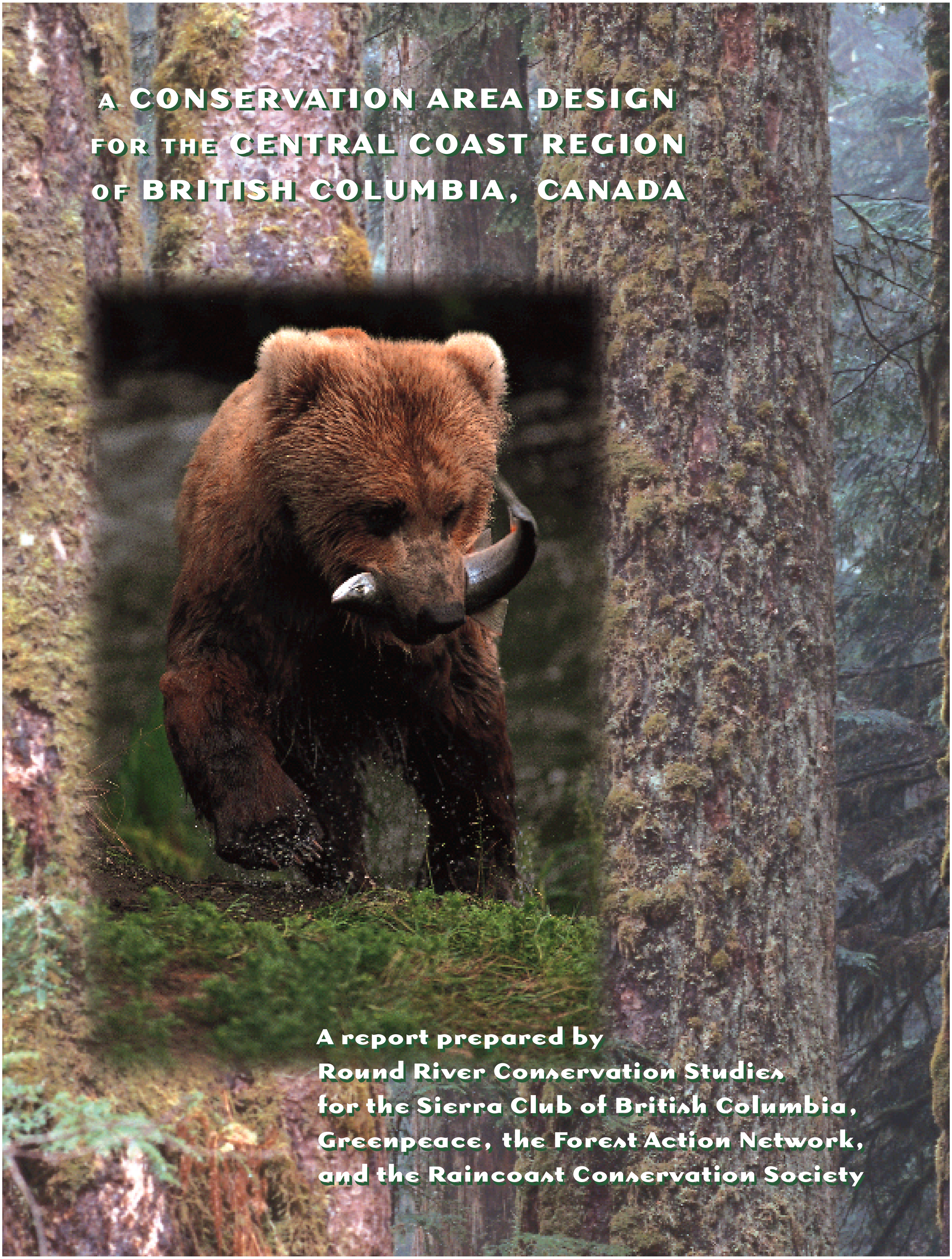

A CONSERVATION AREA DESIGN FOR THE CENTRAL COAST REGION OF BRITISH COLUMBIA, CANADA

A report prepared by
Round River Conservation Studies
for the Sierra Club of British Columbia,
Greenpeace, the Forest Action Network,
and the Raincoast Conservation Society

ROUND RIVER
Conservation Studies

Round River is an ecologically oriented research and education organization whose goal is the formulation and carrying out of conservation strategies that preserve and restore wildness. By wildness, we have in mind landscapes that are relatively self-maintaining, with full vegetation and faunal assemblages present, and where the human communities are in a close and sustainable relationship with the local ecosystem. Flourishing, and intact, we view wild landscapes as important in, and of, themselves; for cultural reasons, and as indicators of ecological health.

Round River works closely with local, national and international conservation organizations to ensure the integrity of wild lands and waters for generations yet to come. We employ the principles of conservation biology to formulate strategies to provide our partner organizations and communities confidence in their decisions and to provide a well founded scientific basis for their long-term conservation planning efforts.

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ROUND RIVER CONSERVATION STUDIES

A CONSERVATION AREA DESIGN FOR THE CENTRAL COAST REGION OF BRITISH COLUMBIA, CANADA.

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A REPORT PREPARED FOR THE:

SIERRA CLUB OF BRITISH COLUMBIA
GREENPEACE
FOREST ACTION NETWORK
RAINCOAST CONSERVATION SOCIETY

PREFACE

As British Columbians debate the future of our last remaining intact temperate rainforest valleys, one simple fact has become increasingly clear to all parties - very little is known about the basic biological functioning of these forests. The First Nations peoples of the B.C. coast, who have lived in harmony with the land for millenniamillenia, are the guardians of much human knowledge about these rainforests. Roots, berries, leaves and fungi have been harvested for centuries for both food and medicinal purposes by coastal tribes. They know where the oolichan run, where the herring spawn, and where and when the salmon leap and the grizzly bears fish. If traditional knowledge can be complemented by modern scientific analysis, western society may begin to truly appreciate the role of these rich, biologically diversebiodiverse forests and the value they offer to humankind. But modern science has only just begun to scratch the surface of knowledge of these forested ecosystems.

As recently as June 1998, entomologists from the University of Victoria, conducting research into insect life in the rainforest canopy of the Carmanah Valley on Vancouver Island, announced the discovery of 300 to 500 new species of insects. Species totally unknown to science worldwide. Such a recent and startling discovery clearly illustrates the paucity of our understanding of these ancient forest ecosystems. Yet their destruction continues at a rapid rate.

In 1997 several B.C. groups, including The Sierra Club of B.C., Greenpeace, the Forest Action Network and the Raincoast Conservation Society, recognized the need to assemble scientific data about the coastal temperate rainforest in the central coast region of B.C. These groups recognized that as ancient forests fell around the world, and over 50% of B.C.'s large rainforest valleys had already been impacted by development, these last intact valleys were a global treasure house of undiscovered knowledge and ecological wealth. Working with these groups, Round River Conservation Studies, an ecological research and education organization, agreed to complete a conservation biology based analysis and design for the central coast. The resulting conservation design is intended to aid all British Columbians in understanding what will be required if we want to ensure the future of salmon runs and grizzly bears, salal and devil's club, eagles and otters, and the rich, fully functioning biodiversity of these magnificent temperate rainforests. The four groups sponsoring this project would like to acknowledge both what this report is, and what it is not.

The Conservation Areas Design is based on western science and offers a biological perspective only. It does not contain any Traditional Ecological Knowledge or include this type of information in the analysis. We recognize that this cultural and social information is essential to understanding this coastal region of B.C.. It is our hope that the scientific perspectives offered in our report may be of some small assistance to the coastal First Nations already embarked upon extensive efforts to map their territory and consolidate both traditional and scientific knowledge. We acknowledge and respect their efforts. The Conservation Areas Design also contains no information about human communities and economic concerns. While we value the integral place of human communities in the ecosystem our objective was to discover what is required to keep these ecosystems functioning and capable of supporting life - all life.

The report focuses on terrestrial conservation concerns only, and only due to a lack of resources. The role of the marine ecosystem, of rich estuaries and the nutrients derived from the sea, is critical to forest and human health. We hope that future, similar analysis will be conducted for marine species and functions to allow for the development of a B.C. marine conservation plan and to assist with critical decisions on integrated coastal zone management.

This work was undertaken in recognition of the fact that if we fail to imagine how to protect the well-being of the entire landscape, the survival of the rainforest and the human and non-human communities dependent upon the rainforest will be in jeopardy. This Conservation Areas Design represents one contribution to an ongoing dialogue about how to maintain and perpetuate the landscape, cultures and communities of B.C.'s central mainland coast. It is our hope that the information and scientific findings contained herein may be useful as together we discuss how to conserve, protect and sustainably use the forests of British Columbia.

Sierra Club of B.C.
Greenpeace
Forest Action Network
Raincoast Conservation Society

ACKNOWLEDGEMENTS

Round River Conservation Studies wishes to thank the following organizations and individuals that contributed to this work. Jill Thomas of the Canadian Rainforest Network first recognized the need for this work and greatly assisted with its fulfillment. Rick Tingey of the Utah Wildlands Project and Round River Conservation Studies completed much of the GIS mapping. He was assisted by John Deck from the University of California at Santa Cruz and by David Leversee and Steve Young of Sierra Club BC. Fieldwork was conducted by Round River Conservation Studies and the Raincoast Conservation Society with assistance from the Forest Action Network and the Temperate Rainforest Research Project. Barrie Gilbert, Utah State University, also helped with the 1997 Grizzly Bear surveys. In particular, this project would not have been possible without the local insight of Ian McAllister of the Raincoast Conservation Society about this rainforest and the many hours of field work provided by Jerry Scoville and Allison Gabel of Round River Conservation Studies and Karen McAllister of the Raincoast Conservation Society. Barbara Dugelby and Michael Soulé of The Wildlands Project generously shared their scientific expertise and knowledge of reserve design planning in countless different ways. Jamie Mazer of the University of California at Berkeley and Tom Annau aided with data analysis. Kitty O'Doherty and Tina Joe helped edit the report. Thanks also to: Catherine Stewart, Karen Mahon and Tamara Stark, Greenpeace Canada; Tzeporah Bermann, Greenpeace International; Gavin Edwards and Greg Higgs, Forest Action Network; Jody Holmes and Allan McDonnell, BC Wild; Merran Smith, Sierra Club of British Columbia; Liz Barrett-Brown, Natural Resources Defense Council; and Chris Hatch, Rainforest Action Network for providing invaluable guidance and assistance with this project.

We would further like to thank the following individuals for participating in scientific workshops and reviewing the project; David Bayles, Pacific Rivers Council; James Bergdahl, Conservation Biology Center; Lance Craighead, Craighead Environmental Research Institute; Barbara Dugelby, The Wildlands Project; Christopher Filardi and Bruce Baizel, Round River Conservation Studies; Bristol Foster, Raincoast Conservation Society; Jody Holmes, BC Wild; David Mattson, University of Idaho; Wayne McCrory, Valhalla Wilderness Society; Allan McDonnell, BC Wild; Troy Merrill, LTB Consultants; Jim Pojar, BC Ministry of the Environment; Paul Paquet, Conservation Biology Institute; Tom Reimchen, University of Victoria; Michael Soulé, The Wildlands Project; Jim Strittholt, Conservation Biology Institute and Steve Trombulak, Middlebury College.

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EXECUTIVE SUMMARY

Ian McAllister

Originally covering 25 million hectares, the once continuous coastal forest between Alaska and northern California occupied more land than the combined total of all other areas of coastal temperate rainforest worldwide. Over the last century, the North American coastal temperate rainforest, a globally rare ecosystem, has been reduced by human activities, primarily logging, to about half its former range. However, large, contiguous, relatively intact areas remain in the central coast of British Columbia (BC) – a region where viable populations of all native terrestrial carnivores and salmon still persist.

We were commissioned to develop a Conservation Areas Design (CAD) for the central coast of BC in order to delineate and prioritize areas for protection and restoration based on current scientific knowledge, the tenets of conservation biology, and the precautionary principle. A comprehensive protection plan for vulnerable species, keystone species, historically impacted communities, and ecosystem attributes is necessary if the overarching goal of conservation of biodiversity[1], in perpetuity, is to be achieved in BC. History has shown that without such a plan, central coast biodiversity and ecosystem functioning will continue to be eroded by human impacts until it eventually resembles the severely depleted forest remnants now found in the lower 48 states of the United States.

Large carnivores are particularly vulnerable to human induced disturbance and have been extirpated over the last 100 years from much of their former range in North America. Such species are either directly impacted by habitat loss, hunting, poaching, over-harvesting, or indirectly threatened by road construction, habitat fragmentation, human development, and increased disturbance. Numerous studies have shown that top-carnivores are often essential to the integrity of ecological communities and, while ecosystems are simultaneously regulated from both

[1]Biodiversity conservation is defined here as maintaining all native species and communities in their natural range of abundance and distribution. The preservation of ecotypes and ecosystem functions is implied.

the bottom and top of the food web, recent empirical analysis points to strong top-down forces.

Millions of anadromous salmonids migrate each year from the Pacific Ocean to spawn in the freshwaters streams of the central coast. Salmon are extremely vulnerable to human disturbance throughout their range. Many stocks have been extirpated or severely reduced through a combination of human impacts including habitat degradation, overharvest, introduction of hatchery fish and construction of migratory impediments. Migrating salmon provide an important seasonal food source for many wildlife species and this massive biomass influx of salmon carcasses each year enriches aquatic and riparian habitats to the extent that anadromous salmonids are often considered to be "keystone" species.

Old growth forests of the west, particularly communities dominated by sitka spruce, douglas fir, cedar, hemlock, and redwood have also seen massive changes in distribution, composition and age structure in recent times. The reason for this is not because old growth forests are exceptionally vulnerable to human disturbance. Rather the forests themselves, particularly stands of large, old trees, have been targeted by industrial scale logging. Thus, the vulnerability of old growth communities is derived not because of sensitivity to disturbance but due to unparalleled resource exploitation in every place it is found.

In this CAD, we set out to identify and prioritize areas for maintaining and restoring large carnivore populations, salmon stocks and old growth forests. These three taxa or communities, above all, define and represent the coastal temperate rainforest ecosystem of BC. We assume that maintaining these attributes will help conserve biodiversity at natural levels of abundance and distribution. We were limited in our endeavor by the availability of information and scientific understanding about relevant species and communities. Nevertheless, this CAD represents a synthesis of the most current data sets for species, communities, and biophysical attributes of the central coast. As new information becomes available, it should be incorporated making the CAD a truly organic plan. It is this – the establishment of a methodology that is continually refined and tested as a hypothesis against new data – that makes the CAD a science informed and science based document. The primary sets of data used to inform the CAD are as follows:

1. Biogeoclimatic zones and digital elevation models.
2. Watershed boundaries.
3. Old growth forest areas.
4. Salmon stock information, including escapement.
5. Human impacts, such as logging, logging roads, and development.
6. Special elements including estuaries, riparian areas and grizzly bear sightings, marked trees and trails.

Our general approach for synthesis was multi-faceted and multi-scaled. We combined a coarse-filter, ecosystem approach, a fine-filter species-based approach, and special elements mapping to arrive at the final design.

An ecosystem approach is useful for identifying general habitat types that are of special concern. Protecting habitats is assumed to also protect the native species that use the habitat, and thus, management for every species present in the region becomes unnecessary. For an ecosystem approach, we use watersheds as our minimum unit of conservation. Watersheds make biological sense as a unit of conservation because rain and water dominate the coastal temperate rainforest ecosystem. In addition, data limitations prevent effective sub-watershed analysis. Since old growth forests are globally rare and have been historically impacted by logging, we identified, as Core Intact Areas, watersheds with less than 10 % logging that contain forest areas with structural features representative of old-growth forests. In particular, we sought to represent in Core Areas species groups that include sitka spruce, cedars and douglas fir.

To complement and address the limitations of the ecosystem based approach we also assessed the ecological needs of large carnivores and anadromous salmonids. Based on information available, we chose the grizzly bear and salmon (including steelhead) as focal taxa that warrant special attention. In addition to productive habitat, carnivores, because of their home range size, low density, and low reproductive rates, typically need large contiguous protected areas in order to survive. Carnivores also need relatively undisturbed areas as a safe refuge from disturbance, hunting, poaching, and other forms of human induced mortality. As low elevation old growth is important to carnivores, and since this habitat has been and is subject to development, we identified relatively intact watersheds (less than 15 % logged) with high potential grizzly bear habitat (areas with less than 0.35 km/km^2 road density and grizzly bear habitat elements including riparian areas, estuaries, old growth forests and salmon) as core grizzly bear/salmon habitat areas. We also identified partially impacted watersheds (greater than 15 % logged) that still contained high potential grizzly bear habitat, as core restoration areas. Halting industrial resource extraction (possibly phasing out select operations gradually by switching to variable retention forestry and ecoforestry), deactivation of roads, and thinning of plantations could rehabilitate these areas with time.

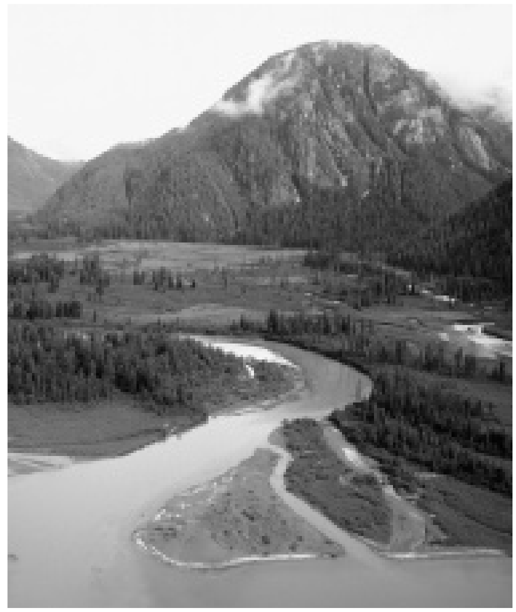
These three areas: 1) intact watersheds, 2) grizzly bear/salmon habitat areas containing relatively intact watersheds and, 3) restoration areas with partially impacted watersheds, make up our *Core Conservation Areas* – areas that receive the highest level of protection from human disturbance. Unacceptable activities in *Core Conservation Areas* include industrial logging, road construction, commercial development, residential development, mining, and trophy hunting.

In order to maintain natural levels of long-term connectivity in the region, we also identified *Linkage Areas*. These are riparian areas, i.e., all creeks, streams, and rivers, appropriately buffered on both banks, and linkage watersheds, mostly composed of alpine and sub-alpine zone watersheds that serve to keep major *Core Conservation Areas* contiguous. Riparian areas also serve as salmon conservation zones that provide habitat necessary to maintain salmon spawning, rearing and migration. *Linkage Areas* can be open to some forms of human activity. Clearly logging or any other major disturbance within the riparian areas is unacceptable. Sustainable variable retention forestry, ecoforestry, hunting, and recreation, however, may be permitted in the linkage watersheds. Activities that may sever these linkages such as road construction, unsustainable hunting, and large commercial development should be discouraged.

The determination and delineation of *Core and Linkage Areas,* as well as the sub-categories contained therein, represents a major synthesis of biophysical and ecological data that is only now becoming available for the central coast region of BC. Without this type of analysis it will be difficult to comprehensively address the needs of both human and non-human denizens of the region. We fully recognize that this is only a first step – but a necessary first step. It is based on incomplete information and current scientific understanding. As such, we expect our delineation maps and accompanying analysis to evolve as others input newly emerging information. We welcome such change and urge researchers to seize the initiative we have provided and fill in the "gaps".

Even the best plan or design will come to naught if it is not implemented. If the extinction crisis, now underway globally, is to be tackled locally, the Conservation Areas Design for the Central Coast of BC must be integrated into all regional conservation and development policies. The fate of this key step is in the hands of local people, environmental organizations, concerned First Nation's and government representatives. If it fails, this unique synthesis of data and the map it provides will become not a map for hope but another postmortem for nature.

SUMMARY OF MAPS



MAP 1. STUDY AREA AND BASE

The Study Area and Base Map depicts the boundaries of our investigation. These boundaries were derived from those of the British Columbia Central Coast Land and Resource Management Planning (LRMP) process. Also displayed on this map are existing protected area boundaries and general landscape features of the central coast— terrain, forested areas, rivers, lakes, bog forest, and glaciers.

Human impacts are also displayed include logging (yellow, taken from Sierra Club BC satellite imagery analysis and forest development plans) and logging roads (red, digitized from TRIM maps). The study area contains about 440,000 ha of logging and 6,415 km of logging roads. Proposed five year logging plans for the study area are displayed and total around 25,817 ha of logging, which includes approximately 9,596 ha of logging in *Core Intact Areas* and 9,498 ha in *Core Grizzly Bear/Salmon Areas* and *Core Restoration Areas.*

Remaining forests with old growth structural components (corrected for recent logging activities) are shown in purple. Large and old trees in the forest cover database area were used to delineate forests with old growth structural components.

MAP 2. CORE INTACT AREAS.

Core Intact Areas (dark green) are watersheds that have had less than 10% logging impact and contain significant stands of forest with old growth structure (as defined in this report, see section following sections) (purple) where large and old trees are used as a indicator of forests with structural components associated with old growth forests. Bog forest (brown) is also displayed. A number of watersheds containing unlogged bog forest (but not old growth structure) are not included as *Core Intact Areas*. Logged areas (yellow), existing protected areas (pink outline) and the CWH biogeoclimatic zone (light green) are also displayed. *Core Intact Areas* make up 1.47 million hectares or about 31% of the study area. *Core Intact Areas* include 111, 600 hectares out of 217,200 hectares (about 51%) of remaining forests with old growth structure. Representation of old growth focal species groups includes 47,600 ha of cedars (51%), 12,500 ha of sitka spruce (66%), and 7,200 ha of douglas fir (22%). Forty-one percent (360/ 871) of total salmon stocks are represented in *Core Intact Areas*. Salmon species representation includes 74 of 184 coho stocks, 16 of 46 chinook stocks, 38 of 86 sockeye stocks, 81 of 191 chum stocks, 149 of 349 pink stocks and 2 of 15 steelhead stocks. These results suggest that chinook, steelhead and douglas fir are not sufficiently represented in *Core Intact Areas*.

MAP 3. CORE GRIZZLY BEAR/SALMON HABITAT AREAS.

Core Grizzly Bear and Salmon Habitat Areas (< 15% logged, dark green) and *Core Restoration Areas* (> 15% logged, dark green with gray hatch) are delineated as areas with low road density (< 0.36 km/km2) and grizzly bear habitat elements (estuaries, riparian areas, old growth forest) and salmon presence.

Core Grizzly Bear/Salmon Habitat Areas encompasses 715,200 ha and *Core Restoration Areas* include 802,000 ha. Together, these areas include 41% of remaining old growth (89,090 ha). Representation of old growth focal species groups includes 32,900 ha of cedars (35%), 8,390 ha of sitka spruce (44%), and 12,830 ha of douglas fir (39%). Forty-one percent of salmon stocks (358/871) are represented including 74 of 184 coho, 34 of 46 chinook, 41 of 86 sockeye, 70 of 191 chum, 127 of 349 pink and 12 of 15 steelhead stocks. Note that additional chinook and steelhead stocks, as well as additional douglas fir areas are found in these areas.

Logged areas (yellow), forests with old growth structure (purple), existing protected areas (pink outline) and the CWH biogeoclimatic zone (light green) are also displayed.

MAP 4. RIPARIAN AND SALMON CONSERVATION AREAS

Riparian and Salmon Conservation Areas (light brown) are the terrestrial salmon habitat areas of salmon bearing watersheds. For display purposes, the CWH biogeoclimatic zone of all salmon bearing watersheds is displayed. The actual spatial extent of *Riparian and Salmon Conservation Areas* is defined by FEMAT (1993) for compatible logging buffers around all streams in salmon bearing primary watersheds. In addition, more extensive protection for sensitive areas (e.g. salmon spawning areas) may be necessary and should be evaluated on a watershed by watershed basis.

MAP 5. CONSERVATION AREAS DESIGN

Core Conservation Areas (dark green) and *Linkage Areas* (light brown) are delineated. Existing protected areas are outlined in pink. Three types of areas make up Core Conservation Areas (see chapter 3 for detailed methods):

1. Core Intact Areas (Map 2) are watersheds with relatively intact old growth forest and low levels of human impacts (< 10% logging).
2. *Core Grizzly Bear/Salmon Habitat Areas* (Map 3) are watersheds with grizzly bear habitat elements, salmon runs, low road density and less than 15% of the forested area logged. Note that there is some overlap between *Core Grizzly Bear/Salmon Habitat Areas* and *Core Intact Areas*.
3. *Core Restoration Areas* (Map 3) are watersheds with grizzly bear habitat elements, salmon runs and low road density but with greater than 15% of the forested area logged. These areas may require extensive watershed level habitat restoration.

We define two types of areas as *Linkage Areas*, that are designated specifically to maintain natural levels of connectivity:

1. *Riparian and Salmon Conservation Areas* (Map 4). These are salmon bearing watersheds outside of *Core Conservation Areas*. The purpose of these areas are twofold:

protection of salmon habitat and providing landscape connectivity for large carnivores. The management guidelines in FEMAT (1993) defining compatible buffers around riparian areas were utilized as starting points for defining *Riparian and Salmon Conservation Areas*. However, some extremely sensitive locations (e.g. habitat surrounding salmon spawning beds) will require more extensive protection.

2. Linkage Watersheds are watersheds with a greater than 2:1 ratio of alpine tundra (AT) to coastal western hemlock (CWH) biogeoclimatic zone area. *Linkage Watersheds* are made up primarily of high elevation "rock and ice" (already sufficiently represented in existing protected areas). These areas connect thin strips of productive low elevation old growth forest containing valuable grizzly bear and salmon habitat. *Linkage Watersheds* play potentially important roles in connectivity between Core Conservation Areas and should be managed to maintain natural levels of landscape connectivity.

Sixty-one percent of all salmon stocks reside in *Core Conservation Areas*. The majority of forests with old growth structure are represented in *Core Conservation Areas* (72% of all old growth, 69% of cedars, 79% of sitka spruce and 47% of douglas fir). These results suggest that the proposed *Core Conservation Areas*, which make up 51% of the total land area (2.4 million hectares), adequately represent salmon and old growth forests. Only 6.6% of *Core Conservation Areas* (157,630 ha) are located in existing protected areas (pink outline).

INTRODUCTION

Bruce Baizel, Round River
Conservation Studies

Ian McAllister

In 1997 a number of conservation groups initiated a project to serve as a proactive tool to help protect the native biodiversity of British Columbia's temperate rainforest. The mission of this project was to delineate and describe a network of core areas and ecological corridors within the coastal temperate rainforest ecosystem that could enhance the long-term viability of key resident species and major ecosystem processes. In accordance with this mission, Round River Conservation Studies (RRCS), with assistance from its partner groups, Sierra Club BC, Greenpeace, Forest Action Network, and Raincoast Conservation Society, initiated work to produce a Conservation Areas Design (CAD) for the central coast.

This report uses the concepts and theories of western science, and specifically the perspective of conservation biology, both because there has been a dearth of such scientifically based attention to the central coast as a whole and because we believe that conservation biology is well-suited to address landscape level ecological issues. In order to make the report as strong as possible, the CAD has been through an initial scientific review process, including a review workshop in Victoria in October of last year, and will be subject to additional scientific review during the coming months.

PREVIOUS REPORTS

A large part of the need for the CAD was due to the absence of any other publicly available, scientifically-based, reports or documents that specifically address the ecological condition of the central coast landscape. In the context of British Columbia coastal forests, the closest similar efforts are the ecological assessments contained in the reports by the Scientific Panel for Sustainable Forest Practices in Clayoquot Sound. (1994a; 1994b; 1995) Other related assessments are the Vancouver Island Mapping Project of the Sierra Club of Western Canada (1993), and their satellite imagery mapping of coastal rainforests (Sierra Club 1997), the series of reports developed by the Haisla and Ecotrust for the Kitlope watershed (Travers 1991; Copeland et al. 1992; Schoonmaker and Kellogg 1994), and Round River Conservation Studies' (1995; 1996a; 1996b) watershed assessments in Heiltsuk territory. There are also assessments contained in the collection edited by Schoonmaker et al. (1997); however, each of these reports either covers the entire coastal temperate rainforest bioregion of the Pacific northwest or focuses only on specific watersheds or areas outside of the central coast landscape of concern here.

The most similar of these assessments are the Scientific Panel reports. The terms of reference for the Clayoquot Sound Scientific Panel were addressed to a review of forest practice standards, and recommended changes to those practices, in light of their cultural and ecological sustainability for Clayoquot Sound. (1994b) In a subsequent report, Ecotrust has taken the Scientific Panel's recommendations and developed an analysis of the Clayoquot Sound landscape based upon GIS mapping of constraint layers, in a manner somewhat similar to the process used in developing this CAD. (Ecotrust 1997) By comparison, the goals which guided preparation of this CAD, such as maintenance of ecological and evolutionary processes, preventing habitat fragmentation and restoration of connectivity and protection of biodiversity and ecological integrity, are consistent with the ecological guiding principles identified by the Scientific Panel. (1994b: Appendix I) However, this CAD report is looking at an area many times larger than Clayoquot Sound.

At the provincial level, there are primarily three relevant sets of reports that apply to the central coast. First, the provincial Protected Areas Strategy (Province of British Columbia 1993), and its subsequent application to the central coast (Province of British Columbia 1997), represents an administrative approach to the central coast landscape that is tied to 'balancing' the perceived interests of various stakeholders. The 1997 Revised Study Areas report begins with the existing provincial administrative management designations and then assesses ecosystem representation, recreation inventories and existing cultural heritage areas to generate areas recommended for protected area study. This 'long' list of recommended sites is then modified by short-term socioeconomic implications and land ownership/control boundaries to arrive at a 'short' list of recommended study areas for the central coast LRMP area. While this 1997 report does use grizzly bear habitat, salmon spawning rivers and old growth coastal temperate rainforest as criteria for generating its 'long' list of recommendations, these 'conservation' indicators are subordinated to the perceived sociopolitical interests of stakeholders in the final 'short' list of recommendations. Therefore, the recommended study areas in this report represent a largely administrative, and not ecological, baseline.

A separate, though linked, provincial report derives 56 'draft' landscape units within the Mid Coast Forest District using three main criteria: (1) watershed boundaries, (2) the scale of both habitat type and the predominant natural disturbance regime, and (3) other ecological criteria. (Province of British Columbia 1998) The report then goes on to establish biological diversity management emphasis options for the landscape units, based upon a ranking of six biodiversity values: ecosystem representation, ecosystem complexity, identified wildlife, area sensitivity to development, connectivity, and current condition. Based upon a provincial Chief Forester mandate, this 'coarse filter' biodiversity ranking is then combined with a timber ranking for each landscape unit. This ranking is then used to identify the 11% of the timber landbase to be managed with a higher biodiversity emphasis, the 45% of the timber landbase to be managed with an intermediate biodiversity emphasis and the 44% of the timber landbase to be managed with a low biodiversity emphasis. As with the Revised Study Areas report, this landscape ranking approach is situated within an administratively determined framework that takes as its starting point the primacy of industrial forest management.

The third provincial report of relevance to the central coast landscape is the Conservation of Grizzly Bears Background report, prepared by the Ministry of Environment, Lands and Parks. (1995a) This report uses a biophysical habitat capability model developed by the Habitat Inventory Section of the Wildlife Branch to identify prime grizzly areas throughout the province that should be considered for potential protection or special management. This habitat capability model uses population estimates and current land use activities, and while consistent with our grizzly bear watershed index, it is intended only as an overview of current grizzly bear habitats, requiring more detailed inventory and mapping within specific landscapes of the province. (1995a: 30) Furthermore, as Horejsi et al. (1998) point out, the information and analysis presented in this background report seem to have been politically screened for the resulting provincial Grizzly Bear Conservation Strategy. (Province of British Columbia 1995b)

ROUND RIVER'S ROLE

Round River is an ecologically oriented research and education not-for-profit organization whose goal is the formulation and carrying out of conservation strategies that preserve and restore wildness. By wildness, we have in mind landscapes that are relatively self-maintaining, with full vegetation and faunal assemblages present, and where the human communities are in a close and sustainable relationship with the local ecosystem. (Snyder 1990; Turner 1997)[2] We view wild landscapes as important for three main reasons. They are important in, and of, themselves; (Leopold 1949) they are important for cultural reasons, in that communities coevolve with particular landscapes, developing relations of interdependence over time; (Whitt and Slack 1994; Hebda and Whitlock 1997; Suttle and Ames 1997) and they are important as indicators of ecological health. (Constanza et al. 1992)

Round River's perspective is based in conservation biology, a mission oriented discipline that focuses on solving conservation problems. (Soulé 1986; Soulé and Sanjayan 1998) Where specific groups or communities and Round River have mutually identified a need and agreed to work together, Round River offers western science-based expertise in conservation biology[3]. Such a commitment to real world application does not mean that the analysis and recommendations contained in this report are any less valid. The scientific analysis presented here represents a reasoned judgment, using the best available data, that can be used as a guide as to what might occur on the central coast under different land use regimes. The recommendations are scientifically well grounded, justifiable and strong. We view this to be the particular strength of the CAD - it is a western science based statement made independent of specific economic or political interests. As an 'outsider', we can provide such a relatively open assessment of the ecological conditions on the central coast.

Our 'outsider' status, however, also places limitations on the CAD. This report does not include community-specific cultural knowledge, traditional ecological knowledge (Turner 1997), or industrial production knowledge[4], limitations which we recognize. So, in this sense, the CAD remains only a partial snapshot of the central coast landscape, and therefore, we believe that the larger social validity of the CAD will ultimately be determined in the course of the dialogue about the future of the central coast.

USE OF THE CAD

Our primary partners in the development of the CAD are the members of the Canadian Rainforest Network (CRN). It is the CRN which identified the need for a western science-based ecological 'snapshot' of the current state of the central coast landscape, rather than a watershed by watershed assessment. This need, in part, was stimulated by requests of CRN members to acquiesce, in the absence of knowledge about the ecological status of the central coast landscape, in watershed-by-watershed decisions by logging corporations, decisions that had larger scale, landscape level ecological consequences. (Sierra Club 1999) In order to gain a better picture of how specific watersheds fit ecologically into the larger coastal landscape, it was decided to have this CAD analysis carried out.

We hope that the information contained in this report meets these needs. Beyond meeting these specific needs, however, we believe that the information provided in this report can be used by central

[2] Wild is not the same as wilderness, (Peepre 1999) the latter being a political and cultural construct developed to meet the linked North American challenges of expansive resource development and the liberal democratic state. (Morrison 1997) We would only note here that this CAD does not specify the type of social mechanism or management status that might be used to ensure the integrity of the core areas, for example. We believe that it makes sense for such decisions to be made by those who will live most immediately with the consequences of the decisions (Western et al. 1994). This approach is also consistent with the Saanich Statement on Community Forestry, a statement developed at a workshop in North Saanich, British Columbia, by eighty-two citizens from eighteen different countries in October of 1998. (Saanich Statement of Principles on Forestry and Community 1998)

coast First Nations, communities and groups to evaluate the potential localized impacts of proposed economic development activities, more generally. Our experience on the central coast has shown that such evaluations, based at least in part on western science, may be useful in negotiating in a variety of different contexts[5].

In the long run, we believe that specific communities and groups who live within the central coast landscape may be the most effective actors for perpetuating that landscape. We also believe that they can potentially be the most effective players for maintaining the current level of biological diversity, a view held by others as well. (Dove 1996; Rankin and M'Gonigle 1991)

This report provides an ecological framework within which economic development proposals may be viewed. It is not a report defined by issues of economic efficiency and economic growth, both of which have been strongly argued by others involved in the LRMP process. Nor is it a report about specific predictions and scientific control over, for example, First Nation cultural frameworks. Rather it is a report about ecological likelihood and probabilities at the landscape level.

We hope that this report will be useful and that those who use it will recognize its strengths and limitations.

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[4] Given the resources of the logging corporations active on the central coast and their historic advantage in terms of access to provincial decision-making on forestry matters (Beyers and Sandberg 1998; Doyle et al. 1997; Wilson 1997; M'Gonigle 1997; Gunton 1997), we are confident that they will continue to provide industrial production knowledge.

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1. CAD BACKGROUND


M.A. Sanjayan

Given the critical loss of populations, species, communities, habitats, and ecosystems worldwide, the value of the extant wildlands remaining along the central coast of British Columbia (BC) cannot be overstated. These areas represent some of the last remaining examples of intact coastal temperate rainforest - a globally rare ecosystem occupying less than 1% of the earth's land surface. Half of the world's still standing coastal rain forests are in North America and until this century stretched from central California to southern Alaska (Schoonmaker 1997). About half of the North American coastal temperate rain forest has been severely altered by commercial clearcut logging, farming, urban development and other anthropogenic activities, so that essentially no undisturbed watersheds remain in California, Oregon, or Washington. Top predators such as the grizzly bear *(Ursus arctos),* wolf *(Canis lupus)* and wolverine *(Gulo gulo)* have been extirpated from these states, as have the majority of historic salmon stocks. Although extensive areas of the coast of BC have been heavily impacted by commercial clearcut logging, commercial fishing, hunting and road building, some relatively unfragmented expanses of lowland old growth forest still remain and viable populations of salmon, grizzly bear, wolf, and wolverine can still be found. Commercial logging appears to be the most serious and imminent threat to this unique ecosystem. Hunting, particularly of carnivores, and commercial, sport and food fishing may also exert unsustainable pressures on certain species and ecosystem processes they contribute to.

In this report, we attempt to identify a system of conservation areas designed to protect and restore ecological values in the face of the many pressing threats and existing wounds to the region. While we engage a scientific process for determining the necessary extent of protected areas in this region, we acknowledge that such a system cannot operate totally independent from value judgements. What is the value of wild areas, valleys with centuries-old stands of cedar and spruce, enormous runs of pacific salmon and top predators like grizzly bears, wolverines and wolves? Such values are difficult to quantify, although some have attempted to do so in socioeconomic terms (Randall 1990). As such, a key assumption we make in developing this conservation area design is that the protection and restoration of biodiversity has intrinsic value and is generally good. Further, while we acknowledge that biodiversity may have economic and social values that are considerable and should be accounted for in management decisions (Hanemann 1990; Norton 1990), for the sake of clarity, we do not attempt to include these anthropocentric values here. Instead, our work focuses on defining conservation goals based solely on ecological values and defining and delineating areas that are high priorities for protection, based on meeting conservation goals. Taken together, these values, goals, area selection, and maps make up a Conservation Area Design (CAD) for the central coast of British Columbia.

1.1. DESIGNING AREAS FOR CONSERVATION: A HISTORY

Conservation through protected areas is not a recent phenomenon. Emperor Ashoka of India is often credited with enacting the first laws establishing wildlife sanctuaries during the 5th century AD. However, the era of modern conservation really began with the establishment of the first internationally recognized national park - Yellowstone National Park in 1872. Protection of biodiversity was not necessarily the primary consideration for determining the size and location of early parks. For example, parks such as Banff, Waterton, Jasper, Yosemite, Glacier and Grand Canyon were created primarily as scenic attractions valued for aesthetic reasons. Other parks were created to enhance the ability to meet human needs, such as clean drinking water. For example Sooke Hills on Vancouver Island was created to protect the drinking water of Victoria, British Columbia, Sequoia/Kings Canyon National Park was created in part to protect the agricultural and drinking water source for much of California and the largest protected area in the eastern U.S., Adirondack Park, was established to protect New York City's drinking water supply (Meffe et al. 1997).

Although protection of biological resources or values is often cited as a criterion for the establishment of a protected area, existing protected areas managed strictly for biological conservation make up only a small proportion of the terrestrial land base worldwide - about 3% (McNeely 1994). Compounding this problem is the fact that most North American protected areas are located in alpine or sub-alpine zones and are usually too small and isolated to maintain viable populations of certain species, particularly wide-ranging animals such as carnivores (Newmark 1995). According to British Columbia's recent protected area strategy, 75 % of parks in the province are less than 1000 hectares in size and greater than 65% are in alpine or sub-alpine zones with the coastal temperate rain forest ecosystem grossly under represented (Sanjayan and Soulé 1998). This limited coverage is by no means a purely North American phenomenon. In a recent presentation at the Society for Conservation Biology Annual Meetings, Eric Dinerstein, chief science officer for World Wildlife Fund-US, showed that although the protected area system of the Himalayan range contains over 160 reserves, many of these reserves (33 %) are in marginal habitat serving only to inflate statistics on protection.

The encouraging news is that over the last twenty-five years science has begun to play an increasing role in the design of conservation areas, wilderness sanctuaries, and national parks. A number of significant advances in the design of conservation areas have been made and some general principles of conservation area design have emerged (see Terborgh 1974; Willis 1974; Diamond 1975; Wilson and Willis 1975; Diamond and May 1976). However, a number of unresolved issues still exist in the theory of conservation area design, including the "SLOSS" (single-large-or-several-small) dilemma, (see Simberloff and Abele 1976; Jarvinen 1982; Kindleman 1983; Simberloff and Gotelli 1984; Kobayashi 1985; resolved in part by Soulé and Simberloff 1986), the "nestedness" dilemma (it is unclear that the species composition of a relatively small fragment will necessarily be a subset of the composition of a relatively large arrangement, see Jones et al. 1985;

Neimela et al. 1985; Nilsson 1986) and the optimum shape of reserves (see Game 1980 and Blouin and Conner 1985). However, despite these ongoing debates in the scientific literature, some general principles for designing conservation areas have withstood the test of time and can be applied to a wide variety of regions and species (Noss et al. 1999).

One of the most detailed descriptions of a science based network of reserves comes from the work of Diamond (1986) who, based on the principles of conservation biology and island biogeography, in particular, designed a system of national parks for Papua New Guinea and Irian Jaya. This reserve design accounted for biological considerations such as the most likely causes of extinction, major habitat types, and areas of high endemism. Diamond not only specified *where* reserves should be located, but also *how big* reserves needed to be, based on minimum area requirements for the species that the reserves were attempting to protect. What was perhaps most surprising was that Diamond was able to make some of his recommendations based on fairly incomplete biological information. When the Kumawa Mountains were recommended as a reserve, no biologist had ever entered those mountains. Nevertheless the recommendations were made based on the degree of isolation, geography, and spatial configuration of the mountain range. Later visits by cadres of biologists confirmed the validity of this decision.

Many other organizations including the Wildlife Conservation Society, World Wildlife Fund, The Nature Conservancy, Conservation International, and The Wildlands Project, have followed Diamond's lead and now use, to varying degrees, science-based approaches to designing and prioritizing areas for conservation. A number of increasingly sophisticated techniques included in many regional designs include gap analysis, focal species analysis, inventories of native species, landscape linkage analysis, population viability analysis and habitat suitability modeling. While these techniques are far from perfect, these organizations are spearheading the effort to ensure that future protected areas are designated based on conservation science rather than primarily on aesthetic, social, political, or economic considerations.

1.2. GOALS FOR REGIONAL CONSERVATION

What does it mean to conserve biodiversity and maintain ecosystem integrity? Noss (1992) and Noss and Cooperrider (1994) stated four goals of regional conservation that must be satisfied in order to achieve the overarching mission of maintaining biodiversity and ecological integrity in perpetuity. These goals are:

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

These four goals are often cited and have become central to regional conservation strategies and reserve designs produced by The Wildlands Project (Trombulak 1996), and its regional affiliates (e.g., Sky Island Alliance 1998). In addition, many conservation organizations and government agencies echo some of these goals when designing strategies for biodiversity conservation.

For example, The Nature Conservancy, the largest private owner of protected areas in the world, has in its mission statement the explicit goal of ensuring the long-term survival of all viable native species and community types through the design and conservation of portfolios of sites within ecoregions. Similarly, the BC provincial government stated that the first goal of its protected area strategy is "to protect viable, representative examples of natural diversity in the province, representative of the major terrestrial, marine and freshwater ecosystems, the characteristic habitats, hydrology and landforms ... of each ecosection". Further, the provincial government recommended in its Forest Practices Code that an ecosystem management approach be taken in order to provide adequate habitat and to sustain genetic and functional diversity in perpetuity for all native species across their historic ranges, along with the maintenance of ecological processes. Even the private sector in British Columbia is getting into the act. Bunnell et al. (1998), in a recent report for MacMillan Bloedel, state that sustaining ecosystem health and biological diversity are two new broad objectives for this logging company.

Conservation plans or conservation campaigns that do not meet or address the goals set by Noss (1992; 1994) must be considered incomplete. Unfortunately there are many such plans and campaigns. For example, old-growth forests are often used as the sole basis for conservation campaigns in the Pacific Northwest of the U.S. These forests, often containing large, ancient trees, are widely promoted as a symbol of ecological health and intactness. Although old growth forests are unquestionably valuable, it is entirely possible to save old-growth trees while losing species and ecological functioning at the same time. This conundrum is further confounded by the economic value of old growth forests; economic considerations often focus community conservation efforts on trees and how to harvest them in a sustainable manner. Yet, studies by Janzen (1988) and Redford (1992) suggest that many large animals, particularly large carnivores, are already extinct in areas that still contain large trees and apparently intact vegetation. These authors warn that it is possible to save the trees and still lose significant faunal richness and ecological functioning, leaving behind forests they describe as the "living dead".

This CAD attempts to prevent similar ecological disaster by identifying necessary areas for conservation guided solely by the four goals stated by Noss (1992) independent of economic considerations. This does not mean that economic considerations are inconsequential. Rather, we believe that in order to maintain the application of the best available science to the CAD, socio-economic considerations can be brought to bear in a separate process after a biologically based CAD is complete.

1.3. THE PRECAUTIONARY PRINCIPLE

Problems associated with managing natural resources are often blamed on incomplete information. The call for 'more research needed' often accompanies reports documenting failures in natural resource management. Much of this thinking is based on a fundamentally flawed assumption that natural systems are predictable, stable, and manageable given "complete information" while in truth; nature is often inherently stochastic. Thus understanding uncertainty and stochasticity must be an integral part of natural resource management.

The "precautionary principle" states that the uncertainty in managing natural systems should be explicitly acknowledged and managers should make every effort to err on the side of caution. This principle suggests that, given the finality of extinction, conservation planning should incorporate wide margins of safety against the potential loss of organisms, populations or ecological processes.

Increasing degrees of uncertainty should be met with increasing levels of caution and margins of safety. For example, fisheries managers are frequently faced with the problem of setting catch quotas based on the best available, but incomplete, information. They may be quite aware of the fact that this information is incomplete, and know that sustainable catch levels cannot be determined with a high degree of certainty. But how are managers to take this uncertainty into account? Unfortunately, history shows that any admission of uncertainty often encourages industry representatives to demand that resource extraction quotas be set at the upper bounds of uncertainty chiefly on the grounds that science has not "proven" the necessity for lower quotas or lower levels of human impacts. This reasoning, when applied to managing Atlantic fisheries in Canada, has led to catastrophic losses of important ground fish populations on the famous Grand Banks of Newfoundland. These fish resources were heavily overexploited under international regulations, and it was hoped that under more conservative Canadian management, stocks would be replenished. The most important of these resources, the northern cod

(*Gadus morhua*), was expected to yield sustainable annual harvests of 4 x 108 kg by the late 1980s (Canada 1983). These sustainable harvests were not achieved, and the Canadian government drastically reduced the harvest in the late 1980s and then imposed a temporary 2 year harvest moratorium on Northern cod in 1992. Much to the surprise and dismay of fishery managers, northern cod stocks continued to decline and the harvest moratorium remains in place. While the cause of the fisheries collapse is much debated, what is clear is that the collapse came as a complete surprise to authorities. One commentator remarked that the resource collapse would have had no credibility as a worst-case scenario, just a few years prior to the moratorium. This example demonstrates that natural systems, especially those under the pressures of human exploitation, are subject to a far greater degree of uncertainty than heretofore had been realized and appreciated (Gordon and Munro 1996).

Perhaps the single most important component of achieving long term conservation of biodiversity is an operational admission of the limitations of science in predicting and controlling complex natural systems. Certain aspects of natural systems may be intrinsically unknowable and must be regarded as such. Authorities, managers, industry officials, and environmental activists must take these limitations into account and deal with the inherent uncertainty of nature with the utmost care and caution.

1.3.1. THE BURDEN OF PROOF

Conservation area design and natural resource management must somehow allow for uncertainty and potential inaccuracies in projected levels of human impact on natural systems. Plans should attempt to address the worst-case rather than the best case scenarios for species declines and ecosystem degradation (as the example of the northern cod collapse illustrates). A substantial body of scientific work describes a variety of techniques for dealing with uncertainty and managing risk. In particular, biodiversity conservation plans must carefully consider the consequences of further human impact and loss of natural habitat, even when no obvious role or effect on the ecosystem has been empirically described. In other words, the absence of ecological data does not equate with the absence of ecological importance. Under the precautionary principle, the burden of proof should be placed on development or resource extraction advocates. It is these advocates who must prove that additional human impact, including cumulative impacts, would not have any significant negative effects on the environment. For example, logging advocates often argue that it is unclear how forestry practices are associated with low numbers of large carnivores, including lynx *(Felis canadensis),* wolves and grizzly bears; it is therefore reasoned that biodiversity management principles only need to be centered around species with proven late-successional habitat associations. Such an approach is incompatible with the precautionary principle. Application of the precautionary principle suggests that logging advocates must prove that forest practices do not impact large carnivores, either directly or through secondary effects. Failure to implement the precautionary principle and embed it within all conservation plans will no doubt result in the extinction of species and degradation of ecological processes in essentially unforeseeable ways.

1.4. SPECIFIC TECHNIQUES FOR CONSERVATION AREA DESIGN

To implement the goals set by Noss (1993, 1996), a number of approaches to conservation area design have been developed. These include coarse-filter or ecosystem based approaches, fine-filter or species approaches and landscape planning. These techniques are discussed in the following sections.

1.4.1. COARSE-FILTER OR REPRESENTATION ANALYSIS

The coarse filter or representation strategy seeks to protect intact examples of each vegetation or habitat type in a region. This often equates to the protection of ecosystems rather than focusing on any individual species. The assumption with this approach is that if the habitats remain healthy, so presumably will populations of species that depend on those habitats. A further assumption, often implicit, is that gradients in species composition parallel gradients in physical habitat variables or vegetation types, because they reflect environmental gradients, and are surrogates for biodiversity (Noss et al. 1999).

Coarse-filter approaches have wide appeal because they tend to protect a large fraction of biodiversity and are relatively easy to carry out. Many hundreds or thousands of species of yet unknown bacteria, fungi, invertebrates, plants, and even a few vertebrates, reside in BC's temperate rainforest, particularly in the soil or forest canopy. There is little hope for a comprehensive examination of all these species any time soon. However, many of these species not only make up a large portion of the forest biomass, but also perform critical ecosystem functions including decomposition, nitrogen fixation, and nutrient cycling. Large-scale approaches at the level of the ecosystem and landscape are probably the only way to conserve these essential elements of biodiversity (Franklin 1993). From a pragmatic standpoint, a vast amount of vegetation data has already been mapped and additional data is available from analysis of satellite images and air photos. Thus, a major advantage of using a coarse-filter approach is that vegetation and habitat data are widely available and are relatively easy to obtain and map, as compared with demographic and autecological information on a particular species or suite of species.

One concept that is often used in general coarse-filter strategies is gap analysis (Burley 1988). Gap analysis uses maps of actual or existing vegetation that are overlaid with maps showing boundaries of existing protected areas in order to highlight vegetation types that are under-represented in the existing or planned protected area network. Such under-represented types, or "gaps", become priorities for protection. Gap analysis has been used in conservation planning for at least 20 years (Specht et al. 1974; Crumpacker et al. 1988; Keel et al. 1993) and has been formalized as a nationwide program in the United States (Scott and Csuti 1992). The BC protected areas strategy has incorporated a similar approach. One of the primary objectives of the protected areas strategy includes a desire to "protect viable, representative examples of natural diversity in the province." However, a potential problem with such an approach is that all existing vegetation or habitat types are treated as equal, with the goal being the representation of some arbitrary proportion of each type within a protected area network. This means that an historical perspective is lacking and disproportionate losses of particular types of habitats are not addressed.

The coarse filter or representation approach also does not adequately address the question of risk, something that is closely related to historical impacts. Ecosystems that are directly threatened or endangered should be given higher priority for protection. Thus, in addition to simply representing ecosystem types, physical habitats, vegetation types, plant associations, or natural communities (defined by floristics, structure, age, geography, or condition) in a conservation areas design, ecosystems that have suffered disproportionate losses through human impacts should also be identified. Both the level of decline and the level of threat should be explicitly considered in designing a conservation area network and prioritizing areas for protection and restoration.

Because ecosystems are dynamic, not static, the limits to the ranges of variation in ecosystem components and functions should be identified. All ecosystems have a natural range of variation in structure and processes. A major challenge for developing effective management plans is to prevent changes in the natural range of variation of all ecosystem components. Suppression or destruction of the natural variation well beyond the natural range will result in loss of ecosystem function and the resilience of the system will be compromised. Thus, conservation of ecosystems should also address external forces that threaten the integrity of ecosystem components and processes. Any uncertainty regarding ecosystem management must be dealt with through the application of the precautionary principle; that is, components of ecosystems should be assumed to be critical to ecosystem function and health unless it can be shown otherwise. Note that precise definition of ecosystems or prior definition of precise ecosystem boundaries is not necessary for effective representation analysis or ecosystem management, as long as factors contributing to ecosystems can be defined and identified for consideration.

Overall, most biologists agree that a coarse filter approach is likely to capture the majority of species and is especially useful for species that are difficult to inventory and about which little is known. On the central coast of BC, these species include soil and canopy invertebrates, fungi and bacteria. In practice, a course filter approach should consider historical impacts, and be combined with both a species based approach and with a landscape planning approach. These additional, complementary approaches to conservation area design are discussed in the following sections.

1.4.2 SPECIES CONSERVATION

The protection of individual species is at the very essence of conservation. Questions about ecological patterns and processes cannot be answered without reference to the species that live in a landscape (Lambeck 1997) and plans that fail to include and explicitly account for the ecological needs of native species are incomplete.

Single species have been the focus of some of the most powerful conservation legislation in the world, including the U.S. Endangered Species Act (ESA) and the Convention on International Trade in Endangered Species (CITES). Individual species efforts have had tangible successes, including recovery of species such as the American alligator, the bald eagle, the relict trillium (*Trillium reiquum*) and the wood stork. However, confrontations between the needs of single species and economic interests frequently occur with economic interests most often prevailing. These conflicts often obscure the larger issues of habitat protection and the erosion of biodiversity that underlies losses of species. Single species campaigns often provide no systematic, ecosystem-level protection and usually focus on short-term damage control. With anywhere between 5 million and 100 million species on the planet, most of which are unknown or unclassified, species-by-species approaches will likely fall short of comprehensive biodiversity protection.

Because it is practically impossible (and possibly counterproductive) to determine the ecological needs for every species resident in a region, researchers have suggested that instead of single-species conservation plans, a suite of multiple focal species should be identified (Lambec 1997; Miller et al. 1999). Focal species are selected such that their protection, as a group, would concurrently protect all or at least most remaining native species. Focal species thus warrant specific management attention. Planning for maintaining or restoring healthy populations of multiple focal species can provide a manageable set of objectives for identifying and prioritizing areas, and for determining the necessary size, location and configuration of conservation areas. Focal species monitoring can also be a useful tool in judging the adequacy of the conservation plan once implemented.

CRITERIA FOR SELECTING FOCAL SPECIES

Keystone species, defined as species that play a disproportionately large role (relative to numerical abundance or biomass) in ecosystem function, are ideal focal species, around which conservation plans can be designed. Paine (1966; 1969) introduced the concept of keystone species and established the importance of top-down influences of starfish in rocky intertidal zones. Further ecological studies have shown that keystone species can exert effects through varied interactions and processes including competition, mutualism, dispersal, pollination, disease and by modifying habitats and abiotic factors as "keystone modifiers" (reviewed by Bond 1993; Mills et al. 1993; Menge et al. 1994; Power et al. 1996). The loss of keystone species can trigger changes in relative abundance and distribution (including local extinction) of many other species present in an ecosystem.

Anthropogenic changes can affect keystone species with dramatic consequences for other species and communities. For example, a recent study by Estes et al. (1998) reports on the deforestation of kelp beds in the nearshore communities of western Alaska brought on by elevated sea urchin densities responding to abrupt declines in sea otter populations. Increased killer whale predation on sea otters, a consequence of anthropogenic changes in the offshore oceanic ecosystem, is the likely culprit for the loss of sea otters and the subsequent deforestation of the kelp beds.

Both diversity and trophic level considerations suggest that keystone species are most likely to occur near the top of the food chain. Top predators typically have high per capita effects and low collective biomass relative to lower trophic levels. Nevertheless, keystones may occur at other trophic levels. Soil cyanobacteria and endolithic lichens may be keystone producers in the Negev Desert. They fix nitrogen and support snails, whose grazing break down rock and creates soil (Shachak and Steinberger 1980; Shachak et al. 1987). The community impacts of Negev cyanobacteria and lichens appears to be large relative to their small biomass. Soil bacteria and fungi in the BC rainforest may carry out similar keystone ecological functions.

Species whose primary impacts on the community are not trophic can also be considered keystone. Possible examples include keystone modifiers or "ecosystem engineers", such as beavers which swamp forest and meadows (Jenkins and Busher 1979; Naiman et al. 1989; Pollock et al. 1995). Although such species would not have been considered keystone in Paine's original formulation, their impacts are disproportional to their abundance.

Two additional classes of species, umbrella and indicator, warrant consideration in designing conservation area networks. Protection of umbrella species, by definition, provides protection of other native species. Umbrella species have large area requirements and cover large areas in their daily or seasonal movements (Frankel and Soulé 1981; Noss et al. 1999). For example, on the Indian subcontinent, tigers have declined in number but are still found in many areas throughout the region. Because their distribution overlaps with the most important areas for biodiversity in these landscapes, they make an ideal umbrella species for conservation planning (Dinerstein et al. 1999). In general, an umbrella species approach is suited to answering the questions of how much land is necessary in a conservation area network and how that land should be configured (Noss et al. 1999). Note that although large mammalian carnivores are typically proposed as umbrella species, large herbivores and raptors can also fill this role (Meffe and Carrol 1997).

Identification of indicator species can also play a role in the design of conservation areas. Species that are highly sensitive to ecological change, sensitive to human disturbance, or require undisturbed habitat warrant special management attention. Indicator species are tightly linked to specific biological elements and are vulnerable to changes in these elements. The presence or absence of such species can be used to assess ecological health and ecosystem integrity. Indicator species can play important roles for monitoring and assessment of the ecosystem status and for the implementation of adaptive management procedures.

LIMITATIONS OF SPECIES APPROACHES

At first glance, species may seem ideal units around which comprehensive conservation plans for protecting biodiversity can be designed. However, despite the necessity of species planning, approaches that rely solely on individual species to protect biodiversity suffer a number of limitations.

The most common limitation of species-based approaches is a lack of data and understanding of the autoecology of the species in question. Basic ecological research is notoriously difficult, expensive, and often requires years to complete. In addition, time-constraints on management decisions often preclude the inclusion of such information. Thus, even if an ideal focal species is chosen because it acts as a keystone or umbrella species, it may not be adequate for inclusion into a CAD because of a general lack of information about its distribution, demography, and ecology. For example, on the mid-coast of BC, several species including wolverine, wolf, and goshawk should be part of a comprehensive CAD but limited information regarding their distribution and demography limited their inclusion at this stage.

A number of studies have reported problems using particular species as umbrellas for conservation of other species. Berger (1997) noted that the spatial needs of a small herd of 28 black rhinoceros was not sufficient for populations of six other herbivores. However, when the number of rhinoceros increased to 100, the population numbers of other herbivores included under the umbrella increased significantly (Berger 1997). Kerr (1997) points out that using carnivores for conservation area selection does not protect a number of invertebrates. Similarly, an analysis of the umbrella function of grizzly bears in Idaho was carried out by Noss et al. (1996). This study found that while protection of grizzly bears in Idaho would protect 71 % of other mammalian species, 67 % percent of birds, and 61 % of amphibians, only 27 % of native reptiles would also be protected. These studies have several implications. First, they suggest that area requirements should be based on a viable population of the umbrella species, not on a smaller number of individuals. Second, it should not be assumed that protection of an umbrella species would be sufficient to protect all other species present - some taxa may be better captured under the umbrella than others. It appears that the selection of a species as an umbrella should be treated only as a testable hypothesis; that is, how well does the protection of the umbrella species protect other native species. Where it deviates, new species or elements should be added.

Species diversity is often mistakenly confused with biodiversity. The concept of biodiversity includes attributes such as genetic diversity, habitat diversity and diversity of ecological and evolutionary processes, in addition to species diversity. Plans to protect species may not provide sufficient protection for biodiversity in general, especially if such plans are designed for species that thrive in the presence of human disturbance.

Another problem is that the species concept in biology, like the ecosystem concept, is not entirely fixed. This is partially because the species as a biological unit is not a clear and unambiguous entity, in that species (like ecosystems) are part of a larger continuum of biological organization and are subject to long term evolutionary change. Species are dynamic, changing entities containing a great deal of population variation that is relevant to conservation efforts. Classifying species, and determining the levels of lumping and splitting, can lead to variable effects on conservation, usually leading to an overly optimistic assessment of the retention of biodiversity. For example, a species can continue to exist even if many of its populations are destroyed. Potentially lost populations would represent a decline in biodiversity, especially if they contained unique genetic or phenotypic traits, even though the species approach tells us that diversity has not been lost because our global species richness count remains unchanged. This suggests that regional protection of species should be directed at maintaining or recovering natural population levels, rather than merely attempting to protect species from extinction.

In summary, the limitations of species approaches suggest that focal species planning should be combined with other approaches, such as coarse-filter, ecosystem level approaches and landscape planning, as proposed by Noss et al. (1999).

1.4.3 LANDSCAPE PLANNING

Representing a species or a habitat type in a conservation area network will not necessarily ensure that a species will persist. Thus, coarse-filter and species approaches must be complemented by a landscape-level analysis of connectivity or a spatially explicit population viability analysis. Although some habitats are naturally fragmented, human induced habitat fragmentation and habitat degradation are major contributors to the failure of protected areas to maintain component species (Wilcove et al. 1986; Laurance and Bierregaard 1997). Protection and/or restoration of landscape connections are meant to ameliorate the effects of habitat fragmentation on wildlife (Frankel and Soulé 1981; Hudson 1991; Hobbs and Hobkins 1991; Hobbs 1992). Even within *Core Conservation Areas*, natural levels of connectivity may require explicit management and restoration measures.

Landscape connections have two functions. First, they permit seasonal or daily movements of animals thus ensuring access to resources and enhance interbreeding. Second, connectivity facilitates the dispersal of animals from their place of birth to their adult home ranges and essentially helps augment the available habitat. Thus the goal of landscape planning should be to build on focal species analysis and representation analysis by ensuring that natural levels of connectivity are maintained at the regional scale.

NATURAL LANDSCAPE FEATURES

Natural ecological processes are closely associated with landscape-level features. Consideration of such ecological and evolutionary processes suggests that landscape-level features be used as criteria for conservation area design. For example, conservation area boundaries should avoid severing areas of active terrain or geological features such as sinkholes, eskers and end moraines (Noss 1995).

In the central coast of BC, watersheds are a prominent natural feature, largely because the region is dominated by high levels of rainfall. Conservation area designers should consider entire watersheds and not leave out headwater areas or sever drainages because the ecological processes within watersheds are more closely linked that those between watersheds. Depending on the scale of analysis, watersheds can provide a logical framework for assessing human impacts on ecological processes. Soil, water, sediment, minerals, chemicals and debris move down slopes into tributaries and eventually to rivers and estuaries. Thus, a watershed context is crucial to link upstream causes with downstream effects, as well as to understand the cumulative effects of land impacts that are distributed throughout a landscape. Watersheds often provide an ideal analysis framework for many aspects of resource management and nature-reserve design (Naiman et al. 1992).

HABITAT FRAGMENTATION

Although some ecological effects of habitat fragmentation are subtle and vary species by species, the overall consensus among biologists is that habitat fragmentation and habitat loss represent the greatest threats to biodiversity worldwide (Wilcove et al. 1986; Heywood 1995; Laurance and Bierregaard 1997). Habitat fragmentation is not entirely an anthropogenic phenomenon. Natural disturbances and geological events can act to separate ecosystems and landscapes into isolated parts. Some habitats are naturally isolated, such as oceanic islands, mountaintops, deep-sea hydrothermal vents and desert springs. However, humans are currently the primary agent of habitat fragmentation worldwide, and anthropogenic habitat disturbances rival naturally occurring phenomena in both scale and frequency. Application of the precautionary principle suggests that conservation plans should consider the ecological needs of species and ecosystems that are most sensitive to habitat loss and fragmentation effects.

Habitat fragmentation can be broken down into two separate components: 1) reduction of total amount of natural habitat; and 2) separation of remaining habitat into smaller, non-contiguous patches. In general, the effects of either or both these components can act to reduce biodiversity in a number of specific ways:

1) Fragmentation can reduce population size. Population reduction can occur through direct mortality or reduction in fecundity through the loss of necessary breeding, migration or denning sites. This problem is magnified because some habitats are richer than others are and these are often the targets for resource extraction.

2) Fragmentation can isolate populations. Modified landscapes in which fragments exist may be inhospitable to some native species and habitat fragmentation will act to prevent or impede normal movements and dispersal.

3) Fragmentation serves to create habitat islands. Small, isolated habitat remnants support fewer native species and smaller populations, which are more susceptible to extinction. In addition, smaller habitat remnants are less likely to be recolonized.

4) Fragmentation results in increased edge exposure or edge effects. Edge effects have been the subject of a number of ecological investigations (Wilcove et al. 1986). The outer boundary of any habitat island is not a line drawn on a map, but rather a zone of influence with variable width within which microclimates, community structure, and species composition can vary greatly from interior habitat.

5) Ecological processes can be disrupted by fragmentation. These effects have been little studied and may have long-term detrimental effects on ecological communities. For example, fragmentation may disrupt natural fire regimes, and lead to the loss of native species that cannot exist in fire suppressed habitats.

Some authors argue that timber harvest has marginal and undocumented effects on most terrestrial vertebrate species and that managed forest landscapes are actually beneficial to many species. However, history has shown that the end result of human impacts, beginning with natural resource extraction and infrastructure development, is a landscape of isolated habitat remnants accompanied by a severe reduction in biodiversity. Therefore, extreme caution should be exercised when evaluating empirical studies of species' responses to habitat fragmentation. The very species that benefit from habitat fragmentation can be a major source of ecological problems. For example, cowbird parasitism increases significantly along forest edges, and is a major reason for the decline of forest songbirds in managed forests (Terborgh 1989, 1992; Robinson et al. 1995). This example illustrates that certain species can survive or even thrive in a fragmented landscape. Species with modest area requirements might maintain viable populations entirely within fragments. The presence of resilient species does not negate the dire consequences that arise as a result habitat fragmentation for more vulnerable species, and usually it is the large carnivores and habitat specialists that are most susceptible to the effects of habitat fragmentation (Diamond 1986).

Many researchers have suggested that conservation areas be connected by a series of corridors as a means of addressing isolation and the other problems that arise as a consequence of habitat fragmentation. While the utility of corridors has been the subject of considerable scientific debate, no legitimate scientists have suggested that habitat loss and fragmentation are in any way positive. Moreover, if landscape connectivity can be maintained and fragmentation minimized, corridors do not have to be created, in the first place, thus making any objections regarding the use of corridors moot.

ROADS

No discussion of habitat fragmentation is complete without a discussion of the ecological impacts of the most prevalent cause of anthropogenic fragmentation – roads. Roads are defined as linear human disturbances that can accommodate a motorized vehicle, including rights-of-way such as powerlines, fencelines, pipelines, etc.

A number of studies have described patterns of landscape fragmentation caused by roads (Miller 1996; Reid 1995) and the direct and indirect impacts on biodiversity due to the presence of roads. In fact, the density of roads is often a good indicator of the ecological value of an area. Areas with high road densities tend to have a lower probability of retaining all their native species than comparable areas with low road densities.

Roads directly impact biodiversity through traffic caused mortality which can often exceed mortality rates in hunted populations. Roads also indirectly impact biodiversity. Roads are often referred to as a "keystone disturbance" in that the construction of a new road has a proliferation effect that facilitates further human impacts on an ecosystem. Roads also serve as a well documented avenue for hunting and poaching because they allow greater access to target species (McLellen 1990). Some species such as grizzly bears show a marked avoidance of roads (Archibald 1987; McLellan 1990; Mattson 1990; Kazworm and Manley 1990) thereby causing further fragmentation of home ranges and reduction in potential habitat. Finally, roads serve as an active avenue for the spread of exotic species.

2. CAD GOALS

2.1. SPECIFIC GOALS

Our general approach involved integration of principles from reserve design methods described in the scientific literature. We used a combination of methods, including a coarse-filter approach focusing on endangered ecosystems, a multiple focal species approach, and regional landscape connectivity planning. This combination of complementary methods was used in order to address the limitations and shortcomings of each individual technique, and to meet the goals set by Noss (1993,1996). In practical terms, given the scientific information available for the central coast of BC, the CAD focused on identifying and delineating conservation areas to meet four primary goals:

1. Maintain and/or restore viable populations of large carnivores.
2. Maintain and/or restore viable populations of all salmon stocks.
3. Maintain and/or restore representation of all native ecosystem types and successional stages across their natural range of variation.
4. Maintain and/or restore natural landscape connectivity.

In order to identify areas necessary and sufficient to meet these goals, we considered a number of factors including:

1)Current and historical human impacts to species, processes, or ecosystems. Restoration of current and historical impact or wounds to the land has been forwarded as a valid criterion that underlies the design of conservation areas, where the implementation of the conservation area is meant to "heal the wounds" (Sky Island Alliance 1998; Erlich 1997). The Wildlands Project specifically targets species and/or systems with a history of human persecution or over-exploitation. We have adopted a similar approach and have included current and historical human impact as a major consideration in meeting the objectives of this CAD.

2)Current biotic value including the ecological importance of species, communities, processes, and ecosystems. We applied methods forwarded by Given and Norton (1993) and Allendorf et al. (1997) who suggest the inclusion, but separate treatment, of both current biotic value *and* future threats (see 3, below). Intrinsic and economic values for biodiversity are assumed, but excluded in this CAD.

3)Current threats to species, communities, processes, or ecosystems as well as probable future threats and risks, based on biological trends, human development plans, long-term management decisions and expert predictions. Threats and risk include both anthropogenic factors (e.g., logging plans) as well as sensitivity or vulnerability (e.g., species susceptible to extinction or near extinction).

4)Ecological needs based on current scientific knowledge.

Biological factors, human impacts, risks and threats to biodiversity and other relevant considerations necessary to meet these objectives are reviewed in the following sections.

2.2. GOAL 1: MAINTAIN AND/OR RESTORE VIABLE POPULATIONS OF LARGE CARNIVORES

2.2.1. SUMMARY

Large carnivores have been subjected to intense human persecution throughout North America, especially during the last century, and most top predators have been extirpated from a large proportion of their former range. Large carnivores are vulnerable to human-induced extinction because of a combination of large body size, large home range size, specific habitat needs and high levels of human induced mortality.

Both anecdotal and experimental evidence overwhelmingly supports the importance of top carnivores to natural communities. Top carnivores regulate and stabilize the trophic structure of ecosystems. The disappearance of top predators can result in a superabundance of prey species and can have indirect effects on other predators (mesopredator release) and on community structure through trophic cascades (Soulé et al. 1988; Crooks 1999). Top predators, it seems, play a crucial and non-substitutable regulatory role in natural ecosystems (Terborgh et al. 1999). Ecosystem simplification is a consequence of losing or altering the density and diversity of carnivores.

To ensure that top carnivores are protected from human induced extinction, carnivores must be maintained in their natural abundance and diversity – a prospect only feasible through a network of large and interconnected conservation areas.

Because little information exists on most top carnivores present in the central coast region of BC, we have identified the grizzly bear as a focal species representative of carnivores. Grizzly bears also may serve an ecological role as keystone predators and are a classic "umbrella species", that is, protection of grizzly bears would also protect a number of other species with similar habitat requirements and associations. Grizzly bears have known habitat needs that include low elevation old growth forests and riparian habitat for foraging. Grizzly bears also require large areas of refugia from human persecution and protection of salmon populations. Thus, conservation efforts should focus on identifying and protecting large, connected areas of high quality grizzly bear habitat and limiting human-induced mortality in these areas.

2.2.2. HISTORIC IMPACTS

Since humans appeared on the North American continent at the end of the Quaternary, over 25 species of large mammals have gone extinct (Martin and Szuter 1999). Extinct species include several large carnivores such as the dire wolf, the giant short faced bear, and the saber-tooth tiger. While the cause of this Pleistocene extinction is much-debated (Winterhalder and Lu 1997; Martin and Szuter 1999), it is well established that the arrival of Europeans into North America has been particularly disastrous for several species of still extant carnivore. The range and abundance of all large carnivores in North America have contracted (Table 1) as the result of direct or cumulative human action and several subspecies have gone extinct within recent human memory. Paquet and Hackmann (1995) eloquently state, "even a cursory review of the condition of carnivore populations in North America leads to the inescapable conclusion that their present status is ecologically untenable".

Both the mountain lion (*Felis concolor*) and the grizzly bear have been extirpated from the majority of their historical range within the last two centuries. Grey wolf and black bear *(Ursus americanus)* ranges have been reduced by over a third. In the lower 48 states, the situation is particularly dire for the grizzly bear and grey wolf, which are hanging on to a miniscule fragment (< 5 %) of their historic range. While the mountain lion, once the most widely distributed land mammal in the Western Hemisphere, has lost more of its historic range than any other carnivore, certain western populations appear to be viable and even increasing. The same can be said of the grey wolf where since the 1980s some populations have been recolonizing former ranges when direct persecution is reduced. No such trend can be detected for the grizzly bear and outside the lower 48 states, its population has been the hardest hit. Although once ranging from Alaska to Mexico and out to the Dakotas in the East, by the mid 20th century, virtually all that remains of the grizzly bear in the contiguous US are a few insular populations in Wyoming, Montana, Idaho, and Washington. The total lower 48 states population of grizzly bears is thought to be around 500 animals. In Canada, grizzly bears are still found in parts of British Columbia, Alberta, Yukon Territory, and Northwest Territories but have been extirpated from half of Alberta, the prairies and south central British Columbia, east of the Mackenzie River in the Northwest Territories, and all of Saskatchewan. Historic prime and good grizzly bear habitat has been reduced by 40 – 60 % throughout British Columbia due to habitat alteration and hunting pressures. As such, conservation of the grizzly bear plays a central role in this CAD.

Table 1. Former and current range for selected North American carnivore species (primary information from Novak et al. 1987).

Carnivore Species	Former Range Current (1800 – 1600) km2	Range (1984) km2	% Range Reduction
Mountain Lion	18,900,000	3,983,000	79 %
Grizzly Bear	10,000,000	4,601,000	54 %
Grey Wolf	16,700,000	9,831,000	41 %
Black Bear	15,600,000	9,805,000	37 %
Wolverine	12,600,000	8,426,000	33 %
Lynx	unknown	7,743,000	

2.2.3. ECOLOGICAL IMPORTANCE OF PREDATORS

Trophic level theory emphasizes the importance of predators by predicting top-down regulation and trophic cascades in natural communities. Top-down community regulation implies that top carnivores occupying the pinnacle of trophic webs exert a strong and controlling influence on species in lower levels. By contrast, bottom-up processes imply that primary production and food sources control the trophic ladder. These two processes - top-down and bottom-up - need not be mutually exclusive and both can and probably do operate in most natural systems.

Until recently, there has not been much empirical evidence to convincingly argue that top-down regulation is a major shaping force in natural systems (see review by Polis and Strong 1996). This is probably because carnivores are secretive and quantifying their effects on natural communities is inherently difficult. However, a recent review paper by Terborgh et al. (1999) has documented the many ways in which carnivores can influence natural communities and help maintain ecosystem integrity.

Top-down regulation by predators

The removal of predators from some systems has resulted in superabundance of other animals, particularly herbivores. For example, in suburban landscapes, animals such as deer have become notoriously common. Elsewhere, the introduction of predators has resulted in major changes in ecosystem structure. A classic example of this is the effect of sea otter recolonization documented by Estes et al. (1978, 1989). The extirpation of hundreds of sea otter populations along the pacific coast (a result of extensive hunting early in this century) has resulted in an explosion in the number of benthic grazers, such as sea urchins, and a consequent decimation of the coastal kelp forest. Recovery of sea otter populations in recent years has led to a decline in benthic grazers and a consequent flourishing of the kelp forest.

In terrestrial ecosystems, evidence is amassing that the re-establishment of wolves is having an effect on several prey species including caribou, moose, elk, and deer. Introduction of alien top predators such as Nile perch into Lake Victoria, East Africa, or peacock bass to Lake Gatun, Panama, have also been shown to have significant controlling effects on other species (Mills et al. 1994).

Studies that have monitored predator-prey populations over a long time have also produced compelling evidence supporting top-down effects and trophic cascades. Grey wolves on Isle Royale, Michigan, influence moose populations whose effects on plant growth can be documented through the growth rings in young fir trees. In years where wolf populations are depressed, moose grow abundant and retard tree growth (McLaren and Peterson 1994; Messier 1994).

Controlled experiments that can convincingly demonstrate the impact of predators are difficult to design and implement. However, one well documented comparison in South America, between a site that has lost native predators (Barro Colorado Island) and a similar site that has retained predators (Cocha Cashu Biological Station), has revealed a wealth of information. Terrestrial and arboreal mammals on both sites have been carefully studied for several decades, and researchers have consistently recorded higher mammalian densities on the predator free island than the one that still retains jaguars, mountain lions, and harpy eagles. The difference is large and exceeds an order of magnitude for several species including agouti, armadillo, coatimundi, paca, three toed sloth, and tamandu. Other species are not much effected but importantly, wherever there is a significant difference, its always in the favor of the predator-free island (Terborgh 1988, 1992; Wright et al. 1994). The differences in mammalian densities at these two sites do not seem to extend to small prey species such as rodents and marsupials that are preyed upon by small carnivores that are found at both sites. Terborgh et al. (1997) have also documented a similar superabundance in several other sites where carnivores have disappeared in the last few years. In these areas, animal communities seem to deviate from natural systems and may not be ecologically functional. In addition, in the last few years, new studies designed by Krebs et al. (1995), and others, have been conducted to quantify the extent of top-down regulation. Early results implicate both top-down and bottom-up regulation.

In summary, a variety of studies have consistently produced results consistent with the theory of top-down control. Terborgh et al. (1999) summarized the plethora of anecdotal and experimental evidence by stating that "the consonance of results suggests a much stronger conclusion than does any individual case standing alone".

Ecosystem Integrity Maintenance

It has been argued that the elimination of top predators may unbalance ecosystems through indirect effects and trophic cascades. Recently, several researchers (Soulé et al. 1988; Crooks and Soulé 1999) have put forward evidence to support an indirect effect of predators - a phenomenon named "mesopredator release". Soulé and others found that the elimination of top dominant predators could cause an increase in mid-sized predators (mesopredators), which then begin to assume the role of surrogate top predators and alter small prey diversity and community structure. For example, the extirpation of coyotes in some areas can allow the guild of mesopredators (foxes, raccoons, feral and domestic cats) to increase in number with a subsequent decline in the abundance and diversity of ground nesting birds and small mammals (Soulé et al. 1988; Crooks and Soulé 1999). There is also recent evidence that wolf reintroduction into the Rocky Mountains is resulting in interference and competition among intraguild carnivores.

On some Venezuelan islands, predator free environments have caused generalist herbivore species to increase dramatically in numbers. For example, howler monkeys have attained densities of 500 or more per km2. These high densities are in contrast to predator present populations where densities are typically less than 50 per km^2. Similarly, iguanas and leaf-cutter ant populations have also increased (Terborgh et al. 1997). This increase in herbivore density may be to blame for the poor reproductive success of canopy trees where less than five species (out of seventy) are represented by understory saplings. Terborgh et al. (1999) have stated that in the absence of normal biological control exerted by predators, the ecosystems of these islands have 'spun out of control' and many dozens of animal and plant species will go extinct within a few generations.

Conclusion

Both anecdotal and experimental evidence supports the importance of top carnivores to natural communities. Top carnivores help to regulate prey populations, thereby stabilizing the trophic structure of ecosystems. The disappearance of top predators can result in a superabundance of prey species playing a variety of trophic roles and can have indirect effects on other predators (mesopredator release) and on community structure through trophic cascades. Top predators, it seems, play a crucial and non-substitutable regulatory role in natural ecosystem (Terborgh et al. 1999). Ecosystem simplification is the consequence of losing or significantly altering the density and diversity of carnivores. To ensure that ecosystem integrity is maintained and prey populations are regulated, carnivores must be maintained in their natural abundance and diversity - a prospect made feasible through a network of large and interconnected conservation areas.

2.2.4. CARNIVORES AND THE CAD

In coastal British Columbia, several species of large terrestrial top-carnivores are present, including grizzly bear, grey wolf, mountain lion, and wolverine. Undoubtedly, all of these species play a role in regulating prey populations and maintaining ecosystem integrity as outlined in the section above. However, little is known about the distribution, abundance, and ecological requirements of most of these species making it difficult to incorporate their ecological requirements into this CAD. Therefore, we use one carnivore, the grizzly bear, as a focal species with the assumption that this animal will act as a keystone species and, perhaps more importantly, as an umbrella predator for the other carnivores in the ecosystem that are not individually or directly addressed in this analysis.

Grizzly bears, because of their need for large, ecologically diverse areas, and dependence on relatively undisturbed areas, are an effective umbrella species (Noss et al. 1996; Merrill and Mattson 1998). Grizzly bear habitat and habitat for other disturbance-sensitive species often show a close correlation. In the Rocky Mountains, potential grizzly bear habitat is also suitable for a host of other predators including lynx, wolf, fisher, wolverine, and northern goshawks, as well as for several other bird and fish species. Merrill and Mattson (1998) conclude that ensuring grizzly bear persistence is a large part of the solution to the problem of biodiversity conservation. Grizzly bears may also act as keystone predators; that is; a species that controls community organization through their impact on other species (Paine 1966; Mills et al. 1993). In other ecosystems, it has been convincingly demonstrated that large predators can act as keystone species. In neotropical forests, empirical evidence by Wright et al. (1994) suggests that large predators may limit prey abundance and also have an impact on forest regeneration.

In summary, we have chosen the grizzly bear as a focal species for this CAD because:

1. Grizzly bears are an ideal umbrella species for a host of other predators who collectively may have a direct top-down regulatory effect on prey species and an indirect effect through mesopredator release or trophic cascades, on other species.
2. Grizzly bears themselves may be a keystone predator in this system.
3. Ecological requirements of grizzly bears including large home range size, dependence on different habitats during different seasons, close association with fish abundance and river access, means that maintaining viable populations of grizzly bears in their natural abundance and distribution ensures the survival of many other species.
4. Low fecundity, large body size, and avoidance of disturbance make the grizzly bear an ideal surrogate for wilderness.
5. Information on the natural history and autoecology of most carnivore species specific to mid-coastal BC is absent. However, a wealth of information on grizzly bears exists both in BC and in other regions of North America.

2.2.5. RISK AND THREATS

Ecological factors predispose most carnivores to natural rarity. These constraints include large body size with high metabolic requirements, a high trophic level with diet and habitat specialization, extremely large home ranges, low fecundity, high adult survivorship, and low population density.

When these ecological constraints are coupled with rapid human induced habitat alteration, hunting, and direct persecution, large carnivores become particularly susceptible to local and global extinction. In fact several intensive studies have shown that deaths caused by people markedly increases overall mortality and results in population declines. The impact of harvesting (legal hunting) can be particularly detrimental to carnivores. For example, in two studies employing radio telemetry, 79 % of grey wolf (Ballard et. al. 1987) and 56 % of grizzly bear (Wielgus and Bunnell 1994) were killed by hunters. Even in regions with protected areas, so long as humans come in contact with large carnivores, carnivore mortality is so high that it would appear unsustainable. Data from 22 intensive studies of large carnivores in and around protected areas indicate that 74% of 635 known caused deaths were directly caused by humans, mostly through legal and illegal hunting, road accidents, accidental trapping or snaring, and control of problem animals (Table 3, adapted from Woodroffe and Ginsburg 1998). The extensive use of radio-telemetry to locate dead animals in 20 of these studies make it unlikely that the data are strongly biased towards death caused by people. The surprising result from these studies is that the three species that experience more than 80 % human induced mortality (grizzly bear, black bear, and grey wolf) are all found in North America where human population densities are relatively low, enforcement of hunting restrictions high, and apparent "protected areas" numerous.

Table 2. Proportion of human-caused mortality in large carnivore species.

Species (rank order)	Proportion of Direct Human-Caused Mortality	Sample Size
Grizzly bear	89 %	258
Black bear	85 %	41
Gray wolf	83 %	86
Iberian lynx	75 %	24
Tiger	67 %	3
African wild dog	61 %	105
Lion	50 %	62
Spotted hyena	49 %	56

For North American carnivores, essentially all major identifiable threats to long term viability appear to be human induced (Tables 2 & 3). The four most serious threats are habitat loss, hunting (legal and illegal), roads, and loss of habitat security.

For grizzly bears, Mattson and colleagues have argued that the primary variables influencing grizzly bear numbers are people's attitudes, geographic distribution and presence or absence of firearms (Mattson et al. 1992, 1996). Technological humans are an "extra normal" evolutionary phenomenon for grizzly bears (Merrill and Mattson 1998). Humans kill bears with relative ease and frequency, something that bears are evolutionarily unprepared to deal with. Bears exhibit no morphological or behavioral features aimed at minimizing risk of predation by humans; also they do exhibit behavior designed to reduce bear-bear conflicts. In the southern Canadian Rocky Mountains and the contiguous United States, virtually all deaths of grizzly bears older than 1 year can be clearly attributed to humans (Mattson et al. 1993). In British Columbia over 300 bears a year are legally killed by hunters, while 2 to 3 times that number are likely killed illegally (Figure 1). The central coast region is not exempt from these very high levels of grizzly bear hunting and over 500 bears have been legally killed during the period of 1976 –1997 (Figure 2). This level of grizzly bear mortality is unlikely to be sustainable and represents a major threat to the long-term viability of grizzly bear populations in British Columbia.

Grizzly bears also show a spatial response to the presence of humans by typically under-utilizing areas within 100 to 500 m of roads and up to 900 m in one study (Mattson et al. 1987; McLellan and Shackleton 1988; Kasworm and Manley 1990). There may also be a seasonal component to this avoidance and in Yellowstone National Park, for example, grizzly bears tend to avoid habitat within 3000 m of roads in the fall (Mattson et al. 1987). This under-use of habitat did not vary significantly with road design or human use and was exhibited even at very low levels of traffic, as little as one vehicle every 2 hours (Archibald et al. 1987; McLellan and Shackleton 1988). In coastal British Columbia forests, female grizzly bears used habitat within 150 m of roads 78 % less during log hauling activities (Archibald et al. 1987). Under-use of areas near campgrounds and towns is even more extreme and habitat within 400 m to 2000 m of campsites and cabins is used less (40 - 67 percent) than expected. This zone of avoidance can grow to 5 km around

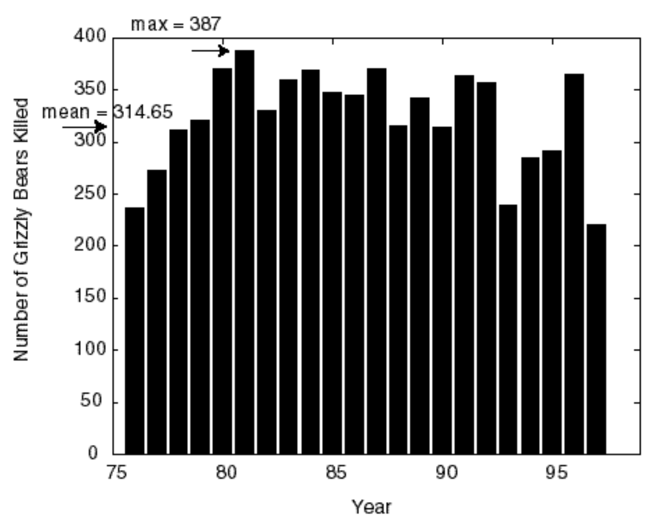
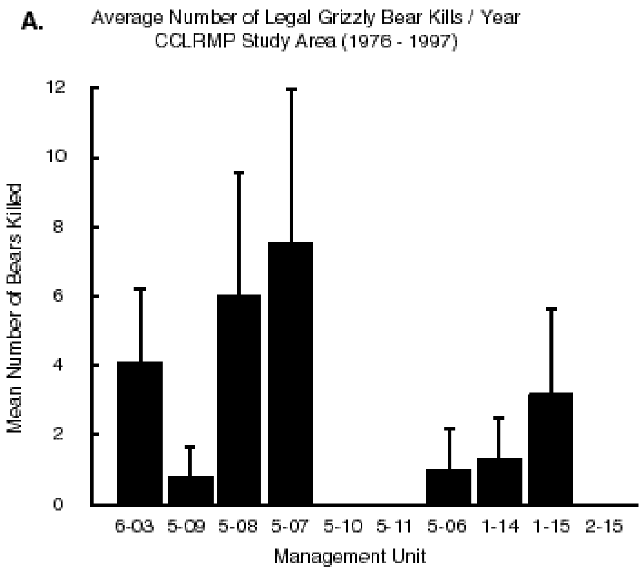


Figure 1. Summary of legal hunter kills by year in British Columbia, Canada from 1976 -1997. Data includes all grizzly bear management areas in BC. Morality from illegal hunting is estimated to be about 1-2 times as great as legal kills, suggesting that about 600 - 900 grizzly bears are removed from BC each year.

major recreational areas in particular seasons (Mattson and Knight 1992). The reason for this avoidance is that the construction of roads and other facilities into formerly inaccessible areas can result in



B. Total Kills / Management Unit (1976 -1997)

6-03	5-09	5-08	5-07	5-10	5-11	5-06	1-14	1-15	2-15	total
89	17	132	166	0	0	22	28	70	0	524

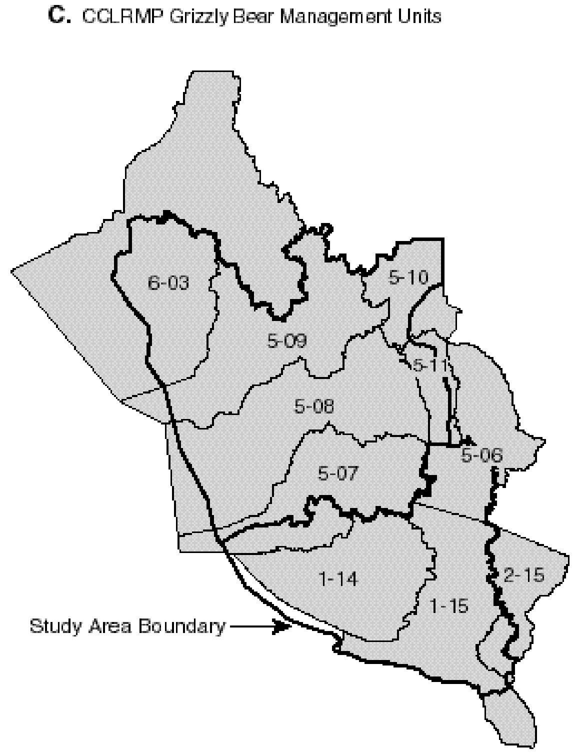


Figure 2. Grizzly bear mortality from legal hunts in the CCLRMP study area. A. Average number of grizzzly bears killed per year from 1976 - 1997. Error bars represent one standard deviation. B. Total number of bears legally killed during 1976 - 1997. Mortality from poaching is likely to be at least equal to legal kills, suggesting that over 1000 grizzly bears have been removed from the study area in a 22 year period. C. CCLMRP study area and management units.

increased mortality from hunting, poaching, defense-of-life, and lethal control of problem bears (McLellan 1990; MacHutchon et al. 1993). The total kill of grizzly bears on part of Chichagof Island, Alaska was significantly correlated with cumulative kilometers of road (MacHutchon et al. 1993).

Interestingly, there are numerous observations of grizzlies foraging within a few meters of humans in daylight hours. Some bears can clearly tolerate the presence of humans, either because of food availability or security from other aggressive bears (Herrero 1985; Mattson et al. 1987; Fagen and Fagen 1994). Unfortunately, habituated bears are also more likely to be killed by hunters or poachers (Mattson et al. 1992) than more wary bears and are also likely to be relocated or killed as ‘problem animals’ (Mattson et al. 1992).

These results suggest that the response of grizzly bears to humans is related to how frequently humans kill bears and the extent to which this killing is directed towards habituated animals. Thus, greater avoidance of human structures (roads, facilities) is to be expected if bears that are able to tolerate humans are killed at a greater rate than they are recruited (Mattson et. al ñ Wright book). Habitat avoidance or the collary need for grizzly bear habitat security or areas secure from humans devolve to the rate at which humans kill bears and to the degree of human tolerance for bears that tolerate humans (Mattson et al. 1993).

Habitat loss is also a major threat to large carnivores worldwide. In British Columbia, grizzly bears are probably most at risk from habitat loss, fragmentation, or alteration. Grizzly bears can have an enormous lifetime range of over 700 km^2 in western Canada and the northwestern U.S., (Woodroffe and Ginsberg 1998) and on occasion home ranges of up to 900 km^2 have been recorded (Blanchard and Knight 1991). Within some of the best habitat in British Columbia (e.g., Khutzeymateen valley), the annual home range size can be as small as between 30 km2 and 125 km^2 (MacHutchon et al. 1993). In the focus region of this CAD, which is under Pacific Maritime influence, lifetime female range is about 300 km2 (Merrill and Mattson 1998). They also have seasonal requirements of foods that require specific habitats in different seasons. There may also be year-to-year variations in food requirements because of food failures or changes in availability of foods that require a variation in habitat use. This means that if a certain critical part of their habitat is altered, even if that part is only a small fraction of the whole, it can have a significant effect on survival.

In much of coastal British Columbia, the critical habitat for grizzly bears is along the narrow valley bottoms that are rich in roots, sedges, berries, ungulate carcasses, and most of all fish. In all seasons, grizzly bear activity is highest in valley bottom

Table 3. Summary of threats to large carnivores in North America.

Species	Major Threats to Long-Term Viability	Select sources
Grizzly bear	Habitat loss Hunting and poaching Habitat fragmentation Roads Loss of habitat security	Kasworm and Manley 1987 McLellan and Shackleton 1988 McLellan 1994 Archibald et al. 1987 Mattson et al. 1987 Wielgus and Bunnell 1994
Wolverine	Habitat loss Loss of habitat security Trapping Roads and access (ATVs and snowmobiles)	Weaver 1993 Paquet and Hackman 1995
Grey wolf	Roads and vehicular collisions	Paquet 1993
Mountain lion	Hunting, trapping, incidental kills Predator control programs Prey loss Habitat loss Roads Competition	Hornocker 1970 Paquet 1993 Beir 1993 Paquet and Hackman 1995
Black bear	Hunting and poaching Management (problem bears) Loss of habitat security	Paquet and Hackman 1995
Lynx	Habitat loss Overharvest (trapping) Roads	Weaver 1993 Paquet and Hackman 1995 Koehler and Brittell 1990

habitats (MacHutchon et. al. 1993). The issue is that there is not much of this valley bottom habitat available over the whole area and in order to meet the feeding requirements of a population of bears, a large area is needed. In the Khutzeymateen, most of the valley is over 500m in elevation and there is very little valley bottom (below 100 m) habitat. This means that there is not a great deal of habitat that is good for bears and less than 25 % of the available habitat in the Khutzeymateen valley is actually used by bears. In all seasons, but particularly when salmon move into the river, bears concentrate near the river in the valley floors. The majority of bear activity in all seasons is within 150 m of class 1 streams.

In coastal British Columbia, these moist nutrient-rich riparian areas, the preferred habitat of grizzly bears, are also among the best timber growing sites. Thus, commercial logging activities that alter the biological and physical characteristics of these low elevation valley bottoms pose a clear and present danger to the preferred habitat of the region's largest land carnivore. In addition, the succession of harvested areas to closed-canopy second growth, usually within 20 – 30 years post logging (Schoen et al. 1988), can reduce plant species cover and diversity to a point where production of grizzly bear food species is minimal at best. Unless the production of grizzly bear food species is maintained on much of the naturally productive lower slopes, valley bottoms, and riparian corridors, a significant reduction in the capability of the area to support grizzly bears can be expected (MacHutchon et al. 1993).

2.2.6. HOW BIG SHOULD RESERVES FOR CARNIVORES BE?

In light of these risks and threats, how big should conservation areas for carnivores be? The simple answer is big, very big. Preferably, carnivore conservation areas should be composed of several large core areas (each one sufficient to maintain a viable population of the target species) linked with one another via corridors. Recent research has demonstrated the minimum critical size of protected areas for a number of large carnivores, including African wild dogs, snow leopards, gray wolves and grizzly bears (Woodroffe and Ginsberg 1998). This study showed that after controlling for phylogeny, average female home range size was an extremely good predictor of critical reserve size ($r2 = 0.84$, $P < 0.0005$). This implies that in a conservation area of given size, wide-ranging carnivores are more likely to become extinct than those with smaller ranges, irrespective of population density. Thus, critical core area size for animals like grizzly bears, with large home ranges, will have to be very large in order to maintain the species. Based on female home range data from western Canada and the northwestern U.S., Woodroffe and Ginsberg (1998) predict a critical reserve size of over 3900 km^2 for grizzly bears. We emphasize that this is a minimum size and should be a floor, not an upper limit or a target, for any established conservation area.

The goal of a protected area strategy is to represent all elements of biodiversity (Noss and Cooperrider 1994) and to conserve enough large blocks of land so that all elements of biodiversity, even those species with enormous home range requirements, remain viable for the long-term. In other words, setting aside enough of the landscape so that a sense of wilderness can be maintained. Because few conservation areas or systems of conservation areas can do all of this, ultimately the decision of how much is enough, so long as it is below 100 percent, must represent some trade-off. However, using the best available science to determine where and how much land should be afforded protection can minimize the trade-off. Perhaps in the short term, the easiest way to approach the question of how much is enough, is to identify what populations, species, and ecosystems are of concern both regionally and world wide and then focus on meeting the space requirements of these elements. In addition, the actual and projected land use patterns outside the protected area (including population density, roads, industry, etc.) are important factors to be considered.

Where large predators such as the grizzly bear, Canada lynx, or wolverine are a focus of a protected area strategy, large contiguous or linked blocks of habitat are necessary to encompass the home ranges of a viable population of these territorial carnivores.

For example, the territory of a single adult grizzly bear is often as much as 700 km2 or more (Blanchard and Knight 1991; Woodroffe and Ginsberg 1998). For such keystone species, population viability needs to be assessed to determine how many individuals are necessary to insure a high probability of long-term survival. For Florida panthers, a minimum number for short-term planning purposes is 150 individuals within the region (Cox et al. 1994). This number, however, is too low to protect against the loss of genetic variability, only protecting against environmental fluctuations (drought, hurricanes, etc.) and random "accidents" of birth and death.

To completely safeguard a population against the erosion of genetic variation and the consequences of inbreeding, population sizes would have to be much higher, usually requiring more attention to landscape connectivity, facilitating genetic continuation over a larger region (Soulé and Simberloff 1986). For example, in the United States, the goal of the official recovery plan for grizzly bears is an *effective* population of 500 individuals (adult-breeding individuals, contributing to the gene pool). Biologists assume that this number is sufficient to buffer the population against most factors contributing to regional extinction (Harris and Allendorf 1989). Even this number, though, represents an actual population size of about 2000 individuals requiring 129,500 km^2, and some recent theoretical studies (Lande 1994, 1995) suggest the number may be considerably higher. It should be noted however, that in some instances even small areas of land can be valuable to overall conservation efforts. For example, where rare populations of endemic plants are the species of concern, then small populations occupying even a few hectares are worth preserving (Soulé and Simberloff 1986; Lesica and Allendorf 1991).

It is instructive to compare the level of protection afforded by recent policy in BC, which called for 12 % of the land area to be set aside for conservation, with suggested targets developed for other regions by conservation biologists. Table 4 summarizes the proportion of regions recommended for protection motivated by ecological factors rather than political considerations. The implicit objective is to reduce extinction rates to near-background levels, maintaining the integrity of all ecosystems, and to sustain natural ecological flows and process on a regional scale. In all cases except one, much more than 12 percent has been recommended for protection. The average is about 50 percent. In the case of Idaho, Noss and Cooperrider (1994) explain that the low target percentage is derived from a gap analysis based only on vegetation cover. In part, they say, this low estimate is an artifact of the relatively small number of vegetation types in this state. Moreover, this proportion does not take into account the quality of the habitat, nor does it provide for viability and habitat connectivity of wide-ranging animal species. Noss and Cooperrider (1994) predict that such a comprehensive estimate would be several times larger.

It is clear that all experts believe that some degree of protection for about half of the terrestrial lands and fresh waters would be required to sufficiently protect biodiversity. Indeed if just 12 percent of BC were "successfully" protected, the well established principles of island biogeography (MacArthur and Wilson 1967) would predict that in the absence of immigration from surrounding areas, half the province's species could be pushed over the brink into extinction (Soulé and Sanjayan 1997).

Some researchers have speculated that the proportion might be a little lower in temperate and polar regions, and higher in regions with considerable local endemism and greater habitat heterogeneity, the tropics in particular. A caveat is that not all of this habitat needs to be in strictly protected reserves. However, the entire landscape must be managed with the objective of protecting ecological integrity and species diversity, and there should be a system of inviolate (free of commercial activities), large, and interconnected core areas throughout to serve as wildlife refuge population reservoirs, and to protect evolutionary processes.

It has been shown in several recent studies on protected areas in North America, Canada, and East Africa, that parks become island-like over time. Isolated parks have been shown to lose mammalian

Table 4. Percentage of land recommended for protection in a number of regions.

Source	Region	Area to be Protected
Protected Area Strategy 1993	British Columbia	12 percent
Odum 1970	Georgia	40 percent
Odum and Odum 1972	General	50 percent
Noss, 1993	Oregon Coast	50 percent
Cox et al. 1994	Florida	33.3 percent
Mosquin et al. 1993	Canada	35 percent
Noss and Cooperrider 1994; Kiester et al. 1996	Idaho	8 percent
Ryti 1992	San Diego Canyons	65 percent
Ryti 1992	Islands in Gulf of California	99.7 percent
Margules et al. 1988	Australian river valleys	44.9 percent - 75. 3 percent
Noss 1996	General	25 - 75 percent

species over time. In 14 western North American park assemblages, only the very largest park complex did not lose any mammals (Newmark 1995). This same pattern was observed in a more recent study of East African parks (Newmark 1996). These parks or park complexes that escaped the loss of mammal species over time were exceptionally large, over 1000 km2 and usually around 10,000 km^2. Parks of this size represent just 4 percent of all the parks in BC. The truly large parks that are likely to maintain all their component species for the foreseeable future represent just 1 percent or 6 out of 663 parks in BC. There is no sign that this pattern of establishing a preponderance of small parks is changing. Of 24 recently announced protected areas in the Vancouver area, one park is 3,000 hectares in size, the remaining 23 are less than 1,000 hectares. Thus, while small parks are useful in some circumstances for providing a refuge for remnant endemic plants, invertebrates, or amphibians, if the province of BC is committed to protecting its mid to large mammal species, very much larger, connected parks must be established. One useful way of determining area requirements is to conduct a spatially explicit demographic analysis for an area-dependant species.

2.2.6.1. A PROPOSAL TO CONDUCT A DEMOGRAPHIC ANALYSIS FOR AN AREA-DEPENDANT SPECIES

A necessary next step for this CAD but one not accomplished by this report, is to carryout a demographic analysis for an area-dependant species such as the grizzly bear. Without such an analysis, it is impossible to quantitatively determine the viability of a particular species given the upper and lower limits for land area set aside for conservation purposes.

Demographic modeling is now widely used to synthesize population information on species of special concern. Modeling can provide a venue for the testing of different or alternate scenarios on long term viability of a population and can reveal surprising, sometimes counter intuitive results (Crooks et al. 1998). A demographic analysis of grizzly bears in Coastal BC would help determine the bearís future viability under different management and environmental conditions. Such an analysis would include:

Data Assembly and Synthesis

Assembly of both data and expert opinion on bear demography is a necessary first step to both modeling and prudent conservation decisions. All available data from British Columbia, Alaska, and the Greater Yellowstone Ecosystem should be collated. Data from different areas and sources is useful in estimating variance in demographic parameters. Expert opinion is useful in estimating vital rates when field data is unavailable. Examples of data necessary include:

• Mean and variance of basic demographic vital rates such survival rates and reproductive rates for each stage or age class.
• Juvenile or young adult dispersal rate and survival. Relationship of demographic rates to food availability, in this case salmon runs.
• Relationship of demographic rates to habitat disturbance including logging and roads.
• Anticipated changes in quality of bear habitat.
• Kill data from both hunting, incidental take, and illegal poaching estimates.

Population Viability Analysis (PVA) and Extinction Probabilities & Sensitivities

PVA's are often used to signify the use of demographic models to synthesize and explore a populationí s chances of persistence and the effects of various controllable and uncontrollable factors on the probability of persistence. A set of matrix population models should be developed in order to determine estimated population growth (or decline) and the probability of extinction in the future. Such a model should not rely on a single mean for each vital rate but instead utilize a stochastic simulation process to account for poor data quality and variances that may occur in nature.

2.2.7. GRIZZLY BEAR HABITAT CHARACTERISTICS AND NEEDS IN COASTAL BC

As discussed earlier, we have identified the grizzly bear as a focal species representative of carnivores for the central coast of BC. In part, this is due to the fact that grizzly bears have known habitat needs. We discuss some of the most significant of these habitat needs in relation to delineation of conservation areas below.

Riparian Areas

In all seasons, grizzly bears heavily use low elevation riparian areas. High bear use (> 55 %) of this relatively rare zone (< 5 %) suggests a strong preference for this type of habitat (Schoen et al. 1990). In the Khutzeymateen valley, the majority of bear activity was concentrated at elevations lower than 100m and within 150 m of Class 1 streams (MacHutchon et al. 1993), due to major diet items occurring in abundance in the riparian zone. Grizzly bears in BC are known to feed on at least 49 species of plants. Such diversity is only found in the most productive areas of coastal BC - the riparian zones. Favorite plant food items in this zone include devil's club berries, salmon berries, skunk cabbage and other herbaceous vegetation.

Riparian areas and the dense surrounding forests also provide important security cover for bears allowing the normally solitary animal to coexist in a productive but heavily occupied habitat. Bear trails are abundant throughout riparian forests, as are marked trees and day beds. In one survey, 83-day beds were discovered along both sides of a 1.6 km riparian strip where the mean distance to the streams was 52 m (Schoen et al. 1990). The vast majority of these day beds (88 %) were also associated with live sitka spruce or western hemlock trees with a mean dbh (diameter at breast height) of over 1 m.

Riparian areas are, of course, also associated with a favorite and essential food of coastal grizzly bears - salmon. Starting in early summer and continuing in some locations well into late fall, several species of salmon make their way up coastal inlets and enter the mid-coast river systems. Bears begin to feed on this protein and fat rich bounty with increasing vigor peaking in a gorging session in the late summer and early fall. At major salmon spawning streams, bear activity concentrates in these areas during late summer. Predation on spawning salmon can be intense. Along a 200 m stretch of stream on Chichagof Island in southeastern Alaska, 56 % of the over 1100 chum salmon carcasses showed signs of bear predation and many living fish showed wounds from bear attacks (Willson 1998).

Estuaries

Grizzly bears also congregate in estuaries where sedges and marine invertebrates (soft-shell clams, acorn barnacles, blue mussels, etc.) are prevalent, particularly during spring and early summer. During this time, other food sources for hungry bears emerging from their winter dens are not available. As such, bears are reliant on these areas where green forage is emerging and where carrion and invertebrates can be found. Because estuaries have limited cover, bears are particularly vulnerable to hunting when foraging in these areas.

Denning sites

Bears seek steep broken terrain (>30 degrees and above 300 m) for denning (Schoen et al. 1987). The majority of all dens (52 %, n = 121) were located in old-growth forest habitat, although there does seem to be some difference in preference for den sites depending on location. On some islands, preferred den sites include rock caves while at other sites, for example on Chichagof Island, bears excavate dens most frequently under large-diameter sitka spruce trees or at the base of large snags. The important point is that bears carefully pick their den sites and show strong preference for particular habitats when choosing these sites. The lack of suitable den sites could have an inhibitory effect on population density.

Human avoidance

As discussed in the previous sections, bears, like other carnivores, strongly avoid human activity. Logging in old growth forests in the Tongass National Forest in southeastern Alaska has been seen as a major threat to the long-term carrying capacity for grizzly bears because it results in more human-bear interactions (Schoen 1990). Radio-collared bears in the Tongass avoid using clearcuts in all seasons. Some bears never used clearcuts. In over 20 hours of roadside surveys, only four observations were made of bears in clearcuts. This avoidance is likely to be caused by the low quality of clearcuts as foraging habitats. Although clearcuts produce an abundance of shrub species, this production is relatively short lived and is usually followed by impoverished understories of second growth conifer that prove unsuitable to most wildlife species including herbivores and bears (Schoen et al. 1988).

Human activity, signified by roads, frequent use of inlets and rivers by boats, logging, recreational facilities, hunting, and settlements, is avoided by grizzly bears. Numerous studies have documented the extreme under-use of habitats modified or utilized by humans (Archibald et al. 1987; Mattson et al. 1987; McLelland and Shackleton 1988; Kasworm and Manley 1990; Mattson et al. 1992, 1996 and others). In coastal BC, human access is facilitated by the many inlets and numerous rivers navigable by jet boats and small zodiacs. Although few studies have specifically looked at this form of access, it is likely that the use of jet boats and zodiacs to gain access via inlets and rivers into remote watersheds is analogous to motor vehicles and secondary roads.

Landscape analysis

Landscape evaluation of grizzly bear habitat in other areas of North America, such as western Montana, lead to surprisingly similar results, even though the ecotypes of Montana and coastal BC are very different. Recent models that evaluate grizzly bear habitat in western Montana conclude that female grizzly bears were positively associated with low- and mid-elevation habitat during spring, although they tended to move to higher elevations in the summer and fall (Mace et al. 1999). In western Montana, unlike coastal BC, there are no massive fish runs that the bears can feast on during the fall. These bears also showed a negative correlation with all roads and human activity variables in all seasons. According to Mace et al. (1999), habitat restoration and protection in western Montana should focus on low elevation spring habitats with high human activity (either roads or urbanizations) - similar to the recommendations of Schoen et al. (1990), Mattson et al. (1996), Horejsi et al. (1998), and others for coastal North American grizzly bears.

Conclusions

In summary, critical grizzly bear habitat in coastal North America has been identified as low elevation riparian old growth habitat. Other important habitats include upland old-growth forest, estuarine grassflats, avalanche slopes, and subalpine meadows (Schoen et al. 1990). Relative to their availability within home ranges, clearcuts were generally avoided by bears. In addition, grizzly bears also significantly under-used habitat that was modified by humans including areas near roads, settlements, recreation areas, and logging activity. These general findings seem to hold true even for grizzly bear populations in other parts of North America (Mace et al. 1999). Access to salmon spawning areas is also of critical importance to coastal bears. This means not only areas with abundant salmon numbers, but also areas with numerous runs (correlated with species), and security for fishing. Finally, bears may also have particular denning requirements and in some areas this seems to be correlated with the presence of large diameter trees and old snags.

2.3. GOAL 2: MAINTAIN AND/OR RESTORE VIABLE POPULATIONS OF ALL SALMON STOCKS

2.3.1. SUMMARY

Anadromous salmonids, numbering in millions, migrate each year from the Pacific ocean to spawn in freshwater streams. Many pacific salmon stocks have been extirpated or severely reduced through a combination of human impacts including overharvesting, introduction of hatchery fish or non-local stocks, migratory impediments such as dams and habitat degradation via road construction and other forest practices. Stock declines are probably the result of multiple factors acting in concert.

Numerous studies have suggested that anadromous salmonids are essential for ecosystem function. Migrating and spawning salmon provide an important seasonal food source for many wildlife species and the massive influx of salmon carcasses each year significantly enriches aquatic and riparian habitats.

Protection of salmon populations requires protection of entire watersheds that support salmon stocks in order to protect necessary spawning, migration and rearing habitat. Minimum protection for all terrestrial and freshwater salmon habitat should be riparian buffers of at least the width recommended by the FEMAT (1993) thoughout entire salmon-bearing watersheds (Sheldon 1988; Williams et al. 1989; Moyle, 1991; Naiman et al. 1992). In addition, key watersheds should receive comprehensive protection (FEMAT 1993). Different salmon species have differing requirements for spawning, rearing and migration and protection of both in-channel and floodplain habitat is necessary for comprehensive salmon protection. In order to restore salmon populations to

Table 5. Selected fish species found in the central coast region of BC

Species	Common name(s)	Information available
Oncorhynchus tshawytscha	chinook, tyee, king salmon	Yes
O. kisutch	coho, silver salmon	Yes
O. keta	chum, dog salmon	Yes
O. nerka	sockeye, red salmon	Yes
O. gorbuscha	pink, humpback salmon	Yes
O. mykiss	steelhead	Yes
O. clarkii	coastal cutthroat trout	No
Thaleichtys pacificus	eulachon	?
Clupea harengus pallasi	Pacific herring	?
Ammodytes hexapterus	Pacific sand lance	?

desirable population levels, active restoration of impacted areas in addition to halting destructive human activities may be necessary. FEMAT (1993) provides a solid, defensible framework for salmon conservation and restoration.

Anadromous fish: species and life histories

The best known anadromous fish are the seven species of Pacific salmon of the genus *Oncorhynchus* (see Table 5). The CAD focused on these species, largely because of the availability of information. Other less studied and less well known species include the chars (*Salvelinus spp.),* smelt including the eulachon (*Thaleichtys pacificus*) and a number of marine "forage fishes" that use intertidal and subtidal zones. These forage fishes include Pacific herring (*Clupea harengus pallasi*) which spawn on rocky coastlines, and Pacific sand lance (*Ammodytes hexapterus*) which can be found buried in soft sands, often near the mouths of streams (Table 5). We strongly recommend that future work includes consideration of these and other anadromous fishes.

Pacific salmon have strong homing abilities and individual fish tend to return to the location of their birth. This trait has contributed to the evolution of locally adapted populations or stocks. Thus, stocks are defined as spatial or temporal spawning isolates (Ricker 1972). Under this definition, a single river often has more than one stock. For example, the Fraser River in BC historically contained over 40 separate stocks of sockeye salmon (Ricker 1972).

2.3.2. HISTORIC IMPACTS: SALMON HABITAT DESTRUCTION

Salmon populations have declined dramatically and considerable aquatic and riparian habitat has been altered or lost over the past century (NRC 1996). The cumulative effects of timber harvest, road construction, agriculture, livestock grazing, hydroelectric development, mining and other land-use activities have resulted in significant degradation and decline of historical anadromous salmonid habitat. Such habitat degradation has been associated with over 90% of the documented salmon extinctions or declines (Nehlsen et al. 1991).

Historic impacts of logging

Anecdotal evidence documenting the historic effects of logging on salmon habitat is extensive. Before the construction of logging roads, rivers and streams served as early routes for transporting cut logs (Sedell and Luchessa 1982). Structurally complex habitats within these streams were destroyed to facilitate log transportation. Splash dams were often constructed to generate sufficient flows for moving the logs down rivers. During relatively low flow conditions, water and logs were accumulated and after sufficient buildup, the resulting slurry of water, logs, soil and debris was released, destroying riparian zones and aquatic communities as it moved downstream.

The techniques of splash damming and log driving down rivers had been used in timber harvest across the North American continent as settlers moved west and had also been used in Europe for centuries. At the same time that log drives were first appearing in western North America, detrimental effects of log drives were being documented in Sweden (Malmgren 1885). Splash damming and log drives from as early as the 1870s altered streams and rivers to such an extent that they never fully healed (Sedell et al. 1991).

Off-channel habitat loss

Loss of off-channel and floodplain habitats in both montane and lowland riparian forests has been one of the most pervasive and unregulated forms of habitat loss in the Pacific Northwest (NRC 1996). In some cases, habitats have been completely destroyed through diking and filling, land draining, channelization or stream rerouting. Other forms of habitat alteration significantly reduce major aspects of salmonid habitat, including a reduction in the number of deep pools, reduction in wood accumulation, and elimination of side channels and lateral off-channel floodplain habitat. Because of the forest productivity in these habitats and the relatively moderate terrain, floodplains are typically eliminated piecemeal, beginning with extractive resource use and ending with human habitation and industrial development. Patterns of historic salmon habitat destruction in western North America suggest that once habitat quality has significantly declined, adaptive management procedures have been unable to reverse the trend (Hicks et al. 1991; Bisson et al. 1992).

In-channel impacts

Forest practices directly and indirectly impact stream channel structure. A number of studies have shown that measurable degradation of in-channel stream habitat can been attributed to forest practices. For example, McIntosh (1993, 1994) showed that decreased heterogeneity of channel units and loss of pool habitat are caused by forest practices. The comparison documented substantial decreases in the number of large, deep pools, which are a primary indicator of high quality in channel habitat conditions (FEMAT 1993). McIntosh resurveyed 116 stream systems in the Pacific Northwest from 1987 - 1992 and compared the number of large, deep pools (>50m long and >2m deep) per stream kilometer with those surveyed during 1935-1945. Within the Columbia River basin, streams in managed watersheds lost an average of 31% of their pools, whereas streams in wilderness areas or other areas without timber harvest, road building, or livestock grazing, increased 200% in pool frequency during the past 50 years. This reduction in the frequency of large pools appears to be the direct result of land management activities (McIntosh et al. 1994).

Conclusion

Thus, both experimental and anecdotal evidence suggest that human impacts, especially forest practices, have dramatically reduced freshwater salmonid habitat, through changes in channel structure, hydrologic regimes and sedimentation load. Specific mechanisms by which humans impact freshwater salmonid habitat include sedimentation from roads, mass failure and landslides, changes in rooting and vegetative cover, reduction of large woody debris, changes in channel structure, and direct channel modification by heavy equipment (Cederholm et al. 1981; Chamberlin et al. 1991).

Current Status

Many stocks of pacific salmon are in decline or extinct (Nehlson et al. 1991). A total of 214 stocks of anadromous salmonids in the U.S. (California, Oregon, Washington and Idaho) were considered "at risk" of extinction or "of special concern" by a committee of the American Fisheries Society (Nehlsen et al. 1991). This same committee documented 106 additional stocks that already were extirpated from the four-state area.

In British Columbia, the status of anadromous salmonids is potentially more positive, largely because there are fewer dams and urban developments. For the central coast region, the overall trend for six species of salmon for which there is sufficient data for analysis (Table 5) is stable (Northcote and Burwash 1991) or increasing slightly (from 1953 - 1992). These data are heavily dependent on records of escapements to major watersheds made by Fishery Officers of the Canada Department of Fisheries and Oceans. Although this escapement data may be somewhat suspect and varies considerably between species, watershed and region, it represents the best available information regarding salmon populations for the central coast. Species differences in the data are discussed by Northcote and Burwash (1991) based on their discussions with senior fishery managers. Escapement estimates for sockeye and pink are considered to be the most reliable, followed by those for chum, chinook and coho salmon, in that order.

The most notable trend in this data is the fact that coho salmon escapements have declined sharply in all areas of BC (except possibly the trans-boundary region, bordering the Alaska panhandle). Coho are notoriously difficult to count in streams and the escapement counts are probably less accurate than for other species. However, there is no reason to believe that counts have become less accurate in recent years. Coho salmon use tributaries and off-channel habitat extensively, and most juvenile coho remain in freshwater for 1 or 2 years before migrating to the sea. Thus, of the salmon species in question, coho are probably the most sensitive to logging and road construction, which directly impacts small streams and off-channel habitat. Additionally, stock declines due to logging and road construction may have significant time delays and we might not expect to see declines for several years or even decades after habitat impacts occur.

An additional problem with using these general escapement trends is that averaging the numbers over large regions is not sensitive to extinction of small stocks, which may use smaller streams and tributaries. Such stocks are probably important in terms of wildlife consumer usage and genetic diversity. Also, there may be significant time lags between habitat impacts and salmon population decline, as discussed in the next section.

2.3.3. ECOLOGICAL IMPORTANCE OF ANADROMOUS FISHES IN COASTAL BC

Pacific salmonids play a number of critical roles in ecosystem function. They bring the productivity of the ocean to forest organisms and serve as a food source for numerous terrestrial predators and scavengers. The sheer biomass of salmon carcasses also serves as a significant component of nutrient cycling in both aquatic and terrestrial communities. Thus, salmon play critical roles in the food web and trophic structure of both aquatic and terrestrial ecosystems.

Seasonal food resource

A wide range of consumers utilize pacific salmonids. Some feed on adult salmon and carcasses, others on eggs or juveniles (Wilson and Halupka 1995). These wildlife species can congregate in large numbers around spawning and migration areas. Large crowds of gulls and eagles have been observed to gather along the shallow streams when salmon are running in the late summer and fall. Black and grizzly bears often congregate around the best fishing areas. Coastal bears consume vast amounts of salmon in order to develop fat stores necessary for overwinter survival and reproduction (Miller 1994; Samson and Huot 1995). A number of other species also depend on the availability of salmon. For example, mink (*Mustela vision*) feed extensively on salmon during spawning seasons (Ben-David et al. 1997). Physiological changes due to salmon availability have also been described in some animals. For example, in mink, delays in breeding timing and lactation have been correlated with the timing of salmon availability (Ben-David et al. 1997). Bald eagles that had access to salmon carcasses were shown to be more likely to breed and laid eggs earlier than eagles that lacked access (Hansen 1987).

Nutrient cycling and trophic interactions

Salmon biomass is a critical component of nutrient cycling in both aquatic and terrestrial communities. Most salmon die after they spawn, and their carcasses accumulate in streams and along lakeshores (Cederholm and Peterson 1985). A rich community of algae, fungi and bacteria utilizes and breaks down these carcasses, while populations of aquatic invertebrates thrive in otherwise nutrient poor habitat (Newbold et al. 1980; Hawkins et al. 1982; Culp 1988). These aquatic invertebrates serve as food sources for many freshwater organisms, including juvenile salmon. Thus, spawning salmon continue to contribute to the survival of their offspring long after they are dead. Additionally, the aquatic invertebrates that depend on salmon carcasses are used by other freshwater fish including resident rainbow trout, bull trout, dolly varden, and cutthroat trout, as well as a number of terrestrial insectivores.

Interactions between salmon species are also important and have been described in the scientific literature. For example, the reproductive success of coho salmon in the Skagit River in Washington was correlated with the biomass of pink salmon spawners in the system. This result was due in part to nutrients provided by the pink salmon carcasses (Micheal 1995). Juvenile survival in sockeye salmon may depend on the presence of a rich aquatic community, which in turn, depends on the presence of salmon carcasses.

Salmon are also important components of nutrient cycling in terrestrial communities. Bears and other carnivores commonly haul salmon, living or dead, onto stream banks and into the forests Cederholm and Peterson 1985). Eagles sometimes move carcasses to the streamside, and ravens and crows cache salmon tissue in trees and under grass and rocks. Digested salmon material is deposited throughout the forest by consumers in the form of fecal material. Thus, a significant mass of marine-derived nutrients are passed from bodies of salmon into the soil and forest vegetation (Bilby et al. 1996).

The developing picture from the scientific literature shows that terrestrial predators and scavengers act in a reciprocally beneficial fashion with anadromous fish and provide vital trophic linkages between marine and terrestrial ecosystems. Input of dead salmon nutrients contributes to healthy terrestrial ecosystems, which, in turn, has a number of essential benefits for salmon habitat and freshwater aquatic ecosystems.

Salmon are a keystone species

Because of their disproportionately large input (even when compared with the very large biomass of salmon that spawns every year) to terrestrial and aquatic ecosystems, through their wide utilization by many wildlife species, salmon have been identified as keystone species (Wilson and Halupka 1993). The production of salmon and contributions to the ecosystem are so great that they have been referred to as cornerstone or foundation species, because they provide a resource base for the majority of the coastal ecosystem. The reciprocal transfer of nutrients from aquatic to terrestrial ecosystems may prove to be components of one of the richest, most complex and fragile ecosystems yet described.

2.3.4. RISK AND THREATS

The causes of salmon declines are multifaceted, but generally fall into three categories: over-fishing, habitat degradation and introduction of hatchery fish (Hicks et al. 1991; Nehlsen et al. 1991). Over-fishing includes commercial, sport and food fishing, in both fresh and saltwater bodies of water. Habitat degradation includes logging, road construction, dam construction, human habitation and industrial development. Determining the relationship between these factors and the declines and future risks to salmon populations is difficult because of the complex life history pattern of salmon and the absence of necessary data for all salmon stocks, particularly those that exist on the central coast of BC.

Logging and road construction

Construction of logging roads probably represents the largest threat to terrestrial and riparian salmon habitat. Road construction increases the rate of landsliding from 30 – 350 fold (Sidle et al. 1985). In contrast, logging itself only increases mass movement by several fold (Ice 1985; Swanson et al. 1987). Compounding the problem is that existing roadless areas are probably roadless because they contain significant amounts of unstable lands.

Ocean conditions

A review of ocean harvest conditions and regulations and necessary changes in conditions and fishing practices is beyond the scope of this CAD. However, because the interactions between terrestrial and aquatic ecosystems are so profound along the central coast of BC, protection of terrestrial biological integrity may require drastic changes in ocean harvest management practices. Identification and implementation of marine conservation areas may hold the best hope for changing harvest conditions, while at the same time maintaining healthy commercial, sport and First Nation food fisheries. A number of recent reports have suggested that such conservation areas are currently the best known method for dealing with the uncertainty associated with ocean conditions on fish populations. However, several authors also note that such marine conservation areas may not be sufficient for long term conservation and additional modification of ocean harvest methods must be implemented for long term conservation to be successful (Lauck et al. 1998). Thus, designation of marine conservation areas and changes in harvest practices are both necessary to prevent catastrophes similar to the North Atlantic cod collapse in the 1980s (Lauck et al. 1998). Although marine conditions are relevant to the necessary size and extent of terrestrial conservation areas, our focus was limited to estuarine and freshwater conditions that are necessary for long-term protection of salmonids. We emphasize, however, that the implementation of terrestrial salmon conservation areas are necessary but not sufficient for comprehensive salmon protection and that the delineation of sufficient marine reserves and dramatic changes in ocean harvest conditions are necessary components to ensure the persistence of salmon populations.

Risk assessment and PVA

Assessment of the risk of extinction for each stock has been suggested as an important criterion for prioritizing salmon stocks for conservation (Allendorf et al. 1997). Considerable caution is necessary when evaluating human impacts on salmon populations and in assessing the risk of extinction, especially assessments of population stability. Certainly, stocks that are under immediate extinction threat should receive immediate and comprehensive protection and restoration. However, models and management options that suggest that populations are not at risk should be examined very critically. A number of simple deterministic models relating recruitment to spawning stock have been used to predict future numbers of fish returning to spawn (Ricker 1954; Beverton and Holt 1957). Simple models often rely only on an estimate of the 'average' stock-recruitment relationship. Such models commonly underestimate risk because they do not account for demographic and environmental stochasticity. Disregarding stochasticity contributed to the collapse of several stocks that were managed using such deterministic models (Beddington and May 1977; Hilborn and Walters 1992).

Non-linear dynamics in populations may also be a source of error in management, and might cause managers to underestimate the risk of extinction (Doak 1995). This is especially true if monitoring or escapement data is used as the sole basis for management decisions. For example, salmon population impacts that result from destructive forest practices may not be observable for many years after significant habitat impacts occur. Sudden population crashes are possible after years of observed stability, and can occur long after it is too late for restoration efforts. Destruction of spawning, rearing and migration habitat can alter a number of long-term ecosystem processes (e.g., hydrologic regimes, delivery of sediment, thermal loading and periodic flooding) and changes in habitat structure and ecosystem processes probably influence populations over very long time periods (Naiman 1992). A combination of these factors suggests that salmon escapement data can dramatically underestimate salmon population health and population viability. In other words, observed stability does not mean that the population is stable over the long-term.

Both qualitative (Mace and Lande 1991; IUCN 1994; Nehlson et al. 1991; Allendorf et al. 1997) and quantitative methods for assessing extinction risk for salmon have been published. Population viability and risk analysis for salmon should include an assessment of habitat quality and habitat trend. Future logging plans should also be incorporated into assessment of population viability and risk of extinction. Thus, population viability analysis for salmon should include both demographic data, as well as current habitat quality and habitat impact trends, and should identify priority areas for restoration.

2.3.5. POPULATION UNIT OF CONSERVATION: STOCKS VS. SPECIES

What is the appropriate unit of management and conservation for pacific salmon? Allendorf and colleagues (1997) suggest that pacific salmon conservation should be prioritized and managed at the stock level. They have detailed a ranking procedure developed for stocks at risk in the lower 48 states of the U.S. In contrast, Waples (1991) suggests that an 'evolutionarily significant unit' (ESU) is a more appropriate conservation unit under the U.S. Endangered Species Act. However, ESU's are difficult to define in practice largely because an ESU for salmon may be made up of more than one stock and there may be considerable genetic exchange between stocks within and between ESU's. While we recognize that ESU's are important theoretical units of conservation, we believe that for this CAD, stocks are the appropriate population unit of conservation for salmon for several reasons:

1. ESUs are largely theoretical. In practice, we cannot accurately define ESUs from currently available data. We therefore do not know which sets of stocks make up large ESUs and, more importantly, we do not know where only a few or a single stock comprises an ESU.
2. Protection at the level of stocks avoids Type I errors (error of omission) and is thus consistent with the precautionary principle. In other words, stock protection will protect larger ESUs, while ESU protection will not necessarily protect stocks.

3. Within theoretical ESUs, individual stocks represent reservoirs of genetic diversity that may allow for natural restoration of depleted stocks.
4. Some small stocks within theoretical ESUs are likely to have significant value to wildlife and community trophic structure because of temporal and spatial availability or physical accessibility of runs to wildlife species (Wilson and Halupka 1995).
5. Extensive escapement data are often available at the stock level.

Thus, we have used stocks as our primary unit of salmon conservation, with the assumption that stock protection will necessarily protect ESU's. However, we recognize several limitations in using stocks protection as a major focus of this CAD. Equivalent quantitative data may not be available for all stocks and many stocks are not accounted for in the government databases. Considerable 'noise' is present in the currently available data. For example, the escapement information across the watersheds is likely to reflect a combination of characteristics, including management priorities, accessibility of streams for counting and institutional history. Many stocks are simply not counted or are not even defined. Additional data cannot be collected in time for management decisions. Therefore, our emphasis was to use the available data and apply the precautionary principle to account for known uncertainties. This problem also highlights the need for primary data sharing and cooperation between organizations, if responsible management decisions are to be made.

2.3.6. HABITAT NEEDS FOR SALMON CONSERVATION

Salmon require high quality spawning, rearing and migration habitat and conservation areas should focus on entire primary watersheds (Moyle 1991). Several authors have noted that previous attempts to protect or restore fish populations have failed because they did not protect entire watersheds (Sheldon 1988; Williams et al. 1989; Moyle 1991; Naiman et al. 1992). Salmon are strongly old growth dependent, as old growth, especially that found in riparian areas, contributes a number of critical habitat elements including shade, filtration of sediment, woody debris and a host of complex hydrological functions. Protection of salmon habitat should include consideration of ecological processes including hydrology, sedimentation, flow regimes and nutrient cycling.

Area unit of conservation: entire watersheds

The effects of forest practices are frequently evaluated at the scale of known stream reaches for salmonids. However, a number of studies have shown that the most important scale for analysis of land-use practices on channel structure is the entire watershed (Sullivan et al. 1987; Ryan and Grant 1991; Sheldon 1988; Williams et al. 1989; Moyle 1991; Naiman et al. 1992). Therefore, in order to conserve salmon stocks, we have identified the entire watershed as the unit of conservation, including all freshwater streams that share a common saltwater exit point.

Old growth

Salmon are highly dependent on high quality freshwater and riparian habitat found in old-growth forests. As such, pacific salmon may be among the species whose persistence is most strongly associated with intact old growth habitat for a number of reasons. First, productive old growth forests contribute large coarse woody debris to salmon streams over a long-term time scale. (Table 6) Wood input helps positively shape the hydrology of salmon streams (including the creation of large, deep pools) and also contributes to the productivity of the stream, by adding a steady supply of nutrients and acting as traps for salmon carcasses after spawning. Second, canopy cover and riparian vegetation help regulate the temperature of salmon spawning and rearing areas. Third, riparian and forest vegetation and soil (all products of healthy, productive old growth forests) are major factors controlling the overall hydrology of the system. For example, old growth forests and riparian areas provide buffering and filtering capacity, which controls and prevents spawning ground siltification during heavy rains.

Table 6. Some necessary salmon habitat features, salmon contributions by old growth forest and interim FEMAT habitat objectives.

Habitat Feature	Old growth contribution	FEMAT restoration objective
Pool frequency	Large woody debris, complex hydrology, natural channel processes	Varies by channel width as follows: width (m): 3 | 8 | 23 | 38 | 61 pools/km: 154 | 76 | 37 | 23 | 14
Water temperature	Shade, complex hydrology, silt filtration by riparian soil, natural riparian vegetation communities	Maximum water temperatures: 18° C within migratory and rearing habitats 16° C within spawning habitats
Large woody debris	Large woody debris	> 129 pieces/km; > 60 cm diameter; > 15 m length
Bank stability	Natural riparian vegetation communities	> 80% stable
Width/depth ratio	Complex hydrology, large woody debris	< 10

Riparian habitats and floodplains

Floodplains are fundamental and often overlooked components of stream channels and alluvial valleys (Gregory et al. 1991). These areas are often the most productive forest areas from a silvacultural viewpoint and have therefore been destroyed over much of the range of Pacific salmonids. Riparian forests in lower valley floodplains, particularly secondary channels and off-channel ponds and wetlands are of special importance for the survival of healthy salmonids populations. Secondary channels provide important refugia in moderate to high gradient streams during floods (Seegrist and Gard 1972. Seasonally flooded channels and riverine ponds support a major component of the populations of coho salmon and other fish species during winter months (Peterson and Reid 1984; Brown and Hartman 1988), and also provide cold water refuges and oxygen sources during warmer periods of the year (Ward et al. 1982; Peterson and Reid 1984; Brown and Hartman 1988). Floodplains also perform critical hydrology functions, and affect stream discharge, flow variation, sedimentation and surface erosion.

Coarse sediment present in the floodplain acts as a trickle filter and maintains high water quality and contributes nutrients to the aquatic ecosystem (Stanford and Ward 1992; Triska et al. 1989). Channel characteristics such as the size and distribution of pools typically develop during periods of high flow and sediment transport. Thus, management practices that alter flows, sediment transport or riparian vegetation (such as clearcut logging and road construction) are likely to affect channel morphology. Alterations to pool size or frequency are highly likely to have significant adverse effects on aquatic biota. Naturally occurring pools in stream channels vary widely in configuration, size and frequency depending upon the flow regime, sinuosity and gradient of the channel, composition of bed material, sediment sizes and transport rates, and streamside vegetation (Beschta and Platts 1986).

Ecological processes

Salmon are extremely vulnerable to logging and other forest practices that threaten old growth forest ecosystems and thus, objectives for managing habitat should focus on maintaining the full range of aquatic, riparian and terrestrial conditions and processes. Because streams are dynamic, establishing fixed habitat standards and necessary buffer sizes may not protect the ecosystem over the long term. Management should be designed to adapt to accommodate natural changes in stream flow and course. Understanding of hydrogeomorphic processes that occur over a range of spatial and temporal scales is prerequisite to developing salmon habitat conservation strategies. Streamflow plays an essential role in forming and maintaining channels and establishing riparian vegetation. It is crucial to understand both seasonal patterns and variability of flow to be able to formulate strategies for protecting and restoring riparian aquatic systems. High and low flows, subsurface flow dynamics, sediment transport, channel adjustments and other events combine in various ways to influence stream channel characteristics and adjacent riparian systems (Hill et al. 1991).

For example, an important disturbance regime associated with streams in the central coast of British Columbia is the occurrence of snowmelt peaks in late spring and early summer, as well as smaller peaks associated with heavy, periodic rainfall throughout the year. The flow patterns are intrinsically intertwined with sediment movement, seed and plant dispersal and recruitment, riparian plant community establishment, watering and rewatering of floodplains and subsurface riparian environments, nutrient transfer and more.

In summary, channels may respond differently to physical change depending on geology, climate, sediment loading, vegetation, slope and watershed position (Montgomery and Buffington 1993). Therefore, management decisions should not be based on simplistic assumptions of channel dynamics (Sullivan et al. 1987; Montgomery and Buffington 1993), and managers and conservationists should make efforts to err on the side of caution.

2.3.7. FEMAT AND RIPARIAN CONSERVATION AREAS

Salmon conservation requires riparian habitat protection and restoration. The U.S. Forest Service and the U.S. Bureau of Land Management have developed an ecosystem-based management strategy, known as PACFISH, to restore and maintain habitat for the natural production of anadromous salmonids. The Forest Ecosystem Management Team (FEMAT 1993) adopted PACFISH recommendations for protection and restoration of riparian areas and salmon spawning habitat in its report to U.S. President Clinton's Pacific Northwest Forest Conference.

Riparian and salmon management under FEMAT consists of the following components:

1) riparian goals;

2) quantified riparian management objectives;

3) standards and guidelines for all land management activities within broad riparian reserves; and

4) designation of riparian habitat conservation areas, networks of key watersheds that receive priority analysis, protection and restoration, and watershed monitoring.

A complete list of FEMAT standards and guidelines (which vary somewhat region by region) can be found in National Environmental Policy Act documents implementing FEMAT (U.S. Forest Service and U.S. Bureau of Land Management 1995). Riparian Reserves (FEMAT, 1993; also referred to as Riparian Habitat Conservation Areas in PACFISH), are portions of watersheds where riparian and aquatic resources receive primary emphasis and where FEMAT standards and guidelines should apply at minimum. FEMAT identified areas that are necessary to protect

Table 7. Summary of FEMAT guidelines for Riparian Habitat Conservation Areas.

Habitat Area	Riparian Habitat Conservation Area Width
Fish bearing streams	Top of inner gorge; extent of 100 year floodplain; distance equal to height of 2 site potential trees or 91 m, whichever is greatest
Permanently flowing non-fish bearing streams	Top of inner gorge; extent of 100 year floodplain; distance equal to height of 1 site potential tree or 46 m, whichever is greatest
Ponds, lakes and wetlands > 4 ha	Outer edges of riparian same as forested vegetation, extent of seasonally saturated soils; distance equal to height of 1 site potential tree or 46 m, whichever is greatest
Intermittent streams, wetlands < 4 ha, landslide areas in key watersheds	Distance equal to height of 1 site potential tree or 30 m, whichever is greatest
Intermittent streams, wetlands < 4 ha, landslide areas outside of key watersheds	Distance equal to height of 1 site potential tree or 15 m, whichever is greatest

in order to maintain hydrologic, geomorphic and ecological processes that directly influence the quality of aquatic and riparian habitats.

2.3.8. RESTORATION OF IMPACTED AREAS

An ecological approach to restoration involves increased understanding across stream reach, watershed and ecoregional scales. PACFISH and FEMAT (1993) have outlined such an approach, with explicit goals for salmon habitat restoration. This approach involves an understanding of vegetation's multiple roles in riparian and aquatic habitats, the historical context of human impacts, and an appreciation of a range of hydrological processes and disturbance regimes.

Land use practices that cause adverse impacts on both riparian and aquatic systems need to be modified or eliminated to assist in recovering degraded systems. Specifically, logging buffers should protect all water features (Table 7), existing roads should be decommissioned and no new roads should be constructed in these watersheds.

2.4.
GOAL 3. REPRESENT ALL NATIVE ECOSYSTEM TYPES AND SUCCESSIONAL STAGES ACROSS THEIR NATURAL RANGE OF VARIATION

Formal GAP analysis was not applied to the CAD, largely because of the unavailability of detailed vegetation data. However, because intact, undisturbed old growth forests are now increasingly rare, they represent a "gap" in the current landscape and therefore merit extensive representation in this CAD.

2.4.1. OLD-GROWTH FORESTS

What are old-growth forests? We define old growth forests, similar to the definition of the U.S. Forest Service, as ecosystems distinguished by old trees and related structural features. Old-growth encompasses 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.

For the coastal temperate forest of British Columbia, we have used both size and age class of several tree species (sitka spruce, western red cedar, yellow cedar, western hemlock, amabilis fir and douglas fir) to define and delineate stands of old-growth. We do this in order to help capture some of the structural, functional, and age characteristics of old growth forests, as implied in the definition. Twenty five species of conifers inhabit the coastal rainforest of BC - a region characterized by moderate climates, high rainfall (192 cm or more), and proximity to both mountains and the Pacific Ocean (Meidinger and Pojar 1991). The most common species is western hemlock, which dominates the low and mid-elevation forest of the coast and extends inland in fingers tracing the path of rivers flowing from the mountains. Other common species are the western red cedar, and on the outer coast, sitka spruce and shore pine (Meidinger and Pojar 1991). Small stands of douglas fir trees are also found, but they tend to dominate east side slopes, and most of the original stands have been cleared by logging or for human settlements.

2.4.2. HISTORIC IMPACTS: OLD-GROWTH FORESTS

Globally, temperate rainforests are naturally rare and cover less than 0.2 % of the earth's land surface. It is estimated that today, well over half of these forests have been subjected to large-scale industrial logging, so that over a quarter of what remains globally can be found in coastal British Columbia. Temperate rainforests once stretched in a thin continuous band from southeastern Alaska to northern California. Today, all the rainforest valleys south of the Canadian border have been developed by logging, road building, or permanent human settlements (Schoonmaker et al. 1997).

Industrial logging has taken place on the coast of BC for over a century and only 5.8% of the temperate rainforest in the province is currently protected. Many of the remaining, unimpacted watersheds are scheduled for road building and clearcut logging within the next decade.

2.4.3. BIOTIC VALUE: OLD-GROWTH FORESTS

Structural and functional characteristics found in old-growth forests provide habitat for a large number of species, many of which are dependant on these ecotypes for a significant part of their life history.

Small mammals (Muridae, Soricidae, and Talpidae) contribute to the biodiversity of BC's coastal temperate forest. Small mammals are prey for reptilian, avian, and mammalian predators and prey upon invertebrates that often affect forest ecosystems. In addition, small mammals consume plants, seeds, lichen, and fungi and are important disseminators of ectomycorrhizal fungi that are obligate symbiotes with many tree species. Forest floor mammal communities in the western hemlock zones of the Pacific Northwest show a similar species composition in naturally regenerated, clearcutting regenerated (managed), and old-growth forests. However, old-growth forests support 1.5 times more individuals and small mammal biomass than managed forests (Carey and Johnson 1995). Thus, protection of old-growth forests is essential for maintaining a high abundance of small mammals. In addition, riparian areas also seem to support a high abundance and diversity of forest floor generalists (Anthony et al. 1987; Doyle 1990; McComb et al. 1993), arboreal rodents (Carey et al. 1992), bats (Thomas and West 1991) and small mammals adapted to exploiting aquatic habitats (Anthony et al. 1987; Doyle 1990).

Indices of diversity, a measure of the relative grouping of numbers and species, have been applied to compare species diversity in understory herb and shrub cover between old growth (> 180 years) and mature forests (80 years). These indices consistently show old-growth forests as containing more diverse vegetation than the mature stands (Berg and Clement 1992). This association even extends to cryptogamic plants. Epiphytic lichens, in particular, are a key component of coastal old-growth forests in BC and are notably absent from young managed stands. Many of the lichens found on the central coast of BC are nitrogen-fixing cyanolichens, which are involved in nutrient cycling processes. The presence of epiphytic lichens in significant numbers tends to indicate prolonged environmental continuity (Rose 1992; Esseen 1996). Many epiphytes rely on decaying wood and complex, multi-layered canopies not found in logged areas. Epiphytes comprise a huge biomass in old-growth coastal forests and play a key role both in nutrient cycling and as habitat for other organisms.

In examining several classes of forest in BC - old growth and second growth of different ages - bird diversity and abundance peaked in old-growth cedar-hemlock-fir forests. Bird communities in second growth forests consist mostly of species that winter outside Canada and old-growth bird communities are comprised largely of species that are year round residents of BC. Different species respond differently to forest age. Ground nesting and shrub nesting species such as the orange-crowned warbler, song sparrow, and dark-eyed junco, were abundant in recently logged environments but others, such as cavity nesters (hairy woodpecker, brown creeper, and chestnut-backed chickadee) and insectivores (winter wren, varied thrush, and pacific slope flycatcher) were most abundant in unlogged old-growth forests. Still other species (Vaux's swift, red breasted sapsucker, pileated woodpecker, red-breasted nuthatch, western tanager, and red crossbill) are found almost exclusively in old-growth forests (Bryant et al. 1992). This association with old-growth means that clearcutting of temperate rainforests may produce dramatically altered bird communities and, for some species, (marbled murrelet, red-breasted sapsucker, and red-breasted nuthatch) the decline of the availability of old-growth forest is cause for serious concern (Bryant et al. 1992). In another study focusing on breeding birds in BC, the lowest diversity and abundance of forest birds were found in clear-cuts and 70 year-old stands, whereas undisturbed riparian areas contain an extremely rich and abundant avifauna. Species that were associated with snags and tree cavities were most impacted in young stands and it appears that structural diversity is the most important feature in old-growth forests for many habitat specific bird species (North and Franklin 1992).

Old growth forests are also important for amphibians and in the Pacific Northwest, populations of several species of amphibians have apparently become locally extinct with drastically reduced ranges (Blaustein and Wake 1990; McAllister and Leonard 1990). Most of these population declines have occurred in forest-dwelling species. In many areas, amphibians can be so numerous as to be a significant source of biomass and secondary productivity (Bury and Corn 1990). For example, some riparian habitats on Vancouver Island can support as many as 11,600 salamanders/ha (Ovaska and Gregory 1989). The small median size of amphibians enables them to exploit small prey items of low food value (Feder 1983) and convert these food items into biomass available to large vertebrates (Pough 1983).

Amphibians are also closely associated with riparian areas and even during the non-breeding season, adults of many aquatic breeders are still restricted to riparian zones and most peripheries of water sources. In general, the density and biomass of amphibians is significantly higher - as much as seven times - in streams of uncut forests in the Pacific Northwest (Corn and Bury 1989). Although there is a general lack of data on the effects of logging on amphibians in Canada, one recent study provides crucial BC-specific evidence about the close association between amphibians and old-growth (Dupis et al. 1995). This study is important because amphibian species in Canada are nearer the northern limits of their ranges and may be more sensitive to microclimatic changes that accompany logging than species near the center of their range. Dupuis et al. (1995) examined the abundance of terrestrial salamanders in old-growth forests (within the Coastal Western Hemlock Biogeoclimatic Zone in BC) with that in young and mature post-harvest stands. The study showed that clearcutting decreases the number of terrestrial amphibians (as much as 70 %) probably by reducing the availability of moist microhabitats and by limiting foraging and reproductive opportunities. For one species, *P. vehiculum*, abundance was six times greater in old growth forests than in managed stands during one year. In addition, there appears to be a narrower window of activity for salamanders in managed stands as compared to old growth, possibly reflecting poorer habitat quality. Dupis et al. (1995) recommend preserving streamside buffers, retaining understory growth as a source of shade, and maintaining stable microhabitats as possible mitigation against reduction of amphibian abundance. Lower abundance has also been recorded for other salamander species (e.g., pacific giant salamander) in logged areas probably because of increasing levels of sedimentation in cracks and crevices where the animals live (Corn and Bury 1989).

Of all the anurans found in BC, *Ascaphus truei,* the tailed frog, is probably the most likely to be affected by old growth habitat loss and destruction. Tailed frogs are intimately associated with fast-flowing streams in forested areas and old-growth forests (Corn and Bury 1989). Walls et al. (1992) suggest that continued logging of old-growth forests without leaving appropriate buffers adjacent to streams will certainly spell doom for the most important biodiversity values in this area. Others have speculated that the elimination of top-leaf predators, like the pacific giant salamander, may have serious cascading effects throughout the rest of the community.

In summary, the coastal temperate rainforest of BC is extremely rich in vertebrate diversity, although with few endemic species (11 % of total). Habitat use by the vertebrate fauna is closely associated with old-growth forest cover and riparian areas, reflective of the major characteristics of the coastal temperate rainforest - specific forest cover and water. According to Bunnell and Chan-McLeod (1997), about 75 % of vertebrate species (94 % of mammals; 53 % of birds) in the coastal temperate rainforest are forest dwelling and directly influenced by the nature of the forest cover. A similar number of forest-dwelling vertebrate species (72 %) in this region also make significant use of riparian areas (Bunnell et al. 1991) and the use of riparian or shore habitat by all species is even higher (85 % of mammals; 85 % of reptiles and amphibians; 76 % of birds). For some species (e.g., green-backed heron, hooded merganser, and common mergansers), both forest cover and proximity to water are requisite for successful breeding values.

Bunnell (1995) also showed that the close association shown by the majority of native forest-dwelling vertebrate species to forest cover and old-growth habitat are an adaptation to the major natural disturbance regime in the area (infrequent forest fires) and the forest structure resulting from that regime. It appears that the natural fire cycle in the coastal temperate rainforest of British Columbia is about 250 years or longer (Bunnell 1995), leading to fire initiated stands that are 450 to 750 years of age (Agee 1993). The longevity of trees and the long intervals between stand-initiating disturbances means that most natural stands in the coastal temperate rainforest of BC are dominated by old trees and in pristine areas, even-aged young stands are extremely small (Bunnell and Chan-McLeod). The richness and habitat specificity exhibited by the vertebrate fauna of the coastal temperate rainforest appears to be an adaptation to large, long-lived trees (a product of infrequent disturbance) and the structural complexity and ecosystem functions they provide (Bunnell and Chan-McLeod).

2.5. GOAL 4: MAINTAIN AND/OR RESTORE NATURAL LANDSCAPE CONNECTIVITY

2.5.1. BIOLOGICAL NEED TO MAINTAIN CONNECTIVITY

Protection and/or restoration of landscape connections is meant to ameliorate the effects of habitat fragmentation on wildlife (Frankel and Soulé 1981; Hudson 1991). While it is clear that habitat fragmentation contributes to declines of species, the precise mechanisms have not been elucidated for all species. Little is known about the autoecologies of many species present in the central coast region of BC and we cannot predict for which species, on what spatial and temporal scales and under what circumstances, island-biogeographic, or other models of decline in richness might be appropriate (see Boecklen and Gotelli 1984; Jarvinen 1984; Simberloff and Abele 1984; Pahl et al. 1988).

However, it is generally accepted that spatial connectors provide both additional habitat and may also function as a pathway for the movement and exchange of individuals among otherwise isolated habitat remnants. Even within *Core Conservation Areas*, natural levels of connectivity may require explicit management and restoration measures. Spatial connectivity between habitat patches may promote local persistence of species through both genetic and demographic mechanisms. The demographic "rescue effect" is an example of the benefits of immigration (Brown and Kodric-Brown 1977). The advantages of genetic interchange may include a decline in inbreeding depression and an increase in potentially adaptive genetic variance.

Landscape connectivity has at least two critical functions at the species level. First, connectivity allows species movement, including both regular daily and seasonal movement. In either case, core areas alone are unlikely to encompass the entire home ranges of wide ranging nomadic species (such as the wolverine) or the entire migration route of a species. Thus, connectivity serves to provide movement areas for these species even when core protected areas are not large enough to comprehensively cover the spatial needs of a species. Second, connectivity allows species to disperse from birth location to their adult home range and breeding sites. In many species, dispersal precedes the reproductive period. Dispersing animals may move short distances to occupy recently vacated adjacent territories or they may move long distances and enter other populations or settle in marginal areas. The maintenance of natural dispersal routes may be important to maintain social systems in a number of mammalian species. Unnatural dispersal events or routes may disrupt social systems in species such as lions, elephants, various primates and grizzly bears. Long distance dispersal provides demographic and genetic exchange between populations while maintaining the potential for the reestablishment of populations in areas from which the species has been extirpated or severely reduced in numbers as a result of human impacts.

2.5.2. CONNECTIVITY: CAD CONSIDERATIONS

There are many ways to maintain and/or restore natural levels of landscape connectivity, including identification and protection of potential wildlife corridors, "stepping stone" or stopover reserve patches or managing the matrix habitat to be compatible with native species.

Connectivity should be viewed from a species perspective and thus the physical dimensions of any connectivity plan are determined by the movement patterns of the species in question. Plans to connect landscapes should therefore consider the full range of native species present and protect or restore natural levels of connectivity and fragmentation through representation of a full range of habitats and ecosystem features.

It is possible to have too much connectivity. Connectivity beyond natural levels may expose native species to disease and invasion of non-native species. The conundrum is that there are no longer any unfragmented systems remaining to determine natural levels of fragmentation and connectivity. Identifying distinct populations and quantifying movements between populations are non-trivial problems but recent advances in molecular genetics may yield clues, since more isolated populations become more genetically differentiated (see Avise 1994; Slatkin 1994, 1995; Goudet 1995; Templeton and Geogiadis 1995; Paetkau et al. 1998).

For our purposes, protection of large contiguous blocks of habitat should serve to both maintain and restore natural connectivity without artificially creating habitat corridors. Additionally, riparian protection necessary for salmon restoration can also serve as natural landscape level linkages (Naiman et al. 1993). In the central coast region of BC, riparian zones form natural connections between highland areas and the surrounding lower elevation lands and often lead to high elevation passes between otherwise isolated watersheds. Because habitat is preserved in large contiguous areas connected by riparian zones, natural levels of connectivity are maintained and restored at several spatial scales, both within and between watersheds.

3. CONSERVATION AREAS DESIGN FOR THE CENTRAL COAST OF BC

Dennis Sizemore

3.1. ABSTRACT

Numerous studies have investigated and defined general goals and principles for the design of conservation areas, but relatively few studies have attempted to develop region specific, usable methods that are consistent with these stated goals and principles. We developed a Conservation Areas Design (CAD) for the central coast of British Columbia that defines specific and usable methods for identifying and delineating conservation areas based on representation of forest with old-growth structural features, and high potential habitat for grizzly bears and Pacific salmon.

Because the region is dominated by rain and many small freshwater river systems, we used watersheds as our unit of both analysis and protection. At the scale of watersheds, we identified *Core Conservation Areas* that comprise about 51% of the study area and include 74% of remaining old growth forests and 61% of known salmon stocks. *Core Conservation Areas* are made up of three types of areas: *Core Intact Areas, Core Grizzly Bear/Salmon Habitat Areas* and *Core Restoration Areas*. Using each of these types of areas alone does not sufficiently represent all elements of biodiversity (based on our focal element analysis) in the region. However, taken together, we suggest that *Core Intact Areas, Core Grizzly Bear/Salmon Habitat Areas* and *Core Restoration Areas* make up a sufficient set of biological elements for comprehensive conservation planning in the region.

All efforts should be made to maintain native species at their natural levels of distribution and abundance in *Core Conservation Areas*; therefore, unacceptable human activities are those that threaten the long term viability of grizzly bears and salmon including hunting of carnivores, logging, road construction, mining, motorized access to freshwater rivers and development of permanent human settlements.

Linkage Areas are made up of two types of areas: *Riparian and Salmon Conservation Areas,* and *Linkage Watersheds.* We suggest that *Linkage Areas* play potentially important roles in connectivity between *Core Conservation Areas*, existing protected areas and

areas outside the study area. Thus, *Linkage Areas* should be managed to maintain natural levels of connectivity and human activities within these areas should not threaten connectivity. As such, *Linkage Areas* may be open to a number of human activities, including recreational use, sustainable development and variable retention forestry or ecoforestry (with adequate safeguards for salmon habitat). Activities that threaten connectivity should not be allowed, including mining, road construction, unsustainable logging and hunting of large carnivores.

3.2. INTRODUCTION

The coastal temperate rainforest of North America once stretched from central California into southern Alaska. Large populations of grizzly bears, wolves, and salmon were found through out this region and their legendary abundance is sometimes difficult to comprehend. One and a half million kilograms of salmon would routinely swim up the Sacramento River and over 40 grizzly bears were spotted at one time from a high point near Humboldt Bay in the 1800s. During this century, much of this contiguous rainforest has been destroyed or altered by direct or indirect human activity and today only a small fraction of this ecosystem remains intact. Three elements of the coastal temperate rainforest have been subjected to particularly heavy human impacts: 1) predator – prey systems regulated by large carnivores, 2) pacific salmon populations, and 3) old-growth forest ecosystems.

The coast of British Columbia (BC) contains the majority of the ecologically intact remnants of the coastal temperate rainforest. Some areas in this region still contain ecologically significant stands of intact forest with potentially viable compositions of native species that may be restorable to their historic levels of abundance. A comprehensive protection plan for vulnerable species, keystone species, historically impacted communities, and ecosystem attributes is necessary if the overarching goal of conservation of biodiversity, in perpetuity, is to be achieved in BC. History has shown that without such a plan, central coast biodiversity and ecosystem functioning will continue to be eroded by human impacts until it eventually resembles the severely depleted forest remnants now found in the lower U.S. 48 states. To this end, we have developed a Conservation Area Design (CAD) for the central coast, consistent with the principles of nature-reserve design described in the literature (Terborgh 1974; Willis 1974; Diamond 1975; Wilson and Willis 1975; Diamond and May 1976; Soulé and Simberloff 1986; Noss 1992; Noss et al. 1997; Soulé and Terborgh 1999). Because resources and information are limited and threats to the ecoregion are immediate, we sought to identify a minimum, yet sufficient set of focal elements as the basis of this CAD. We combined a coarse-filter, ecosystem approach with a fine-filter species-based approach using old growth temperate rainforest ecosystems, grizzly bears and pacific salmon.

Old-growth temperate rainforest ecosystems have been historically impacted and are directly threatened by commercial logging to the extent that intact areas of coastal temperate rainforest are globally rare. Thus, remaining old growth coastal temperate rainforest, especially in relatively intact watersheds, was a primary focus for this CAD.

To complement the ecosystem approach we analyzed the needs of two groups of species, large carnivores and anadromous salmonids. Large carnivores are particularly vulnerable to human induced disturbance and have been extirpated over the last 100 years from much of their former range in North America. Such species are either directly impacted by habitat loss, hunting, poaching, over-harvesting, or indirectly threatened by road construction, habitat fragmentation, human development, and increased disturbance. Numerous studies have shown that top-carnivores are often essential to the integrity of ecological communities and while ecosystems are simultaneously regulated from both the bottom and top of the food web, recent empirical analysis points to strong top-down influences.

Millions of anadromous salmonids migrate each year from the Pacific Ocean to spawn in the freshwaters streams of the central coast. Salmon are extremely vulnerable to human disturbance and many stocks have been extirpated or severely reduced through a combination of human impacts including habitat degradation, over-harvesting, introduction of hatchery fish and construction of migratory impediments. Migrating salmon provide an important seasonal food source for many wildlife species and the massive influx of salmon carcasses each year enriches aquatic and riparian habitats to the extent that anadromous salmonids are often considered to be "keystone" species.

Grizzly bears and 6 species of pacific salmon were chosen as focal species for our CAD based on their sensitivity to disturbance, usefulness as a keystone species, usefulness as an umbrella species and availability of information. We developed methods for prioritization, based on the ecological needs of these species.

Prioritization can tell us which areas should be protected first, but how much area should receive protection? Conservation targets have been widely criticized, and the precautionary principle suggests that as much area as possible should be protected. However, because implementation is ultimately a political and societal issue and involves complex interactions and compromise between government, industry, local communities, indigenous people, environmentalists and other stakeholders, relatively few reports in the scientific literature have focused on implementation. Thus, a second objective of this CAD was to provide tools for the analysis of potential conservation areas for biological sufficiency and to attempt to bridge the gap between the general principles of nature-reserve design and implementation of these principles. Iterative analysis, applied in parallel with prioritization, can provide estimates as to whether or not proposed conservation area configurations are enough to meet biological needs (Murphy and Noon 1992; Noss 1992; Noss and Cooperrider 1994; Reid and Murphy 1995). If necessary, additional areas can be identified and included in order to meet biological demands, and other proposals for conservation areas can be evaluated. We used representation of six species of salmon, three species of trees and representation of coastal western hemlock maritime subzones to test our CAD. In this manner, our biologically based CAD can inform implementation campaigns while remaining scientifically sound.

In summary, this CAD is made up of two distinct components: 1) prioritization of areas and, 2) iterative analysis of potential conservation area configurations. Separation of iterative analysis and prioritization allows the CAD to remain consistent with the principles of nature-reserve design in the face of political reality and compromise. The best areas for conservation are prioritized and known ecological risks, such as the loss of remaining old growth habitat and possible extinction of salmon stocks, are explicitly and quantitatively described in the resulting CAD.

3.3. METHODS

3.3.1. CAD GLOSSARY OF TERMS

Core Conservation Areas

Three types of areas make up *Core Conservation Areas*. The methods for delineating these areas are described in detail in the following sections. The *Core Conservation Areas* are:

1. *Core Intact Areas* are watersheds with relatively intact old growth forest.
2. *Core Grizzly Bear/Salmon Habitat Areas* are watersheds with grizzly bear habitat elements, salmon runs, low road density and less than 15% of the forested area logged. Note that there is some overlap between *Core Grizzly Bear/Salmon Habitat Areas* and *Core Intact Areas.*
3. C*ore Restoration Areas* are watersheds with grizzly bear habitat elements, salmon runs and low road density but with greater than 15% of the forested area logged. These areas may require extensive watershed level habitat restoration.

Linkage Areas

Regional Conservation Area Designs should account for long term connectivity between core conservation areas, as well connectivity in both north-south and east-west directions. We define two types of areas designated specifically to maintain natural levels of connectivity:

1. *Salmon Conservation Areas and Riparian Linkage Areas* are salmon bearing watersheds outside of *Core Conservation Areas.* The spatial

extent of *Salmon Conservation Areas and Riparian Linkage Areas* is defined as the area necessary to maintain salmon spawning, rearing and migration habitat and the area necessary to maintain connectivity for large carnivores. FEMAT (1993) compatible buffers around riparian areas are an adequate starting point for defining *Salmon Conservation Areas and Riparian Linkage Areas* (see Tables 6 and 7). However, some extremely sensitive locations (e.g., habitat surrounding salmon spawning beds) will require more extensive protection.

2. *Linkage Watersheds* are watersheds with a greater than 2:1 ratio of alpine tundra (AT) to coastal western hemlock (CWH) biogeoclimatic zone area. Thus, *Linkage Watersheds* are made up primarily of high elevation "rock and ice" (already sufficiently represented in existing protected areas). However, many *Linkage Watersheds* are adjacent to, and connect the thin strips of, productive low elevation old growth forest containing valuable grizzly bear and salmon habitat. We suggest that *Linkage Watersheds* play potentially important roles in connectivity between Core Conservation Areas and should be managed to maintain natural levels of connectiity.

3.3.2. UNIT OF ANALYSIS

Because the region is dominated by rain and many small freshwater river systems, we used watersheds as the primary unit of both analysis and protection. These units define the scale of this CAD and are appropriate for the scale of accuracy of the information we used. Primary watersheds are defined as all watersheds that share a common saltwater exit point and thus represent an aggregation of one or more watersheds (which are often referred to as sub-watersheds or secondary watersheds in the scientific literature).

3.3.3. INTACT AREAS

Watersheds with intact old growth coastal temperate rainforest are globally rare and are thus internationally significant. Intact watersheds contain many characteristic features of coastal temperate rainforest ecosystems including a wide range of plant, wildlife and invertebrate species. Globally significant features are found in some intact watersheds including coastal muskeg, intact predator – prey systems, intertidal habitat, fiord habitat and salmon and grizzly bear habitat. Of all the features found in intact watersheds, forests with old growth structure are among the most heavily impacted, most threatened and most globally significant. Old growth forest ecosystems are distinguished by late-successional plant communities (including old trees) and related structural features. Old-growth structural characteristics encompass 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.

We identified *Core Intact Areas* as intact watersheds with old growth forest structural characteristics, using logging data, road data, BC biogeoclimatic zone classification, and forestry data (Table 8 and Map 2).

To further rank and prioritize intact areas, we used both size and age class of three focal tree species groups (sitka spruce, western red cedar/ yellow cedar and douglas fir) and developed an old growth index for all watersheds (see Equation 1 for details). Forest cover data were corrected for recently logged areas (see Table 8). For each focal tree species group, total area was calculated and normalized by the maximum area for that species in the database. The sum of the normalized values was computed for each watershed. As such, the index accounts for both the total amount of old growth, and the amount of old growth of the species listed above (Equation 1).

Equation 1.

$$OGI_{ws} = \sum_{1}^{n} area_{ws}^{n} / \max(area_{all}^{n})$$

where:
ws = watershed code
n = species group defined as:

species group	height class	age class	inventory type group
cedars	>37.5m	>250 years	9,10,11,12,14
sitka spruce	>37.5m	>250 years	16,20,21,22,23,24,26
douglas fir	>30m	>141 years	1,2,3,4,5,8
all species	>37.5m	>250 years	any

Table 8. Criteria for *Core Intact Areas*.

Watershed attribute	Definition
< 10% of forested area logged	BC MOF forestry database (1:250,000 generalized from 1:20,000 forest cover data). Forested area was defined as basic class = 0 in the database. Logging data was taken from Sierra Club of BC satellite imagery analysis (1993 and 1998) and from digitized forest development plans.
< 0.2 km/km2 road density	Digitized 1:20,000 TRIM roads
< 1/2 AT/CWH biogeoclimatic zone area ratio (to eliminate areas that are primarily rock and ice)	BC biogeoclimatic zone classification
Old growth structure presence	BC MOF forestry database (1:250,000 generalized from 1:20,000 forest cover) Forests with old growth structure were defined as having large and old trees (height class > 37.5 m tall and age class > 250 years old). In addition douglas fir polygons of height class > 30 m and age class > 200 years old were also included (our criteria for delineating douglas fir old-growth are more inclusive than for other tree species because of disproportionate historic human impact). This forestry data was updated using logging data taken from Sierra Club of BC satellite imagery analysis (1993 and 1998) and from digitized forest development plans.

We did this in order to help capture and represent in *Core Intact Areas* the structural, functional and age characteristics of old growth forests which differ according to species composition. These three focal tree species groups tend to capture different aspects of old growth forest structural and functional characteristics.

For example, douglas fir tends be associated with drier areas such as east side slopes in submaritime areas. Sitka spruce tends to be associated with floodplain and riparian areas and is found throughout maritime and hypermaritime areas. Western red cedar is associated with low elevation wet hypermaritime and maritime areas and is typically found on steeper slopes and areas with low levels of disturbance (e.g., windthrow) and is replaced by yellow cedar at higher elevations (Meidinger 1991).

3.3.4. GRIZZLY BEAR HABITAT POTENTIAL

We developed a simple model (Equation 2) for ranking watershed-level grizzly bear habitat potential (summarized in Figure 3). A number of studies suggest that road densities for grizzly bear habitat should not exceed 0.6 km/km^2 (where bears avoid roads) and target levels of road density for long term persistence of grizzly bears should be no more than about 0.35 km/km^2. Therefore, we eliminated watersheds

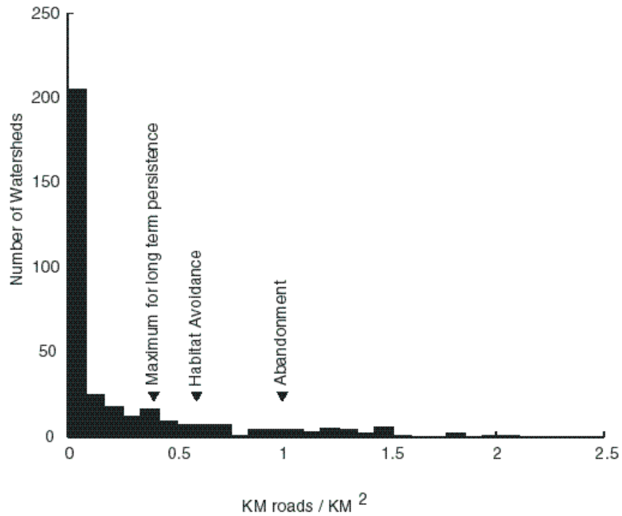


Figure 3. Distribution of watershed road density in the study area. Grizzly bears tend to avoid areas with greater than 0.6 km/km2 road density and abandon habitat at around 1 km/km2 road density. Our threshold for including watersheds as Core Areas was set at 0.35 km/km2 road density.

with high road densities ($>0.35 km/km^2$) from consideration as core grizzly bear habitat areas. Mean road density by watershed was calculated from the length of logging roads in the watershed, digitized from 1:20,000 TRIM maps. Figure 3 shows the distribution of road density by watershed in the CCLRMP study area and the thresholds described above. Road density can be calculated at any scale. We suggest that watersheds are appropriate units of analysis for road density because they represent natural landscape units, especially in the central coast.

In addition to low road density, grizzly bears have well studied habitat associations and requirements. We combined a number of these habitat elements into a grizzly bear habitat potential index (GBI, Equation 2) as follows:

1. Estuaries based on Raincoast Conservation Society, Round River Conservation Studies field data, and LRMP data. Because we did not have data on estuary size, each watershed was assigned a presence or absence score (0 or 1).

2. Salmon index based on salmon escapement data (SEDS & FISS). For each watershed, the

Equation 2.

$$GBI_{ws} = \sum_{1}^{n} element^{n}_{ws} / \max(element^{n}_{all})$$

where:
ws = 45 digit watershed code
n = number of habitat elements in the model
element = habitat element as follows:

habitat element	definition
Estuary	Presence or absence score (0 or 1)
Riparian area	100m buffer around all streams
Old growth area	Large, old trees (> 37.5m tall and >250 years old)
SI	Salmon Index, see equation 3.

salmon index is the normalized mean abundance (calculated by mean escapements for each stock over the last 40 years) by stock (identifiable run that is counted separately). In this way the abundance of salmon and the stocks (species and separate runs) are accounted for (Equation 3).

3. Riparian index from a 1:50,000 watershed atlas based on streams in watersheds with 100 m buffering on either side. The riparian index

Equation 3.

$$SI_{ws} \quad \sum_{1}^{n} stock^{n}_{ws} / \max(stock^{n}_{all})$$

where:
ws = 45 digit watershed code
n = number of stocks.
stock = mean stock escapement values for the following salmon stocks:
coho, chinook sockeye, chum, pink (odd years),
pink (even years) and steelhead.

was a 0–1 value for each watershed, scored as the riparian area in a watershed (sum of the area within 100 m of any stream) normalized by the maximum riparian area for all water sheds in the study area.

4. Old growth area from forest cover data corrected for recent logging. Old growth is defined as forest areas with old growth structure (see Table 8).

How do we determine which areas are considered to be *Core Grizzly Bear/Salmon Habitat Areas*? We used field data collected by Raincoast Conservation Society and Round River Conservation Studies (1997-1998) to calibrate and test our model and to set thresholds for determining *Core Grizzly*

Bear/Salmon Habitat Areas. A number of watersheds were assessed as high grizzly bear activity areas (based on tracks, day beds, bear trails, scat, sign, and sightings) based upon field data. Although we did not randomly sample the entire study area for grizzly bear activity (which would require resources beyond the scope of this report), this information can be used to test and calibrate our habitat potential model because it does identify known high grizzly bear activity areas. Indeed, there was good correspondence between the model and field assessments (Figure 4). High bear use areas (point B, assessed using field data) had significantly higher GBI scores ($p < .01$) than randomly chosen watersheds (point A, Figure 4). We wanted to be reasonably certain that the thresholds for determining core areas captured known high grizzly bear activity areas. Thus, we set our threshold for assigning core watersheds at a level that captured 95% of high bear use areas (GBI =0.17, point C, Figure 4).

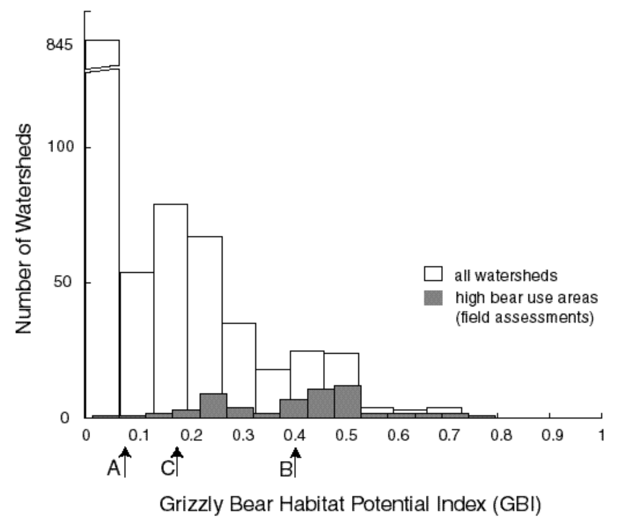


Figure 4. Grizzly bear habitat potential model compared with fieldwork results. White bars show the distribution of Grizzly Bear Habitat Potential Index (GBI) scores by watershed. Most watersheds have a low GBI value. The gray bars show the distribution of scores for watersheds that were assessed in the field as high grizzly bear use areas (see text for details). B is the mean GBI score for field assessed high bear use areas. High bear use areas have significantly higher ($p < 0.01$) GBI scores than expected through random selection of watersheds (A) using monte carlo statistical methods. We used the scores from high bear use areas to calibrate our habitat potential model. C is the threshold for including watersheds as Core Grizzly Bear/Salmon Areas, set to include 95% of high bear use areas.

Comprehensive conservation of salmon requires protection of the entire primary watershed (Sheldon 1988; Williams et al. 1989; Moyle 1991; Naiman et al. 1992). Additionally, large carnivores require large areas of contiguous habitat (Woodroffe and Ginsberg 1998). Thus, watersheds with a GBI > 0.17 that also had salmon presence (in the primary watershed) were expanded to the boundary of the entire primary watershed. Within these expanded boundaries, three types of areas where delineated (see Figure 5 for a summary of the decision process and Map 3): 1) *Core Grizzly Bear/Salmon Habitat Areas* were defined as areas with less than 15% logging impacts (of the productive forest); 2) *Core Restoration Areas* were defined as areas with greater than 15% of the forested area logged; and 3) *Linkage Watersheds* were defined as those with greater than 2:1 ratio of alpine tundra to coastal western hemlock biogeoclimatic zone area.

3.3.5. REPRESENTATION ANALYSIS

We identified several elements to test potential *Core Conservation Areas* for sufficiency. Elements include:

1. Old growth forest species groups (cedar, sitka spruce, douglas fir). The rationale for this is reviewed above (see Intact Areas).
2. Salmon stocks (see Chapter 2 for a review)
3. Coastal western hemlock (CWH) maritime subzones. These subzones (hypermaritime, maritime, and submaritime) are characterized by different climate, vegetation and soils found in the CWH zone. Hypermaritime forests are dominated by mixtures of western hemlock, western red cedar, sitka spruce, amabilis fir and variable amounts of yellow cedar. Bogs and associated floristic species are abundant. The drier maritime subzone covers the majority of the CWH zone as a whole. Maritime forests are characterized by western hemlock, amabilis fir, western red cedar, stika spruce and yellow cedar (at higher elevations). Windthrow plays a key role in succesion and dominance of western hemlock and amabilis fir, and an

extensive shrub layer dominated by vaccinium and salal. Drier still, submaritime forests have a substantial component of douglas fir, along with western hemlock and western red cedar. Shrub layers are poorly to moderately developed, with the appearance of several interior species of moss and herb. We sought to represent sufficient components of all three CWH maritime subzones.

How much is enough for all these elements? We did not explicitly set targets for the conservation (Soulé and Sanjayan 1998) of these elements, but rather view representation analysis as a means to expose potential shortcomings and glaring omissions of various algorithms for prioritizing and selecting areas for conservation.

3.4. RESULTS

3.4.1. CORE CONSERVATION AREAS

Core Conservation Areas (Map 5) are made up of three types of Core Areas: 1) *Core Intact Areas* (Map 2),

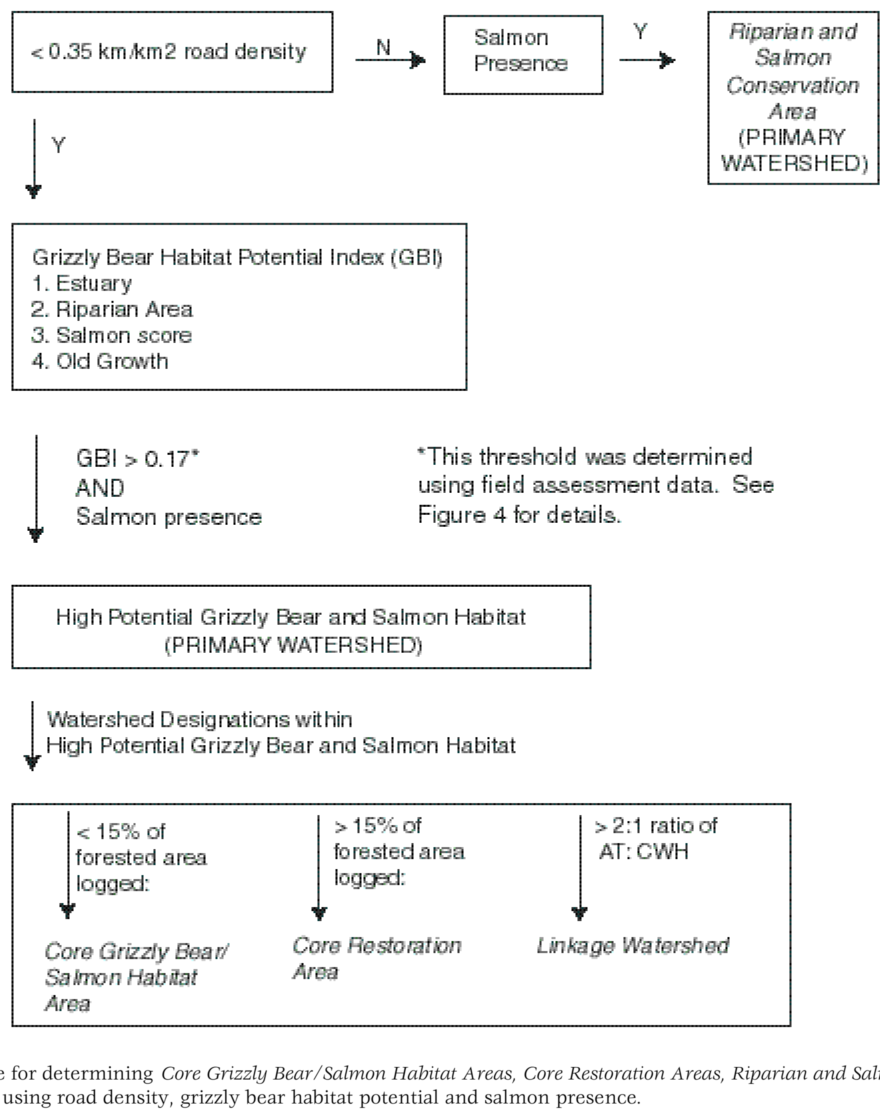


Figure 5. Decision tree for determining *Core Grizzly Bear/Salmon Habitat Areas, Core Restoration Areas, Riparian and Salmon Conservation Areas* and *Linkage Watersheds* using road density, grizzly bear habitat potential and salmon presence.

2) *Core Grizzly Bear/Salmon Habitat Areas* (Map 3), and 3) *Core Restoration Areas* (Map 3). In all, *Core Conservation Areas* comprise 50.3% (2.39 out of 4.75 million hectares) of the land in the study area (Figure 6). Seventy-two percent of the remaining forest with old growth structure and 61% of all salmon stocks in the study area are represented in *Core Conservation Areas* (Figure 6). Mean road density in *Core Conservation Areas* is about 0.07 km/km2 suggesting that current wilderness values remain high.

Core Conservation Areas are clustered in three general locations in the study area. A large cluster of core watersheds is located around the Rivers/Smith Inlet area. There is a cluster of core intact watersheds in this area (including the Koeye River, Johnston Creek, Allard Creek, Lockhart-Gordon Creek and the Smokehouse River) that also qualify as *Core Grizzly Bear/Salmon Habitat Areas* (see Maps 2 and 3). Another cluster of core areas is found north of Knight Inlet and includes the Klinaklini River, the Stafford and Apple rivers and the Anahutniti watershed complex. This general area has also been identified as a study area in the BC Protected Areas Strategy (rated #1 priority for protection of grizzly bears and represents the final remaining intact watersheds in the southern extent of the study area). Additionally, the Klinaklini River provides a north-south connectivity route to the southern extent of Tweedsmuir Park. The third large cluster of *Core Conservation Areas* is located in the northern extent of the study area, including a large portion Princess Royal Island, the Khutze River and surrounding watersheds that are adjacent to the Fjordlands Recreation Area. A number of intact watershed that flow into the upper Dean Channel and including the Dean River watershed are also included in this cluster.

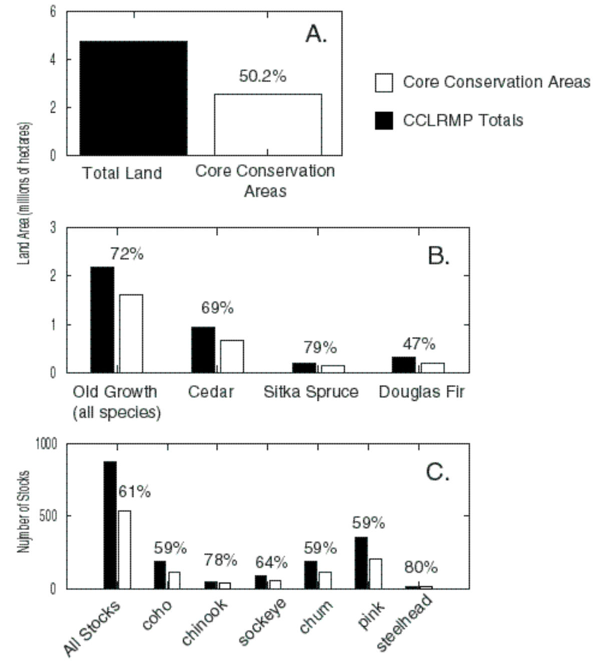


Figure 6. A representation analysis for *Core Conservation Areas*. A. Amount of land proposed in *Core Conservation Areas* is 2.39 million ha or about 50.3% of the land in the study area. B. Representation of remaining forests with old growth structure in proposed *Core Conservation Areas* includes 157,000 total hectares (out of 217,200 hectares). Representation of focal species groups includes 64,600 ha of cedar, 14,900 ha of sitka spruce, and 15,300 ha of douglas fir. C. Representation analysis of salmon stocks. 61% (530/871) of total stocks are represented in *Core Conservation Areas*. Species representation includes 108 of 184 coho stocks, 36 of 46 chinook stocks, 55 of 86 sockeye stocks, 112 of 191 chum stocks, 207 of 349 pink stocks and 12 of 15 steelhead stocks.

3.4.2. CORE INTACT AREAS

Core Intact Areas (Map 2) make up 31% (1.48 million ha) of the total land in the study area. Fifty-one percent of remaining old growth forest is represented in *Core Intact Areas*. However, only 22% of the remaining old growth douglas fir is found within *Core Intact Areas* (Figure 7). This is probably because douglas fir stands have been heavily targeted for logging over the past 100 years and most watersheds that contain douglas fir have been impacted by logging. Thus, underrepresentation of old growth douglas fir suggests that intact areas alone are not sufficient for designing comprehensive conservation areas.

Additionally, only 41% of all salmon stocks are found within intact watersheds. Of these stocks, chinook (34%) and steelhead (13%) are particularly underrepresented (Figure 5) in *Core Intact Areas*. This suggests that habitat features that are correlated with chinook and steelhead spawning and rearing requirements have been targeted disproportionately by logging and that additional areas are necessary for a comprehensive CAD.

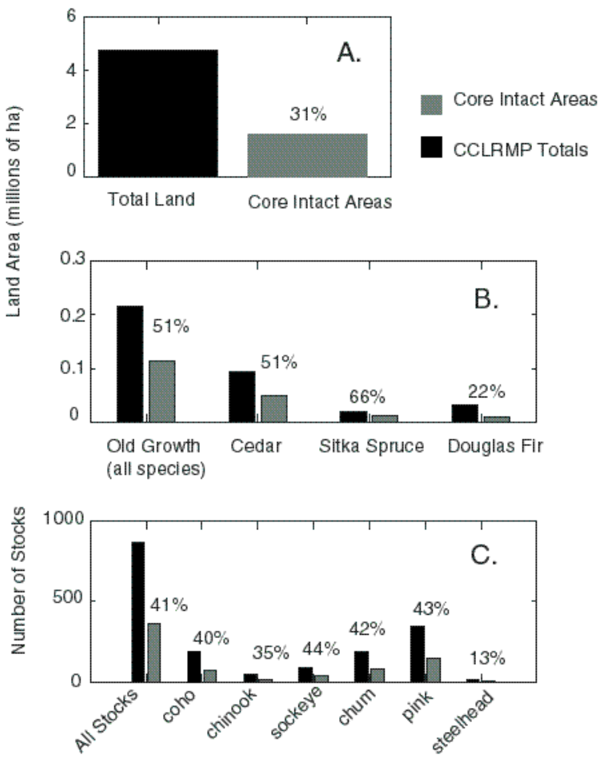


Figure 7. A representation analysis for *Core Intact Areas*. Few intact watersheds remain (only 1.47 million hectares total or about 31% of the study area). B. Representation of remaining forests with old growth structure in proposed *Core Intact Areas* includes 111,600 total hectares (out of 217,200 hectares). Representation of focal species groups includes 47,600 ha of cedar, 12,500 ha of sitka spruce, and 7,200 ha of douglas fir. C. Representation analysis of salmon stocks. 41% (360/ 871) of all stocks are represented in *Core Intact Areas*. Species representation includes 74 of 184 coho stocks, 16 of 46 chinook stocks, 38 of 86 sockeye stocks, 81 of 191 chum stocks, 149 of 349 pink stocks and 2 of 15 steelhead stocks. Results suggest that chinook, steelhead and douglas fir are not suffciently represented in intact watersheds.

3.4.3. CORE GRIZZLY BEAR/SALMON HABITAT AREAS AND CORE RESTORATION AREAS

Figure 8 summarizes area inclusion and representation in *Core Areas* with high potential grizzly bear and salmon habitat (*Core Grizzly Bear/Salmon Habitat Areas* and *Core Restoration Areas*). Interestingly, high potential grizzly bear habitat areas are split almost evenly between *Core Grizzly Bear/Salmon Habitat Areas* (715,200 ha) and *Core Restoration Areas* (802,200) ha. Slightly more total old growth is found in *Grizzly Bear/Salmon Habitat Areas* (46,180 ha) than in *Core Restoration Areas* (42,910 ha). More sitka spruce old growth is found in *Grizzly Bear/Salmon Habitat Areas* (6,300 ha) than in *Core Restoration Areas* (2,090 ha), suggesting that sitka spruce stands are among the first targeted species for logging, and may be absent in even partially impacted watersheds.

Salmon stocks are well represented as a whole in these *Core Areas* with high potential grizzly bear and salmon habitat. In all 358 total stocks are present (74 coho, 34 chinook, 41 sockeye, 70 chum, 127 pink and 12 steelhead stocks). Of these stocks, 45 coho, 18 chinook, 28 sockeye, 42 chum, 78 pink and 4 steelhead stocks are found in *Core Grizzly Bear/Salmon Habitat Areas.*

Thus, a combination of *Core Grizzly Bear/Salmon Habitat Areas,* and *Core Restoration Areas* and *Core Intact Areas* seems to adequately represent old growth focal species as well as salmon species.

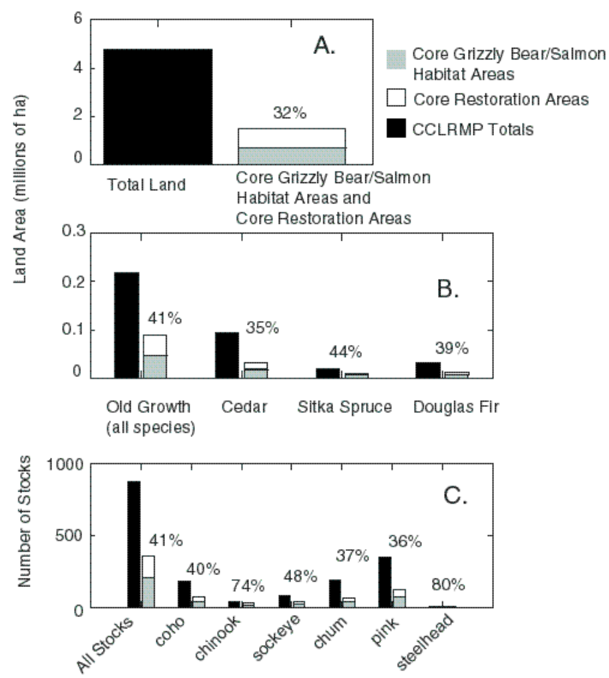


Figure 8. A representation analysis for *Core Areas* with high potential grizzly bear/salmon habitat (includes both *Core Grizzly Bear/Salmon Areas* shown in gray and *Core Restoration Areas* shown in white). A. Total grizzly bear/salmon cores includes 715,200 ha in *Core Grizzly Bear/Salmon Habitat Areas* and 802,200 ha in *Core Restoration Areas*. B. Old growth representation in *Core Areas* with high potential grizzly bear/salmon habitat. C. Salmon stock representation. Note that chinook and steelhead stocks are well represented in these areas in contrast with *Core Intact Areas.*

3.4.4. CWH REPRESENTATION

We tested *Core Conservation Areas* for representation (Figure 9) of the three CWH maritime subzones and found that they are relatively evenly represented (48% of hypermaritime, 61% of maritime and 53% of submaritime subzones). However, using either *Core Intact Areas* or *Core Grizzly Bear/Salmon Habitat Areas* and *Core Restoration Areas* alone reveals some disproportionate representation. Most intact watersheds are found in the hypermaritime subzone. The majority of watersheds in submaritime areas have had significant human impacts and are thus underrepresented by intact areas alone. Grizzly bears are not prevalent in outer coastal areas and islands, so hypermaritime areas are severely underrepresented in *Core Grizzly Bear/Salmon Habitat Areas* (Figure 9). However, taken together, *Core Conservation Areas* seem to adequately represent the three CWH subzones.

In total, 55% of all CWH area (1.39 out of 2.53 million ha) is represented in *Core Conservation Areas*. CWH in *Core Conservation Areas* makes up only 29% of the total land in the study area (1.39 out of 4.75 million ha).

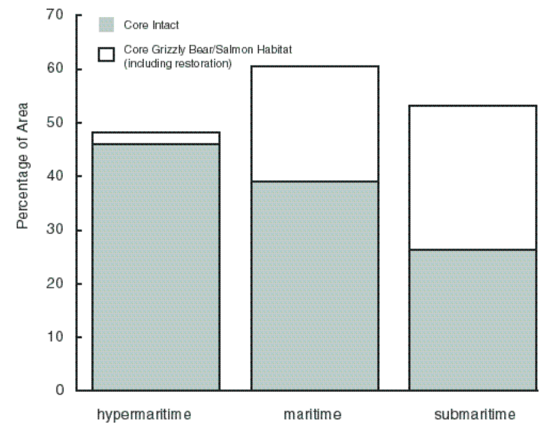


Figure 9. A representation of maritime subzones of the Coastal Western Hemlock biogeoclimatic zone. The three subzones are relatively evenly represented in *Core Conservation Areas*. In *Core Intact Areas* alone, the submaritime subzone is underrepresented. Hypermaritime areas are underrepresented in *Core Grizzly Bear/Salmon Habitat Areas*. In total, 55% of all CWH area (1.39 out of 2.53 million ha) is represented in *Core Conservation Areas*. CWH in *Core Conservation Areas* makes up only 29% of the total land in the study area (1.39 out of 4.75 million ha).

3.4.5. RIPARIAN AND SALMON CONSERVATION AREAS

Riparian and Salmon Conservation Areas (Maps 1 and 4) are designed to protect salmon habitat and maintain landscape connectivity for large carnivores. FEMAT (1993) compatible buffers surrounding all streams and water features in salmon bearing watersheds provide a good starting point for defining the spatial extent of *Riparian and Salmon Conservation Areas.* However, additional protection for sensitive salmon spawning and rearing habitats may be necessary in some areas. In particular, streams supporting coho populations should be further analyzed.

Of the three large watersheds in the northeastern portion of the study area, only the Dean River is included in *Core Grizzly Bear/Salmon Habitat Areas.* The remaining two large watersheds, the Bella Coola River and the Kimsquit River, both have high road densities, disqualifying them for inclusion as *Core Grizzly Bear/Salmon Habitat Areas.* However, the location and size of these watersheds, along with their extremely high salmon production potential, merits special consideration. The Bella Coola River provides one of the only east-west linkages from the study area to Tweedsmuir Park, and the Kimsquit River lies between Tweedsmuir and the Kitlope watershed. Maintaining connectivity and protection and restoration of salmon habitat is critically important in both of these areas.

3.4.6. LINKAGE WATERSHEDS

Watersheds that are primarily rock and ice (alpine tundra biogeoclimatic zone) that belong to primary watershed groups with high potential grizzly bear and salmon habitat have been designated as *Linkage Watersheds* (Maps 5 and 4). These areas are primarily found in the eastern portion of the study area (e.g., above the Klinaklini River). Although these areas are not currently at risk from by development plans, they should be managed to maintain landscape level connectivity.

3.5. DISCUSSION

3.5.1. CORE CONSERVATION AREAS

Representation analysis indicates that it is likely that protecting *Core Intact Areas* alone would not provide adequate protection for salmon stocks, and would not provide enough contiguous grizzly bear habitat and refugia to maintain long-term viable populations. Thus, we identified areas that have high potential salmon and grizzly bear habitat and used these areas as guides to delineate entire watersheds for protection. Because large portions of these primary watersheds contain partially impacted habitats, we have separated these high potential grizzly bear/salmon areas into *Core Grizzly Bear/Salmon Habitat Areas* and *Core Restoration Areas* (see Methods for details). We suggest that areas presently in good condition can serve as anchors for recovering salmon and grizzly bear habitat. These *Core Restoration Areas* can become good quality habitat for both grizzly bears and salmon spawning, rearing and migration if current impacts are eliminated and comprehensive restoration is undertaken.

3.5.2. LINKAGE AREAS

We did not define linear corridors connecting *Core Areas*. Instead, we delineated *Linkage Areas*, as entire watersheds (*Linkage Watersheds*) or as *Riparian and Salmon Consevation Areas*. Further analysis could be performed to assess whether or not *Core Conservation Areas* are sufficiently connected with one another. The level of connectivity for grizzly bears is partially determined by the human impacts that take place outside of core areas. We performed a number of landscape analyses that suggest that current barriers to movement between core areas are minimal. However, any development that takes place in *Linkage Areas* should account for long term connectivity for large carnivores and should not disrupt movement of large carnivores.

3.5.3. HUMAN ACTIVITIES

Core Intact Areas and *Core Grizzly Bear/ Salmon Areas*

We recommend that maintaining/conserving species at their natural levels of distribution and abundance be the first priority in *Core Intact Areas* and *Core Grizzly Bear/Salmon Areas*. To achieve this goal, we recommend that these areas be exposed to very limited human activity. Commercial logging, hunting of carnivores, road construction, and establishment of permanent human settlements should be excluded in core areas. Motorized access to freshwater systems should be prohibited. Subsistence level use and recreational use should be permitted subject to adequate safeguards.

Core Restoration Areas

A number of biologically important areas have been subjected to a significant level of industrial clear cut logging and linear disturbances (i.e., logging road construction) that have undermined their ecological integrity. We recommend that restoring ecological processes and natural levels of species distribution and abundance should be the first priority in the management of *Core Restoration Areas*. In these areas we recommend that industrial resource extraction be halted and active ecological restoration undertaken to restore ecological values. This would involve stopping clearcut logging, de-activating roads and thinning existing plantations to enhance ecological attributes. Where appropriate, variable retention silviculture may be practiced as long as it is consistent with, and does not undermine, the primary management goal of ecological restoration in these zones.

Linkage Watersheds

We recommend that providing adequate connectivity for the unimpeded movement of large carnivores should be the first priority in the management of *Linkage Watersheds*. We recommend that these areas be closed to road construction, mining and hunting of large carnivores. Recreational use and ecologically appropriate resource extraction are acceptable as long as they are consistent with, and do not undermine, the primary management objective for these watersheds.

Riparian Linkage/Salmon Conservation Areas

Human activities in *Riparian Linkage/Salmon Conservation Areas* should not threaten salmon spawning, rearing and migration habitat and should not disrupt long-term connectivity for large carnivores. We recommend that conservation and restoration of watershed hydrologic function and fully-functioning riparian ecosystems should be the first priority in the management of these areas. Riparian reserve zones should be established to provide adequate protection for riparian and aquatic ecosystems. We recommend buffers along all streams that meet or exceed the recommendations of FEMAT (1994; see tables 6 and 7 for more detail).

Recreation, trapping and subsistence level use are appropriate, provided that they do not adversely affect riparian zones or salmon runs. Variable retention silviculture may be practiced in these zones, subject to adequate safeguards for riparian habitat and watershed hydrologic function. Watershed assessments should be undertaken and used to determine adequate levels of forest protection to maintain watershed hydrologic functions. We recommend that hunting of large carnivores in these areas be prohibited.

A Continued Role for Logging? - A Note About Variable Retention Forestry

Commercial logging is not the major driver of the economy of the Central Coast of British Columbia, given the limited commercial forest land base and the significance of other resource values, such as the salmon fishery and tourism. Nonetheless, forestry is an important part of the central coast economy and if conducted in an ecologically appropriate manner, remains an option for economic development in the area. However, if commercial timber extraction is to continue within *Linkage Watersheds*, and *Salmon Conservation & Riparian Linkage Areas* (and possibly *Core Restoration Areas* to a limited extent), it must be practiced in a manner greatly different to the predominant current practices on the central coast.

Natural disturbance, unlike most current harvesting and silvicultural practices, leaves behind a variety of stand structure. Even stand-replacing catastrophic fire, windthrow, disease and insects, often leave behind live and dead standing tree, large woody debris, and multi-layered forest canopies. In addition, coastal forests in BC have only rarely been subjected to large-scale disturbance. Infrequent harvesting and silvicultural operations that mimic natural disturbance regimes and maintain a greater amount of forest structural elements are more likely to maintain natural levels and composition of biological diversity than current " clear-cutting" practices.

Variable retention is a new silvicultural system (Franklin et al. 1997) that has been developed to address a wide array of forest management goals as an alternative to conventional systems that focus on the regeneration and growth of trees. Variable retention differs from all other forms of commercial forestry by always retaining part of the forest after harvesting – similar to natural disturbance models. It recognizes the role of structural complexity to forest ecosystems and biodiversity and as such retains structural features including snags, large woody debris, live trees of varying size including the largest age and size classes, and canopy layers. Traditionally, silvicultural systems (clearcut, seed tree, shelterwood, and selection) have been defined as a method for regenerating forest crops and all common systems eventually cut every tree in the forest. Even seed tree and shelterwood systems that retain some trees to help with the regeneration of a new "crop" eventually cut down the retained trees after some amount of regeneration.

Variable retention can be implemented with a wide range of harvesting systems – various levels of retention can be used with different types, amounts and spatial patterns of structure. Retention can be dispersed throughout a cutblock or aggregated in patches. Currently, this system is being implemented with success by MacMillan Bloedel. MB pledged to abandon clearcut logging on all its forest tenures in coastal BC in June 1998 and move to a new management paradigm based on increased conservation of old-growth forests and replacement of clearcutting with a more ecologically-driven approach involving a system of stewardship zones (Old-Growth Zone, Habitat Zone and Timber Zone) and variable retention silvicultural systemsMacMillan Bloedel's innovative approach, which combines various levels and designs of retention with rigorous monitoring and adaptive management has drawn praise and qualified support from scientists and environmental groups and is recognized as a a major improvement over clearcut logging and a step towards ecologically responsible forestry.

We suggest that in areas open to some levels of commercial logging (non-core, non-riparian, non-sensitive slopes) two broad zones (Forestry Zone and Habitat Zone) be defined for the purposes of variable retention silviculture. Within Forestry Zones, for any old growth stand, a minimum of 15 % aggregated (or patch) retention of the stand is maintain in every cutblock and a maximum distance of 4 tree heights (or 200 m) observed between patches. Cut blocks themselves should be of varying sizes but no more than 30 – 40 ha in size. Non-old growth stands should be handled using shelterwood (100- 200 trees per hectare) or group selection (openings about 0.5 ha or less) systems. Within the Habitat Zone (chosen for the presence of larger, contiguous old growth areas), harvesting will use uneven-aged silvicultural systems and all cutblocks will leave more than 20 % of the stand in aggregated tree patches. Until experimental data show otherwise, the aggregated retention stands should remain untouched in perpetuity.

In addition, rotation lengths should be greatly extended and silvicultural practices should emphasize native species and non-chemical vegetation management. All riparian areas, regardless of what zone or area they are found in should have a wide streamside buffer similar to that proposed by FEMAT 1993.

How much area should be allocated for variable retention forestry? Our methods for delineating *Core Conservation Areas* assume continued grizzly bear hunting outside of *Core Conservation Areas* and other current protected areas. Certainly, changing hunting regulations (i.e. elimination of large carnivore hunting) and increasing enforcement of poaching in the central coast region could potentially increase the amount of area available for variable retention forestry, particularly in *Core Restoration Areas*. However, under current hunting levels, variable retention forestry should be confined to non-core, non-riparian and non-ecologically sensitive areas.

3.6. CONCLUSIONS

The determination and delineation of *Core and Linkage Areas*, as well as the sub-categories contained therein, represents a major synthesis of biophysical and ecological data that is only now becoming available for the central coast region of BC. Without this type of analysis, it will be difficult to comprehensively address the needs of both human and non-human denizens of the region. We fully recognize that this is only a first step – but a necessary step. It is based on incomplete information and current western scientific understanding. As such, we expect our maps and accompanying analysis to evolve as others input newly emerging information. We welcome such change and urge researchers to seize the initiative and fill the "gaps".

Even the best plan or design will come to naught if it is not implemented. If the extinction crisis, now underway globally, is to be tackled locally, the Conservation Areas Design for the central coast of BC must be integrated into all regional conservation and development policies. This is in the hands of First Nations, local people, environmental organizations, forest industry, and government representatives. If it fails, this unique synthesis of data and the map it provides will become not a path of hope but another post mortem for nature.

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