EXTENDING CONSERVATION AREA DESIGN FRAMEWORK TO THE NORTH COAST REGION OF BRITISH COLUMBIA, CANADA

ROUND RIVER CONSERVATION STUDIES

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EXECUTIVE SUMMARY

Although theory behind science-based selection of conservation areas has been extensively developed, protected areas decisions are seldom based on biological criteria; instead, decisions are usually based on emotional, aesthetic or political grounds. To reduce this gap between theory and application, we applied a modified Conservation Area Design (CAD) framework that was previously developed for the central coast of B.C. (Jeo, Sanjayan and Sizemore 1999; Sanjayan, Jeo and Sizemore 2000) to the adjacent north coast study area in order to rank and prioritize conservation areas based on biological criteria. We produced a contiguous CAD for a large portion of the coastal temperate rainforest in B.C. that included both central and north coast regions. We used simple and repeatable methods for ranking watersheds that included both coarse-filter and species-based approaches. We identified 682 *Core Intact Areas* (3.2 million hectares); these were watersheds that had relatively little historical logging, low road density and highly productive old growth forests (characterized by presence of tall and old trees). We also identified 443 *Core Grizzly Bear/ Salmon* and *Core Restoration Areas* (4.8 million hectares); these were watersheds that contained relatively high quantities of habitat features required by grizzly bears and salmon (including estuaries, riparian areas, productive old growth and low road density). Taken together, *Core Conservation Areas* consisted of 882 watersheds and covered about 55% of the study area (6.08 million hectares). The human activities in *Core Conservation Areas* that are consistent with long-term ecological integrity would probably exclude most conventional forest practices.

However, *Core Conservation Areas* alone are probably not sufficient for long-term conservation as these areas will likely experience local extinction as they become increasingly fragmented and isolated. Because maintaining or restoring connectivity between *Core Conservation Areas* is vital to the long-term conservation efforts, we identified two types of *Linkage Areas* that are critical for landscape connectivity. These included *Linkage Watersheds*, which consisted of areas within *Grizzly Bear/Salmon Primary Watersheds* that had lower assessed habitat values, and *Salmon/Riparian Linkage Areas*, which were salmon bearing systems outside of *Core Conservation Areas*.

We suggest that conservation of these *Linkage Areas* will serve to maintain and restore landscape connectivity.

Human activities tend to proliferate and fragment once contiguous habitat, and road density has been used as an indicator of the level of fragmentation. We identified *Grizzly Bear Vulnerability Areas* as watersheds that had both high road density and relatively high value scores for grizzly bear habitat characteristics. These are probably current or potential population sinks, where grizzly bears may be vulnerable to human-caused mortality. These are also areas where landscape connectivity has been severely disrupted and where impacts will likely proliferate into adjacent areas.

INTRODUCTION

The coastal temperate rainforest of North America once extended from northern California through the Alaska panhandle and covered 30 - 40 million hectares; over half of this area has been logged or developed during the past 200 years (Kellog 1992; Schoonmaker, von Hagen and Wolf 1997). Coastal temperate rainforest is a globally rare ecosystem type, occurring on only about 1% of the earth's surface (Smith and Lee 2000). Many native wildlife species have been extirpated from the southern portion of the region, including catastrophic reductions of many salmon stocks and the extermination of top carnivores (grizzly bears, wolves and wolverines) from the coastal forests of the lower 48 US states. Some of the last remaining large contiguous areas of intact forest are found in British Columbia -- forests that still contain a full assemblage of large carnivore species, prolific stocks of pacific salmon and thousands of identified and unidentified species. Coastal forests of B.C. also supply woody debris and other materials that are vital to river system integrity and ecological functioning and provide storage of massive amounts of carbon. Nevertheless, despite their biological diversity and global significance, the future of the coastal temperate rainforest of British Columbia is uncertain. The primary threat to the region is industrial logging and recent conflicts between environmentalists and the timber industry have generated both national and international interest. Which areas should receive highest priority for conservation? How much area is enough? What types of human activities are acceptable? How should conservation policies be implemented? We sought to develop science-based tools to address these sorts of questions, through the development of a *Conservation Area Design* (CAD) for the region.

What is a CAD?

Over the past 30 years, biologists have developed a number of principles and tools to aid in systematic selection of conservation areas, with the overall goal of biodiversity conservation (MacArthur and Wilson 1967; Diamond 1976; Diamond and May 1976; Diamond 1986; Noss and Cooperider 1994; Noss 1996; Soulé and Terborgh 1999; Margules and Pressey 2000). A CAD applies well-accepted principles of conservation biology and thus provides a science-based framework for identifying and prioritizing areas for sustainable conservation, based upon biological values, threats, and opportunities for implementation. As such, it provides a mechanism for identifying biological limits and standards for proposed resources development and human activity within specific subareas or watersheds of the area covered by the CAD. This broad-scale approach moves away from disjointed and fragmented efforts at conservation planning that prevail in most locations (Schwartz 1999; Soulé and Terborgh 1999). A CAD should incorporate the best existing knowledge and planning for a region, including an emphasis on landscape and biological integrity, connectivity, long-term viability and the precautionary principle. A fundamental basis for a CAD is the utilization of a set of focal species, selected for their ecological requirements, status, vulnerability, and social importance in the region. Additionally, a CAD incorporates key ecological and landscape processes that are integral to maintaining the long term integrity of a region, including disturbance regimes such as fire and flooding, as well as natural succession, climatic conditions, and ecological interactions. Other key analytic tools used in CAD development are representation analyses and vulnerability assessments to ensure that all ecological communities have received appropriate conservation consideration and protection.

Our primary objectives were, therefore, to delineate and prioritize areas for protection and restoration based on current scientific knowledge, the tenets of conservation biology, and the precautionary principle. A 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 (i.e. maintaining all native species and communities in their natural range of abundance and distribution, with implied preservation of ecotypes and ecosystem functions) is to be achieved in BC. History has shown that without such a plan, coastal BC 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.

Focal Species for the ecoregion: Grizzly Bears and Pacific Salmon

Considerable work has been devoted to developing methods for identifying a suite of focal species, suitable for directing the design of conservation areas (Lambeck 1997; Miller *et al.* 1999). Species that have utility for Conservation Area Design include vulnerable, umbrella, historically impacted and keystone species. We selected two groups of focal species for the coastal forests of B.C.: large carnivores and pacific salmon (for a more extensive review of focal species selection criteria for this ecoregion, see (Jeo *et al.* 1999). In brief, we selected large carnivores because they 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. They are also directly impacted by habitat loss, hunting, poaching, over-harvesting, and indirectly threatened by road construction, habitat fragmentation, human development, and increased disturbance. Additionally, 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 forces. We selected grizzly bears as representative large carnivores, largely because of their vulnerability to human impacts and also because much is known about their habitat requirement and life history.

We selected salmon as focal species for a number of reasons. Salmon are a critical component of coastal temperate rainforests of North America, and provide a direct link between the productivity of the oceanic environment to the coastal forests of the pacific. Migrating salmon provide an important seasonal food source for many wildlife species (for an extensive review see (Cederholm *et al.*)) 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 (Willson and Halupka). Additionally, salmon are extremely vulnerable to human disturbance and throughout their range; many salmon 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.

Another important reason for utilizing salmonids as focal species is that much is known about salmon life history and considerable research has been done related to salmon conservation requirements. For example, salmon are strongly old growth dependent, as old growth, especially that found is riparian areas, contributes a number of critical habitat elements necessary for various stages of salmon life-history, including shade, filtration of sediment, woody debris and maintenance of a host of complex hydrological functions. Salmon can also determine the scale at which conservation actions should occur in order to be effective. For example, a growing body of evidence suggests that the most important scale for analysis of land-use practices on channel structure is the entire watershed (Sullivan *et al.* 1987; Sheldon 1988; Williams *et al.* 1989; Moyle and Sato 1991; Naiman 1992; Naiman *et al.* 1992; Naiman, Decamps and Pollock 1993; Naiman, Bilby and Bisson 2000). This is partially because salmon are dependent on the maintenance of ecological processes that require protection of primary watersheds such as sedimentation control, regulation of flow regimes and nutrient cycling.

In summary, we selected salmon and grizzly bears as our primary focal species because of their ecological importance, their vulnerability to human impacts and because sufficient data (both spatial and specific life-history data) exists to identify habitat requirements and suitable habitat areas.

Old Growth Forests

Identification and representation a range of ecological community types is central to coarse-filter design strategies. In particular, threatened, critical or rare vegetation types are key components of CAD. 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 (Smith and Lee 2000). The reason for this is not because old growth forests are exceptionally vulnerable to human disturbance. Instead the forests themselves, particularly stands of large and 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. Some of the last intact areas of productive old growth temperate rainforest are found along the coast of B.C.

Intact watersheds containing productive old growth forest are globally rare and contain characteristic features of coastal temperate rainforest ecosystem biodiversity including a range of plant, wildlife and invertebrate species. Additional features found in old growth forests include coastal muskeg, intact predator – prey systems, intertidal habitat, riparian areas and other necessary habitat features for many native wildlife species. 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. These structural characteristics are pronounced in highly productive areas containing large and old trees.

Thus, we developed methods to identify and rank intact areas based on woody species composition and structural characteristics, with the goal of representing a range of structural and functional features that are characteristic of highly productive old growth coastal temperate rainforests.

Riparian areas: hydrological processes and landscape connectivity

Riparian areas (often call "riparian zones") represent another critical vegetation community that includes a range of features important for Conservation Area Design. Riparian areas include the biotic communities living on and around the shores of streams, rivers, ponds lakes and wetlands. Riparian areas are the most species rich and structurally diverse habitat type found in the coastal temperate rainforest. These areas provide crucial habitat for the majority of native species in the region, and they are among the most threatened and ecologically sensitive habitat types across the landscape (Naiman *et al.* 1993; Gregory 1997; Naiman *et al.* 2000).

Additionally, comprehensive conservation planning calls for consideration and protection of ecological processes (Noss and Cooperider 1994). Riparian area conservation is critical for maintaining key hydrological processes and complex dynamics between aquatic and terrestrial ecological systems. On a landscape scale, riparian areas also form natural wildlife corridors critical for maintaining landscape connectivity both within and between watersheds.

Finally, a huge body of research exists related to the management of riparian areas, including substantial research directly on the ecology and management of riparian areas of the coastal temperate rainforest (FEMAT 1993; Naiman *et al.* 2000). Thus, conservation of riparian areas is a crucial component of this CAD.

Use of the CAD

In summary, we set out to identify and prioritize areas for maintaining and restoring large carnivore populations, salmon stocks, old growth forests and riparian areas with specific consideration of hydrological processes and landscape connectivity. We suggest that these taxa, communities and processes define and represent the vulnerable, historically impacted and keystone elements of the coastal temperate rainforest ecosystem of BC. We assume that maintaining these attributes will help conserve all components of biodiversity at natural levels of abundance and distribution.

We identified conservation areas using modified methods that were developed for the central coast region. Results are summarized in Table 3 and presented in Maps 1-3. Although 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 BC's coastal temperate rainforest. 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. In fact, this version of analysis builds on a previous CAD for the central coast of B.C. While there is much overlap in areas delineated, the addition of new information necessarily changes the results to some degree, based on new information and improved quantitative approaches. We suggest that this process of refinement should continue over time and is necessary for responsible management and decision-making.

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 coastal temperate rainforest 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 step towards eventual conservation – but a necessary step. It is based on incomplete information, limited spatial resolution and current scientific understanding. As such, we expect our delineation maps and accompanying analysis to evolve (as this work has evolved from the central coast CAD) as others input newly emerging information. We welcome such change and urge researchers to seize the initiative we have provided and continue to fill in the "gaps". Nevertheless, we suggest that this CAD contains usable and defensible tools, and identifies and prioritizes conservation areas for the coastal temperate rainforest of B.C.

METHODS

Study area and data sources

The study area (Maps 1-3) extends roughly from Johnstone Strait in the south to Portland Inlet in the north. The study area is defined by the occurrence of coastal temperate rainforest, defined as watersheds containing coastal western hemlock (CWH) biogeoclimatic zone. The western boundary was originally intended to include all primary watersheds containing CWH. However, portions of some primary watersheds (e.g. Skeena river) were excluded because of lack of spatial data. Ideally, this CAD would have spanned the entire coastal temperate rain forest of North America, including areas in southern B.C., California, Oregon, Washington, and Alaska. However, we were limited by the availability of digital spatial data, and we were motivated by an immediate need for analysis of B.C. areas that are currently under development threat. We assume that methods developed here are generally applicable to other areas of coastal temperate rainforest, should data become available. Data was taken from several government sources and included information on forest cover, terrain, elevation, salmon escapement and watersheds (Tables 1 and 2).

Watersheds: Units of analysis and Management

Watersheds defined both the unit of analysis and management *a priori*. In general, we believe that watershed boundaries are appropriate for delineating different management prescriptions because 1) the region is dominated by rain and has many discrete freshwater river systems and, 2) ecological linkages within watersheds tend to be stronger than those between watersheds. We also believe that the scale of watersheds was appropriate compared to the information used in analysis. In addition, our primary focal species, grizzly bears and pacific salmon, tend to be strongly linked to ecological processes at a watershed-scale.

Watershed boundaries were taken from the B.C. watershed atlas and *watersheds* were defined as those with unique 45 digit identifiers. *Primary watersheds* include all *watersheds* that share a common saltwater exit point. *Primary watersheds* were thus composed of an aggregation of one or more *watersheds* (which are sometimes referred to as sub-watersheds, secondary watersheds, tertiary watersheds etc.; see Figure 7 for an example). Note that *primary watersheds* can be sub-divided into any number of arbitrary units. We used the B.C. watershed atlas to define our unit of analysis and management for convenience, since it is an established, systematic and well-documented method to divide primary watersheds into discrete units.

We calculated several indices for comparing watershed characteristics. To allow direct comparison of watershed values, we first normalized the quantity of any particular physical attributes by log transformation, then calculated a standard z-score (Figure 1). This was done for several physical characteristics of watersheds including old growth area, riparian area and salmon escapement numbers. This procedure allowed us to directly compare the physical characteristics of watersheds using meaningful units, since the mean z-score for the entire study area is, by definition, approximately 0 and 1 unit represents one standard deviation from the mean value. For example, a z-score of 0.5 for riparian area means that particular watershed has 0.5 standard deviations greater than the mean for riparian area compared to all watersheds in the study area. Using z-score values also allows values to be combined such that each characteristic receives equal weight and with explicit consideration of the relative rarity of any watershed characteristic. For example, in order to rank watersheds based on grizzly bear habitat, we combined known habitat characteristics into a single index score.

Area Classification

Several area classification types were defined *a priori*. These were *Core Conservation Areas* (composed of three sub-areas: *Core Intact Areas*, *Core Grizzly Bear/Salmon Habitat Areas*, and *Core Restoration Areas),* and *Linkage Areas (*composed of two sub-areas (*Linkage Watersheds* and *Riparian & Salmon Conservation Areas*). Methods and brief justifications for identifying each type of area are described in the following sections.

Core Conservation Areas

Core Intact Areas

Core Intact Areas were defined as watersheds that had relatively low levels of human logging and low road density that also had productive and structurally diverse old growth forest ecosystems, which were distinguished by late-successional plant communities and related structural features. We employed coarse-filter methods to identify *Core Intact Areas*. We used logging data, road data, BC biogeoclimatic zone classification, and forestry data (see Table 1 for details). Forest cover data was corrected for recently logged areas using satellite imagery (1993 –2000) from Sierra Club of BC. 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 (OGI) for all watersheds to further rank and prioritize areas (Figure 2). For each focal tree species group, total area was calculated and normalized by calculating a standard z-score. The OGI consisted of the mean z-score (for all focal tree species) for each watershed. As such, the OGI accounts for both the total amount of old growth, and amount of old growth of the three focal species listed above, with each receiving equal weight in the index (Figure 2).

This is done in order to capture and represent in *Core Intact Areas* the structural, functional, and age characteristics of old growth forests that differ according to species composition. For example, Douglas fir is associated with drier areas on East Side slopes in sub-maritime areas while Sitka spruce tends to be associated with floodplain and riparian areas. Western red cedar is usually associated with low elevation wet hyper-maritime and maritime areas, most notably on steeper slopes with infrequent disturbances (e.g. wind-related mortality) and it is replaced by yellow cedar at higher elevations (Pojar, Klinka and Meidinger 1987; Meidinger and Pojar 1991). In this way watersheds containing more rare species groups, a combination of species groups, or larger areas of productive old growth were assigned higher scores.

We assumed that *Core Intact Areas* include a range of native plant, wildlife and invertebrate species characteristic of coastal temperate rainforest, and conservation of *Core Intact Areas* also promotes conservation of all such native species (even those that are largely unknown). We also acknowledge that different types of impacts (e.g. logging in sensitive areas) will differentially influence the ecological intactness of any particular watershed. As such, we also assume that percentage of logging and road density are sufficient surrogates for ecological intactness.

High Value Grizzly Bear/Salmon Watersheds

We developed a simple model to identify and rank watersheds based on habitat elements known to be important for grizzly bears and salmon populations. Our model utilized the fact that grizzly bears have well know habitat associations or requirements and we log normalized each element, computed a standard z-score, and computed the average z-score for all elements to derive a GBI for each watershed (Table 2 and Figure 3). The GBI is a measure of potential for grizzly bears, it is not a measure of relative bear numbers present today.

Individual watersheds with a high density of roads were screened out from consideration as a *High Value Grizzly Bear Watershed*. Roads and road characteristics are primary determinants of long-term grizzly bear habitat suitability. Most bears are killed by humans within 2.5 km of drivable roads and a number of studies suggest that road densities for grizzly bear habitat should not exceed 0.6 km/km2 and target levels of road density for long-term persistence should be no more than about 0.35 km/km2 (Mace *et al.* 1996). Therefore, we eliminated watersheds with high road densities from consideration as *High Value Grizzly Bear Watersheds*. Many of these areas that were eliminated due to high road density probably had some of the most productive habitats for grizzly bears in B.C., and probably retain substantial positive habitat characteristics. Nevertheless, history has shown that, because humans are the primary source of grizzly bear mortality, road density is an accurate predictor of long-term grizzly bear persistence (for reviews, see Mattson *et al.* 1996; Horejsi, Gilbert and Craighead 1998) .

Following the calculation of indices for all watersheds, and excluding heavily roaded areas (> 0.35 km/km2 road density), we set a threshold for inclusion as a *High Value Grizzly Bear/Salmon Watersheds.* The threshold was derived from field data collected in 1997 & 1998 by Raincoast Conservation Society and Round River Conservation Studies.

A number of watersheds were assessed as having high grizzly bear activity areas (based on tracks, day beds, bear trails, scat, sign, and sightings) from field data. Although we did not randomly sample the entire study area for grizzly bear activity, we believe that our field data can be used to test and calibrate our habitat potential model because it does identify known high value grizzly bear areas. Indeed, there was good correspondence between the model and field assessments (Figure 4). High bear use areas had significantly higher GBI scores ($p < 0.01$, Figure 4 arrow) than randomly chosen watersheds. Since we wanted to be certain that the thresholds for delineating high value watersheds included known areas of high grizzly bear activity, we set our threshold for assigning core watersheds at a level that captured 95% of high bear use areas (GBI = 0.364, Figure 4). Thus, all watersheds that had GBI scores greater than threshold and low road density were delineated as *High Value Grizzly Bear Watersheds*.

Grizzly Bear/Salmon Primary Watersheds

Grizzly bears, and many other wildlife species found on the coast of B.C., are highly dependent on healthy salmon runs. Salmon, in turn, require the conservation of entire primary watersheds -- the encompassing watershed that is serviced by a river or inlet that flows directly into the ocean -- not just the smaller, secondary, or tertiary watersheds upon which the analysis was carried out. Additionally, large carnivores require large areas of contiguous habitat for long-term persistence. Since the long-term fates of salmon and grizzly bears are closely linked, we delineate *primary watersheds* as our unit of conservation (Figure 7). However, much of our data was sparse and the quality of data between areas is not known. To reduce the bias against areas that had lower quality (i.e. areas that had more errors of omission), we employed a modified winner-take-all strategy for identifying *Grizzly Bear/Salmon Primary Watersheds*. The score for each *Grizzly Bear/Salmon Primary watershed* was assigned the highest value of any component watershed located within its boundary. Any primary watershed that contained a *High Value Grizzly Bear/Salmon* watershed was delineated as a *Grizzly Bear/Salmon Primary Watershed.* Thus, watersheds with GBI > 0.36 and road density of < 0.35 km/km2 were expanded to include their entire primary watershed.

Core Grizzly Bear/Salmon Conservation Areas and Core Restoration Areas

We suggest that management within the primary watersheds should differ according to habitat values and level of historical human impact. *High Value Grizzly Bear Watersheds,* i.e. those with both high habitat value and low road density (Figure 6), should receive highest priority, and indeed, all these areas are designated as core conservation areas within the overall primary watershed unit. We further separated core areas according to the amount of logging that has impacted the watershed. *High Value Grizzly Bear Watersheds* with greater than 15 % logging impacts (on the productive forests) were designated as *Core Restoration Areas* where substantial habitat still exists but has been impacted by logging and associated activities. *Core Grizzly Bear/Salmon Habitat Areas* were High Value Grizzly Bear Watersheds that have had less than 15% of their productive forested area logged. The remainder of the watersheds present in the *Grizzly Bear/Salmon Primary Watersheds* were designated as Linkage Watersheds (see below). Note that some of these areas are also *Grizzly Bear Vulnerability Areas*.

Linkage Areas

Regional Conservation Area Designs should account for long-term connectivity between core 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 – *Riparian and Salmon Conservation Areas*, and *Linkage Watersheds*.

Linkage Watersheds

Linkage watersheds are delineated as part of *Grizzly Bear/Salmon Primary Watersheds*, but have relatively low amounts of grizzly bear habitat elements. Many of the *Linkage Watersheds* are made up primarily of high elevation “rock and ice”. They nevertheless serve to connect the thin strips of productive low elevation old growth forests that they are often found adjacent to. As such, *Linkage Watersheds* play a potentially important role in maintaining natural levels of connectivity between *Core Conservation Areas*.

Riparian and Salmon Conservation Areas

These are salmon bearing watersheds outside of *Core Conservation Areas*. The spatial extent of the *Riparian and Salmon Conservation 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 compatible buffers (FEMAT 1993) around riparian areas are used as the starting point for this linkage area but some sensitive locations (e.g. habitat surrounding spawning beds) may require more extensive protection.

Grizzly Bear Vulnerability Areas

We identify watersheds that had both high grizzly bear index scores (> 0.364) and road density greater than thresholds described in the scientific literature (0.6 km/km2). These are areas where grizzly bear habitat is located in accessible areas, and we suggest that these are areas where grizzly bears either avoid habitat with high road density, or become vulnerable to human caused mortality.

RESULTS

Core Area Summary

A summary of results is shown on Table 3. In total, all core conservation areas cover about 54% of the land area yet harbor approximately 84% of the remaining productive old growth forest and 65% of the salmon stocks. Omitted from *Core Conservation Areas* are the most highly impacted areas, including the main stem of the Skeena River, the Kitimat river watershed and substantial areas in the southern portion of the study area. Although these areas are not considered Core Conservation Areas, their size, diversity and historical productivity suggests that they should not be ignored in conservation efforts and planning, and are especially important for maintaining connectivity through the conservation of riparian zones. Also omitted are watersheds with little productive habitat, especially those that contain primarily alpine tundra, consisting of primarily rock and ice. These results are consistent with previous findings that suggest alpine habitats are sufficiently represented in the B.C. protected area network and are not immediately threatened. Nevertheless, non-core areas are important components of the coastal landscape, especially for overall landscape connectivity and maintenance of ecological processes that require entire primary watersheds. The spatial configuration of the Conservation Area Design is shown on Map 3. We define 3 types of Core Conservation Areas, which are described in the following sections.

Core Intact Areas

Core Intact Areas are shown on Map 1. These are watersheds that have less than 10% of their forested area logged and a road density of less than 0.2 kilometers of linear road per square kilometer. Such watersheds are increasingly rare in the landscape. Figure 8 shows results from ranking Core Intact Areas, and the watersheds with the highest old growth index scores are shown. Note that intact watersheds that have larger stands of rare species types (e.g. douglas fir) tend to get a higher index score.

Core GB/Salmon and Core Restoration Areas

Core Grizzly Bear/Salmon and *Core Restoration Areas* are shown on Map 2. These were areas that had relatively large amounts of identified habitat characteristics necessary for grizzly bears and relatively low road density. Core areas for the central coast were defined in a previous study, using similar methods (Jeo *et al.* 1999). Note that these areas have changed slightly. The reasons for the differences include the fact that we revised the model for ranking areas to provide better comparison of values (we are now log transforming data and using the z-score for normalizing scores). More important, however, is the fact that we are examining a larger study area -- some central coast watersheds score higher relative to their northward neighbors and are thus included as *Core Conservation Areas*. Additionally, there have been changes in logging, and we used the latest logging data (Satellite imagery analysis from the Sierra Club of B.C.)

Figure 9 shows the top 25 ranked watersheds based on their grizzly bear index score. Note that many of these are Core Restoration Areas, watersheds that had relatively high grizzly bear index scores, and moderate, but below threshold, road densities. These areas probably had much higher historic biological value, but have been impacted by recent logging and road construction. Nevertheless, they retain substantial conservation value, which could be enhanced through select restoration efforts. These might include road deactivation, selective thinning and removal of human infrastructures.

Linkage Areas

Linkage Watersheds are shown on Map 2. These are watersheds within the boundaries of *Grizzly Bear/Salmon Primary Watersheds*. Although *Linkage Watersheds* have varying (sometime low) amounts of grizzly bear habitat elements, the conservation of these areas is critically important for maintaining inter- and intra-watershed connectivity. They are also necessary for maintaining the integrity of the entire watershed, and necessary to preserve ecological functioning for salmon As such, human activities within these areas should not impede natural movement of large carnivores and should not impact terrestrial or aquatic salmon habitat.

Additionally, impacted areas that have salmon presence and are not *Core Conservation Areas*, were defined as *Riparian and Salmon Conservation Areas*. Riparian areas comprise one of the few known natural corridors in the landscape. Human activities in these areas should not impact terrestrial or aquatic salmon habitat and should not impede the movement of large carnivores through the landscape.

Grizzly Bear Vulnerability and Human Conflict Areas

Grizzly Bear High Vulnerability Areas are shown on Map 2 and figure 10. These arere areas that had both high grizzly bear index scores and high (above threshold) road densities. As such, these were once high value grizzly bear habitat, but may have been converted through human impacts into low value habitat. Some of these areas may still harbor positive habitat characteristics and attract grizzly bears into these areas, but human accessibility may eventually lead to conflict. Thus these areas may eventually become substantial population sinks, where grizzly bears are more vulnerable to human-induced mortality. We recommend that these areas should be closely monitored, as they are likely areas where poaching and other forms of legal and illegal bear harvest could potentially occur.

DISCUSSION

Human Activities

Our goals for conservation include protection of viable populations of all native species, representation of all ecosystems types, and consideration of large-scale ecological processes and long-term evolutionary potential. As such, we chose salmon and grizzly bears as focal species, and productive old growth ecosystems as the primary coarse filter target for guiding the design of conservation areas. We then identified a number of watersheds that are conservation priorities, based on focal species or coarse-filter analysis. Implementing protection mechanisms and policies in these areas represents a far more challenging task, and to that end, we discuss briefly some human activities associated with the different area designations. Determining the types of human activities that should occur in such areas and implementing conservation oriented management policies are both critical factors that will determine the success or failure of conservation in these identified areas. For example, simple designation of strictly protected areas may not be ideal for the long-term protection of some species, since areas designated as national or provincial parks may eventually be developed for recreation and tourism, and permanent park infrastructure is often located in inappropriate locations for wildlife. In addition, because species tend to go extinct in strictly protected areas as thesey areas become isolated {Newmark, 1995 #33;Newmark, 1996 #111}, management of the entire landscape becomes an important factor for long-term species persistence. We believe that a combination of management designations, that may include strictly protected areas (that are not necessarily parks), wildlife management zones, community-based conservancies, and ecologically-based forestry areas, could provide a sound and defensible design for conservation in the region, as long as human impacts on wildlife are thoughtfully considered in each type of management area. The exact designations and management prescriptions remain an unanswered challenge for policy makers in the region. Nevertheless, no matter what the exact designation, human activities in these designated areas should be limited.

Core Intact Areas

Core Intact Areas were designed to identify and conserve a range of coastal old growth forest ecosystems. As such, human activities in these areas should not impact long-term ecosystem functioning. Large-scale industrial logging, road construction and unrestricted commercial hunting of top-carnivores will likely have ecosystem-wide impacts and therefore may need to be excluded. We recognize that a number of ecosystems types are not included in this coarse-filter approach. These include many coastal island ecosystems, which may contain substantial endemic species and rare vegetation assemblages. However, because island ecosystems are under less severe development threats and are well-represented in the current protected area network, we did not perform extensive analysis that included these ecosystems types. We suggest that further analyses should be performed, centered on representation of a range of ecological targets, and then used to update and refine the CAD, if necessary.

Core Grizzly Bear/Salmon areas and *Core Restoration Areas*

We suggest that very limited intensive human activity take place within these *Core Areas*. For any area to safeguard grizzly bear populations, human access, which is closely linked with human/grizzly bear conflict, should be minimized. For grizzly bears, their persistence is largely determined by human-caused mortality (for reviews see Mattson *et al.* 1996; Horejsi *et al.* 1998). As such the decline of grizzly bears over the last 100 years is clearly linked to human-caused mortality, which continues to account for virtually all deaths of grizzly bears older than 1 year old in studied populations in Canada and the US. The conclusion from the few available demographic studies suggests that survivorship of females, which is largely determined by the frequency and lethality of human contact, is the primary determinant of population growth and decline (Mattson and Reid 1991), modified by the effects of food abundance on recruitment (Bunnell and Tait 1981; Stringham 1990). As such, conservation areas for grizzly bears must provide security areas, free from potential human contact, as well as productive habitat areas. Thus, we have attempted to identify where productive habitats and low road density are found together at an appropriate biological scale (watersheds). We determined habitat productivity based on identifiable characteristics that are known to be important for grizzly bear populations. Consequently, some of these areas might not contain the highest current or historical population densities. We suggest that this is probably due to two principal factors, 1) many of the most productive areas have already been developed and, 2) many populations in highly productive area have declined due to legal hunting, poaching and predator control activities. Nevertheless, we suggest that maintaining habitat and low levels of human impacts (especially roads and other forms of human access) in the *Core Grizzly Bear/Salmon Areas* represents the most efficient means to promote long-term grizzly bear conservation in the region, and will be far cheaper and more effective than attempting to mitigate predator conflicts in developed areas. As such large-scale industrial logging, unregulated commercial hunting of carnivores, road construction, and establishment of permanent human infrastructures are all activities that may need to be excluded from these core areas. In addition, the scientific literature indicates that motorized access to freshwater systems should also be evaluated very carefully with regard to its impacts. Subsistence and recreational uses could likely continue with monitoring plans and adequate safeguards in place. Because core areas in isolation may not be sufficient for long-term persistence of grizzly bears, determining the minimum area necessary and evaluating the human activities occurring in areas adjacent to core grizzly bear/salmon areas may prove to be necessary "next steps" in conservation planning for the region (see discussion below of "how much is enough?").

Many key areas have been subjected to some industrial logging and road construction, yet still have substantial grizzly bear habitat characteristics and relatively low road density. Therefore, in addition to limiting industrial resource extraction in *Core Restoration Areas*, active ecological restoration (including the deactivation of roads and plantation thinning) may be necessary in these areas. Current industrial logging activities should be phased out with a short time frame. One possible mechanism for phase out is the immediate application of ecologically-based forestry techniques (e.g., variable retention forestry). Access control and strict monitoring may also be necessary to prevent these areas from becoming grizzly bear population sinks.

Linkage Watersheds

Although the threats to many of the *Linkage Area* are relatively low, these are key areas for maintaining landscape connectivity. In addition, because *Linkage Areas* encompass entire primary watersheds containing *core* habitat, they are critical for providing buffer zones against human-caused mortality and for maintaining large-scale ecological processes. In general, these areas should be specifically maintained to provide adequate connectivity for large carnivores. As such, they may be open for a number of human activities to occur, including recreational use and sustainable resource extraction with adequate safeguards. Activities that significantly impact *core* areas and connectivity should not be allowed.

Riparian Linkage / Salmon Conservation Areas

Human activities that occur 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. Hhuman activities y that have relatively low risk of significant disruption could occur an in these areas, including ecologically-oriented. In particular, adequate streamside riparian habitat should be safeguarded from human activity (roads, logging, etc.). We propose buffers along all streams that should at a minimum follow the recommendations of FEMAT (1993). Subsistence level harvesting (e.g., hunting, fishing, etc.) could continue with adequate safeguards, as could recreational use, provided they do not significantly affect riparian processes, salmon viability or landscape connectivity.

Economic costs and benefits of forest conservation

Conservation is more likely to succeed when potential benefits outweigh costs for all relevant decision makers. Unfortunately, where valuable natural resources are present, the potential short term economic gain from resource extraction often exceeds the direct economic benefit derived from conservation at national and local scales. Largely ignored, however, are the longer-term global economic benefits related to conservation. Consideration of the economic driving forces at these multiple scales could better inform conservation efforts. In the absence of formal analysis, a brief examination of recent research related to the economic costs and benefits associated with conservation can lend substantial insight into conflicts surrounding use of forests in British Columbia.

A recent study (Kremen *et al.* 2000) examined costs and benefits associated with a proposed new protected area on the northeast coast of Madagascar. Much like the coast of B.C., forests in Madagascar have globally significant biodiversity characteristics and are threatened by industrial logging plans. In addition, forests in Madagascar are also subject to subsistence hunting and local forest clearing for agricultural use, so long-term conservation in Madagascar must also account for the economic forces that motivate local residents. In order to assess the sustainability of conservation efforts (including the creation of a new national park), various economic analyses were performed which compared economic benefits associated with the new park with industrial logging. Kremen and colleagues found that economic benefits derived from conservation (e.g., large-scale ecosystem services, small enterprise job creation, tourism revenues, etc.) outweighed those associated with industrial logging (e.g., tax revenue, jobs with logging companies, stumpage fees, etc.) at global and local scales, although in order for conservation to be beneficial at a local scale, substantial outside input, in the form of an Integrated Conservation Development Project (which included job training and development of local industries in a buffer zone surrounding the new park), was necessary. However, at a national scale, benefits from industrial logging were several times greater than those from conservation. In other words, creation of the new park would only come at a substantial cost to the Malagasy government, although the local residents and the global community would benefit greatly Kremen suggested that carbon-banking procedures, under the Kyoto protocol, could help the national government subsidize some of the costs of maintaining and conserving forests.

A number of recent studies have highlighted the potentially enormous economic losses due to the degradation of biological diversity (Heywood 1995; Daily 1997). Worldwide environmental goods and services have been valued at between 3 and 33 trillion US dollars annually (Pimentel *et al.* 1992; Costanza and et.al. 1997). The massive, intact biomass found in the coastal rainforests of B.C. contribute to these ecosystem goods and services through the maintenance of ecosystem services that are derived from ecological functions. These ecosystem services include nutrient and water cycling, carbon sequestration and organic matter decomposition. Coincidentally, many of these services are intricately intertwined with wildlife habitat requirements.

Economic benefits to local residents are somewhat more difficult to quantify. . A huge amount of research has been conducted around the world to understand the linkage between the interests of local people and conservation (e.g., Western, Wright and Strum 1994). Although the success of such programs has been mixed, lessons learned from these "conservation development" efforts suggest that directly linking conservation with economic benefits can be a successful strategy for sustainable conservation under a variety of circumstances. From a purely economic perspective, any substantial reductions in wildlife (especially salmon populations) would be massively expensive to mitigate. Additionally, opportunities exist for local enterprise creation, once the disruption of industrial logging operations is removed, although substantial infrastructure and policy changes admittedly must be in place before local communities could implement such operations. These enterprises could include both consumptive (e.g., small forestry operations) and non-consumptive (e.g., ecotourism) operations. Careful economic analysis could include detailed exploration of such opportunities, highlighting where strategic local development could facilitate conservation efforts.

Nevertheless, although local communities and First Nations may potentially benefit from conservation of coastal forests in B.C. , most of the benefits associated with conservation are reaped outside of the country. Thus, to promote conservation in the region, some of the economic burden should be transferred to those who stand to benefit (i.e., the global community). Indeed, the interests of the global community have already been a driving force for conservation in the region. For example, the vast majority of philanthropic grants for conservation on the B.C. coast originate from outside of Canada. Additionally, the European wood-product market campaign, initiated by environmental organizations, has also been a driving force behind land-use negotiations. Continued global interest in B.C. coastal forest conservation is likely and recognition of such interests is critical in order to resolve conflicts between conservation and industry interests

How much is enough?

Ecological Processes

A number of scientists have taken a quantitative approach to defining the areas necessary to protect ecological processes. Pickett and Thompson (Pickett and Thompson 1988) define a "minimum dynamic area" as the smallest area that contains patches unaffected by the largest expected disturbances. Large size is required to allow decolonization from undisturbed patches within the reserve. Shugart and West (Shugart and West 1981) argue that in order to maintain a landscape's dynamic ecological processes in equilibrium, a reserve ought to be 50- 100 times larger than a typical large disturbance. However, calculations at this scale are unrealistic to conservation planners and agency decision makers. For example, the fires in and around Yellowstone National Park in the US were larger in size than the park itself, suggesting that in order to maintain ecological processes, the park would have to be much larger. Nevertheless, exactly how much bigger should the park be to maintain ecological functioning remains uncertain, and the issue is unlikely to be addressed at a policy-level. We again emphasize that the control of human activities and development is the key to the maintenance of ecological processes. As such, strictly protected areas may not be necessary, and will certainly be too small, to maintain some ecological processes. For example, we suggest that recommended human activities in salmon/riparian conservation areas and linkage areas (see above section, **human activities**), are consistent with the maintenance of two key ecological processes, namely the maintenance of hydrological processes and population connectivity. Substantial human development could take place within these areas, as long as necessary precautions are taken to ensure that development does not impair ecosystem functioning, and therefore, designation of strictly protected areas based on these ecological processes may be an inefficient use of conservation resources. However, a notable exception may be the maintenance of predator-prey dynamics, which requires conservation of top carnivores (discussed in the following sections).

Population Viability and Habitat Area

Although estimating population viability has been forwarded as a major objective of conservation science (Shaffer 1981; Boyce 1992), the necessary data required to accurately determine the viability of populations are usually absent. These data include vital demographic rates (e.g. age-specific mortality rates, mean litter size, sex ratio, inter-birth intervals etc.) that influence population growth and decline, as well as the natural level of variance in all vital rates. Determining vital rates is costly and time consuming, and can take years of intensive study. Consequently, most attempts to assess population viability and subsequently determine "how much is enough" often result in a correct and responsible conclusion of uncertainty. Even when vital rates are known (or estimated), the exact linkages between habitat area requirements and vital demographic rates are often not well enough understood to draw conclusions of any confidence regarding "how much is enough".

Nevertheless, recent work on large carnivore extinctions in protected areas, grizzly bear population viability in B.C. and source-sink dynamics can illuminate the "how much is enough" question. A recent study (Wielgus 2002) circumvented the lack of demographic data for B.C. grizzly bear populations by estimating vital rates using data from studied populations. Wielgus then used these estimates of vital rates to project population growth rates for B.C. grizzly bear populations. The general goal of the study was to determine the minimum number of bears that make up a "benchmark" grizzly bear population, defined as a naturally regulated populations, (i.e., uninfluenced by human-caused mortality) that was large enough to accommodate environmental and demographic stochastic effects above local extinction thresholds (set at $N < 100$ animals), based on the estimated demographic rates. Benchmark populations can serve as source populations for surrounding hunted areas, and also provide information on natural population processes in the absence of hunting. Wielgus then extrapolated the area required to house the benchmark population, based on estimated population density and home range size. Wielgus suggests that the minimum number of bears to make up a benchmark population is approximately 250. He concluded that the necessary area for benchmark populations varied between 8556 km2 and 17,843 km2, depending on population density estimates.

These estimates are consistent with recent work by Woodroffe and Ginsberg examining the relationship between edge-effects and other factors with carnivore persistence in protected areas (Woodroffe and Ginsberg 1998). Substantial work in the 1980's in conservation biology was focused on the problems inherent to small populations, and theory generally predicts that small populations may be driven to extinction by random fluctuations in demography and genetics. In contrast, Woodroffe and Ginsberg found that initial population size was a poor predictor of extinction of large carnivores inhabiting protected areas. Instead, the primary determinant of large carnivore persistence was the level of conflict on the reserve border, and the species most likely to disappear from small reserves were those with the largest home ranges, irrespective of initial population size. They calculated a "critical reserve size" for several large carnivores, where logistic regression models predict a 50% probability of population persistence based on home range size. For grizzly bears, critical reserve size was estimated to be 3981 km2; increasing reserve size by a factor of 10 (i.e., to a size on the order of 10,000 km2 – 40,000 km2) was necessary to increase persistence probability to approximately 80%. This work is also consistent with research by Doak (1995), who examined spatial source-sink dynamics in Yellowstone grizzly bear populations. Results from simple source-sink models suggest that grizzly bear populations will thus grow or decline as the ratio of sink (human-accessible) to source (remote) habitat changes, and this also depends on the movement by bears between the two types of habitat.

In summary, the specific reasons that grizzly bears require large contiguous areas in order to persist are twofold: 1) because grizzly bears exist in low densities, large areas are required to maintain a sufficiently large population size to overcome the risk of extinction due to demographic variability, and 2) large areas are necessary to minimize human mortality at the edges of protected areas; these areas must be large enough to maintain a favorable source-sink ratio.

Management Implications

Although it is difficult (and perhaps dangerous) to directly transform these results into specific management prescriptions for coastal grizzly bear populations, the reviewed studies do provide concrete illumination of the question of "how much is enough" and, coupled with the identified *Core* areas and grizzly bear population units, several patterns begin to emerge. First, maintenance of a single population of grizzly bears with relatively low risk of extinction would require a starting population of at least 250 bears and although exact population density is not known, this would probably require somewhere between 3,000 km2 and 10,000 km2 of contiguous area. Furthermore, in order to minimize edge effects, necessary buffers around these areas might increase area requirements to between 10,000 km2 and 40,000 km2. This range is also consistent with published critical reserve size for grizzly bears. Second, because edge-effects are critical and source-sink dynamics should be minimized, the shape and configuration of areas is also important. We suggest that edge-effects would be minimized by incorporating entire primary watersheds that contain *Core* habitat. Ideally, several clusters of primary watersheds would be protected as single contiguous units. We suggest that it would be consistent with a precautionary approach to initially provide a greater degree of protection for several (e.g. 2 –3) benchmark population units based on clusters of primary watersheds that encompass at least 10,000 km2 and minimize road density. If we examine grizzly bear population units, two population units immediately stand out (Figure 10), because of their low human impact and large proportion of *Core* area. Kwatna-Owikeeno contains 5,123 km2 (512,355 ha) and Kitlope-Fjordland contains 5,200 km^2 of *Core Grizzly Bear/Salmon* area, and both contain relatively low levels of human impacts throughout the respective units. Additionally, both are adjacent to existing protected areas; thus large, contiguous areas could be created that contain core habitat and low road density. Although we are currently developing optimization algorithms that could facilitate identification and optimal placement of benchmark areas that could receive greater degrees of protection, we suggest that the combination of *Core Grizzly Bear/Salmon*, *Core Restoration* and *Linkage Area* designations and associated human activity limitations within their respective *primary watersheds* would provide sufficient areas for long-term grizzly bear conservation in the region.

The Case for Large Protected Areas

Although the preponderance of evidence from the scientific literature suggests that there may be no substitute for large, strictly protected areas for meeting conservation objectives, even the largest strictly protected area may not be enough for long-term conservation. Species will eventually decline as protected areas begin to resemble habitat islands and surrounding areas become increasingly inhospitable. Thus, identification and protection of large contiguous areas, coupled with the maintenance of favorable conditions outside of these areas, are both equally important for long-term conservation. Despite theses lessons from science, resource managers and decision makers are often tasked with meeting multiple, conflicting demands and are often forced into compromises that result in the incremental degradation of ecosystems. While developing new and innovative solutions for resolving conflicts surrounding conservation is both attractive and pragmatic, we should continue to keep in mind that large carnivores require vast, unfragmented areas, and protection of this scale (no matter how innovative) may be expensive and somewhat unpopular with existing economic interests,, despite a substantial favorable base of public sentiment towards large and charismatic mammals Nevertheless, we believe that this CAD provides usable and defensible tools for designing conservation areas. However, even the best plan or design will come to naught if it is not implemented. If the extinction crisis, now underway globally, is to be tackled locally, the Conservation Area Design for the coastal temperate rainforest of BC must be integrated into 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.

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