Environmental Risk Assessment: Base Case

COARSE FILTER BIODIVERSITY

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FINAL REPORT

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Executive Summary

An Environmental Risk Assessment (ERA) was performed for the North Coast LRMP planning area, in order to assess the implications of the current forest management scenario (the 'Base Case') on coarse filter biodiversity values.

ERA involves a number of general tasks, in particular

- identifying appropriate indicators for the environmental value
- identifying an ecological benchmark against which risk can be measured
- identifying risk relationships and thresholds
- and summarising trends through time

We use the abundance and extent of old forest (>250 years) ecosystems, by ecosystem type, as our basic indicators of the probability of maintaining coarse filter biological diversity, ecosystem function and ultimately ecological integrity in the planning area over time. These were considered appropriate indicators for the planning landscape because the natural disturbance patterns in the North Coast LRMP area primarily result in old forest dominating the landscape.

In order to identify an ecological benchmark, we predict the mean and standard deviation in stand-replacing natural disturbance frequency based on the current seral stage frequency of Analysis Units in the North Coast area, combined with expert opinion where data are lacking (A. Banner and J. Pojar pers. comm.). The negative exponential equation was then used to predict the mean (and range) percent of old forest that would occur naturally in these ecosystems. Sensitivity analysis shows that predicted old forest abundance is relatively insensitive to variation in stand-replacing disturbance frequency within the range of estimates considered appropriate for these ecosystems (700 – 3000 years).

Output from the North Coast Landscape Model (SELES; D. Morgan et al. 2002) was used to provide data on the projected abundance and distribution of old forest within different ecosystems (defined by Analysis Units within biogeoclimatic variants), through time from 0 – 250 years. Comparing predicted natural abundance of old forest within ecosystems to that from the modeling scenario at each time period is our primary indicator of risk for each ecosystem.

We further modify this base risk level for each ecosystem as appropriate by three factors: Representation of Ecosystems in Protected Areas, Ecosystem Conservation Value (a relative value identifying analysis units with higher potential for rare ecosystems or higher influence on surrounding ecosystems etc.), and Trends in area covered by Old Large Forest Patches through time. Precise relationships between risk and each of these modifiers are poorly documented. However, there is extensive theoretical rationale to support the concept that each of these factors does in fact modify levels of risk to coarse filter biodiversity. We used what we considered to be conservative ratings to modify risk.

For each modifier, patterns were examined for that variable, and risk modified as appropriate:

a) poor ecosystem representation in Protected Areas in the North Coast (most ecosystems have <2% representation) resulted in higher risk. Lack of Protected Areas results in a lack of certainty about future protection, (being located outside the current timber harvesting landbase does not afford certain future protection), and fails to provide representative and reference ecosystems;

b) large changes in the numbers of large old forest patches through time resulted in higher risk. The area of forest covered in large (>500ha) old forest patches declined by more than 30% (moderate change) or 70% (large change), for approximately 2/3rd of the ecosystems. Although the links between patch size/ fragmentation and ecological integrity are unquantified, there is evidence that vertebrate species are adapted to natural disturbance patterns (Bunnell 1995), and so a

substantial decline in numbers of large patches will likely result in increased risk to ecological integrity;

c) impacts on high value ecosystems resulted in higher risk. Ecosystem Conservation Values were assigned to ecosystems and risks modified for those with high designations (high ECV is a combination of high probability for unique/ rare systems and high likelihood of influence on other ecosystems e.g. the hydroriparian types).

Identifying risk thresholds is a key element of any risk analysis. As a base set of thresholds, we interpreted percent deviation from natural (0 –100%) to correspond linearly to 5 equal risk classes from very low to very high (0-20% deviation is considered very low risk; 80-100% deviation is considered very high risk). Sensitivity analyses for this model showed that the risk outputs were quite insensitive to the risk categories used. This gives us increased confidence in the relative risk rankings estimated from the assessment model.

Modeling techniques used include graphical assessment of trends of old forest abundance through time, in addition to a modeling process using a Bayesian Belief Network Model (BBN). The BBN allowed us to incorporate expert opinion and uncertainties into the model, and also presents output in terms of probabilities. This approach will be useful in assessing future scenarios (as the Table develops them) likely including the implications of partial harvesting for coarse filter biodiversity.

Overall, there was high divergence from the naturally predicted percent of old forest both currently and into the future, for all high productivity ecosystems, and for most medium productivity ecosystems. There was little or no deviation from predicted natural abundance of old forest for low productivity ecosystems. We interpret the extent of the deviation from natural for the high and medium productivity systems to indicate that most of these units are at high risk, and that the risk increases through time. The number of ecosystems considered at high risk using the Base Risk scenario was 8 of 47 at time zero, and 19 of 47 in 250 years. Using Modified Risk the number of ecosystems at high risk at time zero was 9 of 47 and 24 of 47 after 250 years.

This final report is a revision of a previous report (Draft, September 2002). A number of changes were made to the model as a result of input from various technical reviews (Appendix 1 summarises relevant changes). A summary report (Holt and Sutherland 2003a) is available – for those interested only in the key results of the analysis. This work was performed as one component of a team approach to ERA on the North Coast. Background on the team can be found in the Introductory Report (Reid and Holt 2002).

Acknowledgements

This work was initially inspired by Greg Utzig, who used a similar approach to assess the potential implications of the Kootenay-Boundary LUP. Discussions with many other people have also encouraged this work, in particular Tory Stevens and Per Angelstam. The ERA team provided invaluable support as a group, in particular Don Reid and Doug Steventon who provided technical assistance with Netica. Jim Pojar and Allen Banner kindly allowed their extensive ecological expertise to be drawn upon and used in the model. A draft report was reviewed by a number of people, including Allen Banner, Davide Cuzner, Bill Adair, Marvin Eng, Dave Daust, and Don Morgan, and their comments were incorporated in this final version. Comments and questions from Table members and others at workshops and Table meetings have clarified issues and improved the approach. We thank all for their input.

Report Audience

This report is intended to be read primarily by the North Coast LRMP Public Table. As a result we have minimised, where possible, the level of technical detail in the background information. However we attempted to provide sufficient details so that the report can be satisfactorily reviewed by technical experts. Any failing to achieve this balance should be addressed to the authors, who will provide additional information where necessary.

1.0 Introduction

Management to maintain general environmental values such as 'biodiversity' and 'ecosystem function' generally uses what is known as a 'coarse filter' approach. 'Coarse filters' are used primarily because it is not possible or even desirable to attempt to manage all species individually – numbers of species are too numerous and the vast majority of species and their requirements are unknown in most ecosystems. A number of approaches to designing a coarse filter strategy have been developed, for example using a wide-ranging species such as a grizzly bear to act as an 'umbrella' or 'focal' species. However, using representative ecosystems as the basis for a coarse filter strategy is perhaps the best supported approach (Franklin 1993; Noss 1996a, b; Nally et al. 2002).

In this Environmental Risk Assessment (ERA), we use the abundance, extent of representation and landscape patterning of old forest ecosystems as our basic indicators of the probability of maintaining coarse filter biological diversity, function and ultimately ecological integrity in the North Coast Land and Resource Management Plan (LRMP) area.

The goal for this "Base Case" ERA is to identify the risks to coarse filter biodiversity associated with the current management scenario planned for the North Coast (the Base Case scenario), through the planning horizon from now (Time 0) to 250 years into the future (Time 250) and for different locations in the plan area (e.g. Landscape Units, Analysis Units and BEC variants). For the coarse filter biodiversity assessment we use outputs from the timber supply model used for the ERA Base Case to determine how much, where and which old forest ecosystems are present on the landscape today and that may be present in the future if current management continues.

In order to determine the risks associated with the harvest of different areas of the landscape, we predict how much of each forest ecosystem would be present under 'natural' conditions, and use this as a benchmark against which to reference how divergent the current and future landscapes are from a natural condition. We will interpret the current and projected trends in old forest through time in terms of the risk levels, presented as very low to very high.

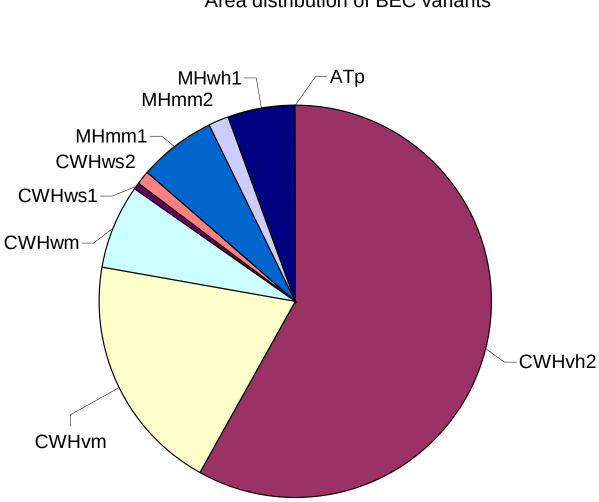
The 'risks' presented and discussed in this report are the probabilities that aspects of ecological integrity will not be maintained in the geographic area, and <u>are not</u> to be translated as 'acceptable' or 'unacceptable' levels of risk.

1.1. Resource description: Global and Regional Importance

The North Coast LRMP area lies within the Coastal Temperate Rainforest. Coastal temperate rainforest is a globally rare biome, represented in North America by the dense evergreen Pacific Coast Conifer Forest, which stretches from northern California through Southeast Alaska (Barbour and Billings 1988; Lawford et al. 1996; Schoonmaker et al. 1997). The ecosystems of this region are not all the same, nor are they all old or oldgrowth. There is a full range of ecosystems, aquatic and terrestrial, forested and non-forested, and a full range of successional stages. Nevertheless, the landscape is overwhelmingly forested, and over most of post-glacial, pre-industrial time most of the forests were old. As a consequence of a history of infrequent large-scale, stand-replacing disturbances in a wet, mild, mountainous environment, productive forests are characterised by big old trees, tremendous accumulations of biomass, coarse woody debris (downed logs + snags) as a key structural component, and gap dynamics (opening sizes typically one to a few tree heights in width, or 0.1 to 3-4 ha in size; larger openings occasional) (Pojar and MacKinnon 1994; Lertzman et al. 1997).It has been estimated that 56% of the world's temperate rainforests have been harvested or converted to non-forest, and that perhaps as little as 3% remain as large areas of unmanaged forest (Bryant et al. 1997). Approximately 25% of the globally remaining coastal temperate rainforest exists in British Columbia (Bryant et al. 1997).

Within the extent of the Coastal Temperate Rainforest in BC, the southern sections have some of the longest harvest histories in the Province, particularly on Vancouver Island and the mainland coast throughout the Georgia Basin where old forest has been harvested extensively. Industrial harvest history is shorter in the North Coast region although A-frame logging, beginning in the 1940's and peaking in the 1970's, has impacted areas accessible from the ocean. Even where harvesting has occurred to date, this region of the province still remains relatively remote due to difficult access, with natural disturbance processes still mostly intact. A 1991 inventory of 354 primary watersheds greater than 5000 ha showed 72 (20%) to be pristine at that time, the majority of which were on the Central and North coast of BC and the Queen Charlottes/ Haida Gwaii (Moore 1991).

Within the North Coast region, there are 5 ecoregions, but the area primarily exists within the Hecate Lowland and Kitimat Ranges (57% and 25% respectively). There are 8 main biogeoclimatic variants[1] (see Current Conditions report for more detail). Figure 1 shows the relative extent of their areas within the NC district.



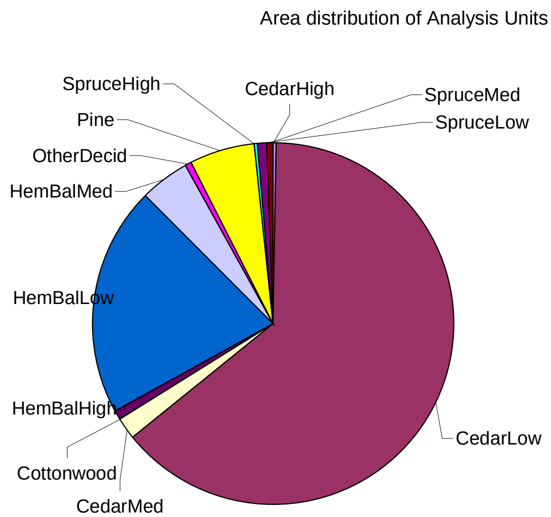


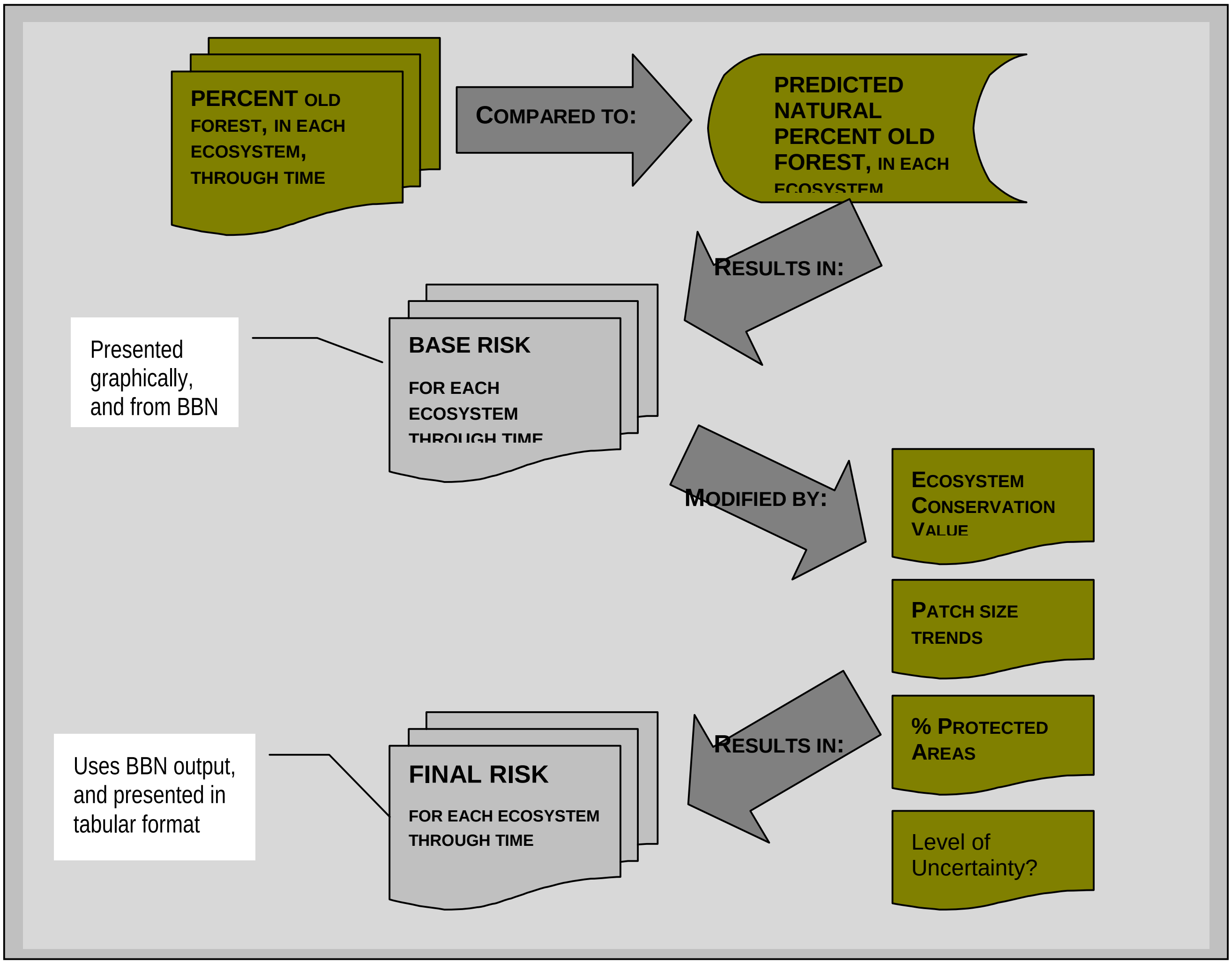
Figure 1. Relative area of BEC variants and Analysis Units within the LRMP region (see Appendix 2).

The primary negative pressure on terrestrial ecosystems in the planning area is assumed to be industrial forest harvesting, and our analysis will focus on this aspect of land use (though note that other activities also affect the terrestrial land base, including reduced salmon abundance resulting in changes to nutrient availability). It is feasible that other resource use (e.g., mining and tourism) may influence the ability of the coarse filter to function adequately. For example, tourism may increase disturbance, or negatively impact key food sources such as salmon in particular areas. Other indicators that link to maintaining ecological integrity may therefore be added at the Table's request, if appropriate, during scenario analyses.

1.2. Conceptual Approach

The ERA for coarse filter biodiversity assumes that the primary parameters influencing the amount of risk for coarse filter biodiversity on the North Coast are the abundance, representation and patterning of old forest present in each ecosystem through time.

[1] the CWHvm is differentiated into variants in some areas of the coast, and not on others. For this analysis the CWHvm is considered undifferentiated.



BBN = Bayesian Belief Network see Methods.

Figure 2. The conceptual model of coarse-filter risk calculation.

1.2.1. Project Scope

This report summarises the results of the Base Case analysis (i.e. the implications of current management). The assumptions of the Base Case analysis are that only cleracut harvesting techniques are used (H. Burger pers. comm.). However, the approach we used was designed to allow more complex scenarios to be analysed in future as they are identified by the North Coast Table. In particular, it is assumed that partial harvesting/ variable retention may be part of a future scenario, and this information was used to guide the approach taken here[2]. The use of Bayesian Belief Networks (BBN) was considered particularly useful because it would in future provide a basis for modeling partial harvest. The approach taken here is therefore not the simplest available, but provides sufficient flexibility that additional factors can later be incorporated.

[2] We have worked with ecological experts (A. Banner and J. Pojar) to identify recovery curves for individual ecosystems that will be used in assessing the implications of partial harvest in future scenarios.

2.0 Definitions

Generic definitions for general forestry terms used in this report can be found in the North Coast Current Conditions report and in the Map and Inventory Handbook[3], including descriptions of biogeoclimatic variants which form the basis of this analysis. This Definitions section provides some additional information for concepts/ parameters relevant to the coarse filter biodiversity model. The definitions given below are not alphabetical, but rather follow a logical flow.

"Environmental Risk Assessment" – a procedure for determining the risks to environmental values based on the premise that divergence from natural patterns increases risks to environmental values (as per MoE 2000). For this analysis we use the abundance, distribution and representation of old forest ecosystems as the general indicator for ecological integrity.

"Bayesian Statistics" – provide a statistical approach to data analysis that is appropriate for complex environmental assessment where a) traditional statistical approaches may fail to identify a problem due to the lack of 'statistical power', and b) where quantitative data are lacking. Bayesian Belief Networks (BBN) are a format for application of Bayesian Statistics that allow expert opinion to be incorporated into a model.

"Biological diversity" - the variability among living organisms from all sources including terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are a part; this includes diversity within species, between species and of ecosystems. The focus of this report is the biological diversity of forested ecosystems in the North Coast.

"Coarse filter" is an approach to management of natural ecosystems that uses broad habitat types as the primary ecological unit to assess consequences of management activities. The objective of a coarse filter is to capture sufficient 'habitat' to maintain the vast majority of ecosystems, populations of species, and genetic variation through time and space. An example is managing for representative amounts and patterning of old forest throughout a landscape. Coarse filter strategies can be applied at the landscape and/ or the stand level. For this assessment we focus at the landscape level, and the coarse filter strategy is primarily associated with managing for old forest[4] throughout the landscape. This 'coarse filter' risk assessment focuses on the risk / probability of failing to maintain an adequate coarse filter management regime which we assume to be related to the probability of maintaining ecological integrity. Failure to maintain ecological integrity is hypothesised to result in species / ecosystem extirpations from areas of the coast. In addition, the complex and largely undocumented processes that maintain the ecosystem will be disturbed and ecosystems will not provide their natural services.

"Fine filter" a management strategy that identifies the environmental values that are not adequately managed using a coarse filter, and identifies specific requirements necessary for management of those elements. An example is management to sustain a rare species with specific habitat requirements. Fine filter management assumes that a coarse filter strategy is managing adequately for the majority of environmental values.

"Landscapes" - large areas (usually in excess of 50,000ha) that are a unit for strategic management planning. The coarse filter assessment focuses at the landscape level, using Landscape Units, which are a Ministry of Forests planning unit. Although not an ecological unit, landscape units (LU) in this region typically comprise a number of watersheds.

"Analysis units (AU)" – we used as a surrogate for ecosystems defined on the basis of leading species[5] in the stand and the productivity of the stand (high, medium and low) – see Appendix 2 for definitions and cross-walk table to most likely site series (A. Banner pers. comm.). AU's were used

[3] Found on the web at: srmrpdwww.env.giv.bc.ca/lrmp/ncoast/mapgallery/index

[4] In other areas of the Province, a coarse filter should also include managing for mature forest, but old forest is the dominant natural seral stage on the north coast, so old forest is the focus of this assessment.

[5] Inventory Type Group

because they provide additional information on ecosystems at a finer scale than that given by biogeoclimatic variants[3], and 'Analysis Units within each BEC variant' are used to define old forest ecosystems for this analysis. Typically, 'site series' are used to identify 'ecosystems' at this scale: site series mapping defines the potential vegetation on a site, rather than what currently occurs there, and is therefore a measure of site potential rather than current condition. However, adequate site series mapping was unavailable for the North Coast at the time of the analysis (M. Eng pers. comm.). AU's can result in an individual site's classification changing through time as species composition changes[6]. This is a potentially significant problem with classification of any areas already harvested, since they will now have designations based on whatever species were planted or came in naturally rather than their original composition. As a result, the area of cedar is likely under-estimated due to stand conversion and the area of spruce may be over-estimated due to an increase in planted spruce in second growth stands (A. Banner pers. comm.). See Section 7.3 for further discussion.

"Old Forest" -described and mapped by the Ministry of Forests as those forests older than 250 years old for most of the ecosystems in the North Coast region. In reality, many of the 'old forests' on the coast are considerably older than 250 years old, and due to the types of natural disturbance in these ecosystems are likely much older than the age of individual trees. For example, gap dynamics produces a stand with trees of many ages (young to old) but the stand itself has existed longer than even the oldest tree.

"Old Forest Ecosystems" - ecosystems can be defined at a range of scales. Implicit in the definition is that one ecosystem is tangibly 'different' from another in terms of species composition, or ecological processes (Kimmins 1987). In this analysis, AU's within BEC variants are used to define ecosystems: this is adequate because AU x BEC[7] does describe significant differences between old forest ecosystems in this landscape (A. Banner pers. comm.). Additionally, large structure (large tall trees) is an ecologically important component of temperate rainforest ecosystems. Although 'high productivity' stands will fail to identify some large structure stands (e.g. slow growing, but old and very large cedar stands on poor sites), using productivity will generally identify the large structure ecosystems. Structure has been shown to be an important component in identifying useful coarse filter indicators (Nally et al. 2002).

"Gap Dynamics" – is the predominant type of disturbance occurring on the North Coast (Dorner and Wong 2003). This involves death of single trees, or groups of trees, and replacement in the canopy with an individual from the understory. The process typically results usually in complex, 'multi-layered' forest stands of great age. Note also that a variation on typical gap dynamics occurs in the low productivity scrub/ bog forest of the Hecate Lowland where trees are effectively 'islands' in a matrix of scrubby openings (J. Pojar pers. comm.).

"Range of natural variability (RONV)" - due to natural disturbances, ecosystems are dynamic and are never static. The RONV is a term used to describe the natural amount of variability in natural disturbances in a given ecosystem. For example, in some ecosystems in the interior of BC, large fires periodically disturb large areas of forest. Describing the mean and variability in occurrence of fires over a given period of time would describe the RONV for that ecosystem. For the North Coast, there are few stand-replacing relatively large disturbances and the area is dominated by gap dynamics, however there is a cumulative set of disturbance (windthrow, avalanche, debris torrents) that continually disturb forest stands, and prevent the entire landscape from becoming old forest (Dorner and Wong 2002).

"Ecological Integrity" - the state of a natural unmanaged or managed ecosystem in which the natural ecological processes are sustained, with genetic, species and ecosystem diversity assured for the future.

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[6] Note that under Base Case assumptions in the timber supply, existing AU's don't change their designation through time as stands are harvested. It is assumed in SELES that there is no species conversion in the landscape (H. Burger pers. comm.).

[7] Read as "analysis unit within a particular biogeoclimatic variant"

3.0 Methodology

3.1. Outline

Following the approach outlined by others (MoE 2000; Utzig and Holt 2002), the ERA for Coarse Filter Biodiversity involves the following specific steps:

- Identify appropriate indicators and project their abundance and distribution through time.
- Identify the natural benchmark for the comparison for each ecosystem (based on 'range of natural variability' – RONV).
- Identify appropriate risk classes for interpreting the deviations between 'natural' conditions and projected future trends.
- Examine trends in old forest abundance for each ecosystem through time in relation to mean predicted natural levels of old forest – using a static analysis of current data and projected values for indicators.
- Combine the basic projected outcomes for amounts of old forest with additional parameters (e.g. patch metrics, ecosystem recovery, younger forest in protected areas) – using static analysis and BBN models.
- Summarise results and repeat for each scenario (as developed by the Table in future).

3.2. Identify Indicators and appropriate data sources

Potential indicators for coarse filter biodiversity were identified at ERA team meetings. Specific indicators used in the coarse filter biodiversity models are shown in Table 1.

Table 1. ERA Coarse Filter Indicators

Indicator	Rationale for inclusions/ non-inclusion
Abundance of old forest ecosystems I: Broad: individual BEC units and individual Analysis Units	The abundance of 'habitat' is the most important factor influencing the success of maintaining environmental values (Fahrig 1997; Andrèn 1997; Fahrig 2001). Ecosystems provide good surrogates for general biodiversity values (Franklin 1993; Nally et al. 2002). Analysis of both BEC variants and Analysis Units will provide a broad overview of trends on the landscape
II: Fine: AU x BEC x Landscape unit	Abundance of smaller defined units will improve the resolution of the analysis, and improve the extent to which it reflects ecological reality. Landscape units provide a geographic reference within the NC region. [Note: the intention is to use PEM[1] data for this analysis once it becomes available.]
Patch metrics of old forest ecosystems	The ecological functioning of a forest patch will vary depending on size and shape (Debinski and Holt 2000). Assessing trends in old forest patch size through time will highlight any broad changes in the sizes of old forest patches remaining on the landscape.
Protected Area (PA)s	Old forest within PA's is included automatically in old forest distribution summaries. However younger forest within PA's is not accounted for in the main model, yet may lower risks due to lack of harvesting, roads, disturbance pressures etc.

[1]: PEM = Predictive Ecosystem Mapping.

General information on source, age and reliability of data are summarised in the LRMP Map and Inventory Handbook[3]. Table 2 summarises relevant information specific to this analysis.

Table 2. Data sources and reliability

Indicator	Measurement Unit	Data Source	Scale/ age of data
Broad ecosystems	Biogeoclimatic variant	Forest cover + BEC theme	Forest cover inventoried at 1:15K
Small ecosystems	Analysis units (Inv type group and site index) x BEC variant	Forest cover BEC	Forest cover inventoried at 1:15K Last re-inventory of forest cover for North Coast completed in 1995. Portions of inventory are updated annually. Current inventory updated to 2000.
Patch distribution	Various	SELES output	N.A.
Protected Area	Percent protected (forested landbase only)	LUCO	Updated 2001

3.3. Forest Cover Data

During the work of the ERA team, we determined that problems with the base Forest Cover layers for the planning area were creating difficulties in interpreting levels of risk for some ecosystems. In particular, the Team recognised that the projected age of some forest cover types is incorrect (A. Banner pers. comm.). The methodology for assigning forest cover ages is to use photo-interpretation associated with field checks. However, in the past, this work has focused on productive stands in the timber harvesting landbase, and has been less concerned with non-commercial stands outside the timber harvesting landbase. Examination of the forest cover data suggested that a substantial area of the landbase was incorrectly labeled as age class 7 and 8 (between 120 and 250 years in age), when this is extremely unlikely – in fact the forest stands are likely in excess of 500 or 1000 years old but are generally scrubby and without a closed canopy, and so have been identified as 'younger' by photo-interpreters. Although a known problem, efforts to fix this problem have been slow because these forests are outside the timber harvesting landbase. However, in our analysis, it is key to correctly interpret the age class of these forest types.

Since it was not possible to reinventory the coastal forests, expert opinion was used to rectify this problem as much as possible. To this end, the following data changes (summarized in Table 3) were made to the Forest Cover data prior to running the SELES model. [Data lumping in Table 3 below refers combining the data that are classified as different ages in the dataset into a single age class assuming they are not in fact different.]

Table 3. Forest Cover Data Update.

AU	Data Solution	Rationale
Cedar / hemlock – high Hemlock/ balsam – high	No data lumping	Large structured stands, usually in the THLB. Better inventory, plus easy to photo-interpret.
All Spruce All cottonwood	No data lumping	Disturbance regimes relatively frequent, so current canopy tree age most closely represents actual stand age
Cedar/ hemlock – medium Hemlock/ balsam – medium Hemlock/ balsam – low	Lump AC 8 and 9 as 9	Intermediate productivity stands and intermediate disturance: Some units have much higher apparent AC8 and lower AC9 than predicted. Difficult to photo-interpret among these age classes.
Cedar/ hemlock – low Pine	Lump AC 7, 8 , 9 as 9	Low rates of disturbance. Very unproductive stands. Very difficult to photo-interpret; tends to be outside THLB (so low effort).

3.4. Defining the natural benchmark

In order to assess the effectiveness of any management strategy for environmental values, it is necessary to define the benchmark against which scenarios will be assessed (MoE 2000; Beasley and Wright 2001).

Over the last 10 years, scientists have developed approaches to characterize environmental risks in managed landscapes based on the concept of approximating natural disturbances. The theory is that the closer selected attributes of managed landscapes resemble those resulting from natural disturbances, the lower are the risks to environmental values. This approach has been used worldwide (Landres et al. 1999; Swetnam et al. 1999; USDA FS 2001; Wright 2001; Angelstam and Andersson 2001) and has been endorsed by the Province of BC as the basic rationale behind the Biodiversity Guidebook and Landscape Unit Planning Guide of the Forest Practices Code (Province of BC 1995 and 1999).

This approach requires a description of what the landscape would look like under a natural disturbance regime (e.g., without harvesting but with natural wind, fires, avalanches etc.). This is termed specifying the "Range of Natural Variability - RONV". The concept of RONV refers to the effects of natural disturbances, and acknowledges that the scale and extent of disturbances will change annually and will therefore be 'variable' through time (see Figure 3). Describing RONV allows us to estimate how much forest of different ages are expected to be present on the landscape if it were not managed.

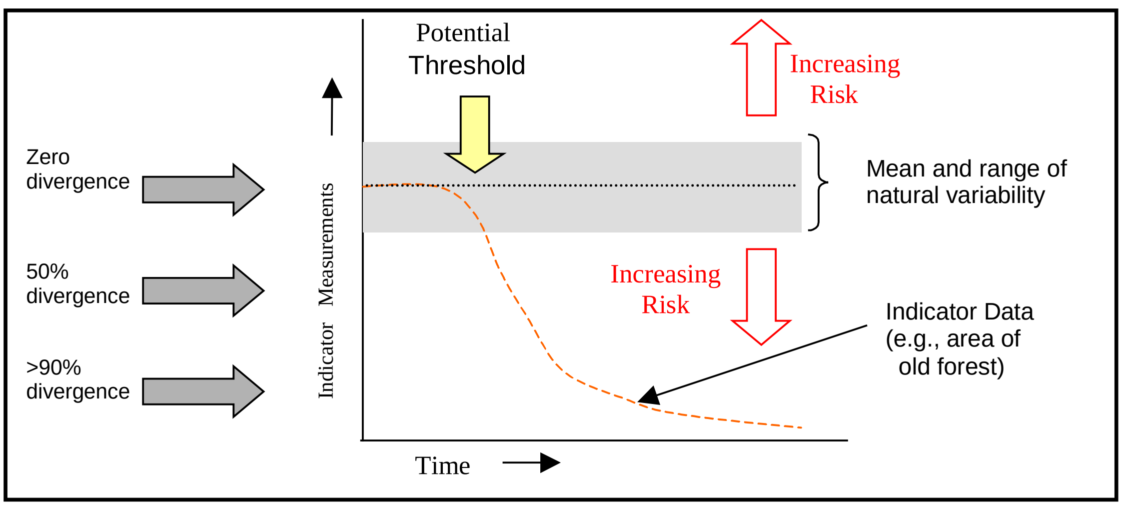


Figure 3. Using range of natural variability as a benchmark to assess ecological risks.

(Adapted from Holt and Utzig 2002). Arrows on the left show how 'divergence from natural' is assessed.

For the North Coast, the following steps were taken to define the range of natural variability of disturbances:

1. Define natural disturbance patterns

The Government Technical Team commissioned a review of natural disturbance processes in the planning area which was reviewed by Ministry of Forests scientists (A. Banner and J. Pojar), among others. This report (Dorner and Wong 2003) concludes that the predominant natural disturbance regime is "gap dynamics", rather than "stand-replacing" dynamics. Gap dynamics means the loss of one or a few trees from the canopy, creating a small gap. This happens repeatedly and gradually, and results in multi-storied very old forest stands. (See definition of Gap Dynamics for discussion of regime in low productivity sites). Consequently a high percentage of the North Coast area is old forest at present, and has been historically. A relatively small percentage of the landscape is affected annually by stand-replacing disturbances such as avalanches, windthrow on exposed areas, or debris torrents on steep and wet areas. These disturbances are generally small, but cumulatively prevent the landscape from becoming 100% old forest. The frequency and size of such stand-replacing disturbances determine the mean and range of variability of area of old growth forests on the land base.

2. Predict disturbance intervals for North Coast ecosystem:

Dorner and Wong (2003, Table A in 3.1.1) point out that the best way to stratify the landscape regarding potential disturbance events is as Disturbance Units defined by terrain characteristics (mostly slope steepness, exposure to wind and hydrologic regime). Our stratification of the landscape is by Analysis Units which are combinations of leading species and site productivity. We worked with MoF ecologist Allen Banner to assess the correspondence between AUs and Dorner and Wong's Disturbance Units, in order to produce groupings of AUs with similar stand-replacing disturbance patterns. They are as follows:

- Cottonwood, Spruce-High, Cedar/ Hemlock - High, Hemlock/ Balsam - High: which have highest rates of disturbance due to association with floodplains, fans, avalanches, gullies and steep productive upland sites.
- Spruce-Low, Spruce-Medium, Hemlock/ balsam – Medium: which have moderate rates of disturbance associated with more subdued yet quite productive upland sites, including some subalpine and estuarine sites.
- Cedar-Low, Cedar-Medium, HemBal-Low, Pine: which have the lowest rates of disturbance associated with poorly drained upland forests and blanket bogs.

Studies that quantify rates of stand-replacing disturbance in the plan area are very limited (Dorner and Wong 2003; Table C in 3.1.1, and Appendix 1). To ascribe a range of return intervals for each of the three classes above, we used the limited data in Dorner and Wong (2003), combined with estimates of return interval derived from the current age class distribution of stands in the Forest Cover inventory, and the expert opinion of field ecologists (Drs. Allen Banner and Jim Pojar) with extensive experience in coastal forests. To interpret return intervals from empirical age class distributions of individual AUs, the ERA team (D. Reid and D Steventon pers. comm.) produced graphs showing the proportion of the forest older than age *t* plotted for each age *t*. These empirical data were plotted along with theoretical data for various Return Intervals (300, 600, 1000, 1500, 2000, 3000 years) based on the negative exponential equation:

$$\%\text{>age } t = e^{[-(t/b)]}$$

where *t* is the current stand age and b is the return interval (Province of BC 1995).

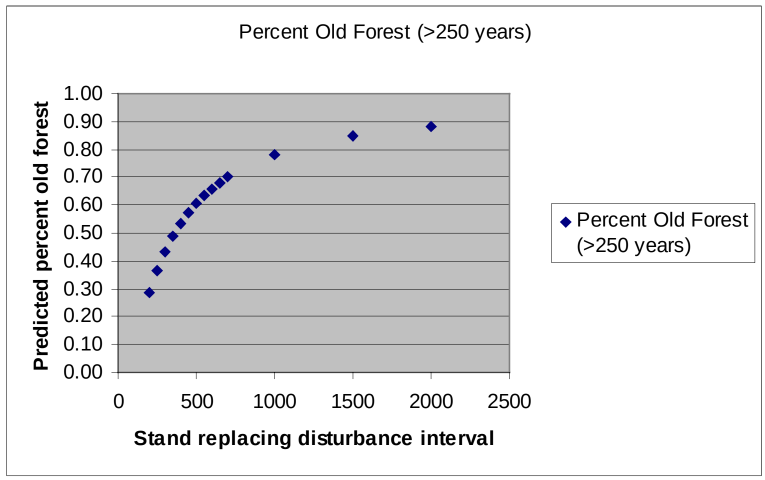
The Return Interval for each age *t* in the empirical data was then interpolated from the position of the empirical distribution with respect to the various theoretical distributions, and the mean was calculated across values interpolated for each 20 year interval from 10 to 310 years. This approach did not work for AUs that had been harvested because their Return Interval estimates were substantially biased by the recent disturbance. However, reasonable estimates were available for Pine (4250 y), Cedar-Low (1675 y), and Spruce-Low (597 y). The resulting *range of mean disturbance rates* is shown in Table 4. For calculations within the model, we used the midpoint of this range as the basis for predicting the amount of old forest under natural disturbance conditions. A sensitivity analysis for the disturbance rate is included (see Section 7).

Table 4. Estimated mean and standard deviation of disturbance interval for Analysis Units on the North Coast.

Analysis Units	Range of Mean disturbance intervals**	General Description
CH High, HB High, S High, Cottonwood,	600 – 800	Floodplain/ productive on steep ground/ cottonwood
S Medium, S Low, HB Medium	900 – 1100	Moderate productivity Upland
CH Low; CH Medium, HB Low, Pine	1500 – 5000	Other Upland

** Note – range of mean disturbance intervals (not RONV).

3. Use natural disturbance data to predict the expected amount of old forest to occur on the landscape:



Application of the 'negative exponential' equation (Province of BC 1995) to the natural disturbance data (Table 4) allows prediction of the mean and range percent of old forest for each BEC variant. Note that the predicted amount of old forest is very insensitive to changes in disturbance frequency between 600 and 3000 years: if the estimates of stand-replacing disturbance interval are incorrect within this range, prediction of mean old forest varies by only a few percent and so will not radically influence the prediction of the natural benchmark of the model (see adjacent Figure).

4. Determine benchmark for patch analysis:
For the patch distribution analysis it was not feasible due to the scope of the project to define 'natural' patch parameters for this large landscape. It was therefore determined that the patch analysis would simply compare trends in patch metrics through time for ecosystems.

3.5. Identify Risk Classes and Thresholds

The output of this ERA can be interpreted in two ways:

*Ecosystems can be compared to each other to assess **relative risks** to each ecosystem*

*Ecosystems can be compared to the predicted 'natural' range to gauge **absolute risks***

The first comparison is useful in focusing on components of the landscape that are at most risk. The second comparison uses the assumption that the more different a managed landscape is from a natural landscape, the higher the risk to the coarse filter, and is useful for gauging whether a particular risk is actually 'high' or just 'higher' than another. Using this premise, we assume that a large deviation from natural results in a high risk to the coarse filter. There are clearly numerous ecosystem or species-specific variables, plus environmental stochasticity (chance variation) that influence how individual ecosystems could respond to changes in the amount of 'habitat' available. We synthesized information from various sources to provide guidance in determining risk classes (see below), but due to the lack of local ecosystem specific information we used five equal linear risk classes (see Table 5).

In a large literature review, a research group from Simon Fraser University[8] summarised available information on risk classes and thresholds (Dykstra et al. In Prep.). We surveyed that review plus other information, and noted that a number of key ideas repeatedly surface in the literature. Primarily it has been shown that habitat loss is the primary variable influencing the probability of survival of individual species (Noss 1996a, b; Fahrig 1997; Fahrig 2001). In particular, the loss of up to about 40% of a species' habitat has been shown to result in a linear negative population response (e.g. Bascompte and Sole 1996). However surpassing 40% change, the rate of decrease in population size increases faster than the rate of habitat loss would predict. Using theoretical models, Franklin and Forman (1987) showed that patches start to become isolated at about 30% deviation from natural (i.e. when 70% of an original landscape remains). As the amount of original habitat declines further, the number of isolated patches increases until at 70% deviation from natural, all the original habitat is isolated to some degree. Similarly in a review of the effects of habitat isolation on community composition, Andrèn (1994) suggests the most dramatic effects occur when only 20-30% of original habitat remains. For plant species migration, habitat availability <25 % of the landscape area was shown to markedly reduce migration rates for a wind-dispersed tree, particularly when habitat was also in smaller patch sizes (Collingham and Huntley 2000). Percolation theory similarly predicts an inherent disconnecting of a landscape to occur at 60 – 70% landscape change (40-30% remaining).

The thresholds identified in the literature correspond reasonably well to the pragmatic approach suggested by MoE 2000, which identifies five equal categories between 0 and 1 and assigns them categories from very low to very high risk. Note that in the Bayesian Belief Network (BBN) model described below, we do not use fixed boundaries between these groups, but instead allow the classes to vary 5% either side of the 'threshold' (see Appendix 2).

Based on the findings of the literature review, but acknowledging the likelihood of highly variability, Table 5 outlines a set of risk classes based on a linear function of 0 – 100% deviation from natural with a change from low to moderate risk at 40% deviation, and a change to high risk at 60 % deviation from natural.

Table 5. Risk Categories

Deviation from mean predicted Natural percent old forest	0-20%	20-40%	40-60%	60-80%	80-100%
Risk Class	Very Low	Low	Moderate	High	Very High

We used sensitivity analyses to assess the implications of using this Base set of risk classes in comparison with two alternative assumptions (see Section 7.0).

4.0 Risk Models

Two approaches are used to present general patterns and model risk to coarse filter biodiversity: 1) a static analysis thata simply presents the output data from timber supply modeling in graphical form, for each ecosystem, and compares it to the predicted amount of old forest and 2) a more complex approach that uses a BBN model at its core and also incorporates additional information in the risk assessment. Both approaches use the same dataset from the North Coast Landscape Model (SELES; Morgan 2002). The two approaches are not different in conceptual approach, but differ in their complexity and the assumptions used. Their pros and cons are summarised below:

4.1.1. Trends in old forest through time: A Graphical Overview

The static analysis simply summarises the output projections from the NC Landscape model (SELES) from now through to the future for each ecosystem, and compares current and future trends with the

[8] Masters students in the School of Resource and Environmental Management

predicted natural estimate based on natural disturbance patterns (i.e. RONV for abundance of old forest). Outputs are presented graphically and risk labels are not applied.

Pros: this analysis is simple, makes no 'hidden' assumptions, and provides easy to interpret trends for each ecosystem. This tool is used primarily to show basic trends at the level of broad ecosystems, and to 'check' the base risk outputs from the BBN model.

Cons: this analysis only addresses the abundance of each old forest ecosystem on the landscape. Due to the number of possible combinations (AU x BEC within landscape units) spatial delimiters are not included. Thus, it is not easy to ask such questions as "what landscape units have the most risk?" In addition, this approach cannot easily be used to run sensitivity analyses (e.g., to determine how much does each assumption affect the outcomes?).

4.1.2. Bayesian Belief "Base Risk" and Risk Modifiers

At its core, this approach uses a Bayesian Belief Network (BBN) model to provide a more complex assessment of the North Coast landscape, incorporating multiple factors into the outcome. This core model output of base risk is then modified using additional data.(Table 6).

The Bayesian Belief Network (BBN) model we developed is a framework for making more comprehensive assessments of possible future risks associated with harvesting patterns in North Coast landscapes. We used the BBN framework to help overcome this dilemma: (1) detailed simulation models of the management of natural systems can never replicate the complexity in nature (Reckhow 1999); and (2) overly simple strategies and models (usually built with information from very specific circumstances, and do not incorporate broader scientific knowledge and data) are not likely to yield useful answers to the actual problems of concern. The BBN approach bridges this information gap by using probabilistic expressions to capture the aggregate response of ecological systems to environmental change. Where measured, these probabilities can be directly incorporated into the model. Where not measured, expert opinion can be used to estimate probabilities. Combining data and scientific understanding of ecological function in a network of "inference" permitting calculation of likely outcomes is an effective way to guide decisions (Wade, 1999; Marcot et al. 2001).

There are both pros and cons to using a probability network model for assessing risks:

Pros:

- BBN models can be as simple or as complex as scientific judgment and data allow.
- BBNs allow incorporation of expert opinion into the model where data are lacking. This combination of observations (data) and knowledge permits drawing conclusion at spatial and temporal scales beyond which the data alone is usually insufficient.
- Uncertainties in ecological relationships and assumptions can be included in the BBN.
- The outcomes are expressed as probabilities, reflecting the fact that the future of any ecological system is uncertain.
- The BBN framework is easy to modify to incorporate new knowledge, and to run sensitivity analyses on. This helps users assess the importance of assumptions and it facilitates assessment of the spatial nature of the planning environment.
- The "inference" network approach requires that the important causal feedbacks in the ecological system be explicitly represented (in graphical form) such that both the outcomes needed by decision-makers, and the assumptions used to calculate them are directly visible and accessible. This means that the basis for making decisions becomes more transparent.

Cons:

- Unless the BBN is well-documented, it can be difficult to separate out "data" from expert opinion in the model. Because the fundamental basis of a BBN is "belief" or probability conclusions about relationships, it is easy to incorporate biases into the model that are indistinguishable from observation errors.

- Any model (simulation, BBN or any other form) is an abstraction of the real world, and can only incorporate what we know. There is no guarantee that important relationships that influence the outcome are not missing from the model.
- Understanding probabilities is not intuitive for many people. Because BBNs are based on probabilities, they can appear as a relatively complex tool. In particular it may require considerable time and effort to become familiar enough with the model to assess assumptions.

Despite these cons, we believe that a carefully constructed and parameterized probability network model has good utility in communicating results between decision-makers, stakeholders and scientists. The graphical format provides a visual and numerical description of the ecological system such that people can grasp the important processes linking the model together. Because probabilities of various outcomes incorporate uncertainties in knowledge, they can be compared in a relative sense to give a realistic appraisal of the chances of achieving desirable goals. Finally, scenarios can be run and compared relatively quickly so that the implications of a range of options are quickly understood.

Table 6. Risk Model Inputs.

Input	Comments / Data Source	Analysed?
Area of old forest through time (AUxBECxLU)	NC Landscape Model – SELES	In BBN model
Ecosystem influence and importance	Expert ecological opinion. See Appendix 3	External to BBN model
Ecosystem Conservation value	Expert ecological opinion. See Appendix 3	External to BBN model
Extent of ecosystem Representation in Protected Areas	Note that amount of 'old forest' present in protected areas is automatically included in the old forest analysis. However Protected Areas provide additional benefit to conservation (see section 5.3)	External to BBN model
Trends in large old patches	Area of old forest in large patches (>500ha) for each ecosystem, through time.	External to BBN model

5.0 Results

5.1. Trends in old forest: a graphical overview

Trends of projected old forest abundance through time for a selection of ecosystems are presented graphically (Fig. 4). Data are shown for all high productivity ecosystems, and for typical examples of medium and low productivity ecosystems.

Data for individual ecosystems (AU x BEC) are summarised for the entire region (i.e. are not separated into watersheds or landscape units). This approach provides a broad assessment of the ecosystems that may generally be at the highest risk through time. Multiple ecosystems are shown on each graph for brevity, grouped by Analysis Units. For each ecosystem (AU x BEC) the predicted range of old forest is compared with the current (time 0) and future (time 20, 50, 100, 200, 250 years) old forest in that unit. Old forest is further separated into two strata: (i) percent in the Timber Harvesting Land Base (THLB) and (ii) percent in the Non-contributing (NC) Land Base[9]. Because

[9] THLB – is the operable forest land base. The NC is the remainder of the forested land base excluding protected areas, and is primarily the physically and economically inoperable areas, plus other retention areas (riparian zones etc.).

much of the landscape is physically inoperable, this separation gives an indication of physical distribution of old forest on the landbase through time. As an indication of the extent and rarity of each AU in the landscape, the percent of the AU (including all BECs) in the LRMP area is shown in each graph title.

For example, the 1st figure shows the Cedar/ Hemlock – High AU within the CWHvh2 and CWHvm BEC variants. The percent old forest for each ecosystem (AU within BEC variant) is shown in yellow and blue (colour themed into THLB and NC landbase). The predicted natural range of old forest based on the low and high predicted mean disturbance intervals is shown on the left in hatched blue (see Table 4). In this figure the mean predicted natural range for Cedar/ Hemlock – High within the CWHvh2 and CWHvm is between approx 65 - 75%. The actual percent of old within the CWHvh2 is currently (Time 0) at 10%, and under current harvest schedules declines to approximately 3% after 250 years. The actual percent of old within the CWHvm is initially low and declines almost to zero over time.

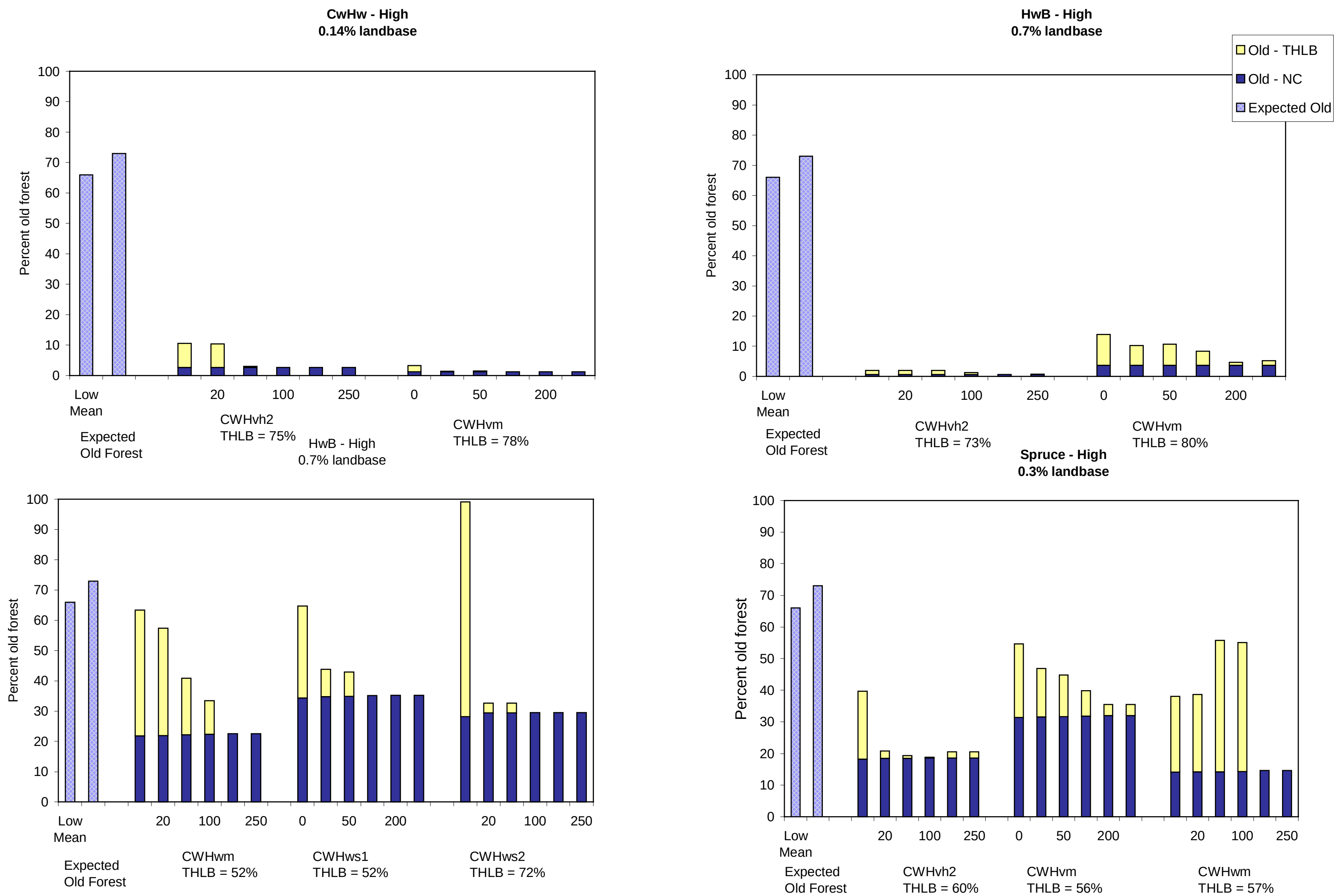
There are some obvious trends apparent from the graphs shown in Figure 4. There is very high deviation from mean predicted percent of old forest at Time 0 or Time 20 for all variants within the Cedar/ Hemlock – High, Hemlock Balsam – High and Spruce – High AU's, which suggests these ecosystems are at high or very high risk both now and into the future.

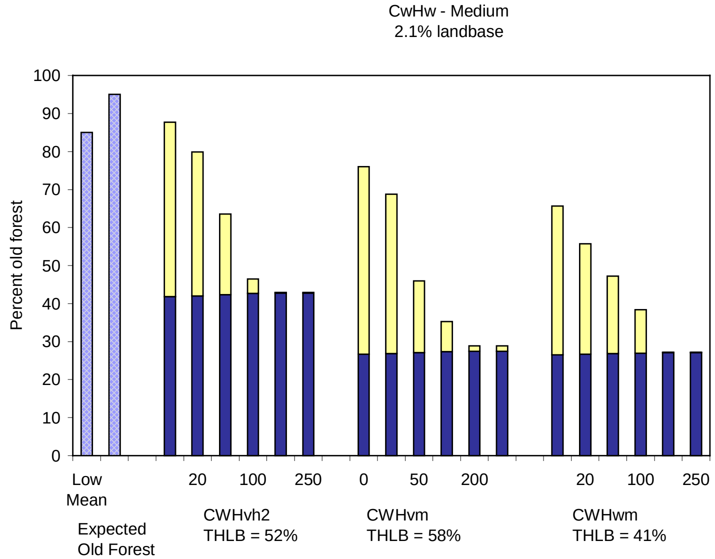
For almost all variants within Cedar/ Hemlock – Medium, Hemlock/ Balsam – Medium and Spruce – Medium there is moderate deviation from mean predicted natural at Time 0 or Time 20, suggesting slightly lower risk now and into the future (see summary in Appendix 4). For all medium productivity units, the deviation from predicted old and actual old increases through time as harvesting progresses. For most medium productivity units (except high elevation BEC variants), the change over the next 50 years is substantial.

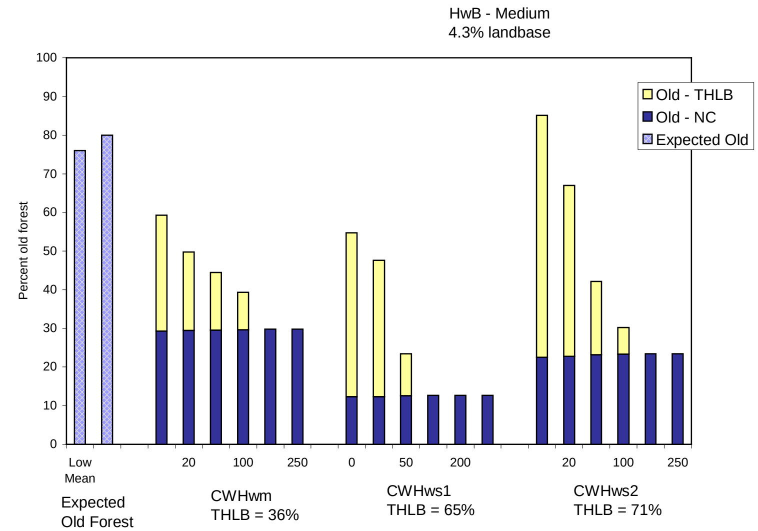
For most low productivity ecosystems (see example for Hemlock/ Balsam – Low), the deviation between predicted and actual old forest is very low, suggesting very low risk for these units. The exception is the low productivity AU's within the CWHwm in the northwest area of the region, where extensive fumekill earlier this century caused extensive forest death and has resulted in significant deviation from natural old forest in these units, and moderate risk (although this was caused by historic fumekill, rather than forest harvesting).

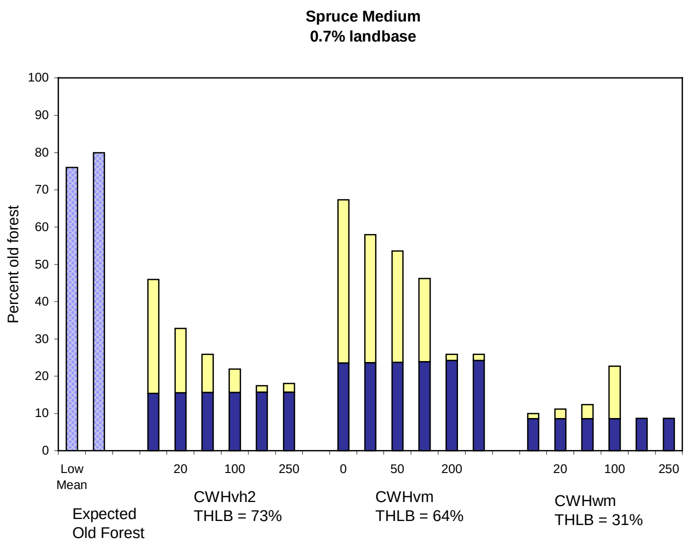
If the percent of old forest in an ecosystem at Time 0 (current year) is very low, we interpret this as a reflection of harvesting pressures to date. This is particularly apparent for the high productivity AU's where historical harvesting has tended to focus, and is confirmed by graphs showing that very little old forest currently remains in these ecosystems. Note that some AU x BEC combinations represent very small physical areas, and as a result, a small amount of harvesting can change the 'percent old forest' quite substantially (note that units less than 100 ha are not shown on the graphs; Appendix 3 summarises the size of individual AU x BEC ecosystems.) However, these small, relatively rare ecosystems are likely a very important component of the diversity of the North Coast and loss of small areas may have very high ecological significance.

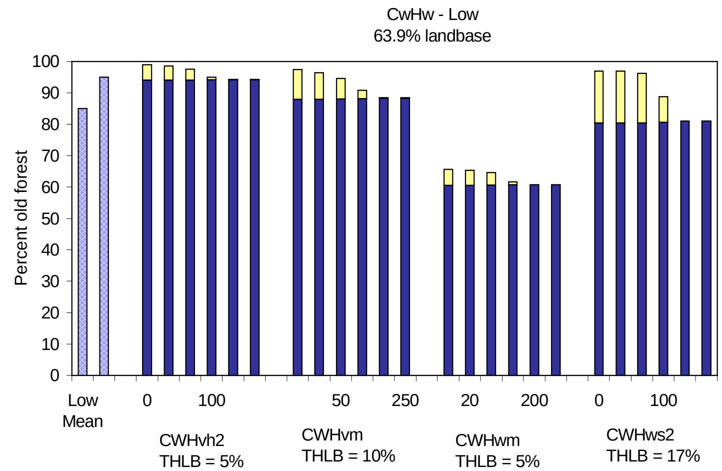
Figure 4. Percent old forest predicted (RONV) and occurring through time for example AU's within BEC variants.




CwHw - Medium
2.1% landbase
Percent old forest
100
90
80
70
60
50
40
30
20
10
0
Low
Mean
20
100
250
0
50
200
20
100
250
Expected
Old Forest
CWHvh2
THLB = 52%
CWHvm
THLB = 58%
CWHwm
THLB = 41%


HwB - Medium
4.3% landbase
Old - THLB
Old - NC
Expected Old
Percent old forest
Low
Mean
20
100
250
0
50
200
20
100
250
Expected
Old Forest
CWHwm
THLB = 36%
CWHws1
THLB = 65%
CWHws2
THLB = 71%


Spruce Medium
0.7% landbase
Percent old forest
Low
Mean
20
100
250
0
50
200
20
100
250
Expected
Old Forest
CWHvh2
THLB = 73%
CWHvm
THLB = 64%
CWHwm
THLB = 31%


CwHw - Low
63.9% landbase
Percent old forest
Low
Mean
0
100
50
250
20
200
0
100
CWHvh2
THLB = 5%
CWHvm
THLB = 10%
CWHwm
THLB = 5%
CWHws2
THLB = 17%

5.2. Base Risk: Model Results

As outlined in the conceptual model, base risk is defined as the amount of deviation between the amount of old forest and the predicted old forest, and can be modified by a number of factors including the representation of Protected Areas, the Ecological Conservation Value of the ecosystem, and the trends in large Patches for the ecosystem.

5.2.1. Broad Trends for Base Risk

Base risk – which is the percent deviation from the mean predicted natural old forest abundance for each ecosystem – was calculated using the BBN and is presented in Figure 5 and 6 below. Note that both Figure 5 and 6 represent mean predicted risk for the undifferentiated Analysis Units and BEC units. Separate evaluation of AU and BEC tends to homogenise the output, reducing the differences between units observed when the more fine scale definition of ecosystem is used (i.e. AU x BEC). However, these coarse summaries provide a useful overview of the general patterns of risk to broad ecological units, and are presented as relative rather than absolute risks as a result.

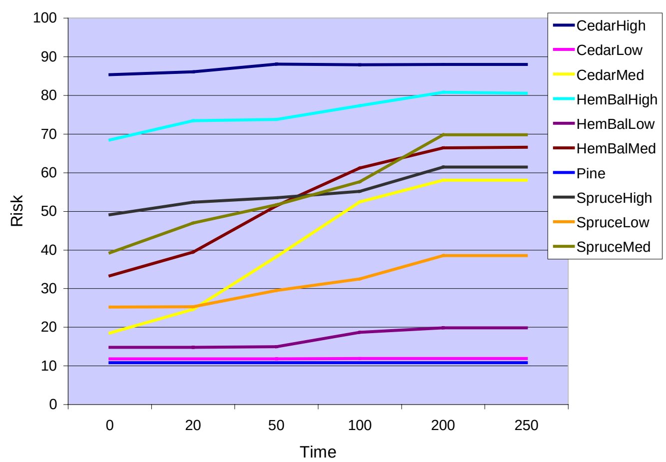


Figure 5. Mean[10] predicted base risk for Analysis Units

Both Cedar/ Hemlock and Hemlock/ Balsam – High ecosystems are initially at high risk, and remain so throughout the 250 years. Note that although the vegetation in all ecosystems grows back during the analysis period, if the ecosystem is located in the timber harvesting landbase it is harvested multiple times in the future, and never allowed to return to old forest conditions (hence risk never decreases for a unit). A number of intermediate ecosystems are initially at low or moderate risk (e.g. Cedar/ Hemlock – Medium and Hemlock/ Balsam – Medium), but increase in risk substantively over the time period.

Both Cedar/ Hemlock and Hemlock/ Balsam – Low plus Pine start at low risk and stay relatively constant at those levels throughout the time period.

[10] averaging risk for each AU x BEC combination into this average by AU.

Presenting risks based on summaries of BEC variants reflects the general location of the high risk analysis units (see Figure 6). The CWHws1 and ws2 increase in risk over the 250 years, but the other BEC variants do not show a change in risk over time at this scale, because risks to smaller ecosystems (AU x BEC) are swamped by the large areas of other ecosystems that do not change (i.e. risks to high productivity portions within a BEC unit may be high, but are not reflected in Figure 6 due to large portions of the BEC unit that are low-risk, low productivity sites).

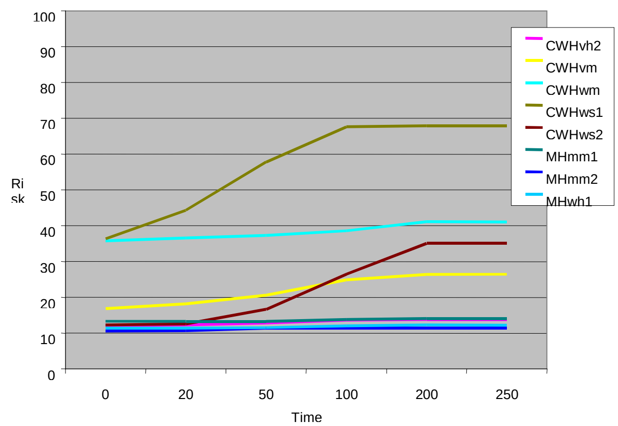


Figure 6. Mean predicted 'risk' for each BEC variant unit.

5.2.2. Ecosystem Trends: Analysis Units within BEC Variants

As stated previously, patterns within AU's or BEC variants show broad trends, but these average values tend to obscure the true variability that occurs within finer-scale definitions of ecosystems. Figure 7, Figure 8, and Figure 9 show the modified risk for the key ecosystems (AU x BEC) that show the highest levels of risk by AU or BEC (in Figure 5 and 6). Within each AU there is a range in risk for individual AU x BEC combinations. To aid interpretation of Figure 7, Figure 8, and Figure 9 consider which ecosystems a) are at high or at highest 'risk' currently, b) increase rapidly in risk in the short-term, c) do not change in risk through the time period (i.e. are reasonably unaffected by harvesting old forest).

In the following three figures, only units greater than 100 ha are included.

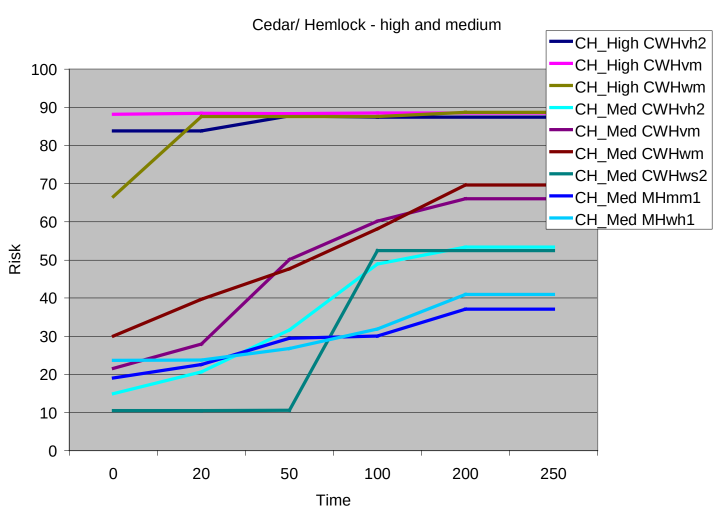


Figure 7.Base risk for C/H High and C/H Medium Analysis Units.

Risk increases for all ecosystems through time and high productivity units are at highest risk. Medium producivity ecosystems increase in risk through time, particularly in the CWHwm, CWHvm, CWHvh2 and CWHws2.

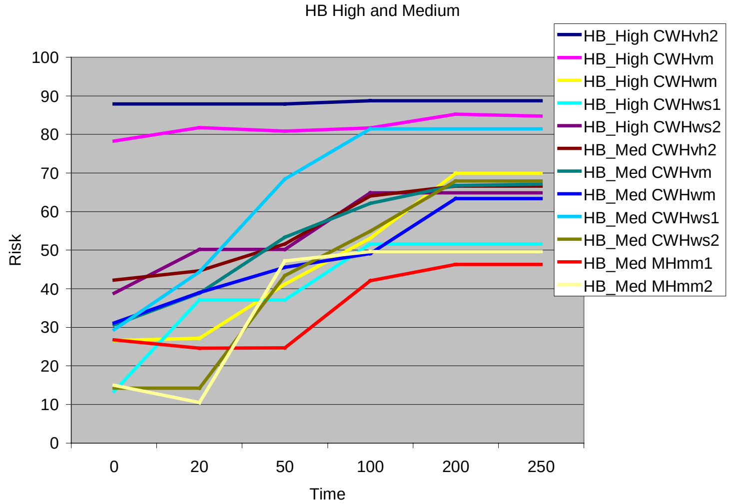
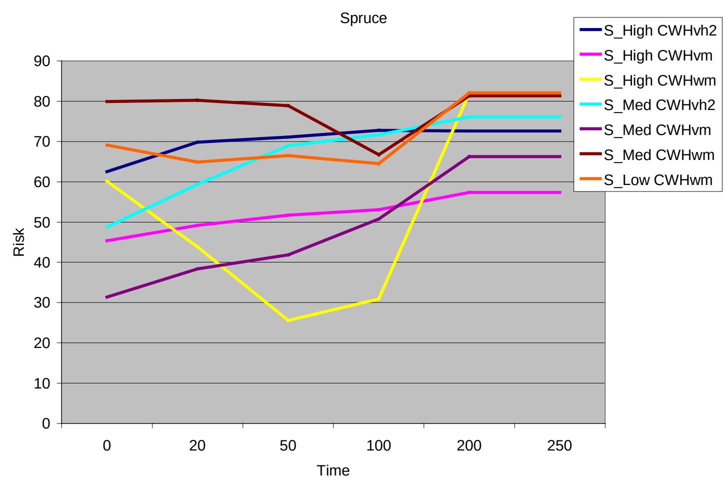


Figure 8. H/B High and H/B Medium Analysis Units.

Risk is highest for H/B – High in the CWHvm and CWHvh2. Risk in all remaining H/B units except in the MH starts at low or moderate risk and rises fairly quickly through time.

Figure 9. Spruce Analysis Units

Spruce – High in the CWHvh2, Spruce – Medium in the CWHwm, and Spruce –Low in the CWHwm start at and remain at high risk through time. Spruce – Medium in the CWHvm is initially moderate but increases rapidly in risk through the time period. Spruce – High in the CWHwm initially decreases in risk as young forest becomes old, but then increases again as this forest is harvested after 100 years.



Summary risk for each ecosystem (AU x BEC) is shown categorically in Table 9 below, for three time periods (0, 50 and 250 years).

5.3. Risk Modifiers

The base risk level represents the percent deviation from natural conditions expected from current and projected levels of old forest. However, other factors influence overall risks to ecosystem integrity and biodiversity. The following risk factors were used to modify the base risk level: a) Ecosystem Conservation Value, b) Patch Size Trends, and c) Percent in Protected Areas. The quantitative science available for determining the extent to which these factors should modify risk is weak. However, we have applied available theoretical rationale for each variable to alter the levels of risk within each ecosystem (see sections below). We did not modify any Base Risk in excess of 1/3rd of a risk class (i.e. 7 points out of 20 for a risk class), and modifications were generally lower than this. We also allowed the modification to vary with respect to our assumption of importance of each modifier, and feel that our modifiers are relatively conservative.

Base and modified risk levels for each ecosystem (AU x BEC) greater than 100 ha are presented in Table 9 for three time periods (time 0, 50 and 250 years). Table 8 summarizes the percentage points used as risk modifiers for Ecosystem Conservation Value, Patch Size Trends, and Protected Areas.

5.3.1. Ecosystem Conservation Value

All ecosystems have value, however it is widely recognised that certain types of ecosystems contribute higher 'biodiversity values' than others. For example, the loss of a unique ecosystem or one containing rare elements would significantly reduce biodiversity values of a given area. The North Coast region includes a wide variety of different ecosystems, some of which are extensive and common, and others that tend to be localised and perhaps more unique. To address these values, experts on the North Coast ecosystems (A. Banner and J. Pojar) were asked to rate the ecosystems used in this analysis in terms of their "Biological Importance" and "Biological Influence". These two terms were defined as:

Biological Importance: A relative measure of the overall biodiversity value (per unit area) of an ecosystem, classified as 'high, medium and low'. High value systems will tend to have some combination of high species richness or productivity, high rarity or high distinctiveness.

Biological influence: The influence of the ecosystem on surrounding ecosystems estimated as 'low', 'medium', or 'high'. The loss of a given area of an ecosystem with high influence value would have tend to have cascading effects higher than that predicted by the area of ecosystem alone.

Each ecosystem (AU x BEC) was classified as very high, high, medium or low for each of these two variables (see Appendix 3 for values). In the BBN model, the two values were then combined in a single Ecosystem Conservation Value Index which, when extracted from the BBN (see Appendix 3), was quantified as very high, high, moderate and low. As Table 8 shows, ecosystems with very high conservation values were given an additional 7 percentage points to their base risk score to reflect the significance of altering these systems, while ecosystems with low conservation value were not given an increase.

5.3.2. Trends in Large Old Forest Patches

Although we are uncertain about their role in each of the ecosystems outlined here, large areas of interior forest habitat are believed to provide important conditions for many species (Noss 1996a). For the purpose of assessing risks to coarse filter biodiversity, we defined a large old forest patch as a contiguous area of forest greater than 250 years in age.

The SELES model was used to output data on patch sizes for old forest patches through time. Figure 11 summarises the output for the trends in large (>500ha) patches by Analysis Unit through time. A considerable decrease in large patches over time is evident for all Cedar/ Hemlock, Hemlock/ Balsam, and Spruce units, although the Cedar/ Hemlock – High unit currently has very few patches. A similar pattern was observed for almost all variants when large patch frequency was summarized by BEC unit (not shown).

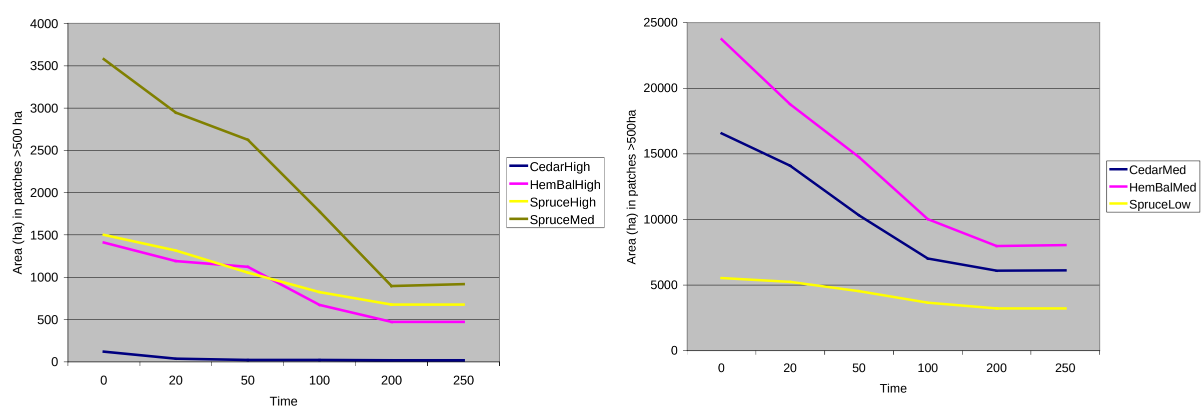


Figure 10.Trends in old forest large patch size frequency through time (for high / moderate risk analysis units)

The changes in the amount of large patches were summarised for each AU x BEC ecosystem as the percent change in large old patches over the time period (0 to 250 years). The percent change was categorised as: *high change* = >70% change in area in large patches; *moderate change* = 30-70% change in large patches; *low/ no change* = <30% change in large patches. The base risk levels were modified using these categories (as shown in Table 8). Ecosystems with high predicted changes in large patch frequency were given an additional 7 percentage points to their Base Risk scores while those with moderate changes were given an additional 3.5 points.

5.3.3. Abundance and Representation in Protected Areas

The amount of old forest in Protected Areas is included with other forests (in the THLB and NC) in the calculation of base risk. However, Protected Areas *potentially* provide additional coarse filter benefits (depending on the specific management regimen), including:

- Maintaining natural disturbance regimes and rates
- No roads
- Managed access control (including hunting / disturbance)
- No resort development
- Natural regeneration of young forest areas (no species conversion)
- Natural forest patch mosaic
- Reduced potential for 'mistakes' causing ecological damage

The need for adequate protected areas is known to play a key role in maintaining ecological values through time (e.g. Noss 1996b). Thus, existing Protected Areas could potentially help reduce risk to biodiversity over and above their contribution of old forest. In addition, Protected Areas provide some level of certainty that an area (and its associated ecosystems) will not be harvested in future. This is particularly relevant on the North Coast where much of the area is currently considered unharvestable due to economic reasons. However, if economic conditions change, the current area of 'non-contributing' landbase may be harvested. The extent (in ha) of protected area within an ecosystem (AU x BEC) is accounted for through risk modifiers based on low (<5%), medium (5-12%) and high (>12%) levels of Protected Areas. Four percentage points were *subtracted* from the base risk levels (%deviation from natural) for ecosystems with a high amount of protected area resulting in lower risk. However, for ecosystems with few Protected Areas, 4 percentage points were *added* to the base risk levels to account for the added risk to biodiversity due to potential habitat changes across a broader portion of the landbase[11].

The area and percent of Protected Area for each Analysis Unit is shown for the LRMP area (Table 7). The amount that is THLB gives an indication of the extent of harvest that may occur in the near future[12]. The distribution of Protected Areas for smaller ecosystems (AU x BEC) is given in Appendix 5, and these data were used to modify risk in Table 9. Note that we did not assess the efficiency of management regimes, although a lack of adequate protection – or mismanagement – is likely to increase risk, so it is important that protected areas be managed in order to maintain ecosystem integrity.

[11] note that the 'modifier' shown for PA (H, M, L) highlights *the amount of Protected Area, not the risk level.* In this case, H (PA) = Low Risk. For the other modifiers a H rating = High Risk.

[12] THLB is determined from economics – so radical changes in timber price could expand or collapse the size of the THLB, hence it provides only a short term indication of the potential for harvest in a particular area.

Table 7. Area, percent and land status of analysis units in the North Coast region*.

Analysis Units	Area THLB	Area PA	Other Crown Forest	Total	Percent Parks
CedarHigh	1125	16	366	1508	1.1
CedarLow	35847	9585	639947	685380	1.4
CedarMed	11467	380	10272	22120	1.7
Cottonwood	281	45	581	908	4.9
HemBalHigh	5680	102	1859	7642	1.3
HemBalLow	29769	9058	182466	221294	4.1
HemBalMed	27432	1783	17325	46541	3.8
OtherDecid		208	4730	4938	4.2
Pine		144	60692	60836	0.2
SpruceHigh	1989	515	1029	3534	14.6
SpruceLow	2605	580	5172	8358	6.9
SpruceMed	4665	594	1986	7246	8.1
Grand Total	122208	23010	926668	1071887	2.15

* Data output from SELES. THLB: Timber harvesting land base. PA = Protected Areas.

5.3.4. Summary of Base Risk and Modified Risk

The level of modification for each risk factor is summarized above and shown in Table 8. Quantitative evidence to determine appropriate levels of modification is lacking - there is little empirical understanding of the specific effects of each of these values. However, the intent of risk modifiers is to stress that the base risk level is dependent on other landscape attributes, and should be interpreted with care. The risk effect ranged from 0 to 7 percentage points for Ecosystem Conservation Value, Protected Areas and Patch Size Trends (Table 8), and was applied to each ecosystem (AU x BEC) for three time periods (0, 50, 250 years) as shown in Table 9.

Actual values applied for each ecosystem are shown in Appendix 6.

Table 8. Risk Modification Values.

Modifier	Value	Effect on Risk	Risk effect (percentage points)
Ecosystem Conservation Value	VH	VH	+ 7
	H	H	+ 6
	M	M	+ 3
	L	L	+ 0
Protected Areas	L (<5%)	H	+ 5
	M (5 – 12 %)	M	+ 0
	H (>12%)	L	- 5
Patch Size Trends	H (>70% change)	H	+ 7
	M (30 – 70% change)	M	+ 3.5
	L (0-30% change)	L	+ 0

Table 9. Base and modified risk for all ecosystems > 100 ha, at each of three time periods (0, 50 and 250 years). (High and Very High risk ecosystems are shaded grey.)

This table shows the Base Risk Groups at three times intervals (0, 50 and 250 years) for each ecosystem. Risk Modifiers: Ecosystem Conservation Value, Protected Areas, and Patch Trends are shown categorically. The resulting Modified Risk is then shown for three time intervals. Modifiers are simply added to scores for Base Risk to produce Modified Risk. (see Appendix 6 for numerical details).

		Base Risk Groups at time 0, 50, 250			*Modifier Risk Level*			Modified Risk Groups at t = 0, 50, 250		
AU	BEC	BR_G_0	BR_G_50	BR_G_250	*ECV*	*PA*	*Patch*	MR_G_0	MR_G_50	MR_G_250
CedarHigh	CWHvm	VH	VH	VH	*H*	*H*	*H*	VH	VH	VH
HemBalHigh	CWHvh2	VH	VH	VH	*M*	*H*	*H*	VH	VH	VH
CedarHigh	CWHvh2	VH	VH	VH	*H*	*H*	*H*	VH	VH	VH
SpruceMed	CWHwm	H	H	VH	*VH*	*H*	*M*	VH	VH	VH
HemBalHigh	CWHvm	H	VH	VH	*M*	*H*	*M*	VH	VH	VH
SpruceLow	CWHwm	H	H	VH	*M*	*H*	*M*	VH	H	VH
SpruceHigh	CWHvh2	H	H	H	*VH*	*H*	*M*	H	VH	VH
SpruceHigh	CWHwm	H	L	VH	*VH*	*H*	*H*	H	M	VH
SpruceMed	CWHvh2	M	H	H	*H*	*H*	*M*	H	VH	VH
SpruceLow	MHmm1	M	M	M	*L*	*L*	*L*	M	M	M
SpruceHigh	CWHvm	M	M	M	*VH*	*L*	*M*	M	M	H
HemBalMed	CWHvh2	M	M	H	*M*	*H*	*M*	M	H	H
HemBalHigh	CWHws2	L	M	H	*H*	*H*	*M*	M	H	H
HemBalLow	CWHws1	L	M	M	*L*	*H*	*M*	M	M	H
HemBalLow	CWHwm	L	L	L	*L*	*H*	*L*	L	L	M
CedarLow	CWHwm	L	L	L	*M*	*H*	*L*	M	M	M
SpruceMed	CWHvm	L	M	H	*H*	*L*	*H*	L	M	H
HemBalMed	CWHwm	L	M	H	*M*	*H*	*M*	M	M	H
HemBalMed	CWHvm	L	M	H	*M*	*M*	*H*	M	H	H
CedarMed	CWHwm	L	M	H	*M*	*H*	*M*	M	M	VH
HemBalMed	CWHws1	L	H	VH	*M*	*H*	*H*	M	H	VH
SpruceLow	MHwh1	L	L	L	*L*	*H*	*L*	L	L	L
HemBalMed	MHmm1	L	L	M	*M*	*H*	*M*	L	L	M
HemBalHigh	CWHwm	L	M	H	*M*	*H*	*M*	L	M	VH
SpruceLow	CWHvm	L	L	M	*H*	*L*	*M*	L	L	M
CedarMed	MHwh1	L	L	M	*M*	*H*	*M*	L	L	M
CedarMed	CWHvm	L	M	H	*M*	*H*	*H*	L	H	VH
CedarMed	MHmm1	VL	L	L	*M*	*H*	*M*	L	M	M
SpruceLow	CWHvh2	VL	L	L	*H*	*H*	*L*	L	L	L
HemBalMed	MHmm2	VL	M	M	*M*	*H*	*M*	L	M	H
CedarMed	CWHvh2	VL	L	M	*M*	*H*	*M*	L	M	H
HemBalMed	CWHws2	VL	M	H	*M*	*H*	*H*	L	M	VH
HemBalLow	MHmm1	VL	VL	VL	*L*	*M*	*L*	VL	VL	VL
HemBalHigh	CWHws1	VL	L	M	*M*	*H*	*H*	L	M	H
CedarLow	MHmm1	VL	VL	VL	*M*	*H*	*L*	VL	VL	VL

		BASE RISK GROUPS AT TIME 0, 50, 250			*MODIFIER RISK LEVEL*			MODIFIED RISK GROUPS AT T = 0, 50, 250		
AU	BEC	BR_G_0	BR_G_50	BR_G_250	*ECV*	*PA*	*PATCH*	MR_G_0	MR_G_50	MR_G_250
HemBalLow	CWHws2	VL	VL	L	*L*	*H*	*M*	VL	VL	L
CedarLow	MHwh1	VL	VL	VL	*M*	*H*	*L*	VL	VL	VL
Pine	CWHvh2	VL	VL	VL	*M*	*H*	*L*	VL	VL	VL
Pine	MHwh1	VL	VL	VL	*M*	*H*	*L*	VL	VL	VL
HemBalLow	CWHvm	VL	VL	VL	*L*	*M*	*M*	VL	VL	L
HemBalLow	CWHvh2	VL	VL	VL	*L*	*H*	*L*	VL	VL	VL
CedarMed	CWHws2	VL	VL	M	*M*	*H*	*H*	L	L	H
HemBalLow	MHwh1	VL	VL	VL	*L*	*H*	*L*	VL	VL	VL
CedarLow	CWHvm	VL	VL	VL	*M*	*H*	*L*	VL	VL	VL
CedarLow	CWHws2	VL	VL	VL	*M*	*H*	*L*	VL	VL	VL
HemBalLow	MHmm2	VL	VL	VL	*L*	*H*	*L*	VL	VL	VL
CedarLow	CWHvh2	VL	VL	VL	*M*	*H*	*L*	VL	VL	VL

BR_G = Base Risk Group; MR_G = Modified Risk Group. ECV = Ecosystem Conservation Value; PA = Protected Areas, Patch = trends in patch size. Values are shown in Table 8.

6.0 Geographic location of risks

This work is intended to inform the North Coast LRMP Table land use decision-making process. In order to understand the potential implications of the results, it will help the Table to understand the geographic locations of particular ecosystems that are at high risk. Due to the large and complex nature of the landscape, it is very difficult to locate areas of high risk on a map. Instead, the area of each analysis unit present in each landscape unit across the region is listed in Appendix 4 and can be used to identify areas of highest risk. The table in Appendix 4 shows two shaded columns with the additive sum of high productivity (high risk) ecosystems, and high plus moderate productivity ecosystems. This table can be used to assess the implications for reducing the risk by setting aside a particular landscape unit, and also demonstrates the complexity of landscape variability.

7.0 Data Uncertainties and Limitations

7.1. Sensitivity Analysis: Range of Natural Variability

Estimates for a range of mean stand-replacing disturbance intervals were determined as outlined in the methods section. In order to test the sensitivity of the results to these estimates, we ran a sensitivity analysis. We used +/- 30% variation from the suggested mean disturbance interval (see Table 10), as this is likely on the outside of the variability expected. We anticipate that only Analysis Units with relatively low disturbance intervals would be sensitive to changing the interval since after about 1000 years the resulting predicted change in the amount of old forest becomes relatively static (see Section 3.4).

Table 10. Estimates of stand-replacing disturbance intervals used in sensitivity analyses.

Analysis Units	Range of Mean disturbance intervals	Mean	High Freq sensitivity	Low Freq sensitivity
CH High, HB High, S High, Cottonwood,	600 – 800	700	490	901
S Medium, S Low, HB Medium	900 – 1100	1000	700	1300
CH Low; CH Medium, HB Low, Pine	1500 – 5000	3250	2275	4225

The results are tallied by summing the number of ecosystems (AU x BEC) that are in each risk class at time period 0 and again at time period 250 (Fig. 11). 'Low Frequency' estimates would potentially result in increased numbers of ecosystems at high risk, however, there are very minor differences between the low and high frequency sensitivity assessment, compared with the 'mean' level used in the model. Therefore, within reasonable bounds, the numbers of ecosystems in each risk class is quite insensitive to natural disturbance frequencies estimated for these ecosystems.

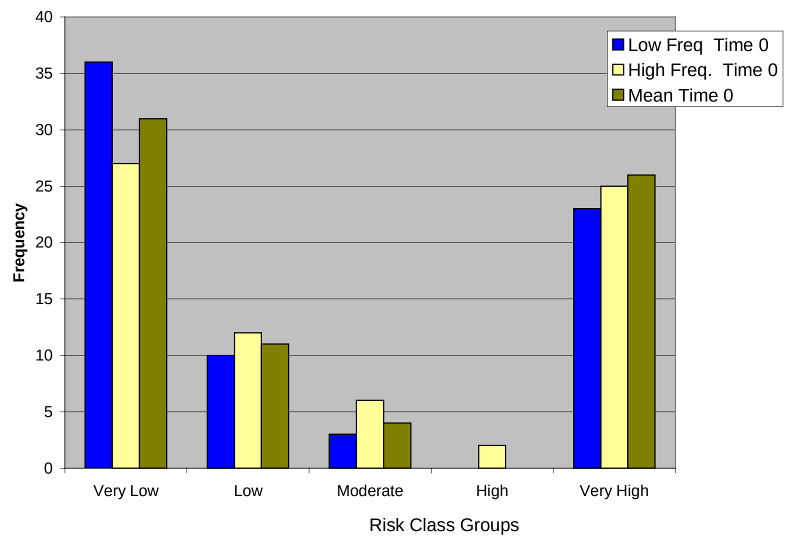


Figure 11. Sensitivity of results to disturbance rate at time zero.

7.2. Sensitivity Analysis: Risk classes

In order to test the implications of assigning different 'risk' categories to particular deviations from natural, sensitivity analysis was used. To simplify the output, sensitivity analyses were performed for AU x BEC for one time period (time 0). Tabular summaries of probability distributions are in Appendix 3 which shows the base risk class, and two sensitivities (see Appendix 3, Table 3):

Base risk model: includes low variability (5% either side) around the cut-off thresholds. For example, if the percent deviation from natural is 0 –20%, then the probability of being 'very low risk' is 95% (with 5% probability of being 'low risk'). If percent deviation from natural is 20-40% then the probability of being low risk is 90% (5% for both very-low and moderate risk). This captures a small amount of uncertainty in the risk thresholds.

Scenario 2: overall widens the risk classes attributed to a given deviation from natural. It acknowledges more uncertainty in risk thresholds, but maintains mean risk approximately as in the base risk.

Scenario 3: maintains a moderate width for each risk class as in Scenario 2, but errs towards reducing risk for a given deviation from natural.

Comparisons of the base risk categories, plus the two sensitivities, shows that for the current Base Case harvest forecast and environmental analysis, the 3 risk threshold sets examined create very little difference in the number of cases (AU x BEC x Landscape Unit) in each risk category. This outcome can be attributed to the fact that the ecosystems (AU x BEC x Landscape Unit) tend to be at extremes in terms of variation from RONV – i.e. they are either very heavily harvested, or not harvested at all – resulting in high numbers of cases in the very low and very high classes respectively, with fewer in the middle categories.

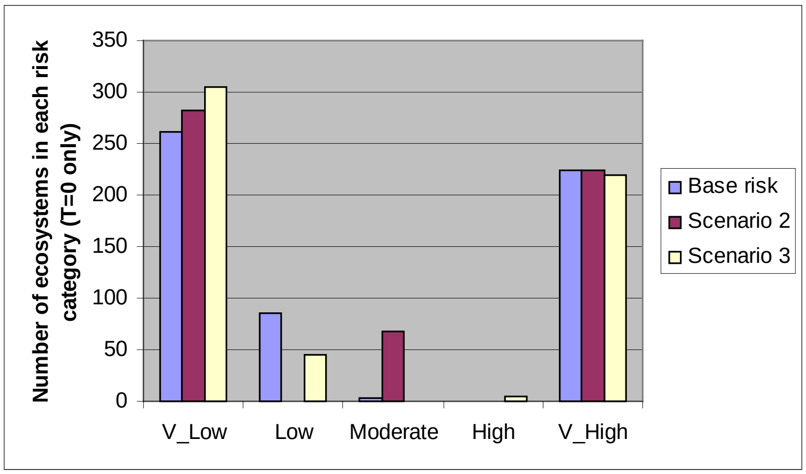


Figure 12. Summary of Sensitivity Analysis to Risk Categories – frequency of ecosystems in each risk class.

The numbers of ecosystems in each risk category varied only a small amount across all three scenarios. Therefore, for this landscape, the analysis results are quite insensitive to the risk classes used, within reasonable bounds.

7.3. Methodological Uncertainties

Environmental analyses contain many uncertainties and assumptions. We will mention here only those that are particularly relevant to the coarse filter ERA output.

7.3.1. Harvest projections

For this ERA the first major set of assumptions occurs within the timber harvest routine of the NC Landscape Model, and the assumptions used to mimic current management practices. In this case SELES models harvest patterns through time, projecting where and when areas will be harvested. Typical harvest models (e.g. the MoF FSSIM model) use basic rules to project harvest patterns (e.g. ‘force the model to log the oldest stand first’). SELES, being a more spatial model, includes more complex assumptions, including elements such as a road network, which allows harvesting to occur first in areas that have access to stands (D. Morgan et al. 2002). The output of SELES is likely more realistic than non-spatial models; however, as with any model of this type, the certainty of projections decreases as it moves further into the future.

7.3.2. Inventory

Any model is only as good as the input data. General data uncertainties have been dealt with elsewhere (see footnote No. 2 in Section 2).The major issues relevant to this analysis are the assumptions made about Analysis Units. There are a number of separate issues:

Analysis Units are created based on leading species and productivity and are not necessarily permanent for a particular site (since leading species may change over time). As a result areas that have been previously harvested and are dominated by early seral species, or have been planted to a different leading species will be under-represented in the current frequency of Analysis Units. In particular, this may be an issue for the amount of area that was originally cedar/ hemlock/ spruce high productivity areas. Once harvested, these sites may be reclassified as having a different leading species, such as cottonwood or other deciduous, rather than spruce/ cedar. This will result in an under-estimate of the impact of risk for these units.

The management assumption is that there is currently no species conversion on the coast– i.e. the assumption is that AU's are harvested and grow back as the same AU (i.e. same leading species). This may not be the case for some areas and may therefore fail to identify loss or modification of some ecosystems through time.

Analysis Units are used to describe ecosystems in this analysis, and this descriptor is also used as a proxy for structural variability across stands. Stands with large structure have high ecological values, and it was considered important to track them through time (S. Liepens pers. comm.). Although it is likely reasonable that most high productivity AU's have large-structured forest stands naturally, there will also be other Analysis Units that have large structures but that are typed as low productivity stands – in particular slow growing, old but very large cedar groves. It is a failing of this model that these stands cannot be directly identified in the inventory. It is possible/ likely that such stands will be targeted for timber harvest in future, but this cannot be identified in the model to date, so the risks associated with harvesting such stands are likely under-estimated through time.

7.3.3. Natural disturbance data

The model output is based primarily on the divergence of current or future abundance of old forest, compared with the predicted level of old forest based on natural disturbance patterns. In general, there is little question that the North Coast primarily consists of old forest, and that stand-replacing disturbances are rare (Dorner and Wong 2002). It is possible however that a number of biophysical units do have significantly higher rates of natural disturbance. For example, it is possible that some riparian ecosystems have higher rates of disturbance than adjacent upland. In order to address this issue, disturbance rates were applied by Analysis Unit which was considered more ecologically relevant than BEC Variant (which was used in a previous draft – A. Banner pers. comm.).

7.3.4. Risk thresholds

Identification of risk classes and thresholds for environmental assessments of this type are currently receiving global attention as environmental concerns push science towards assessing the state of populations, communities and ecosystems (P. Angelstam pers. comm.). The science behind setting thresholds however is complex: data are available for some individual species but the questions become considerably more complex for ecosystems.

At the landscape level, natural disturbance patterns result in landscape level seral stage distributions. It has been shown that individual species in ecosystems are adapted specifically to the types of patterns produced by the dominant natural disturbance regime occurring there (Bunnell 1995). It is therefore reasonable to assume that radically altering the abundance of old forest from that occurring under a natural disturbance regime will put the biodiversity in that ecosystem at risk.

The coarse filter ERA uses linear risk classes and ranks particular 'deviations from natural' into categories of risk - very low, moderate, high and very high. This is clearly an area of uncertainty in the analysis. However sensitivity analysis shows that for this landscape under the current management regime, the model outcome is very insensitive to the width of the risk classes used, even when the risk classes err considerably towards lowering the risk designation. This somewhat surprising outcome results from the pattern of ecosystem distribution and the pattern of harvest on the landscape. In particular, a number of ecosystems are very lightly impacted, while others are very heavily impacted. In this case then, there is reasonable certainty, that the extent of changes within particular ecosystems are difficult to misinterpret.

7.3.5. Uncertainty in the model

The core approach used for this work (Bayesian Belief modeling) can inherently include uncertainties. This was used to account, for example, for expert opinion of uncertainties regarding the biological value of a particular ecosystem – and was represented by a range of probabilities around a particular value. Uncertainty in ecological models is usually very important but has not been examined directly in this Base Case model. In future scenarios it may be appropriate to explicitly examine some of the uncertainties and their influence on the outcome of the model in further detail.

8.0 Conclusions

The Base Risk to coarse filter biodiversity interpreted from an assessment of the abundance and distribution of old forest through time on the North Coast is highly variable with respect to different ecosystems (Appendix 6; Table 9). In general, the abundance of old forest in high productivity ecosystems within all BEC variants is currently much lower than that expected to occur under natural disturbance processes - which we interpret as meaning there is a high or very-high risk to coarse filter biodiversity within these ecosystems. The abundance of old forest in medium productivity ecosystems suggests a generally moderate risk to those systems currently, but predicted harvesting pressure increases the risk to high in most of these variants over the short term (the next 20 – 50 years). Low productivity ecosystems are generally (except spruce and cedar/ hemlock leading ecosystems in 3 landscape units) at very low or low risk through time.

Reporting on Base Risk, 8 of 47 ecosystems were at high or very high risk at time zero, and this increased to 19 of 47 ecosystems after 250 years. Note that although these high risk ecosystems actually represent a relatively small physical area within the entire North Coast (see Appendix 4), the biological values represented within them are likely very high.

A number of Risk Modifiers were used outside the BBN model to examine the potential impact of additional factors on coarse filter risk, in particular: Representation of Ecosystems in Protected Areas, Ecosystem Conservation Value, and Patch Size Trends. The potential modifiers were categorised (see Section 5.3), and allowed to modify Base Risk levels up or down. Although empirical data are largely unavailable to understand the specific implications of reducing the number of large patches, or of having a very small percent represented in Protected Areas, there is however substantial theoretical literature that supports the rationale allowing these parameters to modify risk levels. We used what we consider to be quite conservative levels of modification: risk was allowed to change a maximum of 1/3rd of a risk class (7 percentage points).

Reporting on Modified Risk, 9 of 47 ecosystems were at high or very high risk at time 0, (an increase of 1 over base risk), and 24 of 47 ecosystems were at high or very high risk at time 250 (an increase of 5 over base risk). This is a moderate increase in the number of units at high risk, but could substantially increase the amount of area at high risk over time.

In addition, the intention is to stress the need for comprehensive planning and to suggest that managing to maintain ecological integrity is a complex process, and is only generally represented by this modeling exercise.

Ecological thresholds for ecosystem-based analyses such as this have a relatively weak scientific background. However, in this case, the number of ecosystems in each risk class was quite insensitive to changing the risk probability functions, which increased our confidence that they represent a reasonable picture of the ecological risks to the LRMP area in relation to the Base Case management regime.

8.1. Future Land Use Scenario Developments

This model assumes that the abundance, distribution and pattern of old forest on the landscape is a robust indicator of likely risks to loss of ecological integrity in this landscape. Scenarios for this value should therefore vary these parameters in order to view the potential alternative land use scenarios. In brief, this can be achieved in a number of ways:

- Vary the abundance and distribution of old forest maintained on the landscape. Use Appendix 4 to locate areas with high densities of at risk ecosystems
- Apply patch size requirements to old forest
- Vary the area and distribution of Protected Areas
- Apply partial harvest to areas to increase recovery rate of old forest values
- Apply long rotations to improve extent of recovery through time

The results from this report provide guidance as to which ecosystems are at most risk, during the short, mid and long-term. This should aid in assessing how the above scenarios can be applied to retain ecological values.

It may be appropriate to add additional indicators during scenario assessment, in particular, site series mapping will allow direct assessment of rare ecosystems, and partial harvest scenarios may require additional consideration of road density information.

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Appendix 1. Summary of changes since Draft 1.

A previous version of this report was released as a draft in September 2002. As a result of comments from external reviewers, part of the ERA Team (A. Banner, J. Pojar, D. Reid, D. Steventon, D. Morgan) reconvened with a number of reviewers to determine solutions to various data and model issues:

Two types of changes were made:

1. External Input Changes

a. Range of Natural Variability. In the Draft Report, the base units for application of natural disturbance types were applied by biogeoclimatic variant. However, after review, and on the basis of Dorner and Wong (2003), the ERA team determined it would be more ecologically appropriate to identify natural disturbance units on the basis of Analysis Units because these better reflect physiogeographic units, which change disturbance intervals. The methodology used to produce the disturbance rates was similar in each process. A comparison of the Current and Draft disturbance intervals are shown in the table below.

CURRENT UNITS:	Range of Mean disturbance intervals	General Description
AU: CH High, HB High, S High, Cottonwood,	600 – 800	Floodplain/ productive on steep ground/ cottonwood
AU: S Medium, S Low, HB Medium	900 – 1100	Moderate productivity Upland
AU: CH Low; CH Medium, HB Low, Pine	1500 – 5000	Other Upland
PREVIOUS DRAFT UNITS:	Mean and SD (years) Disturbance intervals	General Description
BEC: CWHvh2	3027 +/- 1323	Hecate Lowland
BEC: CWHvm; CWHvm1; CWHvm2; CWHws1; CWHws2	892 +/- 145	Kitimat Ranges
BEC: ESSFwv; MHmm1	858 +/- 65	Kitimat Ranges
BEC: MHmm2	3088 +/- 1214	Hecate Lowland, higher elevation

Implications of change: altering application of disturbance intervals results in changed risk for individual units (e.g. high productivity units within the CWHvh2 would now have lower risk because of the application of disturbance intervals by AU). However, the overall number of ecosystems in each risk category did not change substantially because all disturbance intervals considered reasonable for the North Coast are relatively high and result in relatively high predicted levels of old forest (>66% < 93%). Units that have or are being harvested often retain considerably less old forest than either of these values, so tend to result in high risk whichever value is used.

b. **Forest Cover Data.** During the work of the ERA team, it was determined that problems with the base Forest Cover layers were resulting in interpretation difficulties for levels of risk for some ecosystems. In particular, it is well recognised that the projected age of some forest cover types is incorrect (A. Banner pers. comm.). The methodology for assigning forest cover ages is to use photo-interpretation associated with field checks. However, in the past, this work has focused on productive stands in the timber harvesting landbase, and has been less concerned with non-commercial stands outside the timber harvesting landbase. Examination of the forest cover data suggested that a substantial area of the landbase was incorrectly labeled as age class 7 and 8 (between 120 and 250 years in age), when this is extremely unlikely – in fact the forest stands are likely in excess of 500 or 1000 years old but are generally scrubby and without a closed canopy, and so have been identified as 'younger' by photo-interpreters. Although a known problem, efforts to fix this problem have been slow because this part of the landbase is outside the timber harvesting landbase. However, in our analysis, it is key to correctly interpret the age class of these forest types. Since it was not possible to reinventory the coast, expert opinion was used to rectify this problem as much as possible. To this end, the following data changes were made to the Forest Cover data prior to running the SELES model.

AU	Data Solution	Rationale
Cedar / hemlock – high Hemlock/ balsam – high	No data lumping	Large structured stands, usually in the THLB. Good inventory, plus easy to photo-interpret.
All Spruce All cottonwood	No data lumping	Disturbance regimes relatively frequent, so current canopy tree age most closely represents actual stand age
Cedar/ hemlock – medium Hemlock/ balsam – medium Hemlock/ balsam – low	Lump AC 8 and 9 as 9	Intermediate productivity stands: Some units have much higher apparent AC8 and lower AC9 than predicted. Difficult to photo-interpret among these age classes.
Cedar/ hemlock – low Pine	Lump AC 7, 8 , 9 as 9	Very unproductive stands. Very difficult to photo-interpret; tends to be outside THLB (so low effort)

Implications of change: in the draft report (2002), there was apparent high risk for some units that have not been harvested because the inventory said there was a low level of old forest. We did not allow the model to classify this as high risk for the obvious cases, however, we could not modify all results, so some units remained at apparent high or moderate risk even though we suspected this was due only to inventory. The inventory change resulted in this problem being fixed, and now, for all units where harvesting has not occurred, there is reasonable or good correlation between the predicted and actual amounts of old forest.

2. Internal Model Changes

a. **Increased the # of categories in % Old Forest table.** Step-by-step examination of the calculations for individual BECxAUxLU units revealed that the Aug 2002 base risks calculated by the BBN tended to jump almost discontinuously from low to high risk levels. This was caused in part by too few categories in % old forest table. As a result, high levels of uncertainty were included in the calculated divergence from RONV, resulting in higher risk (which is influenced by uncertainty). **Implications of change:** Increasing the # of categories has evened out the uncertainty and lowered risk for those affected units.

b. **Reduced uncertainty in the Base Risk tables**. The base risk calculation takes a result from an equation and assigns it to one of 5 states. In principle there are three sources of uncertainty here: 1) it is possible that errors could occur in "discretizing" the results of an calculation (especially complex calculations); the calculation might lead to fine-scale "peaks" or "valleys" below the level that the resolution of the discrete states can capture; and 2) uncertainty in what the discrete states should be; 3) uncertainty created by combinations of ecosystems (e.g. BECxAU) for which no probabilities are specified, but which occur in the model output. This should occur only infrequently. To deal with uncertainties 1 and 2 the model originally used the Netica defaults to assign the probabilities. However, neither of these sources of uncertainty is very high in the case of this calculation (one could reasonably argue that the calculation is perfectly certain), so in the final model total uncertainty was limited to 5% over all states. To deal with uncertainty type 3, a default state with high probabilities was specified (rather than leaving all states as possible with equal probability). **Implications of change:** Reducing uncertainties 1) and 2) reduces the probability of misclassifying risk values. Reducing uncertainty 3) may reduce risk values in rare cases where unusual combinations of ecosystems occur, but probably does not change overall results very much.

c. **Revision of Modifiers on Risk**. Both the "Ecosystem Influence" and "Biological value" tables were reviewed. Not all probabilities for the PinexBEC states had been entered (about 40%), and this would be a major reason why Pine ecosystems were given counter-intuitively moderate / high risk values in the Draft report. **Implications of change:** completing the tables results in risk levels are now much lower for pine.

d. **Presentation of Results re Partial Harvest.** In the previous version of this report, we included reference to preliminary work done to aid in assessment of partial harvesting scenarios – in particular, recovery curves were developed for each ecosystem, and included into a Bayesian Belief Network submodel. In that Sept 2002 report we did not allow these recovery curves to influence risk (since only clearcut harvest techniques were being assessed), but present the information solely as preparation for future work. However, in this final Base Case Report version we do not include the recovery work at all, in order to simplify this final report. A future report will provide the results of this work.

Appendix 2. Analysis Units: based on leading species (ITG) and site index (which is a measure of the productivity of the stand).

AU #	Analysis Unit Name	Inventory Type Groups	Site Index (metres at 50 yr)
1	Cedar, Hem/cedar—High	C, CH, HC (9,11,14)	>22
2	Cedar, Hem/cedar—Medium	“”	15-22
3	Cedar, Hem/cedar—Low	“”	<15
4	Hemlock, Balsam*—High	H, HB, HS, H DEC, B, BH, BS, D CONIF (12, 15, 16, 17, 18, 19, 20, 37)	>22
5	Hemlock, Balsam—Medium	“”	15-22
6	Hemlock, Balsam—Low	“”	<15
7	Spruce-High	S, SH, SB, S DEC (21, 23, 24, 26)	>22
8	Spruce-Medium	“”	15-22
9	Spruce-Low	“”	<15
10	Cottonwood	AC (35, 36)	All

*Balsam = amabilis fir.

Crosswalk between Analysis Units and Site Series. Note overlapping groups, where single site series within BEC variants may be present within more than one Analysis Units. (A. Banner pers. comm.).

	Site Series or groups of site series (by BEC Unit) likely associated with each analysis unit						
Analysis Unit	CWHvh2	CWHvm1	CWHvm2[c]	CWHwm[d]	CWHws[e]	MHwh[g]	MHmm1
1	06, 07, (05)	05, 08	05, 08	04	06	(05)	(05)
2	04, (13)	(04), 01, 06, (14)	01, 06, (04, 14)	04, 03	01, 04, (05)	01, 05	01, 05, 03
3	01, 03, 11	12, 03, (02)	12, 03, (02)	08, 02	03, 05	02, 04, 06, 07, 08, 09	02, 04, 06, 07, 08, 09
4	06, 07, (05)	05, 08	05, 08	04	06	05[f]	(04, 05)[f]
5	04	(04), 01, 06	01, 06, (04)	01, 03	01, 04, 05	01, 05	01, 03, 05
6	04	06	06, (01)	08, 02	03, 05	02, 04, 06, 07, 08, 09	02, 04, 06, 07, 08, 09
7	08, (09)	09, (08)	(08)	05, (04)	07, (06)	N/A[f]	N/A[f]
8	06, 07, (05), (15, 17)[a]	05, 08	05, 08	03	04, (06)	N/A[f]	N/A[f]
9	13, (18, 19)[b], (14, 16)[a]	14	14	09	11	N/A[f]	N/A[f]
10	N/A	10, 11	N/A	06, 07	09, 09	N/A[f]	N/A[f]

Brackets around site series denote that site series is either restricted in distribution or less commonly associated with that analysis unit.

Footnotes: a: Shoreline Forests; b: Brackish Water (Estuaries).; c: Higher elevations; productivity declines; yellow cedar replaces redcedar; d: Redcedar and amabilis fir are uncommon in CWHwm; e: Includes CWHws1 and ws2; f: This analysis unit probably does not occur in the MH zone; g: Yellow-cedar and Mountain Hemlock replace Red-cedar and Western Hemlock in the MH zone

Appendix 3. Biological Influence, Biological Value and Ecosystem Conservation Value.

For background on BBN see Marcot et al. 2001. (**www.spiritone.org)**

This appendix summarises the assumptions incorporated into the the BBN Model, specifically with respect to biological influence and importance, how they combine into Ecosystem Conservation Value, and how risk values were assigned in the sensitivity analysis.

Table 1. Biological Influence and Biological Importance for each Analysis Unit within BEC variant (A. Banner and J. Pojar pers. comm.).

		AU1	AU2	AU3	AU4	AU5	AU6	AU7	AU8	AU9	AU10	Certainty
CWHvh	Biological importance	H	M	M	M	M	L	VH	H	H	H	10
	Biological influence	H	M	H	H	H	L	VH	H	M	VH	9
		AU1	AU2	AU3	AU4	AU5	AU6	AU7	AU8	AU9	AU10	
CWHvm1	Biological importance	H	M	M	M	M	L	VH	H	H	H	10
	Biological influence	H	M	L	H	H	L	VH	H	L	VH	9
		AU1	AU2	AU3	AU4	AU5	AU6	AU7	AU8	AU9	AU10	
CWHvm2	Biological importance	H	M	M	H	M	L	VH	H	H	H	10
	Biological influence	M	M	L	M	H	H	H	M	L	VH	9
		AU1	AU2	AU3	AU4	AU5	AU6	AU7	AU8	AU9	AU10	
CWHwm	Biological importance	H	M	M	M	M	L	VH	H	H	H	10
	Biological influence	H	M	L	H	H	L	VH	H	L	VH	9
		AU1	AU2	AU3	AU4	AU5	AU6	AU7	AU8	AU9	AU10	
CWHws1	Biological importance	H	M	M	M	M	L	VH	H	H	H	10
	Biological influence	H	M	L	H	H	L	VH	H	L	VH	9
		AU1	AU2	AU3	AU4	AU5	AU6	AU7	AU8	AU9	AU10	
CWHws2	Biological importance	H	M	M	H	M	L	VH	H	H	H	10
	Biological influence	H	M	L	M	H	L	H	M	L	VH	9
		AU1	AU2	AU3	AU4	AU5	AU6	AU7	AU8	AU9	AU10	
MHmm1	Biological importance	H	M	M	H	M	L	N/A	N/A	N/A	N/A	10
	Biological influence	L	M	L	L	H	L	N/A	N/A	N/A	N/A	9
		AU1	AU2	AU3	AU4	AU5	AU6	AU7	AU8	AU9	AU10	
MHmm2	Biological importance	H	M	M	H	M	L	N/A	N/A	N/A	N/A	10
	Biological influence	L	M	L	L	H	L	N/A	N/A	N/A	N/A	9
		AU1	AU2	AU3	AU4	AU5	AU6	AU7	AU8	AU9	AU10	
MHwh1	Biological importance	H	M	M	H	M	L	N/A	N/A	N/A	N/A	10
	Biological influence	L	M	L	L	H	L	N/A	N/A	N/A	N/A	9

Biological importance and biological influence values were combined in the model to create Ecological Conservation Value, as shown (Table 2):

Table 2. Ecosystem Conservation Value. Each box is read as the 'probability of a given ecosystem conservation value, given the stated levels of biological influence and biological importance.

Inputs	Ecosystem conservation value

Biological Influence	Biological Importance	Low	Medium	High	VeryHigh
Low	Low	0.90	0.10	0.00	0.00
Low	Medium	0.40	0.55	0.05	0.00
Low	High	0.15	0.70	0.15	0.00
Low	VeryHigh	0.05	0.35	0.35	0.25
Medium	Low	0.40	0.55	0.05	0.00
Medium	Medium	0.05	0.90	0.05	0.00
Medium	High	0.05	0.45	0.45	0.05
Medium	VeryHigh	0.00	0.20	0.55	0.25
High	Low	0.15	0.65	0.15	0.05
High	Medium	0.05	0.45	0.45	0.05
High	High	0.00	0.10	0.80	0.10
High	VeryHigh	0.00	0.10	0.45	0.45
VeryHigh	Low	0.10	0.40	0.40	0.10
VeryHigh	Medium	0.00	0.20	0.60	0.20
VeryHigh	High	0.00	0.05	0.35	0.60
VeryHigh	VeryHigh	0.00	0.00	0.10	0.90

Risk values for the base risk and the sensitivity analyses as shown in the Table 3. The tables should be read as follows: For Base risk, if deviation from natural is 0 –20% the probability that risk is very low is 95%, with 5% probability that risk is low.

Table 3. Risk threshold probabilities – for base risk and two sensitivity analyses

Base risk		Verylow	Low	Moderate	High	Very high
	0-20	0.95	0.05	0	0	0
	20-40	0.05	0.9	0.05	0	0
	40-60	0	0.05	0.9	0.05	0
	60-80	0	0	0.05	0.9	0.05
	80-100	0	0	0	0.05	0.95
Scenario 2		verylow	low	moderate	high	very high
	0-20	0.85	0.1	0.05	0	0
	20-40	0.05	0.4	0.45	0.1	0
	40-60	0	0.05	0.35	0.5	0.1
	60-80	0	0	0.05	0.45	0.5
	80-100	0	0	0	0.05	0.95
Scenario 3		verylow	low	moderate	high	very high
	0-20	1	0	0	0	0
	20-40	0.4	0.6	0	0	0
	40-60	0.2	0.3	0.5	0	0
	60-80	0	0.2	0.3	0.5	0
	80-100	0	0	0.2	0.3	0.5

Assumptions

In typical timber supply modeling, the only 'disturbance' modeled directly is that caused by forest harvesting. Natural disturbance is modeled within the timber harvesting landbase as a reduction in harvest volume. Natural disturbance outside the timber harvesting landbase (i.e., in the non-contributing landbase) can be modelled in a variety of indirect ways, depending on the ecosystem type and natural disturbance regime. In the absence of modeling this natural disturbance outside the timber harvesting landbase, the area is simply assumed to continue growing older for the length of time the model runs. This is a substantive problem for environmental assessment because it suggests there is more old forest than is likely through time. In order to reduce this problem, it was decided to hold the seral stage constant in the non-contributing landbase, for all areas except the landscape units (Stagoo, Ohl and Anyox) affected by fumekill (where the seral stage distribution currently errs towards early seral). This assumption assumes that the current distribution of seral stages represents the natural distribution. This manipulation was part of the SELES run, and was agreed to by ministry staff (H. Burger pers. comm.).

Appendix 4. Area of Analysis Units within Landscape Units.

Shaded columns show total area of higher risk and medium risk landscape units.

LU	CedarHigh	HemBalHigh	SpruceHigh	SUM High	SpruceMed	CedarMed	Sum Medium S and C	SpruceLow	HemBalMed	CedarLow	Pine	Cottonwood	HemBalHighThinned	HemBalLow	HemBalMedThinned	OtherDecid	Grand Total
Big_Falls	119	795	469	1,383	377	628	1,005	290	1,832	5,123	27			6,266		50	15,976
Kitsault		1,051	27	1,078	73	138	211	57	4,109	2,029	1	367		27,189		151	35,192
Bishop	151	564	151	866	267	1,390	1,657	42	1,687	14,722			134	2,566	197	54	21,925
Somerville	155	518	131	804	300	447	747	314	3,438	11,741				10,167		99	27,310
Kumealon	153	502	121	776	328	1,365	1,693	381	1,807	22,497	666			5,133	48	185	33,186
Scotia	4	496	269	769	332	494	826	155	2,852	10,284	13		4	6,664	135	61	21,763
Kwinamass	1	363	374	738	333	152	485	244	1,605	5,953		16		10,093		119	19,253
Kitkiata		626		626	90	223	313	150	969	9,554				10,755		72	22,439
Khutzeymateen		60	512	572	509	72	581	383	1,153	2,660		45		6,859		180	12,433
Gribbell	155	262	64	481	58	976	1,034	96	582	10,059	8			1,370		73	13,703
Quottoon	141	136	203	480	335	587	922	281	1,435	10,595				3,183		230	17,126
Stagoo	6	311	157	474	118	297	415	258	1,790	6,254		55		10,659		124	20,029
Kaien	140	154	117	411	203	1,056	1,259	759	1,630	28,880	1,453			4,954	108	662	40,116
Triumph	65	216	50	331	137	1,325	1,462	9	1,663	5,769	10			1,965		59	11,268
Khtada	10	113	177	300	161	209	370	231	2,062	1,977	19	18		4,262		119	9,358
Sparkling	1	216	60	277	589	166	755	419	570	5,488				4,634		185	12,328
Khyex	12	128	107	247	465	286	751	445	1,441	7,302		25		6,087		239	16,537
Porcher	49	154	5	208	432	543	975	451	1,189	49,586	2,807		3	1,790	953	147	58,109
Brown	62	110	36	208	147	240	387	82	628	9,719				2,766		6	13,796
Chambers	46	90	59	195	252	128	380	179	841	10,574				10,285		11	22,465
Hawkes_South	12	73	92	177	91	78	169	166	779	7,106	17			3,519			11,933
Johnston	36	59	72	167	285	208	493	618	419	7,596				7,718		391	17,402
Marmot	21	118	16	155	37	628	665	19	1,361	4,544				11,031		38	17,813
Hartley	1	117	35	153	83	1,198	1,281	304	1,000	30,494	264			6,882		42	40,420
Red_Bluff		139		139	134	799	933	97	830	21,434	518			4,517		79	28,547

LU	CedarHigh	HemBalHigh	SpruceHigh	SUM High	SpruceMed	CedarMed	Sum Medium S and C	SpruceLow	HemBalMed	CedarLow	Pine	Cottonwood	HemBalHighThinned	HemBalLow	HemBalMedThinned	OtherDecid	Grand Total
Hevenor	90	26		116	42	1.076	1.118	75	573	27.924	1.470			3.848		44	35.168
Skeena Islands		91	20	111	85	167	252	54	289	1,077		75		1,163		418	3,439
Union	1	23	59	83	255	425	680	222	705	13,380	195			2,630		75	17,970
Olh	14	56		70	28	275	303	19	581	4,318				4,889		309	10,489
Belle Bay	12	27	25	64	31	429	460	71	912	14,464	9			6,145		18	22,143
Pearse	16		22	38	20	396	416	209	300	25,435	919			2,153		9	29,479
Gil			33	33		1,257	1,257		377	16,762	3,502			1,281		88	23,300
Kshwan		17	15	32	152		152	86	393	191		302		4,632		22	5,810
Aristazabal			31	31		142	142		23	36,258	5,222			63			41,739
Captain			25	25		934	934	64	170	17,035	33			732		65	19,058
Tuck	19	4		23	397	1,132	1,529	638	2,882	31,192	4,633			3,567		213	44,677
Observatory Ea	12	9		21	18	172	190	56	120	5,507				3,883		3	9,780
Anyox		18		18		200	200	38	653	5,030	167	5		6,354		58	12,523
Dundas	3			3	18		18	162	32	11,391	6,925			379			18,910
Monckton	1			1	10	555	565	45	280	23,807	1,374			2,146		46	28,264
Banks				0		490	490	73	43	76,259	13,973			326		6	91,170
McCauley				0		312	312	6	4	31,484	2,004			103		3	33,916
Pa aat				0	37	209	246	18	284	12,740	3			1,625		45	14,961
Observatory W				0	17	206	223	30	179	7,924				3,657		140	12,153
Chapple				0		73	73			255	117						445
Campania				0		23	23	7	14	4,861	10,746			226			15,877
Kiltuish				0		7	7	4	55	411				83			560
Stephens				0		7	7	5		4,844	2,579			18			7,453
Iknouk				0			0			1							1
Trutch				0			0	46		10,890	1,162			77			12,175
Grand Total	1,508	7,642	3,534	12,684	7,246	22,120	29,366	8,358	46,541	685,380	60,836	908	141	221,294	1,441	4,938	1,071,88

Appendix 5. Percent protected areas for ecosystems.

AU	BEC	Grand Total	Percent Parks
CedarHigh	CWHvh2	766	1.2
	CWHvm	652	1.1
CedarLow	ATp	167	0.0
	CWHvh2	489,228	1.2
	CWHvm	90,814	2.6
	CWHwm	35,495	0.0
	CWHws2	1,429	0.0
	MHmm1	24,782	4.3
	MHmm2	730	0.0
	MHwh1	42,534	1.0
CedarMed	CWHvh2	12,554	1.8
	CWHvm	6,575	2.4
	CWHwm	1,989	0.0
	CWHws2	122	0.0
	MHmm1	179	0.0
	MHwh1	656	0.0
HemBalHigh	CWHvh2	1,261	0.0
	CWHvm	4,642	2.2
	CWHwm	519	0.0
	CWHws1	678	0.0
	CWHws2	325	0.0
HemBalLow	ATp	1,169	0.6
	CWHvh2	35,767	0.5
	CWHvm	70,875	8.2
	CWHwm	29,896	0.0
	CWHws1	2,481	0.0
	CWHws2	7,764	0.0
	MHmm1	44,085	6.7

AU	BEC	Grand Total	Percent Parks
	MHmm2	14,148	0.0
	MHwh1	15,109	0.6
HemBalMed	CWHvh2	13,493	1.0
	CWHvm	22,006	7.4
	CWHwm	5,336	0.0
	CWHws1	2,022	0.0
	CWHws2	1,626	0.0
	MHmm1	933	2.6
	MHmm2	302	0.0
	MHwh1	823	0.0
Pine	CWHvh2	59,370	0.2
	CWHwm	176	0.0
	MHwh1	1,220	0.0
SpruceHigh	CWHvh2	579	0.0
	CWHvm	2,698	19.0
	CWHwm	213	0.0
SpruceLow	CWHvh2	3,544	2.6
	CWHvm	3,733	11.5
	CWHwm	500	0.0
	MHmm1	214	26.6
	MHwh1	335	0.0
SpruceMed	CWHvh2	1,973	0.0
	CWHvm	4,716	12.6
	CWHwm	390	0.0
Grand Total		1,064,459	2.1

Appendix 6. Risk Modification Detail.

This table shows the Base Risk at three times intervals (0, 50 and 250 years), both numerically, and categorically for each ecosystem. Risk Modifiers: Ecosystem Conservation Value, Protected Areas, and Patch Trends are shown categorically and numerically. The resulting Modified Risk is then shown for three time intervals. Modifiers are simply added to scores for Base Risk to produce Modified Risk. Note that under Risk Modifiers, the value (H, L, M,) is the value of the analysis for that modifier, NOT the risk level (this is in contract to Table 9 where resulting effect on risk is shown).

		Base Risk at time 0, 50, 250						Risk Modifiers (score and value)						Modified Risk at time 0, 50, 250					
AU	BEC	BR_0	BR_G_0	BR_50	BR_G_50	BR_250	BR_G_250	ECV	ECV mod	PA	PA mod	Patch	Patch Mod	MR_0	MR_G_0	MR_50	MR_G_50	MR_250	MR_G_250
CedarHigh	CWHvm	88.3	VH	88.4	VH	88.6	VH	H	6	L	5	H	7	106.3	VH	106.4	VH	106.6	VH
HemBalHigh	CWHvh2	87.9	VH	87.9	VH	88.7	VH	M	3	L	5	H	7	102.9	VH	102.9	VH	103.7	VH
CedarHigh	CWHvh2	83.9	VH	87.8	VH	87.4	VH	H	6	L	5	H	7	101.9	VH	105.8	VH	105.4	VH
SpruceMed	CWHwm	79.9	H	78.9	H	81.3	VH	VH	7	L	5	M	3.5	95.4	VH	94.4	VH	96.8	VH
HemBalHigh	CWHvm	78.2	H	80.9	VH	84.8	VH	M	3	L	5	M	3.5	89.7	VH	92.4	VH	96.3	VH
SpruceLow	CWHwm	69.2	H	66.5	H	82.1	VH	M	3	L	5	M	3.5	80.7	VH	78	H	93.6	VH
SpruceHigh	CWHvh2	62.5	H	71.1	H	72.6	H	VH	7	L	5	M	3.5	78	H	86.6	VH	88.1	VH
SpruceHigh	CWHwm	60.2	H	25.6	L	82	VH	VH	7	L	5	H	7	79.2	H	44.6	M	101	VH
SpruceMed	CWHvh2	48.8	M	68.9	H	76.1	H	H	6	L	5	M	3.5	63.3	H	83.4	VH	90.6	VH
SpruceLow	MHmm1	45.6	M	47	M	46.7	M	L	0	H	-5	L	0	40.6	M	42	M	41.7	M
SpruceHigh	CWHvm	45.3	M	51.7	M	57.4	M	VH	7	H	-5	M	3.5	50.8	M	57.2	M	62.9	H
HemBalMed	CWHvh2	42.2	M	51.6	M	66.6	H	M	3	L	5	M	3.5	53.7	M	63.1	H	78.1	H
HemBalHigh	CWHws2	38.9	L	50.2	M	64.9	H	H	6	L	5	M	3.5	53.4	M	64.7	H	79.4	H
HemBalLow	CWHws1	38.1	L	51.2	M	58.9	M	L	0	L	5	M	3.5	46.6	M	59.7	M	67.4	H
HemBalLow	CWHwm	34.9	L	34.9	L	38.9	L	L	0	L	5	L	0	39.9	L	39.9	L	43.9	M
CedarLow	CWHwm	34.8	L	34.8	L	34.8	L	M	3	L	5	L	0	42.8	M	42.8	M	42.8	M
SpruceMed	CWHvm	31.4	L	41.9	M	66.2	H	H	6	H	-5	H	7	39.4	L	49.9	M	74.2	H
HemBalMed	CWHwm	31.1	L	45.6	M	63.3	H	M	3	L	5	M	3.5	42.6	M	57.1	M	74.8	H
HemBalMed	CWHvm	30.6	L	53.3	M	67.1	H	M	3	M	0	H	7	40.6	M	63.3	H	77.1	H
CedarMed	CWHwm	30.1	L	47.6	M	69.6	H	M	3	L	5	M	3.5	41.6	M	59.1	M	81.1	VH
HemBalMed	CWHws1	29.4	L	68.4	H	81.4	VH	M	3	L	5	H	7	44.4	M	83.4	H	96.4	VH
SpruceLow	MHwh1	26.9	L	22.3	L	27.4	L	L	0	L	5	L	0	31.9	L	27.3	L	32.4	L

		Base Risk at time 0, 50, 250						Risk Modifiers (score and value)						Modified Risk at time 0, 50, 250					
AU	BEC	BR_0	BR_G_0	BR_50	BR_G_50	BR_250	BR_G_250	ECV	ECV mod	PA	PA mod	Patch	Patch Mod	MR_0	MR_G_0	MR_50	MR_G_50	MR_250	MR_G_250
HemBalMed	MHmm1	26.8	L	24.6	L	46.3	M	M	3	L	5	M	3.5	38.3	L	36.1	L	57.8	M
HemBalHigh	CWHwm	26.6	L	41.1	M	70	H	M	3	L	5	M	3.5	38.1	L	52.6	M	81.5	VH
SpruceLow	CWHvm	23.8	L	28.9	L	42.7	M	H	6	H	-5	M	3.5	28.3	L	33.4	L	47.2	M
CedarMed	MHwh1	23.7	L	26.8	L	40.9	M	M	3	L	5	M	3.5	35.2	L	38.3	L	52.4	M
CedarMed	CWHvm	21.6	L	50.1	M	66.1	H	M	3	L	5	H	7	36.6	L	65.1	H	81.1	VH
CedarMed	MHmm1	19	VL	29.5	L	37.1	L	M	3	L	5	M	3.5	30.5	L	41	M	48.6	M
SpruceLow	CWHvh2	18.5	VL	24.1	L	28.2	L	H	6	L	5	L	0	29.5	L	35.1	L	39.2	L
HemBalMed	MHmm2	15	VL	47.2	M	49.7	M	M	3	L	5	M	3.5	26.5	L	58.7	M	61.2	H
CedarMed	CWHvh2	14.9	VL	31.7	L	53.4	M	M	3	L	5	M	3.5	26.4	L	43.2	M	64.9	H
HemBalMed	CWHws2	14.2	VL	43.4	M	67.9	H	M	3	L	5	H	7	29.2	L	58.4	M	82.9	VH
HemBalLow	MHmm1	13.7	VL	13.7	VL	14.5	VL	L	0	M	0	L	0	13.7	VL	13.7	VL	14.5	VL
HemBalHigh	CWHws1	13.4	VL	37.1	L	51.6	M	M	3	L	5	H	7	28.4	L	52.1	M	66.6	H
CedarLow	MHmm1	11.5	VL	11.5	VL	11.5	VL	M	3	L	5	L	0	19.5	VL	19.5	VL	19.5	VL
HemBalLow	CWHws2	10.6	VL	10.7	VL	31	L	L	0	L	5	M	3.5	19.1	VL	19.2	VL	39.5	L
CedarLow	MHwh1	10.6	VL	10.6	VL	10.6	VL	M	3	L	5	L	0	18.6	VL	18.6	VL	18.6	VL
Pine	CWHvh2	10.6	VL	10.6	VL	10.6	VL	M	3	L	5	L	0	18.6	VL	18.6	VL	18.6	VL
Pine	MHwh1	10.6	VL	10.6	VL	10.6	VL	M	3	L	5	L	0	18.6	VL	18.6	VL	18.6	VL
HemBalLow	CWHvm	10.5	VL	10.6	VL	18.5	VL	L	0	M	0	M	3.5	14	VL	14.1	VL	22	L
HemBalLow	CWHvh2	10.5	VL	10.6	VL	15.6	VL	L	0	L	5	L	0	15.5	VL	15.6	VL	20.6	VL
CedarMed	CWHws2	10.5	VL	10.5	VL	52.4	M	M	3	L	5	H	7	25.5	L	25.5	L	67.4	H
HemBalLow	MHwh1	10.5	VL	10.5	VL	11.6	VL	L	0	L	5	L	0	15.5	VL	15.5	VL	16.6	VL
CedarLow	CWHvm	10.5	VL	10.5	VL	11.1	VL	M	3	L	5	L	0	18.5	VL	18.5	VL	19.1	VL
CedarLow	CWHws2	10.5	VL	10.5	VL	10.6	VL	M	3	L	5	L	0	18.5	VL	18.5	VL	18.6	VL
HemBalLow	MHmm2	10.5	VL	10.5	VL	10.5	VL	L	0	L	5	L	0	15.5	VL	15.5	VL	15.5	VL
CedarLow	CWHvh2	10.5	VL	10.5	VL	10.5	VL	M	3	L	5	L	0	18.5	VL	18.5	VL	18.5	VL

BR = Base Risk; BR_G_0 = Base Risk Group (at time zero); MR_G_0 = Modified Risk Group (at time zero). ECV = Ecosystem Conservation Value category (very hig, high, medium, low). ECV_Mod = Applied modification factor. PA = Protected Areas Category (Low, Medium, High). PA Mod = Protected Areas Modification Factor. Patch = trends in patch size category (High, Medium, Low).