D	1.0	0.92	0.65	60.8	29.6
3.A	1.0	0.99	0.88	68.3	11.5[1]
3.B	1.0	0.99	0.87	68.1	16.2
3.C	1.0	0.98	0.96	67.4	21.0
3.D	1.0	0.98	0.86	66.6	27.0

[1]compared against existing protected areas.

*Options:

1. Tier 1 analysis units
2. Tier 1 and 2 analysis units
3. Tier 1,2,3 analysis units

**Scenarios:

A. Unconstrained Analysis
B. Base Case – existing protected areas locked in.
C. Candidate Case – existing PA's and candidate areas locked in
D. Option Areas Case – PA's, candidates, and option areas locked in

Fig 6.1 Conservation tiers for CIT ESA analysis units,compared between protected area scenarios

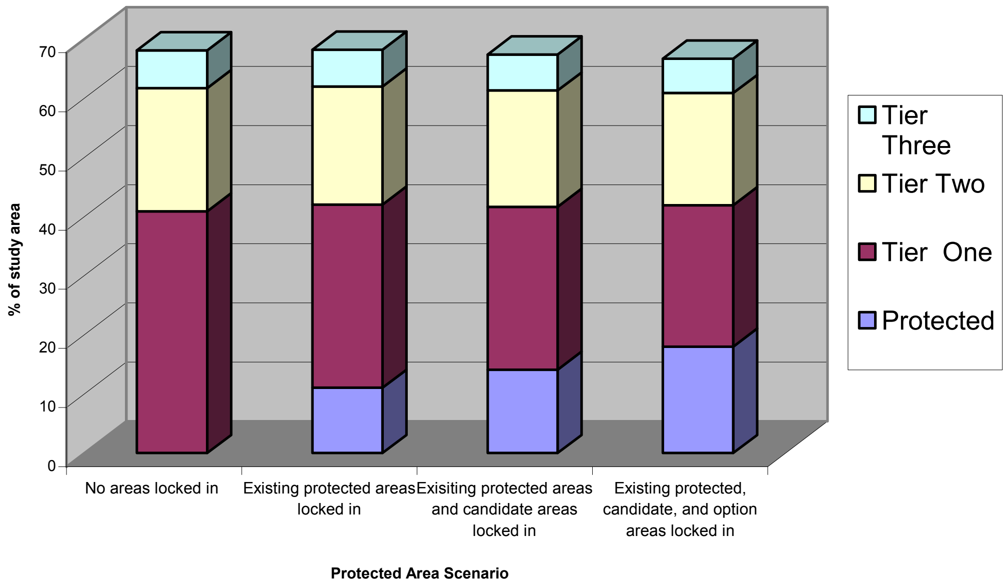
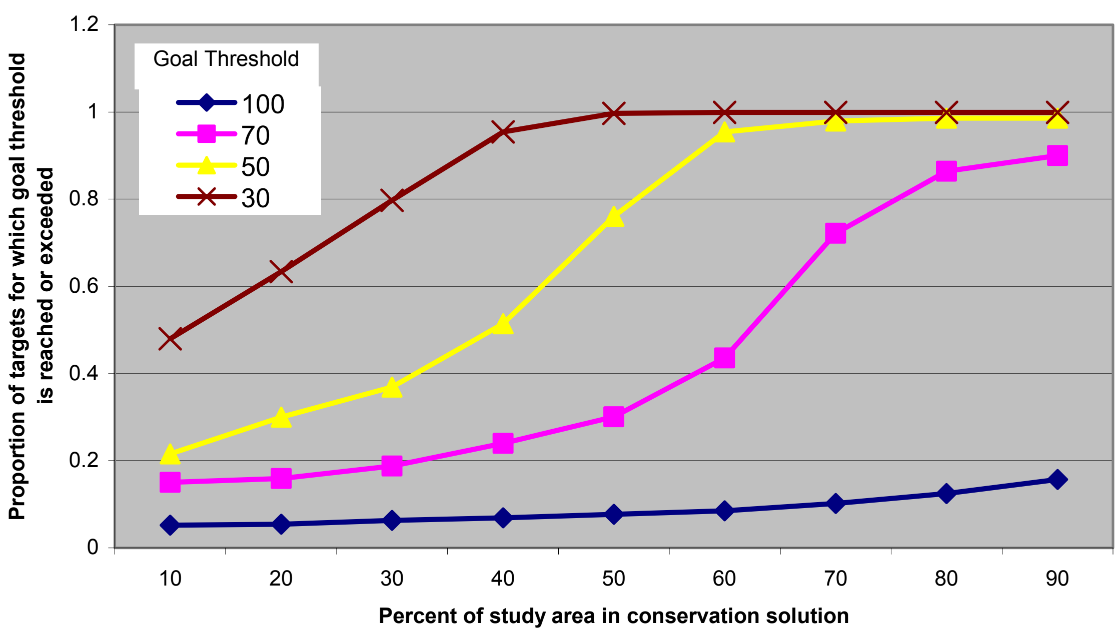


Fig 6.2 Progress Toward Goals for CIT ESA SITES Summed Solutions: Existing Protected Areas Locked In.



Depending on the conservation scenario, between 44% and 50% of the highest conservation value analysis units (equal to 44 to 50% of the study area) were required to satisfy the 30% goal threshold for most targets. As seen in Figure 6.2, increases in solution area bring about proportional increases in solution effectiveness. To achieve 50% goals for most conservation targets, as much as 60 to 70% of the study area was required, with inefficiencies emerging at the top end of a sigmoidal curve, signifying that after approximately 50 to 60% of the study area (50 to 60% of the highest value analysis units) has been incorporated into the solution, subsequent improvements in meeting goals require proportionally larger areas of land and water. This effect is much more pronounced when the 70% goal threshold is examined. In this case, inefficiencies arise to the point where the inclusion of more planning units yields only minute improvements relative to meeting goals.

6.1.2 Protected Areas: Existing and Potential

The current and potential conservation contribution of each land use scenario is presented in Figure 6.3. At a conservation goal of 30%, we see that less than 20% of the conservation elements being targeted by the CIT ESA, meet the goal threshold--under any combination of proposed and existing protected areas. However, it is apparent that there are considerable conservation values within the areas that have been designated and proposed. Table 6.2 shows that up to a quarter of the regions Tier 1 analysis units would be captured in a scenario that designated candidate and option areas as protected.

Fig 6.3 Goal performance for CIT ESA Conservation targets under exisiting and proposed protected area scenarios (Candidate and Options areas limited to Central Coast LRMP Boundaries)

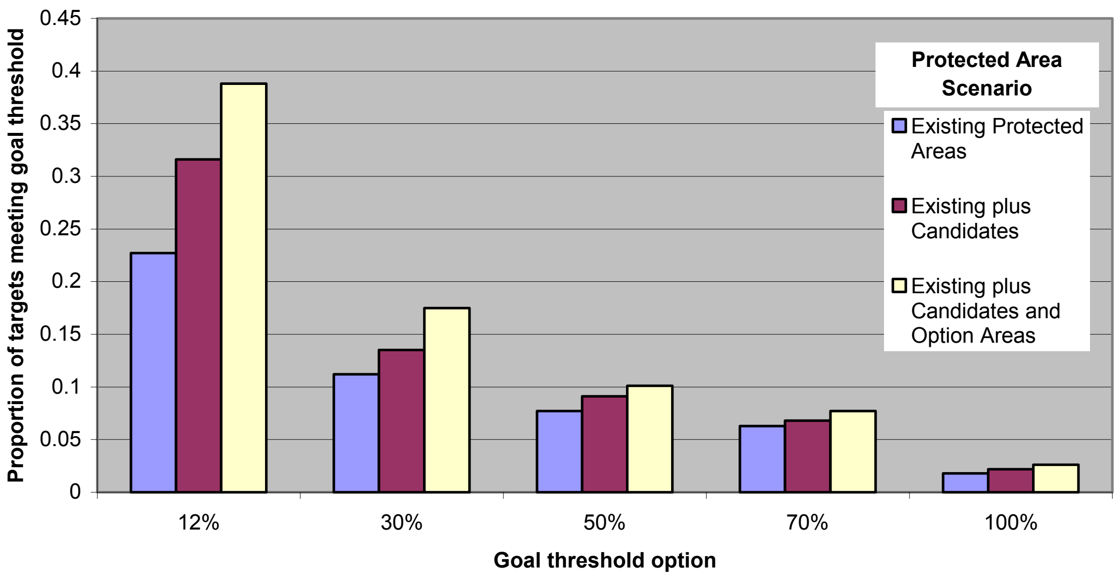


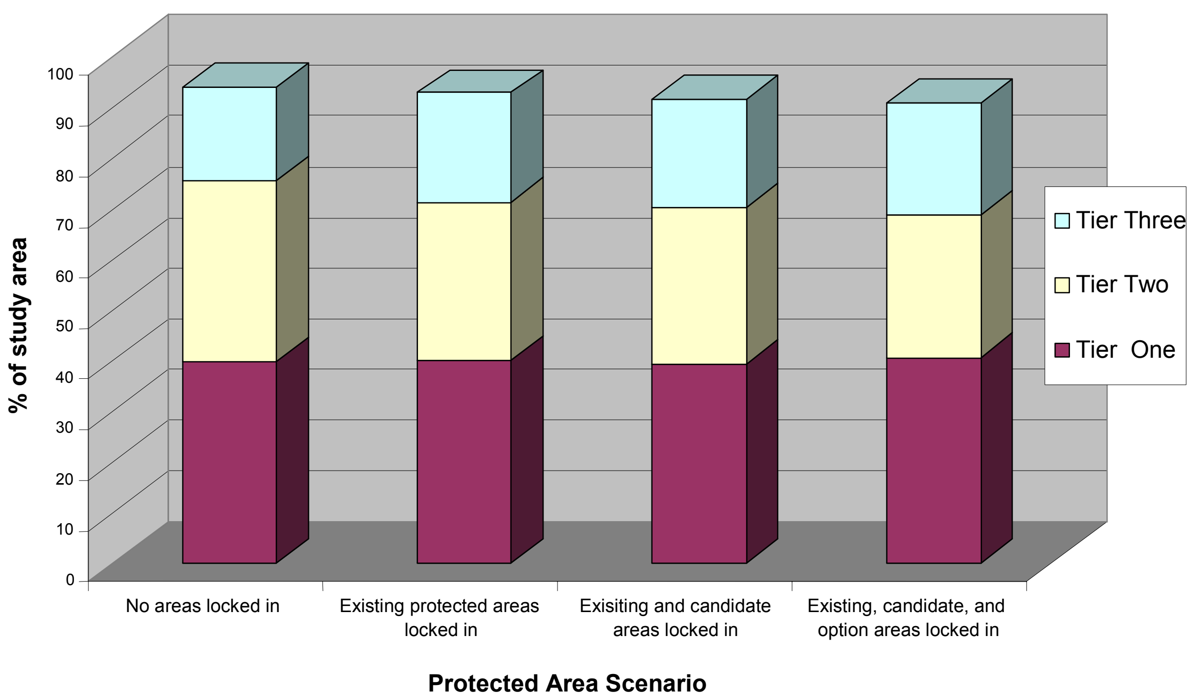
Table 6.2 Protected area status of analysis units from the "No areas locked in" SITES solution.

Conservation Tier	% of study area in solution	% of solution in existing protected areas	% of solution in existing protected areas plus Candidate Areas	% of solution in existing protected areas plus Candidate and Option Areas
1	40.9	13.6	19.0	25.0
2	61.9	12.5	16.9	22.2
3	68.3	11.5	15.5	20.4

6.1.3 Options and Scenarios Compared by Intermediate Watershed

Summaries of conservation tiers for each land use scenerio are presented in maps 41 to 44. Tier thresholds for conservation value were based according to quintiles (section 5.4.4) of the mean summed solution scores of the analysis units within each watershed. These tiers have not however been measured in regards to their effectiveness in capturing target goals and as such, these results are currently best used as a tool for comparing value and condition among watershed units (Table 6.3). Analysis of each tier's absolute performance in terms of goals is forthcoming.

Figure 6.4 Conservation tiers for CIT ESA intermediate watersheds,compared between protected area scenarios



6.1.4 Options and Scenarios Compared by Landscapes/Seascapes

The large size of landscapes and seascape units prevented adequate performance measures to be taken among conservation options. The large size of these units (10,000 to 10,000 Ha) equates to a loss of spatial specificity and coarsens the SITES summed solution significantly. When we calculated the effectiveness of Tier 1 landscapes (124 of a total 565) against a 30% conservation goal for the existing protected areas scenario, we found that just over a third of targets met or exceeded the 30% threshold. Adding Tier 2 landscapes improved effectiveness such that 82.9% of targets met the goal threshold, but well over 70% of the planning area was swept into the Tier 2 option.

From these results it is apparent that more work is needed to examine and find appropriate thresholds among landscape/seascape units. Shortcomings related to finding thresholds among landscapes and seascapes do not however take away from the usefulness of using landscapes as a lens by which to examine the more spatially explicit results based on the 500 Ha analysis units be overlooked. In fact, a more "hands on" approach involving stakeholders themselves to examine these data may prove more useful than the results generated from statistical summary.

6.2 Marine Nearshore Spatial Analysis Results

The purpose of the spatial analysis was to implement and evaluate 12 different MARXAN scenarios to test the irreplaceability and sensitivity of the site selection.

Irreplaceability analyses indicate which sites are consistently chosen. Planning units that get chosen the most often are the least replaceable. These analyses can be evaluated through the "summed solution" output which is the result of the number of times an individual planning unit get chosen within a scenario. The output from all 12 scenarios was combined to form the sum of summed solutions, or the summed solution gradient. With each of the 12 scenarios run 20 times, we had a gradient from 0 to 240 solutions. Within each scenario the algorithm did 1,000,000 iterative selections per run.

Two multiple goal scenarios were run: one optimizing for 10% of the entire shoreline, and another optimizing for 20%. When shoreline ecosystem targets were set to 10%, intertidal vegetation, communities, and fine filter targets were set to 15%. When shoreline ecosystem targets were set to 20%, intertidal vegetation, communities, and fine filter targets were set to 30%. These were applied to all stratification schemes and cost/no cost scenarios. We used three stratification schemes to divide the nearshore zone: marine ecosections, project regions, and no stratification. Marine ecosections provided a stratification scheme based on oceanic and coastal processes. Project regions divided the nearshore by surveying and data collection efforts; and a third scheme was to run the algorithm with no stratification. We also ran the algorithm with and without the cost index (without the cost index means that all planning units were given a cost of 1).

The 12 scenarios are described as follows:

1. 10% shoreline, marine ecosections, cost
2. 10% shoreline, marine ecosections, no cost
3. 20% shoreline, marine ecosections, cost

4. 20% shoreline, marine ecosections, no cost
5. 10% shoreline, project regions, cost
6. 10% shoreline, project regions, no cost
7. 20% shoreline, project regions, cost
8. 20% shoreline, project regions, no cost
9. 10% shoreline, no stratification, cost
10. 10% shoreline, no stratification, no cost
11. 20% shoreline, no stratification, cost
12. 20% shoreline, no stratification, no cost

Sensitivity analyses were conducted by selecting thresholds in the summed solution gradient and evaluating how much representation of the nearshore targets were captured. The area required to meet goals changed as we lowered the threshold along the summed solution gradient. We set three thresholds to illustrate this: 10% (Option A), 20% (Option B), and 30% (Option C) of the entire shoreline length. The summed solution gradient from the 12 MARXAN scenarios provided the basis for setting these thresholds.

There are several ways we are reporting on the results of the sensitivity analysis:

Display the summed solution gradient as the raw output of the nearshore analysis (Map 45).

Display options A, B, and C by setting thresholds to capture 10%, 20%, and 30% of the entire shoreline length. These thresholds along the gradient captured the multiple goal levels set for shoreline ecosystem, intertidal vegetation and habitats, and fine filter targets.

Option A - Nearshore: Upper 10% of the entire shoreline length. Those planning units with summed solution values ranging from 122 to 240 were included in this category (Map 46).

Option B - Nearshore: Upper 20% of the entire shoreline length. Those planning units with summed solution values ranging from 74 to 240 were included in this category (Map 47).

Option C - Nearshore: Upper 30% of the entire shoreline length. Those planning units with summed solution values ranging from 42 – 240 were included in this category (Map 48).

Target amounts captured in Options A, B, and C for the nearshore are detailed in Tables 6.3 and 6.4.

Use the "landscape reporting-out units," or coastal watersheds, devised by the well-being assessment to calculate the amount of selected shoreline captured in these units.

Option A – Coastal Landscapes: Watersheds that contained selected shoreline from Option A – Nearshore, or the upper 10% of the entire shoreline length. Those shoreline planning units with summed solution values ranging from 122 to 240 were included in this category. Watersheds were categorized by classifying the length of selected shoreline within each reporting-out landscape (Map 49).

Option B – Coastal Landscapes: Watersheds that contained selected shoreline from Option B – Nearshore, or the upper 20% of the entire shoreline length. Those shoreline planning units with summed solution values ranging from 74 to 240 were included in this category. Watersheds were categorized by classifying the length of selected shoreline within each reporting-out landscape (Map 50).

Option C – Coastal Landscapes: Watershed that contained selected shoreline from Option C – Nearshore, or the upper 30% of the entire shoreline length. Those shoreline planning units with summed solution values ranging from 42 – 240 were included in this category. Watersheds were categorized by classifying the length of selected shoreline within each reporting-out landscape (Map 51).

We believe it is valuable to illustrate the results of the nearshore analysis as spatially explicit shoreline sites and reporting-out landscapes. The analysis on shoreline planning units provided a level of detail for identifying site specific coastal areas; reporting-out to landscapes or watersheds along the coast provided a look at the integration of terrestrial and nearshore ecosystems.

Table 6.3 Coarse filter targets captured by nearshore Options A, B, and C

Case	Target	Target _id	Shore units	Total length (m)	Goal	Goal amount	High 10% count	High 10% length	10% captured	Medium 20% count	Medium 20% length	20% captured	Low 30% count	Low 30% length	30% captured
1	Channel	1001	3	1,548.5	20%	309.7	0	0.0	0.0%	2	1,329.7	85.9%	3	1,543.0	99.6%
2	ChannelE	1002	9	2,690.1	20%	538.0	1	556.3	20.7%	1	556.3	20.7%	1	556.3	20.7%
3	ChannelP	1003	73	38,751.9	20%	7,750.4	2	3,282.0	8.5%	7	9,657.1	24.9%	9	11,402.6	29.4%
4	Estuary Wetland	1004	40	43,949.0	20%	8,789.8	3	11,193.1	25.5%	5	16,070.9	36.6%	8	23,194.9	52.8%
5	Estuary WetlandE	1005	13	9,942.3	20%	1,988.5	1	207.1	2.1%	4	5,944.5	59.8%	6	8,215.1	82.6%
6	Estuary WetlandP	1006	1134	1,046,811.2	20%	209,362.2	21	94,940.7	9.1%	62	235,475.6	22.5%	115	353,632.9	33.8%
7	Estuary WetlandVE	1007	9	9,323.4	20%	1,864.7	1	428.6	4.6%	2	2,508.3	26.9%	4	5,016.9	53.8%
8	Estuary WetlandVP	1008	47	46,032.7	20%	9,206.5	2	12,229.2	26.6%	3	14,167.6	30.8%	5	16,784.1	36.5%
9	Gravel Beach	1009	215	78,725.4	20%	15,745.1	4	8,850.9	11.2%	11	14,529.0	18.5%	18	22,749.0	28.9%
10	Gravel BeachE	1010	333	93,229.1	20%	18,645.8	12	12,446.9	13.4%	24	19,454.4	20.9%	40	28,924.7	31.0%
11	Gravel BeachP	1011	2983	941,273.4	20%	188,254.7	77	96,079.1	10.2%	162	170,895.3	18.2%	279	254,010.4	27.0%
12	Gravel BeachVP	1012	12	4,336.2	20%	867.2	1	1,081.1	24.9%	1	1,081.1	24.9%	3	2,022.2	46.6%
13	Gravel Flats	1013	28	15,052.7	20%	3,010.5	1	1,580.3	10.5%	3	3,119.3	20.7%	4	4,528.8	30.1%
14	Gravel FlatsE	1014	56	19,683.4	20%	3,936.7	3	3,767.0	19.1%	6	5,732.1	29.1%	10	8,045.7	40.9%
15	Gravel FlatsP	1015	148	76,247.2	20%	15,249.4	4	5,582.7	7.3%	13	18,017.7	23.6%	20	24,584.8	32.2%
16	Gravel FlatsVE	1016	9	3,599.3	20%	719.9	1	2,115.1	58.8%	1	2,115.1	58.8%	2	2,491.0	69.2%
17	High Tide Lagoon	1017	50	85,740.2	20%	17,148.0	1	18,122.6	21.1%	3	25,669.6	29.9%	5	39,864.9	46.5%
18	High Tide LagoonE	1018	10	4,254.7	20%	850.9	0	0.0	0.0%	3	1,776.0	41.7%	3	1,776.0	41.7%
19	High Tide	1019	210	236,286.4	20%	47,257.3	3	14,308.	6.1%	11	77,215.4	32.7%	20	96,726.6	40.9%

Case	Target	Target _id	Shore units	Total length (m)	Goal	Goal amount	High 10% count	High 10% length	10% captured	Medium 20% count	Medium 20% length	20% captured	Low 30% count	Low 30% length	30% captured
	LagoonP							7							
20	High Tide LagoonVP	1020	60	80,393.8	20%	16,078.8	1	14,553.0	18.1%	5	49,823.6	62.0%	7	56,989.1	70.9%
21	Man-made (not a target)	1021	13	5,253.3	0%	0.0	0	0.0	0.0%	0	0.0	0.0%	0	0.0	0.0%
22	Man-madeE (not a target)	1022	5	1,262.8	0%	0.0	0	0.0	0.0%	0	0.0	0.0%	0	0.0	0.0%
23	Man-madeP (not a target)	1023	302	135,230.8	0%	0.0	0	0.0	0.0%	3	18,725.8	13.8%	5	25,781.5	19.1%
24	Mud Flat	1024	7	4,985.3	20%	997.1	2	2,468.2	49.5%	4	3,471.2	69.6%	5	3,788.2	76.0%
25	Mud FlatP	1025	156	107,010.0	20%	21,402.0	6	11,516.1	10.8%	11	19,056.9	17.8%	17	28,454.2	26.6%
26	Rock Cliff	1026	1396	703,588.4	20%	140,717.7	18	59,862.6	8.5%	44	114,028.8	16.2%	78	167,295.1	23.8%
27	Rock CliffE	1027	4314	1,768,132.6	20%	353,626.5	141	208,317.7	11.8%	371	427,208.2	24.2%	562	575,892.1	32.6%
28	Rock CliffP	1028	11822	5,833,450.0	20%	1,166,690.0	231	497,884.3	8.5%	582	1,035,866.8	17.8%	1,097	1,678,133.3	28.8%
29	Rock CliffVE	1029	218	125,300.5	20%	25,060.1	2	24,268.5	19.4%	2	24,268.5	19.4%	4	27,505.7	22.0%
30	Rock CliffVP	1030	68	31,122.4	20%	6,224.5	1	2,207.6	7.1%	3	4,875.0	15.7%	5	6,344.0	20.4%
31	Rock Platform	1031	124	33,573.1	20%	6,714.6	4	5,216.8	15.5%	4	5,216.8	15.5%	8	7,930.7	23.6%
32	Rock PlatformE	1032	1774	661,917.3	20%	132,383.5	50	65,975.0	10.0%	136	159,003.5	24.0%	201	214,936.5	32.5%
33	Rock PlatformP	1033	447	128,569.6	20%	25,713.9	12	13,167.2	10.2%	23	22,847.2	17.8%	39	33,848.5	26.3%
34	Rock PlatformVE	1034	345	162,097.7	20%	32,419.5	2	18,431.6	11.4%	2	18,431.6	11.4%	5	30,694.9	18.9%
35	Rock with Gravel Beach	1035	710	287,587.8	20%	57,517.6	12	19,232.9	6.7%	30	42,396.7	14.7%	68	83,143.3	28.9%
36	Rock with Gravel BeachE	1036	3374	1,394,014.4	20%	278,802.9	141	216,857.4	15.6%	340	436,901.9	31.3%	517	576,347.9	41.3%

Case	Target	Target _id	Shore units	Total length (m)	Goal	Goal amount	High 10% count	High 10% length	10% captured	Medium 20% count	Medium 20% length	20% captured	Low 30% count	Low 30% length	30% captured
37	Rock with Gravel BeachP	1037	9679	4,406,751.8	20%	881,350.4	246	385,559 .8	8.7%	544	742,583.2	16.9%	1,064	1,282,102.0	29.1%
38	Rock with Gravel BeachVE	1038	123	40,373.1	20%	8,074.6	1	4,211.2	10.4%	2	8,161.7	20.2%	3	11,062.2	27.4%
39	Rock with Gravel BeachVP	1039	74	35,028.4	20%	7,005.7	3	5,272.1	15.1%	3	5,272.1	15.1%	5	7,500.6	21.4%
40	Rock with Sand & Gravel Beach	1040	173	57,913.7	20%	11,582.7	2	4,633.9	8.0%	7	12,650.8	21.8%	10	15,839.8	27.4%
41	Rock with Sand & Gravel BeachE	1041	2333	876,653.2	20%	175,330.6	92	143,711 .1	16.4%	218	277,960.5	31.7%	327	366,484.6	41.8%
42	Rock with Sand & Gravel BeachP	1042	7600	2,843,714.0	20%	568,742.8	144	245,869 .2	8.6%	348	487,979.6	17.2%	630	765,906.4	26.9%
43	Rock with Sand & Gravel BeachVE	1043	12	11,238.0	20%	2,247.6	1	2,330.9	20.7%	2	7,880.5	70.1%	2	7,880.5	70.1%
44	Rock with Sand & Gravel BeachVP	1044	39	15,471.3	20%	3,094.3	1	1,458.7	9.4%	3	3,035.9	19.6%	6	4,842.0	31.3%
45	Rock with Sand Beach	1045	19	4,346.8	20%	869.4	2	1,011.4	23.3%	4	1,358.5	31.3%	7	2,848.3	65.5%
46	Rock with Sand BeachE	1046	363	124,830.9	20%	24,966.2	17	22,770. 0	18.2%	35	39,601.5	31.7%	45	48,338.4	38.7%
47	Rock with Sand BeachP	1047	544	182,404.5	20%	36,480.9	12	19,289. 4	10.6%	21	28,422.3	15.6%	36	43,128.0	23.6%
48	Sand & Gravel Beach	1048	173	59,406.9	20%	11,881.4	3	8,605.2	14.5%	5	9,510.8	16.0%	11	14,823.6	25.0%
49	Sand & Gravel BeachE	1049	198	53,307.5	20%	10,661.5	5	5,060.4	9.5%	15	13,005.6	24.4%	23	17,342.6	32.5%
50	Sand & Gravel BeachP	1050	3600	1,339,292.9	20%	267,858.6	81	141,001 .9	10.5%	179	255,142.5	19.1%	285	355,460.4	26.5%
51	Sand & Gravel BeachVP	1051	29	8,876.9	20%	1,775.4	3	2,046.9	23.1%	4	2,417.8	27.2%	4	2,417.8	27.2%
52	Sand & Gravel	1052	96	38,497.7	20%	7,699.5	3	3,393.4	8.8%	9	7,878.0	20.5%	14	11,377.9	29.6%

Case	Target	Target _id	Shore units	Total length (m)	Goal	Goal amount	High 10% count	High 10% length	10% captured	Medium 20% count	Medium 20% length	20% captured	Low 30% count	Low 30% length	30% captured
	Flat														
53	Sand & Gravel FlatE	1053	176	99,267.0	20%	19,853.4	13	17,622.1	17.8%	23	26,674.3	26.9%	34	35,132.2	35.4%
54	Sand & Gravel FlatP	1054	2689	1,298,001.0	20%	259,600.2	65	118,478.0	9.1%	173	251,221.4	19.4%	277	362,535.6	27.9%
55	Sand & Gravel FlatVP	1055	29	12,829.3	20%	2,565.9	1	1,502.8	11.7%	5	2,694.0	21.0%	6	3,293.6	25.7%
56	Sand Beach	1056	19	10,393.3	20%	2,078.7	1	3,729.3	35.9%	3	4,250.5	40.9%	6	6,759.0	65.0%
57	Sand BeachE	1057	242	187,660.8	20%	37,532.2	5	10,508.3	5.6%	17	35,759.7	19.1%	29	53,661.0	28.6%
58	Sand BeachP	1058	298	124,058.7	20%	24,811.7	6	11,313.4	9.1%	18	24,569.5	19.8%	31	38,185.7	30.8%
59	Sand Flat	1059	42	23,653.5	20%	4,730.7	2	2,764.4	11.7%	5	5,379.0	22.7%	9	11,549.1	48.8%
60	Sand FlatE	1060	129	78,238.5	20%	15,647.7	6	10,097.1	12.9%	16	17,054.1	21.8%	24	22,162.8	28.3%
61	Sand FlatP	1061	2179	1,306,395.7	20%	261,279.1	37	126,694.3	9.7%	84	234,122.0	17.9%	148	354,539.1	27.1%
62	Sand FlatVP	1062	40	22,440.9	20%	4,488.2	1	3,052.7	13.6%	5	10,008.9	44.6%	6	10,589.9	47.2%
63	Undefined (not a target)	9999	1026	662,992.3	0%	0.0	0	0.0	0.0%	2	18,830.3	2.8%	2	18,830.3	2.8%
Totals	59 TARGETS		61,095	27,340,266.0		5,468,053.2	1,514	2,748,718.6		3,634	5,540,862.2		6,217	8,297,748.1	

Total shoreline contains 62,441 units with a 28,145,005.1 meters

E = EXPOSED

P = PROTECTED

VE = VERY EXPOSED

VP = VERY PROTECTED

Note: No exposure class indicates that the exposure was not defined

Table 6.4 Fine Filter targets captured by nearshore Options A, B, and C

Target	Target_id	Total Available	Goal	Goal Amount (Meters)	High (10%)	10% captured	Medium (20%)	20% captured	Low (30%)	30% captured
Habitat3	1063	3,674,186.6	30%	1,102,256.0	668,967	18.2%	1,292,947	35.2%	1,655,988	45.1%
Eelgrass	1064	2,780,418.1	30%	834,125.4	545,632	19.6%	906,371	32.6%	1,171,633	42.1%
Surfgrass	1065	2,092,980.4	30%	627,894.1	392,045	18.7%	742,568	35.5%	966,681	46.2%
Saltmarsh	1066	2,669,922.6	30%	800,976.8	468,889	17.6%	861,477	32.3%	1,145,705	42.9%
Kelp	1067	5,134,530.6	30%	1,540,359.2	975,450	19.0%	1,663,440	32.4%	2,219,051	43.2%
Herring Spawning	1068	418,717.1	30%	125,615.1	96,838	23.1%	155,035	37.0%	204,617	48.9%
Thick-billed Murre seabird colony	1075	8,654.3	30%	2,596.3	5,583	64.5%	7,153	82.7%	7,153	82.7%
Cassin's Auklet seabird colony	1074	322,925.4	30%	96,877.6	56,341	17.4%	116,426	36.1%	144,476	44.7%
Common Murre seabird colony	1073	18,896.5	30%	5,669.0	7,483	39.6%	9,053	47.9%	9,053	47.9%
Ancient Murrelet seabired colony	1072	251,716.0	30%	75,514.8	51,487	20.5%	82,559	32.8%	106,600	42.3%
Brandt's Cormorant seabird colony	1071	5,296.6	30%	1,589.0	1,900	35.9%	1,900	35.9%	1,900	35.9%
Horned Puffin seabird colony	1070	15,476.0	30%	4,642.8	3,265	21.1%	6,520	42.1%	7,794	50.4%
Tufted Puffin seabird colony	1069	99,504.6	30%	29,851.4	24,833	25.0%	41,988	42.2%	47,069	47.3%

6.3 Offshore Marine Spatial Analysis Results

Rather than just examining one set of model parameters, we have chosen instead to look at a range of different reserve sizes and a range of reserve fragmentation. From these, we then examined the results for emergent trends. Thus, rather than debating what is the "right" percentage to set aside, or whether larger reserves are better than several smaller ones, we have hopefully avoided these arguments for the time being by focusing on those areas that emerge under a variety of conditions. Those areas that were selected repeatedly we interpret as having a high "utility;" that is, usefulness, to marine reserve network design. While not necessarily meeting all goals, these areas of high overlap give clear direction as to where initial conservation efforts should be focused.

6.3.1 24 Scenarios; 2,400 Solutions

We examined 6 reserve network sizes: 5%, 10%, 20%, 30%, 40%, and 50%. In addition, we examined four MARXAN clumping parameters: very scattered, scattered, moderate, and moderately clumped (BLM = 0.0625, 0.250, 1.00, 4.00). For each of these 24 combinations of variables (6 reserve sizes x 4 clumpings), we ran MARXAN 100 times. Thus, we examined a total of 2,400 MARXAN solutions. For each of those 2,400 solutions, the algorithm performed 15 million iterations.

6.3.2 Utility

By looking at how many times a particular planning unit is included in a solution, we can get an indication of its *utility* in overall reserve network design. That is, those hexagons that are repeatedly chosen likely represent areas that are more useful for effective and efficient MPA network design. While it has been suggested that these hexagons may be "irreplaceable," we have avoided using this terminology for two reasons:

1. This may cause some confusion with the irreplaceability heuristic which is part of the MARXAN software package, and is based on a completely different set of assumptions (Pressey et al 1994, cited in MARXAN v1.8).

2. We are not actually saying that these areas are irreplaceable. While this may be true for some sites that harbour rare species (such as the hexactinellid sponge reefs), it is not necessarily so for all sites. Rather, these areas of high utility represent places that appear to be the most useful in the development of optimal reserve network solutions that best approach our targets, using a minimum of area. Less optimal solutions could possibly be found using larger areas of lower utility.

We have indicated the sum total of these 2,400 solutions as shades of blue (seldom chosen) to yellow (chosen frequently) in Map 52. The examination of various clumping values indicates that regardless of whether reserves are many and small, or few and large, certain areas recur over the course of many runs. For example, within the Central Coast, the following *larger* areas of high conservation utility emerge:

- Hexactinellid Sponge Reefs
- Goose Islands, Bardswell Islands, and vicinity

- Rivers Inlet
- Scott Islands
- Entrance to Queen Charlotte Strait
- Broughton Archipelago
- Head of Knight Inlet
- Cordero Channel

While these areas alone would not constitute a fully representative Central Coast conservation portfolio, it is very likely that were they not included, such a portfolio would be difficult or impossible to achieve. Thus, regardless of what exact percentages were chosen by whatever planning processes, and the exact shape of the boundaries, we would expect the bright yellow areas to be key components of most conservation planning.

Larger areas of high conservation utility within the North Coast include:

- Hexactinellid Sponge Reefs
- West Aristazabal Island (& NW Price I.)
- Kitimat Arm
- Anger Island & vicinity
- SW & N Porcher Island, and Kitkatla Inlet
- S. Chatham Sound
- Mouth of Nass R.

Larger areas of high conservation utility within the Haida Gwaii waters include:

- W. Dixon Entrance
- Naden Hr.
- Masset Inlet
- Skidegate Inlet (Kagan Bay)
- South Moresby Island

Larger areas of high conservation utility off N west coast Vancouver Island include:

- Scott Islands
- Mid-Quatsino Sound
- Brooks Peninsula (Cape Cook) westward to the base of the continental slope

6.3.3 Flexible Solutions

Areas of high conservation utility alone would not constitute a fully representative conservation portfolio. The individual network solutions produced by Marxan can be diverse. Such diversity allows for greater flexibility when considering external factors, such as user interests, parks, local politics, and access & enforcement.

Once an initial selection of conservation areas has been chosen, probably based on the areas of high utility, but also taking into account the needs of the communities and stakeholders, the Marxan algorithm can be re-run, locking these areas into the network. Areas required to complete the portfolio (i.e. meeting the agreed-upon conservation goals) can then be explored.

6.4 Integrated Spatial Analysis

The benefits of performing separate spatial analyses within the same planning effort are many. By examining terrestrial/freshwater, nearshore marine, and offshore marine in separate treatments, we can take a more focused approach at scales that fit those systems and using specialized data sets that might not integrate well across the entire study area. Further, the results that emerge from these separate analyses will be easier to decipher and interpret, since planners and end users will have a clearer sense of what targets and systems are driving site selection.

The separate analytical products can still be compared with one another for the purposes of identifying areas of conservation convergence between these systems. However, it is also desirable to integrate nearshore, offshore and terrestrial/marine assessments into a single analysis for the purposes of optimizing conservation solutions between these environments. Such an integration process is currently being initiated.

7.0 INTEGRATING CIT ESA, EGSA, AND CSA SPATIAL ANALYSES

7.1 Background

Initial results from the ESA indicate that there is considerable variation in the conservation value of planning units within the CIT study area. While some areas contain biodiversity values that can only be captured at that particular place, other areas are more representative of biodiversity values that can be found elsewhere, and are therefore more readily interchanged. If some planning units are indeed interchangeable, a degree of flexibility can be introduced to the challenge of managing competing and complimentary land uses within the CIT study area.

After the completion of the ESA, EGSA and CSA, the CIT hopes to take advantage of this wealth of spatially explicit information to produce a simple and readily understood set of land use options and scenarios that minimize conflict and maximize compatibility between biodiversity conservation requirements, development potential, and places of cultural significance within the CIT study area. Products would be made available in time to assist the Central Coast and North Coast planning tables. Further, the results from this exercise could be readily supplied to CIT Quest for integration into a more sophisticated and dynamic scenario building enterprise.

7.2 Proposed Methods

SITES also allows planners to introduce land use patterns into planning scenarios through a cost function. The cost function is typically set up to push selection of planning units for conservation solutions away from areas of high human use. For the CIT, spatially explicit data emerging from the EGSA could be used to adjust the cost function in SITES so that in cases where conservation values are interchangeable or replaceable, planning units for conservation are selected where conflict with development potential is minimized. In the case of the CSA, it would be possible to encourage the selection of conservation areas that overlap with non-consumptive cultural areas while minimizing the overlap between conservation and consumptive uses.

The SITES model is ultimately driven by pre-determined goals for biodiversity elements, and because some planning units have a high conservation value (and therefore offer little flexibility for being exchanged with other planning units), there will still be many cases where the model must continue to select areas for conservation that conflict with other land uses. However, by running the SITES model with a cost function modified by the EGSA and CSA under a variety of different goal settings, patterns of conflict and compatibility can be uncovered and presented to planning tables in the form of a series of potential land use options and scenarios.

7.3 CIT QUEST

The second Phase of scenarios assessment involves a more stakeholder accessible software tool known as QUEST, developed by the Sustainable Development Research Institute (University of British Columbia) and Envision Sustainability Tools to facilitate scenario development and assessment. QUEST integrates data and models and makes the resulting information accessible via a facilitator-controlled user interface.

CIT QUEST incorporates two models: a Resource Use Compatibility Model (RUCM) and a Well-being Assessment Model (WAM). The RUCM facilitates integration of spatial data into the scenarios on the basis of a common set of spatial units; predefined activities (e.g., protection, fishing), activity classes (e.g., strict protection, low impact fishing), and compatibilities between activity classes, and user allocation of activity classes to spatial units. The WAM links indicators to the allocation of activity classes to measure the impact of each set of choices on ecosystem integrity and human well-being.

8.0 CONCLUSIONS

In progress

9.0 LITERATURE CITED

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