Background Report

Component of British Columbia's Land Use Strategy

North Coast LRMP

An Ecosystem-Based Management Planning Framework for the North Coast LRMP

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This report was prepared by independent consultant Rachel F. Holt, to provide overview information on potential strategic approaches to ecosystem-based management in the North Coast LRMP area. The information in this report was collected from a wide range of sources and was reviewed by government staff for accuracy and completeness. The final product is presented as the professional judgement of the author and does not necessarily reflect the view of the Province.

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Executive Summary

Ecosystem-based management plans consistently have the strategic goal of *maintaining or restoring ecological integrity* within the planning area. Broad principles have been defined by a wide range of authors that are predicted to increase the probability of meeting this general goal. In addition, many authors generally agree on key steps that should be included in an ecosystem-based management planning framework.

However, there remain discrepancies as to how the broad goals and principles of ecosystem management should be operationalised. This variation in how ecosystem management has been applied to existing landbases has raised scepticism and concern from many of the original proponents of ecosystem-based management. This variation is due, at least in part, to a use of ecological terms without a full appreciation of the scope of their ramifications, and without expressly stating assumptions and risks associated with decision-making. The key to successful ecosystem management may be to ensure that goals are fully agreed to and understood by all parties and that assumptions regarding risks to the environment and to social and economic values are made explicit throughout the planning process.

The aim of this report is to provide clarity around some key concepts of ecosystem-based management, and to highlight some others that are more controversial. The report summarises goals, broad principles and key steps of an ecosystem-based planning framework, as suggested by the literature. In particular, the report uses a potential planning framework to highlight the key decisions needed to successfully operationalise the plan. Key ecological components of an ecosystem-based plan are also summarised. Implicit in the report is that in order to be successful, the LRMP should explicitly state planning approaches, management goals and assumptions, and set targets at regional, landscape and stand levels in order to allow both implementation and effectiveness monitoring of the plan. This approach coupled with adaptive management should provide a robust and flexible approach to land use planning.

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1.0 Terms of Reference

The purpose of this report is to provide a technical framework for the development of an ecosystem-based plan for the North Coast LRMP. The document is intended to be strategic in nature rather than to specifically address the North Coast landbase. The framework aims to provide a common language for discussion of ecosystem-related topics at the LRMP table, as well as identifying key decisions that will be fed into a decision support system for the process.

The report includes the following components:

1. A discussion of ecosystem management, and a suggested working definition

2. Identification of key elements of ecosystem-based management at the sub-regional, landscape and stand level

3. Examples of inventory and analysis to support discussion of each of the issues

4. Key questions to feed into a decision support system for long-term spatial and temporal modeling of issues.

The process for land use planning within the LRMP process includes all stakeholders (including forestry, mines, environment, First Nations, tourism, etc). This document does not specifically address how individual sectors would be included in the ecosystem-based planning process, and the appropriate process for each sector will need to be identified by the planning table. However, in general, the ecosystem management framework identifies ecological, social and economic benefits and costs associated with land use decisions and includes them in risk analyses to aid decision-making. The values desired by each sector would be included in this process to determine appropriate land use.

2.0 Ecosystem-based Management: a Brief Review

Ecologists began to identify key components of what would become ‘ecosystem management’ as early as the 1930s in North America (see Grumbine 1994 for early review). By the late 1980s a general ‘ecosystem management’ approach to land management was being advocated by many scientists. Since that time there have been a plethora of academic and ‘applied’ papers on the subject and there is still no single definition or accepted consensus of what constitutes ecosystem management. However, this should not be considered a failing of the concept (Yaffee 1999), rather, it has been noted that ecosystem management includes science and values and therefore is likely to be interpreted differently by people with different backgrounds.

Ecosystem management was initiated, and has evolved because of a concern that ‘traditional’ forest management practices (those that emphasise economic and utilitarian values of the forest) were resulting in the ‘biodiversity crisis’, and because traditional management appears to be failing to decrease the rate of loss of species and forested ecosystems (Soulé 1986; Jensen and Bourgeron 1994; Noss and Cooperrider 1994). In addition, interest in ecosystem management increased as theoretical and scientific approaches to conservation biology have grown.

Grumbine (1994; 1997) identified the general differences in opinion regarding what constitutes ecosystem management. After reviewing a wide array of literature he suggested a working definition of ecosystem management, that is largely agreed to by other authors since this time (Grumbine 1994; Jensen and Bourgeron 1994; Christensen et al. 1996; Haynes et al. 1996; Noss 1999b).

Ecosystem management integrates scientific knowledge of ecological relationships within a complex sociopolitical and values framework toward the general goal of protecting native ecosystem integrity over the long term.

In a review of land management approaches, Yaffee (1999) discusses three different approaches to management which lie along a continuum: i) environmentally sensitive multiple use – which views the environment as a constraint; ii) an ecosystem approach to management - in which the ecosystem is not a constraint, but a goal), and iii) ecoregional management – which is very similar to (ii) but rather than using ecosystems as abstract concepts, specifically identifies ecosystems as individuals places on the ground and tends to manage for processes rather than biota. Options ii) and iii) differ from environmentally sensitive multiple use in terms of the goals: the former maximises production for human use (though within some environmental constraints), whereas the latter two options aim to maximise ecological integrity and allows product production within the ecological constraints. Social and economic objectives are still an integral part of the ecosystem approaches, but they take place within the overall goal of maintaining ecological integrity (Yaffee 1999). Identifying maintenance of ecological integrity as the key goal of ecosystem-based management has been central to almost all authors on the subject (Grumbine 94; Wood 1994; Jensen and Bourgeron 1994; Clayoquot Sound Scientific Panel 1995; Christensen et al. 1996; Haynes et al. 1996; Noss 1996a,c; Noss 1999b; Yaffee 1999). Although it is suggested that there is no definitive point that can be termed ecosystem management, progress can be measured by moving along the continuum of management types towards ecoregional management (Yaffee 1999).

2.1 Key Concepts

Most ecosystem management schemes recognise themes that form the basis for an ecosystem management approach (Grumbine 1994 (which summarised 33 papers on ecosystem management); Peters et al. 1997, Yaffee 1999, Drever 2000, Franklin 2000, Utzig 2000).

Overarching goal:

- Maintain and/or restore ecological integrity.

Dominant themes:

- **Consider a hierarchy of scales:** include variation in both spatial and temporal scales, plus regional contexts outside the planning area

- **Use ecologically derived boundaries** for decision-making rather than administrative boundaries

- **Use scientific data and approaches to inform decision-making:** including composition and structure of ecosystems, processes, functions and inter-relationships. Acknowledge uncertainty and information gaps, and always use the best available information

- **Monitor both implementation and effectiveness of planning:** This includes establishing ecological baselines for analysis and interpretation of monitoring results, and use of reference areas operating at multiple spatial scales

- **Use adaptive management:** this includes active experimentation to use management as a continuous experiment, and the need for flexibility within the management framework (i.e. to change when necessary)

- **Use systems thinking:** recognition of the complexity and dynamism of ecological and social systems, the interdependent roles between humans and nature, and the distinctions between human values and technical information

- **Organisational change:** implementation likely requires change in organisational nature of agencies, and equalisation, or at minimum, acknowledgement of power relationships

- **Co-operation between managers and interested and affected parties:** collaborative decision making, and acknowledgement of power imbalances

3.0 What is Ecosystem Integrity

Franklin (2000) uses a general description of ecological integrity (from Angermeier and Karr 1994), as being “a system’s wholeness, including presence of all appropriate elements and occurrences of all processes at appropriate rates”. Noss (1999b) states that ecosystems remain healthy (i.e. maintain integrity) only when their processes – nutrient cycling, energy flow, hydrology, disturbance regimes, succession, predator-prey relationships pollination etc - remain intact (see section on natural range of variability). Restoration may also be a key feature of maintaining ecological integrity in areas where there has been ecosystem degradation (Drengson and Taylor 1997; Drever 2000).

Note – that these definitions do not require (or intend) that management maintains all species on all areas at all times. Neither do they suggest that ecosystems are in any way static. However, they do mean that *at the appropriate spatial scale*, all elements, populations and processes are maintained.

A number of authors have suggested specific goals that increase the probability of maintaining ecological integrity (Grumbine 1994; Haynes et al. 1996; Noss 1999b; Drever

2000). The sets of goals are often generally similar (though with some subtle differences); for example the set of goals outlined by Grumbine (1994) recommends:

· maintain viable populations of all native species

· represent, within protected areas, all native ecosystem types across their natural range of variation

· maintain evolutionary and ecological processes i.e. (disturbance regimes, hydrological processes, nutrient cycles)

· manage over periods of time long enough to maintain the evolutionary potential of species and ecosystems

· accommodate human use and occupancy within these constraints.

In summary: maintaining ecosystem integrity is the goal for ecosystem-based planning because it protects ecological and evolutionary processes (i.e. it protects biodiversity within the bounds of the natural range of variability (Swanson et al. 94; Holling and Meffe 1996; Noss 1999b). And, it maintains ecosystem and social resilience against catastrophes in biological, economic or political systems (Holling and Meffe 1996; Haynes et al. 1996; Quigley and Arbelbide 1997), and should foster development of diversified economic systems in order to avoid unsustainable boom/ bust cycles.

4.0 Maintaining Ecological Integrity: A Framework

In ecosystem-based planning, priority is given to identifying requirements necessary to maintain or restore ecological integrity. Within this framework, the resulting potential for production of forest products can then be determined. Since ecosystems are not fully understood, analyses that include assessments of data and knowledge uncertainty, and risk assessment play a key role. Monitoring and adaptive management are also key to ensuring that key assumptions stand up to scrutiny.

Although there is no set approach to ecosystem-based management, a number of authors have suggested the following series of steps that provide a framework for an approach (Clayoquot Sound Scientific Panel 1995, Peters et al. 1997, Utzig 2000):

1. Inventory
2. Identify threats to ecological integrity
3. Analysis
4. Formulation of a management plan
5. Environmental impact assessment and plan finalisation
6. Determination of sustainable production levels
7. Operational level planning and implementation
8. Monitoring and adaptive management.

This potential framework is presented as an approach to planning on the North Coast LRMP, and required baseline data and key decisions are highlighted in Tables 1- 4.

1. Inventory: collection and/or compilation of available information sufficient to characterise and adequately inform management of the planning area. Including physical and environmental data, plus natural disturbance regimes and distribution of key ecosystem components (seral stage distributions/ distribution of populations etc), and consideration of potential communities in areas with significant current changes (e.g. invasive species etc). (see Table 1)

2. Identify Threats to Ecological Integrity: identification and characterisation of significant current and future threats to biodiversity and maintenance and/or restoration of ecological integrity within the planning area (see Table 2). This process aims to focus the discussion and allocation of limited resources, to ensure that priority elements are dealt with adequately.

3. Analysis: interpretation and evaluation of inventory information identified in (1) to develop an understanding of the composition and structure of the ecosystems present. Development of ecological baselines in relation to predicted future trends, and risk assessment indicators. Identification of indicator, keystone or sensitive species and their requirements. Plus identification of compatibility between the above and different silvicultural options. Assumptions used during the analysis phase should be explicitly stated. Identify knowledge gaps and how they will be dealt with (see Table 3 and sections below on 'Range of Natural Variability' and 'Risk Assessment'). Threats to ecological integrity (2) should be used to focus this analysis where resources (time/ $$) are limiting.

Table 1. Threats to Ecological Integrity

Type	Examples
Physical Data	Climate, topography, geology, terrain, soils, hydrologic features
Ecosystems and habitats	Forest cover, BEC units, ecosystem types, TEM/PEM mapping, aquatic and wetland habitats, species present, biological communities present, patch size distribution, connectivity
Current state of the land	Changes in ecosystems resulting from past and present management/development (e.g. identify ecological elements that are predicted to have changed significantly) Potential communities in areas with species shifts (e.g. invasive species) Identification of other potentially degraded areas
Social	Cultural sites, and other areas of importance to local communities and First Nations; Recreation areas
Characterise natural disturbance regimes and range of natural variability for baseline variables	Seral stage distribution, ecosystem processes and functions, and their historical range of variability

Table 2. Threats to Ecological Integrity

Type	Examples
Currently under threat	Species, populations, or ecosystems and habitat that are rare, threatened or endangered currently
Potential future threat (i.e. sensitive elements)	Ecosystem components (species, habitat elements, ecosystems) that may be rare, threatened or endangered with current management trends
Sensitive sites	Terrain stability, soil erosion, ecological limitations to growth
Regional context	Use regional information to provide guidance and context (e.g. identification of under-represented ecosystems in protected areas)
External impacts	Identify external impacts, e.g. climate change, and potential cumulative impacts arising from different land use sectors

Table 3. Analysis of baseline data and trends

Type	Examples
Ecological baseline	Develop baseline for environmental risk assessment based on range of natural variation (range of natural variability – RONV). E.g. RONV for seral stage distribution, level of connectivity, patch size distribution, level of structure remaining after natural disturbance
Ecological reference areas	Identify potential reference areas (especially if historically data are weak or lacking)
Identify (ecologically) significant changes in ecosystem components	Identify changes in disturbance regimes, species distributions and ecosystems: compare natural range with current and future trends
Identify key species of concern	Umbrella, keystone, sensitive, indicator, currently rare species
Identify habitat requirements	For selected species above identify habitat requirements, and critical habitat elements
Identify critical ecosystem types	E.g. hydroriparian areas that link landscapes (keystone ecosystems?)
Capabilities and suitabilities	Determination of specific areas for habitat supply, population viability, resource production and First Nations / social values. Identify factors affecting suitability through time.
Knowledge gaps and assumptions	Document knowledge gaps and uncertainties Document assumptions and hypotheses used in the above

4. Formulation of the Management plan

The information compiled in steps 1, 2 and 3 provides the basis for setting objectives and defining management zones by identifying key issues at appropriate scales in addition to knowledge gaps and uncertainties. The key decisions required to formulate a management plan are outlined below and in Table 4.

a) Setting Objectives: definition of future desired conditions; including objectives that span the full hierarchy of spatial scales (e.g. site, stand, watershed, landscape) and an ecological time frame. Table 4 outlines components of an operationalised ecosystem-based plan, identifying key decisions at different scales and identifying information needed to guide those decisions.
Document the assumptions implicit in each objective to allow outside assessment and testing through adaptive management (e.g. an assumption sets out both the operational objective –*maintain 30% of original MaMu habitat*, and the functional objective – *in order to maintain 50% of the original population)* (see Table 4)

b) Defining Management Zones : sequence of spatially locating i) a network of reserves (coarse and fine filter), ii) low intensity managed forest areas, iii) balanced multiple use managed forest areas, and where applicable, iv) plantation areas. Identify specific objectives for each zone (see Table 4)

c) Management Regimes – Treatments and Prescriptions: definition of management practices for each of the management zones that are consistent with overall objectives, and the specific objectives for each zone (see Table 4)

d) Temporal Planning: define harvesting patterns that maintain appropriate landscape attributes over a suitable ecological timeframe. Include roads

5. Environmental Impact Assessment and Plan Finalisation: Through the use of risk assessment or an equivalent analysis (e.g. Ministry of Environment, Lands and Parks 2000), determination of the potential impacts of proceeding with the preliminary management plans outlined in Step 4

6. Determination of Sustainable Production Levels: incorporate objectives, zones and management regimes, to determine sustainable level of production

7. Operational Level Planning and Implementation: preparation of operational level plans and implementation procedures

8. Monitoring and adaptive management: monitoring and experimentation to ensure that objectives are being achieved and ecological integrity is maintained and/or restored. Results of monitoring are used to re-evaluate, and where appropriate, revise inventory and data analysis, environmental assessments, assumptions, management objectives, management plans and implementation measures

Table 4. Identify environmental, social and economic objectives

Type of Protection	Objective	Key Decision Guidance
Large fully protected parks	Maintain natural ecological processes Maintain suite of functioning ecosystems Maintain 'reference' ecosystems	<u>Location:</u> _ Gap analysis of representativeness at regional level. Examine functionality of existing and proposed reserves (e.g. minimum dynamic area). Include consideration of structural / seral stage in this analysis. _ Un-impacted 'reference' ecosystems _ Habitats for rare, endangered, vulnerable species _ Habitats for key species (umbrella, keystone, indicator) _ Areas that provide core centres in a connected landscape <u>Percent protected</u>[1] _ Use RONV[2] to assess extent of change from 'natural' at sub-regional scale and appropriate risk levels _ Population viability estimates in combination with identification of key habitat requirements for rare, endangered, vulnerable species _ Population viability estimates in combination with identification of key habitat requirements for key species (umbrella, keystone, indicator)
Small fully protected parks	Maintain rare or critical ecosystems or habitats	<u>Location:</u> _ Critical or rare habitat components _ Critical or rare ecosystems _ Areas that provide key connectivity requirements <u>Percent Protected</u> _ Extent rare/ critical in combination with risk assessment for individual type
Full protection with managed landscape	Maintain adequate key areas to maintain ecological integrity (e.g. to maintain populations throughout their natural range)	<u>Location:</u> _ Gap analysis of representativeness at sub-regional or landscape level (at appropriate scale e.g. site series or site series group). Examine functionality of existing and proposed reserves (e.g. adequate size?). _ Habitats for rare, endangered, vulnerable species _ Habitats for key species (umbrella, keystone, indicator) _ Other resource values (e.g. winter range) _ Critical or rare habitat components _ Critical or rare ecosystems _ Key ecosystem components (e.g. hydroriparian/ shorelines)

Type of Protection	Objective	Key Decision Guidance
		_ Areas that provide connectivity within and between watersheds/ landscapes Percent Protected[1] _ Use RONV to assess extent of change from 'natural' at sub-regional scale and appropriate risk levels _ Habitat requirements for rare, endangered, vulnerable species _ Habitat requirements for key species (umbrella, keystone, indicator)
Partial protection with managed landscape	Maintain key elements at the stand level (wildlife trees, snags, gappiness, coarse woody debris etc)	Location: _ Biologically significant attributes at stand level _ Critical or rare habitat components (e.g. specific nesting sites) _ Key ecosystem components (e.g. hydroriparian/ shorelines) _ Areas typically retained by natural disturbance Percent Protected _ Natural disturbance patterns _ Rates of attribute decay _ Adequate distances between retained attributes
Management objectives within forest matrix	Focus management to maintain coarse and fine filter values identified plus appropriate connectivity	_ Identify zones required to meet overall objectives _ Identify conflicts and opportunities using management regimes (e.g. as outlined in Pojar and Mackinnon 2000) _ Include assessment of required road access and conflicts and opportunities
Cultural objectives	Protection of First Nation/ cultural values	Location and Percent Protected _ As identified by appropriate groups
Economic objectives	Maintain longterm access to diverse economic values	_ Maintain or establish a diverse forestry industry (timber, value-added, non-timber forest products etc) _ Full cost accounting of alternative values (recreation and tourism) _ Make assumptions about risk and trade-offs explicit.

1: Habitat requirements may be used directly to assess the need for protection, or may be used as a checking mechanism to test the adequacy of an analysis of range of natural variation in combination with risk assessments.

2: RONV = 'range of natural variability' (see section below).

5.0 Key ecological components

Ecosystem-based planning is built on a number of key ecological components and approaches, e.g., reserve design based on ecosystem representation, emulation of natural disturbance frequencies and patterns, a coarse and fine filter reserve systems, and single species management. Some authors have suggested that reserve design, natural disturbance and coarse/ fine filter approaches constitute fundamentally different approaches to land planning (e.g. Quigley and Arbelbide 1997). This notion is suggested because the concept of reserves at first sight, is fundamentally at odds to an approach that acknowledges the dynamism of ecosystems. However, each of these three approaches has positive features that taken in concert can increase the robustness of the planning process. In an ecosystem-based planning exercise on the Klamath-Siskiyou Ecoregion (Pacific Northwest USA) Noss et al. (1999) used a reserve design system that used three parallel processes: i) protection of special elements such as rare species hotspots (e.g. Neitlich and McCune 1997), remaining old-growth forests and key watersheds, ii) representation of physical and vegetative habitat types and iii) maintenance of viable population of focal species (e.g. fisher *Martes pennanti*). Use of a comprehensive plan in this way should reduce the probability that important elements are missed, and therefore increase the likelihood that the plan maintains ecological integrity.

Some key components of the different approaches are outlined below.

5.1 Coarse and fine filter approaches

Coarse filter approaches to maintaining ecological integrity acknowledge that there are hundreds or thousands of species of which we know little or nothing, and that our ability to predict ecosystem processes is at best, very limited (Hunter 1991). Maintaining key ecosystem elements in suitable abundance and distribution at a landscape level therefore likely the only way to maintain this diversity (Franklin 1993). It also provides a pragmatic approach to planning, since there are already mapped vegetation classification schemes which can be analysed and used to provide a coarse filter approach. Assessing whether the distribution of habitat components is adequate can be aided by using the range of natural variability as a benchmark from which to assess change (Quigley 1997, Landres et al. 1999), combined with risk analyses (e.g. MoELP 2000).

However some species will not be adequately protected using a coarse filter. Fine filter species include those with specific habitat requirements, are already rare, or have limited ranges.

Coarse filter strategies would include: i) a system of fully protected reserves outside the managed forest, ii) protected reserves within the forest matrix (e.g. seral stage targets), iii) management zones with specific objectives and linked to particular objectives, iv) baseline stand level retention targets within the working forest.

Fine filter strategies would include identifying: i) sensitive species, or those with requirements not likely to be covered in the coarse filter, ii) rare habitats or ecosystem elements not included in the coarse filter.

5.2 Single species management

Use of a coarse/ fine filter approach to management does not remove the role for considering single species within the planning framework (Noss 1996c). In particular, consideration of the following groups of species will be useful:

i) Keystone species/ species groups. Keystone species play a disproportionate role in ecosystem functioning than suggested by their biomass (Mills et al. 1993). It is particularly important that they are adequately managed for since removing them from the ecosystem likely has impacts of much greater proportion than for many other species. Bears/ salmon and nutrients may be such a group, given the key functions of the hydroriparian ecosystem (Clayoquot Sound Scientific Panel 1995). Identifying keystone species will help to ensure key species/ processes are maintained. This information should factor into risk analyses and implications of decision–making.

ii) Umbrella species. Umbrella species are those with large and broad habitat requirements. Retention of sufficient habitat to maintain these species is thought to provide a coarse filter approach to maintaining other smaller, less well known species. Identifying umbrella species will provide guidance as to adequate levels of retention and positioning of zoning to maintain ecological integrity.

iii) Indicator species are those highly sensitive to changes to the ecosystem, and therefore have been suggested as warranting special attention. Indicator species may be useful for monitoring unsuspected, or unknown subtle impacts of ecosystem changes (e.g.. what impact does opening up historically continuous old growth forest have on species in the remaining adjacent old growth?).

iv) Sensitive species: are those that are currently rare, endangered or threatened, or are likely to be impacted by current development patterns. Identification of these species will ensure a comprehensive fine-filter program.

5.3 Protected Areas

The importance of protected areas as a central feature of an ecosystem management plan has been well documented (Noss 1996a; Margules et al. 1994; Dellasalla et al. 1996). The purposes of landscape level reserves include i) providing refuges for natural processes, ii) retaining representative samples of ecosystems and iii) providing core habitat for sensitive species (though maintaining species solely within a reserve system is considered impractical and does not meet the requirements of maintaining ecological integrity). It has been well demonstrated that *ad hoc* reserve selection is inefficient (Pressey 1994; Pressey et al. 1996). Three main approaches have been suggested to avoid ad hoc selection: i) gap analysis for representation (e.g. Burley 1988; Scott et al. 1993) and ii) reserve selection algorithms (e.g. Pressey and Nicholls 1989; Margules et al. 1994) and iii) protection of special elements (Myers 1990; Noss 1999b). Protected areas that have other management foci (scenic, recreation etc) may fail to meet biological objectives (Noss and Cooperrider 1994).

Gap analysis is a technique that uses existing reserve areas as a central focus, and identifies ecosystems, land formations or habitat types not currently included in the existing reserves. It is a relatively straightforward technique and uses readily available data. The scale of the analysis will impact the utility of the results, and should be appropriate to the size of planning area and the variation in ecosystems throughout the area. Gap analysis can be used within a coarse filter approach (e.g. Burley 1988; Iacobelli 1995) to identify under-represented habitats/ vegetation types. In order to be effective, gap analysis should consider the following: i) the potential need for over-representation of rare features (12% of 5 % is unlikely to provide a functioning ecosystem, i.e. there needs to be *adequate* representation to increase probability of maintaining ecological integrity (e.g. use minimum dynamic area analyses (Peters et al. 1997)), ii) consider increasing representation of widely impacted ecosystem components, iii) assess not only whether ecosystems are present, but whether appropriate structural/ seral stages are present. In areas such as the North Coast, where the timber harvesting landbase is limited to low elevation areas, gap analysis and representation techniques in combination with risk assessment will provide a key approach to determining suitable areas for retention at regional and landscape scales.

Reserve selection algorithms have been designed for use mostly where there are no existing reserves. They aim to select, from a predetermined pool of choices, the combination of reserves that encompasses the most diversity (or other variable as required). The approaches applied to real situation (mostly in Australia and South Africa) have used to concept of 'complementarity' – where the first reserve chosen has highest diversity (usually of species), and further reserves are added chosen based on the maximum *additional* number of species added. Refinements of this process have included using species abundance rather then presence/ absence data to deal with maximising population viability (Turpie 1995), and considering location of reserves to consider meta-population dynamics (at least in theory) – (Nicholls and Margules 1993). Limitations of the process include the necessity for species distribution data or other information on ecosystem distributions. However, a combination of these concepts, even when applied informally, can aid in small and large scale reserve selection (e.g. Holt 1998, 2000).

Special elements can include a number of different variables: species richness (hotspots of diversity), rare ecosystems, critical habitat, etc. Difficulties in reserve design using this method are often based on lack of data about the specific elements in question.

5.4 Retention: How much is enough?

Maintaining ecological integrity includes retaining habitat in order to meet broad goals such as maintaining populations of species across their natural ranges, and maintaining natural processes across the landscape.

Interpretation of what this implies operationally however, is the key phase of an ecosystem management planning process. In particular, within any area of the planning framework, how much retention is enough to meet the broad goals? The following provide some broad guidance on this subject:

1. Science cannot provide a generic answer to this question. However, within a particular geographic area, science can provide guidance on the range of percentages that are likely to maintain ecological integrity with a higher probability. This process is based on assumptions regarding range of natural variability of ecosystem parameters, in conjunction with risk assessments.

2. "How much is enough?" will vary with respect to the natural disturbance regimes, and more specifically, with the natural range of variability of specific landscape components. Most simply, the percent of old seral forest remaining on a landscape needed to maintain ecological integrity will increase as the natural levels of old forest increase. The further

the difference from natural, the higher the probability that ecological integrity will not be maintained.

3. "How much is enough" will depend on specific locations of retained areas. Even high levels of retention may fail to maintain ecological integrity if they fail to identify critical or core areas. This will be a key question on the north coast due to constraints.

4. Linking through the matrix – (ecosystem-based landscape planning) – requires consideration of habitat connectivity and/ or population viability analysis to determine appropriate levels of retention within the matrix. Protection/ restoration of landscape connections are meant to limit the negative impacts of landscape changes on wildlife (Hobbs 1992).

5. Science has suggested some ranges of retention necessary to maintain ecological integrity. These ranges vary widely (8 – 99%; Jeo et al. 1999) depending on the ecosystem and numerous other factors. Note that most studies recognise that a failure to identify and protect key/ critical habitats (somewhat irrespective of the absolute extent of protection) will reduce the probability of maintaining ecological integrity.

6. Answering the question of 'how much is enough' will involve a combination of different approaches to provide guidance, combined with risk analysis, and society will ultimately decide how certain it wishes to be that ecological integrity is maintained in the planning unit.

6.0 Natural disturbances and the range of natural variability

Ecosystems change over ecological and geological timeframes. The 'range of natural variability' is the amount of variation exhibited by ecosystem characteristics (or ecosystem components) over an appropriate timeframe. For example, there may currently be 65% of a particular landscape covered in old growth forest, but the percent of old growth present on the landscape may have decreased to 35% and increased to 85% over a particular time period. Over a relatively constant period of climate change, this variation is due to the stochastic nature of natural disturbances, and natural short-term variation in climatic and other factors impacting natural disturbance rates and patterns. Patterns of rate of change of characteristics are as important as the magnitude of changes (Morgan et al. 1994), since the rate of change affects the ability of species to adapt to new conditions.

6.1 What are relevant scales?

There is no single 'correct' time period for an analysis of range of natural variability. However, the function of a description of natural variation is to define the bounds of system behaviour that remain relatively constant over time (Morgan et al. 1994), and therefore the relevance of the description is decreased if the time period considered is too long (Landres et al. 1999). Considering how ecosystem characteristics have changed over time aid in identifying an appropriate timeframe (Millar and Woolfenden 1999). An analysis used for the Interior Columbia Basin Management Project showed that vegetation was relatively constant over the last 2000 years, and they therefore used 2000 years as their ecological timescale (Quigley and Arbelbide 1997 – see Millar and Woolfenden 1999 for cautions). For forests, the time should generally encompass multiple generations of trees (Morgan et al. 1994).

The spatial scale used for an analysis of range of variability is also critical, and should depend on the scale of interaction of the attribute being measured. Using the wrong scale can result in meaningless ranges in variation e.g., if interested in the amount of old growth over the landscape, consideration of an individual stand will provide a range of old growth from 0 – 100% over a reasonable timeframe, which is clearly meaningless. In this example, as the geographic scale of the analysis increases, the range observed will decrease (e.g. Wimberly et al. 2000). Conversely, failing to break complex landscapes into smaller areas with similar regimes will also result in high variability that makes the concept meaningless (Morgan et al. 1994). The scale used should depend on the scale that the attribute functions at, and on the management scale being considered. Dellasalla et al. (1996) concludes that a regional scale is appropriate for using natural variability concepts to set forest management goals.

In summary: Assessment of variability over relatively consistent climatic, edaphic, topographic and biogeographic conditions should provide the most useful assessment of range of natural variability in relation to ecologically relevant variation (Morgan et al. 1994).

6.2 Goal setting using range of natural variability

Use of the ‘range of natural variability’ concept assumes that recent, ecologically relevant conditions provide context and guidance for current and future land management. This concept is well accepted (e.g. Province of BC 1995; Morgan et al. 1994; Haynes et al. 1996; Cissel et al. 1999; Landres et al. 1999; Swetnam et al. 1999), and is usually expressed using the rationale that the closer current landscapes are to the range of natural variability, the higher the probability of maintaining ecological integrity (Swanson et al. 1994; Cissel et al. 1998; Landres et al. 1999). The rationale is that species have adapted to the range of habitat patterns resulting from historical disturbance events, and so the probability of population survival is reduced if habitat is maintained outside this natural range (Jensen and Bourgeron 1994; Bunnell 1995; Cissel et al. 1998). In practice, determining what is meant by ‘closer to the range of natural variability’ requires some clarification.

The range of natural variability can be used to identify ecosystem boundaries, beyond which the implications of pushing the ecosystem become unknown and potentially unpredictable. The range of natural variability is therefore used as a benchmark or baseline for interpretation and monitoring. When historic data are lacking, ‘pristine’ landscapes can be used as reference ecosystems to set benchmarks. Note that use of the term ‘range’ has been criticised (e.g. Landres et al. 1999) because ‘range’ includes rare extreme events that are not helpful in utilising the concept of natural variability. Depending on the characteristics in question, other parameters that define the midpoint (mean/ median, standard deviation etc) of the range may be more useful.

Natural range of variability, current landscape condition, and desired future condition (that set by land managers under social policy) can be compared to clarify management direction

(Landres et al. 1999). Where desired future condition is outside the natural range of variability, the risks associated with attempting to reach this goal should be explicitly acknowledged in the decision-making process (Morgan et al. 1994), and social goals should perhaps be re-evaluated because of the likely ecological and economic impacts of trying to maintain the landscape outside the natural range (Landres et al. 1999). Where current conditions are outside the natural range of variability, restoration may be the appropriate management tool. Where current conditions, and desired future conditions are within the range of natural variability (though note previous comments on the use of 'range'), management can likely be maintained (Landres et al. 1999).

Some authors have also criticised the concept by suggesting that range of natural variability cannot be used to set single targets for managers. This is of course true, science cannot set targets in this way. However, the aim is to use the concept to provide direction to the manager (Millar 1996) while increasing the probability of maintaining ecological integrity, and is not to set target figures with certainty.

Limitations of the concept include lack of historical data, difficulties of interpretation of historical data, possibility that future conditions may be without precedent and the difficulties of synthesising over appropriate multiple spatial and temporal scales (Swanson et al. 1994; Swetnam et al. 1999).

6.3 Risk Assessment

Environmental risk assessment provides methodology for evaluating the likelihood of a negative outcome resulting from human-caused changes environmental conditions. It provides an opportunity to make informed decisions about complex questions using best available information while acknowledging uncertainties and knowledge gaps explicitly. Risk assessment procedures can be highly complex, or simple 'back of the envelope' processes (Swanson et al. 1996; Ministry of Environment, Land and Parks 2000).

Risk assessment procedures play a key role in examining trade-offs between values in ecosystem-based management. They are useful not only because they provide inference regarding probability of outcomes from a range of actions, but also because they require assumptions to be stated explicitly, allowing the processes to be assessed by others (Everest et al. 1997).

Performed poorly, risk assessments can also provide 'room to continue undertaking non-conserving, non-ecologically beneficial activities (O'Brien 1997), by asking "exactly how risky is this activity?", or "what level of risk is acceptable"?. This process ends up identifying ways to continue poor practices with as small a change as possible. In order to be successful within an ecosystem-based management context, risk assessment procedures have to be allowed to address a wide range of options, and to consider how the precautionary principle overlaps with ecological objectives – as demonstrated by example, there is no point examining in detail the risks of crossing an icy river on foot when a wider viewpoint would identify that there is a bridge just downstream (O'Brien 1997).

7.0 Barriers to successful ecosystem-based management

Implementing a plan that actually maintains ecological integrity

Maintaining ecological integrity is the common goal uniting ecosystem-based management approaches from a whole range of value positions and agencies. Clarification around what broad goals this would involve is also similar from numerous authors. However, operationalising these broad goals (finding product output levels consistent with maintaining ecological integrity) still remains the crucial part of the planning process, and has been the focus of hefty criticism around some plans which claim to meet ecosystem management goals (e.g. Noss 1999b). In order to be successful, the framework needs to be approached with the intent of maintaining ecological integrity, and to use risk assessments, the precautionary principle and adaptive management to increase the probability that integrity is maintained.

In 1997 Grumbine summarised comments received on his earlier paper (Grumbine 1994), in which some readers raised issue with ecological integrity apparently ‘trumping’ other human goals. However, Grumbine notes that this argument results from narrow problem definition, a lack of contextual thinking and tendency to separate humans from nature. He and others (Haynes et al. 1996; Drengson and Taylor 1997; Cissel et al. 1998, Noss 1999b; Drever 2000; Franklin 2000) state that over time, there is simply no way to sustain humans without sustaining nature, particularly because we don’t know enough to decide now what is, or is not, important to maintain.

Mindset change

There is little disagreement amongst the scientific literature at least, that moving further along the continuum from environmentally sensitive multiple use towards ecoregional / ecosystem-based management is a positive step. But, it is also agreed that making a change from traditional product oriented management to a new goal of maintaining ecological integrity, in which sustainability is a precondition rather than an afterthought (Christensen et al. 1996) requires a fairly major shift in thought and approach to land management (Grumbine 1997; Yaffee 1999).

Making this transition while maintaining social values requires complex consideration of ecological, economic and social values. Current economic assumptions need to be questioned, and redressed in light of longterm goals and solutions (e.g. Drever 2000; Joint Solutions Project unpublished reference).

Organisation of planning

Grumbine (1994) notes that many authors on ecosystem-based management fail to identify key process related features of a successful ecosystem management plan. From literature review, he stresses that the key to success lies in ensuring equal and adequate representation by all parties, and that power imbalances between parties must be addressed upfront, and at minimum, acknowledged. Without this, he suggests ecosystem-based management will fail.

8.0 Conclusion

Ecosystem management has two components – to maintain ecological integrity, and to do so within a framework that includes politics and values.

The role of science within ecosystem-based management is to provide the best possible information, and the best tools with which to assess the implications of different management options. Strict science (rigorous experimentation and hypothesis testing) does not work well in the framework of resource management, because of the timeframes involved and the necessity to make almost immediate decisions. However, this stresses the need for an adaptive approach to management, and the requirement to embrace the ability to change management direction as new information arises. There is often a large a role for ‘experts’ in this process because of the lack of ‘scientifically known’ information. However, the role of scientific data and experts should be to present options and the *potential implications* of choosing options, using well informed risk analysis techniques.

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