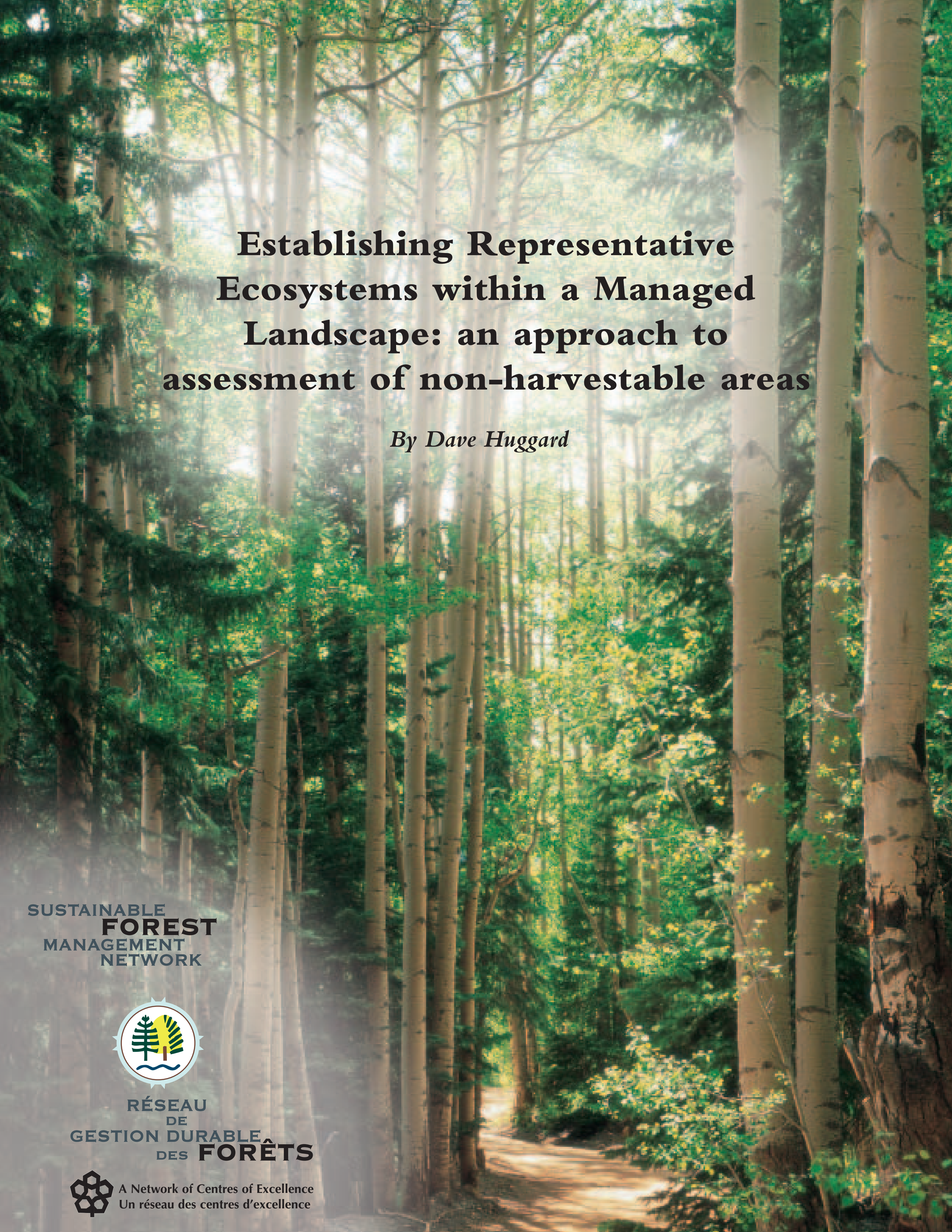

Establishing Representative Ecosystems within a Managed Landscape: an approach to assessment of non-harvestable areas

By Dave Huggard

SUSTAINABLE FOREST MANAGEMENT NETWORK

RÉSEAU DE GESTION DURABLE DES FORÊTS

A Network of Centres of Excellence
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THE SUSTAINABLE FOREST MANAGEMENT NETWORK

Established in 1995, the Sustainable Forest Management Network (SFM Network) is an incorporated, non-profit research organization based at the University of Alberta in Edmonton, Alberta, Canada.

The SFM Network's mission is to:
- Deliver an internationally-recognized, interdisciplinary program that undertakes relevant university-based research;
- Develop networks of researchers, industry, government, Aboriginal, and non-government organization partners;
- Offer innovative approaches to knowledge transfer; and
- Train scientists and advanced practitioners to meet the challenges of natural resource management.

The SFM Network receives about 60% of its $7 million annual budget from the Networks of Centres of Excellence (NCE) Program, a Canadian initiative sponsored by the NSERC, SSHRC, and CIHR research granting councils. Other funding partners include the University of Alberta, governments, forest industries, Aboriginal groups, non-governmental organizations, and the BIOCAP Canada Foundation (through the Sustainable Forest Management Network/BIOCAP Canada Foundation Joint Venture Agreement).

KNOWLEDGE EXCHANGE AND TECHNOLOGY EXTENSION PROGRAM

The SFM Network completed approximately 270 research projects from 1995 – 2003. These projects enhanced the knowledge and understanding of many aspects of the boreal forest ecosystem, provided unique training opportunities for both graduate and undergraduate students and established a network of partnerships across Canada between researchers, government, forest companies and Aboriginal communities.

The SFM Network's research program was designed to contribute to the transition of the forestry sector from sustained yield forestry to sustainable forest management. Two key elements in this transition include:
- Development of strategies and tools to promote ecological, economic and social sustainability, and
- Transfer of knowledge and technology to inform policy makers and affect forest management practices.

In order to accomplish this transfer of knowledge, the research completed by the Network must be provided to the Network Partners in a variety of forms. The KETE Program is developing a series of tools to facilitate knowledge transfer to their Partners. The Partners' needs are highly variable, ranging from differences in institutional arrangements or corporate philosophies to the capacity to interpret and implement highly technical information. An assortment of strategies and tools is required to facilitate the exchange of information across scales and to a variety of audiences.

The preliminary KETE documents represent one element of the knowledge transfer process, and attempt to synthesize research results, from research conducted by the Network and elsewhere in Canada, into a SFM systems approach to assist foresters, planners and biologists with the development of alternative approaches to forest management planning and operational practices.

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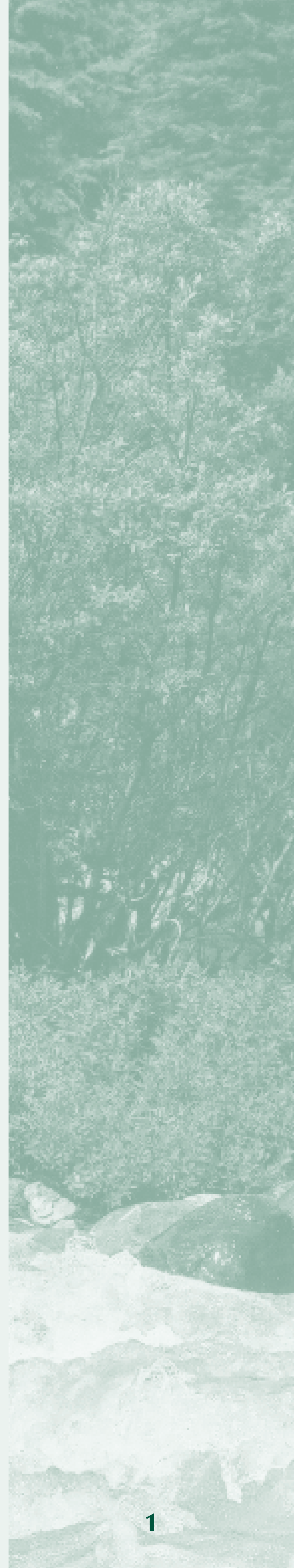


ESTABLISHING REPRESENTATIVE ECOSYSTEMS WITHIN A MANAGED LANDSCAPE - an approach to assessment of non-harvestable areas

SUMMARY

This report outlines the rationale and approach for monitoring the ecological representativeness of the non-harvestable part of managed landscapes, considerations in carrying out this monitoring, and ways the information feeds back to management decisions. A representative system of unmanaged areas is a recognized coarse-filter conservation goal in many areas, with the primary purpose of protecting the huge number of species that are too poorly-known to manage individually. Unmanaged areas in complex forest landscapes include any non-harvestable forest created by the many regulatory and operational constraints on forest harvesting. Examples of non-harvestable forest include parks, riparian areas, inoperable areas, wildlife reserves, old-growth management areas, and areas with no harvesting because of environmental sensitivity, visual quality or watershed protection. Harvesting constraints often produce more unmanaged area than official protected areas, making a potentially large ecological contribution. A main concern in assessing the ecological contribution of the non-harvestable landbase is whether it is representative of all ecosystem types. Secondary concerns include the sizes of non-harvestable patches, their geographic distribution, proximity to harvestable stands, and the age distribution of non-harvestable stands.

Monitoring the representativeness of non-harvestable areas is based on ecosystem mapping or surrogate variables that indicate the distribution of a wide range of species, possibly supplemented by mapping of special ecosystem types or high productivity sites. Three categories of non-harvestable land should be tracked separately in a monitoring program, because they have different degrees of long-term permanence or they may not be as representative of the ecosystem types: 1) regulatory reserves for various resources, which represent more permanent non-harvestable status, 2) areas that are non-harvestable because of physical or economic inoperability, but which may become accessible with changes in technology or markets, and 3) areas that are non-harvestable because they are commercially unproductive, because less productive sites may not represent all the organisms in the ecosystem type. Areas partially constrained from harvesting are also an important landbase to track in a monitoring program, because they provide opportunities for improving poorly-represented ecosystem types with little additional economic cost. Other land uses with biodiversity impacts - such as grazing, mining exploration, or salvage logging - should also be accounted for, as these can diminish the coarse-filter value of non-harvestable areas.

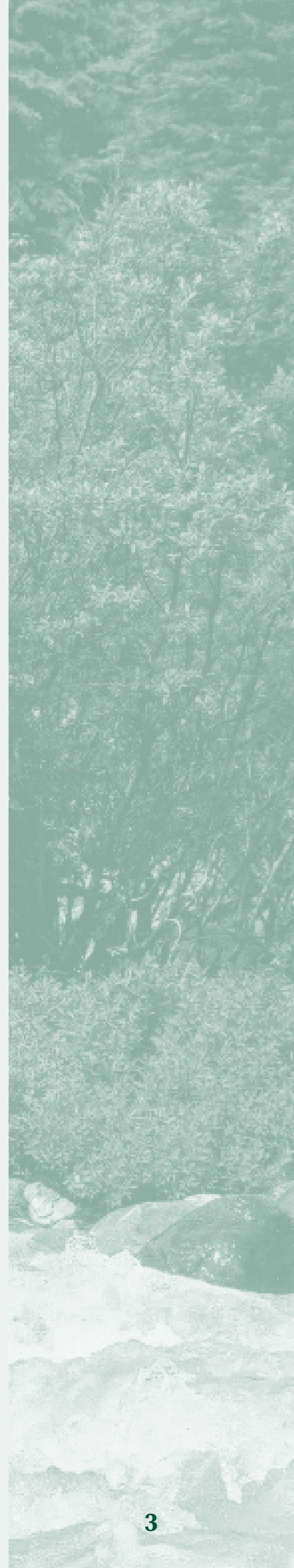
Rather than comparing levels of ecosystem representation to an arbitrary target, it makes sense to recognize that any increase in unmanaged area has conservation benefits, but with diminishing marginal value as area increases. Defining the marginal value curve will depend in part on the natural disturbance regime of the ecosystem type, as well as the intensity of management activity in the adjacent harvestable landbase. Direct management feedbacks from information on the non-harvestable landbase include: 1) locating discretionary reserves and conservation or mixed land-use zones, 2) decisions on amount and location of stand-level retention, 3) landscape planning using the non-harvestable landbase as a "skeleton", 4) focusing finer-filter monitoring in poorly represented ecosystems (and using this monitoring to test assumptions of the coarser-filter representation), and 5) more generally, recognizing the conservation value of the non-harvestable landbase. Overall, monitoring ecological representation in non-harvestable forest helps to focus conservation and monitoring resources, while helping to avoid imposing additional constraints on forest harvesting where they are not necessary.

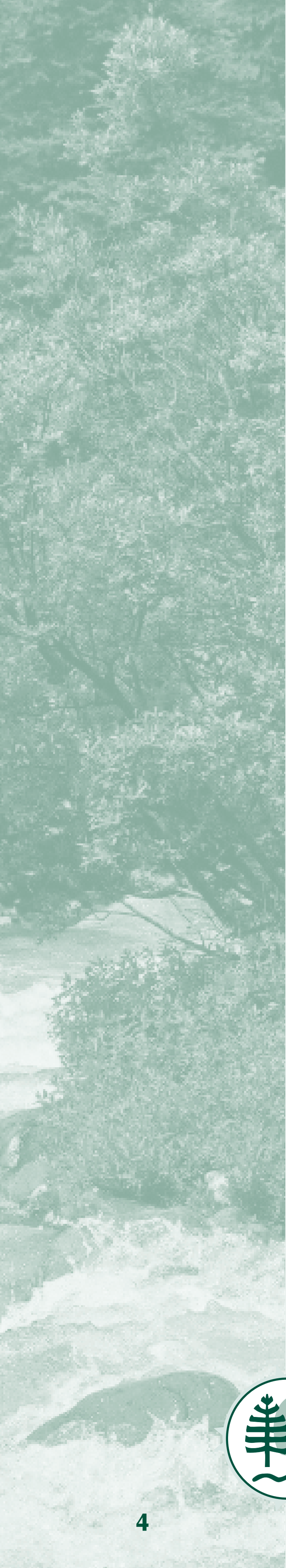
Abstracts from 2 completed representation analyses are provided in Appendix 1 to indicate the type of results and management implications stemming from this work.

REPRESENTATION OF ECOSYSTEM TYPES

A coarse-filter strategy of ecological representation in unmanaged areas has been a well-recognised component of biodiversity conservation strategies since UNESCO's Man and the Biosphere program in 1970 (Dassmann 1972; UNESCO 1974; Austin and Margules 1986). Establishing an ecologically representative system of reserves is the goal of protected area strategies in Canadian provinces, complementarity analyses in Australian parks (Belbin 1993, Pressey et al. 2000, Mendel and Kirkpatrick 2002), Scandinavian reserve evaluation (Sætersdal and Birks 1993; Stokland 1997; Johnson 1999), gap analyses in US states (Caicco et al. 1995, Duffy et al. 1999, Scott et al. 2001a) and efforts in many other countries (e.g., DeVelice et al. 1988, Fearnside and Ferraz 1995, Powell et al. 2000). While many other criteria affect assessments of the conservation potential of different areas (Margules and Usher 1981), ecological representation is the top priority in complex, poorly studied regions or when poorly known organisms are of concern (Austin and Margules 1986; McKenzie et al. 1989). Much of the conservation literature focuses on establishing new reserves, but representation is no less important in evaluating existing reserves or unmanaged areas that may function as reserves.

Unmanaged areas are central to an effective program to maintain biodiversity, for several reasons: 1) They contribute to the maintenance of the thousands of species that are too poorly known to manage on an individual basis (Margules and Usher 1981, Scott et al. 2001a), 2) Unmanaged areas act as a safeguard against inevitable uncertainty in maintaining species in the managed landbase, 3) These areas provide locations for natural disturbances and ecological processes that are critical to many species, but that may be much reduced in managed stands, and 4) Larger unmanaged areas can act as ecological baselines, against which to compare human effects on the rest of the landbase (Arcese and Sinclair 1997). By serving these roles, unmanaged areas can allow more intensive use of the managed part of the landbase, without increasing ecological risk over the landscape as a whole.





The paradigm of "mimicking natural disturbances" broadly shares the first 3 goals. However, we can never be sure how well we are approximating the ecologically important aspects of natural disturbances, and there are major economic and social impediments to closely following natural disturbance regimes. Structure-based management that tries to mimic the structures of naturally-disturbed stands could be seen as a "medium-filter" approach to biodiversity management, compared to the "coarse-filter" approach of maintaining representative unmanaged areas. Ecosystem representation is a broader filter because it is intended to include all those species, including unknown ones, that respond to ecosystem components beyond the particular structures that we can define and monitor in structure-based management. For these reasons, recognition of the role of representative unmanaged areas is a useful complement to natural disturbance and structure-based approaches to ecosystem management.

Recommendations on the proportion of the landscape that should be unmanaged range from typical administrative objectives of 10 or 12% (stemming from the Brundtland Commission) to conservation biology recommendations exceeding 50% (Soulé and Sanjayen 1998). The lower values emphasise minimising economic impacts and assume that the rest of the land base will be managed towards sustainability. The higher values are ecologically conservative, assuming no contribution from the rest of the landbase. In either case, recommendations about total amount of reserve area are of little immediate practical importance, because there is usually little latitude for changing the total amount of officially protected area in the short-term. **More importantly, in many forested landscapes, operational and regulatory constraints ensure that the amount of land unavailable for timber harvest is somewhere between the recommended extremes.** This non-harvestable area can often be greater than area in officially designated protected areas (e.g., DeVelice and Martin 2001, Strittholt and DellaSala 2001), potentially making a major contribution to regional conservation (Noss et al. 1999).

Although the area may be large, the constraints producing non-harvestable areas in managed forests may lead to some ecosystem types having disproportionately low representation, reducing overall conservation value. The immediate question for monitoring the ecological contribution of existing unmanaged areas is therefore how representative those areas are of the landbase as a whole. Most simply, the ideal for a given overall level of non-harvestable area would be proportional representation of ecosystems. Proportionally under-represented ecosystems become the focus for conservation management efforts (see feedback to management section below). The ideal of proportional representation could be modified to include over-representation of some special ecosystem types, such as those that are globally rare, poorly represented in official protected areas, or regionally important for other reasons (e.g., high degree of endemism, concentrations of species of concern).

Analyzing ecosystem representation in the non-harvestable landbase provides direct information for some landscape-level decisions like reserve locations, important context for other management decisions like harvest rates and levels of retention at harvest, and a way to focus monitoring and research programs to ecosystems where they will be most useful. How an analysis of representation can feed back to management is discussed in a separate section below.

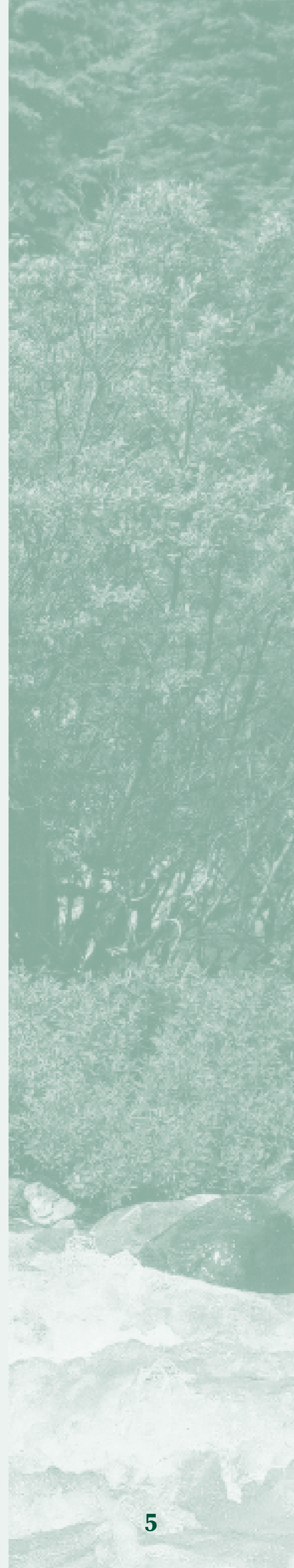
OTHER CHARACTERISTICS AFFECTING VALUE OF NON-HARVESTABLE AREAS

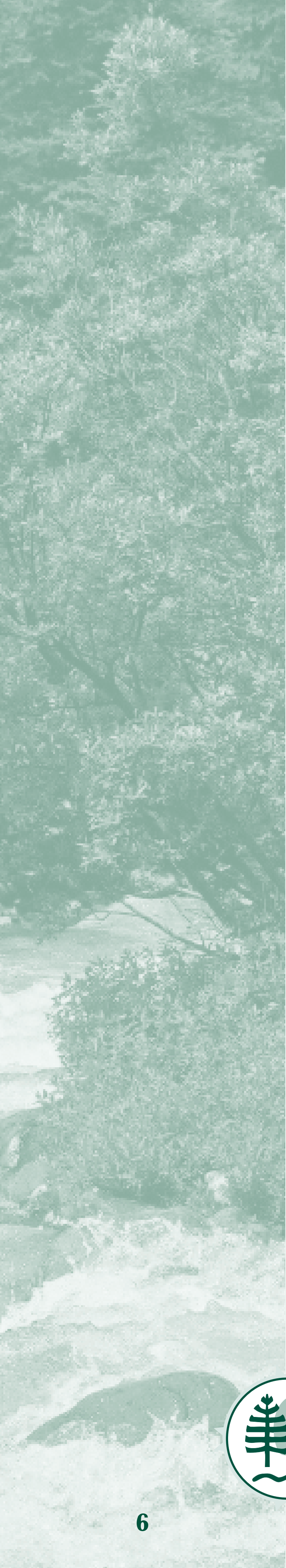
Representation of ecosystem types is the primary criterion for evaluating the ecological contribution of the non-harvestable landbase. However, several other characteristics of non-harvestable areas can affect their functionality, and should be considered in addition to proportional representation. These are discussed in the following sections. These additional criteria also feed back to management decisions, such as spatial landscape planning, locations of reserves within cutblocks and potential salvage decisions within the non-harvestable landbase.

Size distribution and geographic distribution of unmanaged patches

The conservation literature contains hundreds of papers on the design of individual reserves, stemming from island biogeography theory (for reviews, see Diamond 1976, Simberloff and Abele 1976, Lahti and Ranta 1985). The same concepts apply to evaluating existing unmanaged areas. The ecological value of non-harvestable areas, even if they are representative of ecosystem types, can be reduced if the areas occur in patches that are too small or too poorly distributed geographically. Larger patches are considered desirable because they can sustain larger populations of organisms, which tends to reduce the risk of local extinction. All else being equal, larger patches also tend to be less influenced by surrounding habitats, based on simple geometry (Laurance and Yensen 1991). Defining particular categories of patch sizes for monitoring is difficult, because there is little relevant ecological information. This is particularly true for a coarse-filter approach (rather than for populations of particular species) and in complex managed landscapes (rather than isolated islands). In past analyses, size categories of <5ha, 5-40ha, 40-100ha, 100-500ha and >500ha have been used. These size classes were based partly on ecological intuition, partly on existing regulatory guidelines, and primarily because they contained roughly equal percentages of the area of non-harvestable patches. Patch size distributions could be refined based on knowledge of natural disturbances, or, ultimately, on the patch size requirements of a wide range of organisms.

Geographically distributed patches are also desirable, because many organisms have restricted geographic ranges, and genetic or subspecific diversity also increases with distance (Scott et al. 2001b). Additionally, non-harvestable patches of a habitat type that are only in one area are at risk from local catastrophic disturbances. Therefore, the assumption that representative non-harvestable areas will accommodate the many poorly known organisms is less likely to be met if non-harvestable patches are either small or poorly distributed.





For a given area of non-harvestable forest, the goals of larger patches and wider geographic distribution can conflict (paralleling the “Single Large or Several Small” - SLOSS - debate in reserve design). There is no single “optimal” solution to this trade-off, because the best patch size distribution depends on the organisms being considered, and the disturbance regime for the ecosystem type. With no single optimum, a range of conditions is preferred to homogeneity. In this case, a number of patches covering the geographic range of the ecosystem type, including a few larger patches, would probably allow the non-harvestable areas to be most effective.

Edge/interior proportions

The function of representative non-harvestable forest would also be compromised if adjacent managed stands had extensive negative effects on the non-harvestable areas. Most measured edge effects from cutblocks in western forests penetrate a relatively short distance into the adjacent forest, with 50 m being a reasonable upper estimate of most edge effects, and 200 m being an extreme effect (Kremsater and Bunnell 1999). These values do not include much larger “regional” effects attributable to disturbances, such as introduction of exotic species, altered predator-prey systems or increased secondary human disturbances like poaching or fire ignition. Even with a short edge distance of 50 m, some patches of non-harvestable forest could have most of their area near edges. These would include any patches under 1ha in size, and long, thin or convoluted patches, even if they are large. For example, riparian reserve areas, which can be the main source of representation for some ecosystem types, can form a patch of large total area, but with all of it immediately adjacent to harvestable stands. All else being equal, the more interior area in non-harvestable stands, the more likely they are to fulfill their assumed ecological functions. Because analyses of ecological representation are a coarse filter meant to apply to the full range of biodiversity, roads, power line corridors and seismic lines should all be considered to induce edges in non-harvestable areas that they pass through, even when specific edge effects associated with these species have not been documented with well-studied species.

Other spatial aspects

Other aspects of the spatial distribution of representative non-harvestable areas may also affect their ecological value. Many landscape statistics are available to quantify these spatial patterns. However, it is not clear from the literature how organisms respond to the patterns summarized by these statistics, especially the poorly-known non-vertebrate species that make non-harvestable areas so critical. Correspondingly, it is unclear what would constitute inadequate, adequate, or optimal landscape patterns of non-harvestable areas. Spatial aspects of the non-harvestable areas beyond patch size distribution and edge/interior amounts are probably a lower priority for monitoring as part of a coarse-filter approach.

Age distribution

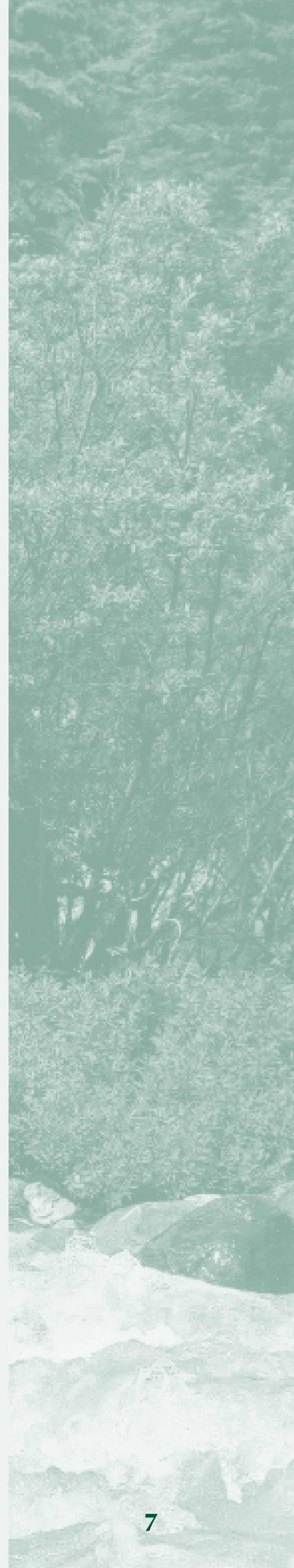
In the short- to medium-term, non-harvestable areas with an age distribution very different from a natural distribution would be a cause for concern. A predominance of young stands, or a single cohort of mid-aged stands would likely reduce the ecological value of the non-harvestable areas until some of the stands had reached an older age. In the long-term, the age distribution of non-harvestable areas will be determined by the rate of natural disturbances that occur in the ecosystem types, which will be affected directly by human activities and indirectly by changes in the adjacent managed landbase. **Maintaining some semblance of a natural disturbance regime is an important long-term goal for non-harvestable areas.** Having a reasonable geographic distribution of non-harvestable areas is necessary to capture some of the spatial and temporal variation in natural disturbances. Knowledge of the disturbance regime can help determine what distribution of non-harvestable areas is "reasonable".

Naturally-disturbed stands can become a rare ecosystem type themselves in some managed landscapes. Effective suppression of disturbances or an aggressive program to salvage naturally disturbed sites in the otherwise non-harvestable landbase would threaten the important contribution the non-harvestable landbase makes in maintaining these highly-diverse naturally disturbed stands. Recognizing the role of representative non-harvestable areas can help provide value to naturally-disturbed stands, counteracting the belief that the "wood will just go to waste" if it is naturally disturbed without salvage.

DEFINING "DISTINCT" ECOSYSTEM TYPES FOR REPRESENTATION ANALYSIS

The preceding discussion has avoided defining "distinct ecosystem types", the basis of representation. Ideally, ecosystem types would be defined by all the organisms they contain. A truly representative set of unmanaged areas would then include the full set of organisms. Complementarity analyses for Australian reserves take this approach, but only use a subset of taxonomic groups, and only apply to a limited number of very discrete patches of habitat (e.g. trees species in remnant patches of Eucalyptus forest; Pressey and Nicholls 1989). For less discrete habitats, some studies have used quantitative multivariate methods, again based on surveys of indicator organisms, to define distinct ecosystem types (DeVelice et al. 1988; Sætersdal and Birks 1993). **At still larger scales, or for poorly known taxa, representation must be based on environmental variables that act as surrogates for the distribution of actual organisms** (McKenzie et al. 1989; Belbin 1993; Johnson 1999). Using surrogate variables reduces confidence that all species are included in the resulting representative units (Margules and Stein 1989), but is a practical necessity. Concern about missing species in representative areas is reduced when multiple areas represent each type (Pressey and Nicholls 1989).

Most jurisdictions have some form of ecological land classification (e.g., Pojar et al. 1987, McCarthy et al. 1994). In British Columbia, the biogeoclimatic



ecosystem classification (BEC) offers a system of ecosystem units with the practical advantages of widespread acceptance and available mapping. The BEC system is hierarchical, with “zones” representing major forest types, “subzones” within zones representing different climatic regimes, and “variants” representing different elevational or geographic expressions of subzones. “Site series” are the finest level of classification, determined by the soil moisture and nutrient regime at each location and identified by the plant assemblage. The BEC system therefore allows assessment of representation at the coarser level of environmental variables (subzone or variant) and at the finer level of the assemblages of indicator organisms used to define site series. Analyses of plant and lichen species suggest that groupings of similar site series, with some geographical representation across regions, may be the most appropriate units for representation analysis where site series mapping is available.

Where a system of ecological classification is not in place, approaches are available to develop surrogates based on broad climatic variables and inventory surveys (McKenzie et al. 1989, Belbin 1993, Pressey et al. 2000), possibly supplemented at a finer-scale with available forest-cover information on leading species. Where this approach with broad surrogates is applied to very large areas, like parts of the boreal forest, ensuring geographical representation would become more important to capture localized species. The appropriate scale for examining geographical representation would ideally be determined empirically, by examining the rate of species change with distance within a given surrogate ecosystem type. Non-vertebrates would again be an emphasis, with their often more restricted ranges.

The main point is that whatever system is used to define ecosystem types for representation analyses, the units need to be meaningful for the biological goal of representing the spectrum of individual species. Developing and testing definitions of distinct ecosystem types should become an integral part of any inventory or research sampling of organisms, which mainly entails simple recording of standardized ecosystem descriptors for any sampling locations. Over time, with inventories of a wide range of taxa, this will help produce more refined, organism-based definitions of ecosystem types.

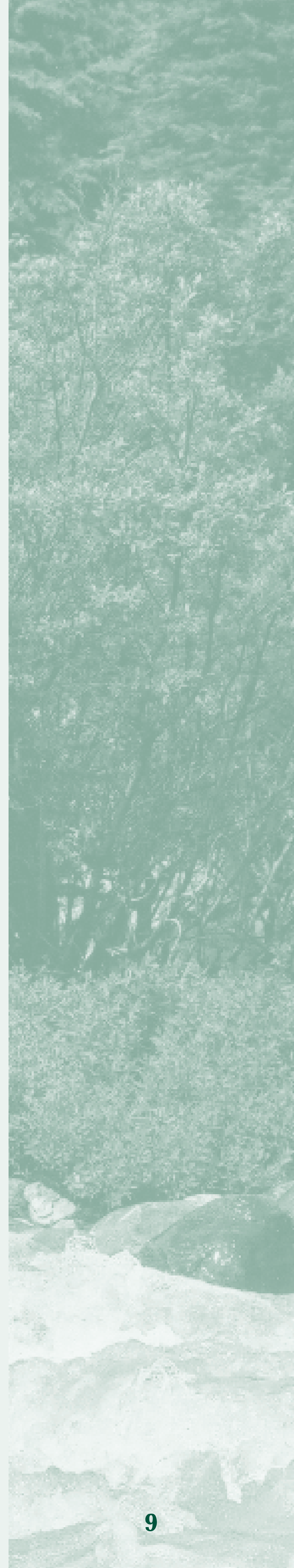
Some additional refinements may help ensure that an ecosystem classification system better captures the range of biological diversity. Special ecosystem types are often not well captured by general ecosystem classifications. Examples in BC include Sitka spruce stands on the west coast, forests on karst formations, or cottonwood riparian in the Interior. Special ecosystem types are important to recognize for regional biodiversity because of their high productivity, overall rarity, and, especially, species that are closely or exclusively associated with these ecosystems. These special types usually require specific mapping efforts, which need to be as unbiased as possible (In BC, most mapping of rare ecosystems is associated with roads, which clearly biases maps of their occurrence towards the timber-harvesting landbase). Riparian ecosystems in general are distinct ecosystem types, with many closely associated species, which should be mapped separately. If the overall ecosystem mapping does not distinguish riparian areas, they should be mapped as special ecosystem types.

Within forests and wetlands of a particular ecosystem type, sites have greater or lesser productivity, indicated operationally by site index or other edaphic factors. Highly productive stands may be important to some components of biological diversity, and may be disproportionately rare in the operationally constrained landbase (Stokland 1997, Mendel and Kirkpatrick 2002). Tracking representation of highly-productive stands is another useful refinement to general ecosystem types.

SOURCES OF NON-HARVESTABLE FOREST

Non-harvestable areas include any forested areas where constraints prevent timber harvesting, and can be classified into two types: (1) areas that are inoperable because of site factors that make harvest operations impossible, and (2) areas that are not available for harvest because of regulatory or legal constraints. Examples of the first type are steep slopes with high landslide risk and sites with ecologically sensitive soils. Examples of the second type are protected areas, designated reserves for old forest (Old Growth zones, Old Growth Management Areas), riparian reserves, preserves for visual quality, domestic watersheds, reserves for featured species (ungulates, listed species), and some recreation reserves where harvesting is prohibited. These constraints can all be considered "permanent", in that official policy or regulations would have to be changed to remove them. An additional set of constraints producing non-harvestable areas is due to inoperability, which includes physically inoperable or inaccessible areas, and economic inoperability. These can currently prevent timber harvesting, but are more susceptible to change when technology or markets change. These potentially less permanent reserves are tracked separately. A final set of constraints arises from forest types that are not suitable for harvest, including areas designated as "problem forest types" or "commercially non-productive". These areas typically have low timber volumes, low growth rates, poor regeneration potential or unfavourable tree species. This third set of fully constrained areas should be tracked separately, because these stands are likely not fully typical of the more productive stands in their ecosystems (Stokland 1997). [Note that the distinction between non-harvestable and harvestable forest in this case is independent of the current state of vegetation on the site (e.g., stand age), but rather is a reflection of the site's permanent community characteristics and longterm capability. "Non-harvestable" indicates that the area will not be harvested in the long-term.]

Substantial areas can also be partially constrained (i.e., < 100% constrained or partial harvesting permitted, for ungulate winter range, riparian management) for timber harvesting, with reduced harvest rates compared to unconstrained areas. Examples include areas where there are regulatory constraints on age distribution, harvest rate and opening size, or severe adjacency rules. Harvestable stands are typically included when there is a >50% reduction in harvest rates in the partially constrained landbase. These areas are worth tracking because they present opportunities for improving representation of ecosystem types with lower additional economic costs. However, they cannot simply be accounted for by adding the amount of area equal to their constraint (e.g., 40%, 50%, 60%, etc.) to



the fully constrained landbase, because harvesting within these partially harvested areas may be disproportionately distributed among certain high-yield stand and site types. Mesic or valley-bottom sites, for example, may be targeted disproportionately, with other stand types used to meet the regulatory constraints in partially constrained areas. Areas with <50% reduction in harvest rates in the standard timber-harvesting landbase are included because these mild constraints are unlikely to contribute much representative unmanaged areas.

These definitions of the non-harvestable and partially-constrained landbases are based on forest harvesting as the only management disturbance. In some areas, other activities can also affect the ecological value of stands, even if they are non-harvestable. Cattle-grazing in dry forest types is one example of a non-forestry disturbance that reduces confidence in the ability of non-harvestable areas to meet their ecological roles. In ecosystem types with grazing, it may be worth further refining the non-harvestable landbase into grazable and non-grazable parts. Areas subject to salvage or "sanitation" harvesting should be considered part of the timber-harvesting (or partially constrained) landbases, even if they are otherwise non-harvestable for normal timber extraction. Areas under oil and gas development or likely to be subject to mineral development should also be considered part of the timber-harvesting landbase for representation analyses, since the area is clearly not non-harvestable if large areas of trees can be felled for non-forestry purposes. Again, the emphasis is on long-term non-harvestability, not whether these other activities have already affected the area.

Regional context

Representation analyses should ideally be done across the entire extent of ecosystem types, rather than within the administrative boundaries of a political unit or forest tenure. However, such a regional analysis requires assembling the required data from many different sources. This is particularly challenging for the harvesting constraints that define the non-harvestable and partially-constrained landbases, because this information is usually held, in various forms, by each company. **When representation analysis is done within non-ecological administrative boundaries, it is worth estimating 2 values for each ecosystem type to establish some regional context: 1) Percentage of the total extent of that ecosystem type that is in official protected areas (provincial and federal parks and other reserves across the full geographic range of the ecosystem type), 2) Percentage of the full range of the ecosystem type that is in the study area. The latter is an indication of the "responsibility" (Dunn et al. 1999) that the study area has for that type as a whole. Ecosystem types that barely enter a study area are of less concern than ones that have a lot of their extent in the study area.**

FEEDBACK TO MANAGEMENT (AND MONITORING)

Representation analyses are intended to help guide management, and associated monitoring and research programs in an adaptive management context. For these purposes, there is no value in asking “How much is enough?” From a conservation point-of-view, more is better. **An increase in the amount of non-harvestable forest in an ecosystem type is an improvement, whether or not the total amount is greater or lesser than a specified target.** Thus, a management decision that increases the non-harvestable representation of some type from 2% to 4% is an improvement, and so is a decision increasing another type from 62% to 64%, even though the former might still be below a target, and the latter above. In any case, target values can be found in the literature ranging from 1.7% to 97%; which one to adopt is an arbitrary decision based on relative value given to ecological risk versus social and economic values, and assumptions about how the rest of the landscape functions. **Since the amount of unharvestable forest is typically large in most areas, the critical issue becomes ecological representation of this area, rather than the amount.**

However, without targets, **it seems clear that an increase from 2 to 4% is more valuable than an increase from 62 to 64%**, and management decisions may involve a trade-off between the two. For this reason, it is better to think in terms of marginal values instead of targets (Fig. 1). The incremental value of additional non-harvestable area decreases as the amount of non-harvestable increases, but in a continuous curve, rather than the step function of a target or threshold. The trick is to specify the shape of the curve. One possible aid is the natural disturbance regime in the ecosystem type, with high-disturbance types having a steep initial slope and reaching an asymptote faster. This recognizes that such systems would naturally have less undisturbed area. However, this simple logic is complicated by the fact that the non-harvestable landbase is also subject to natural disturbances.The shape of the marginal value curve would also presumably be influenced by how the harvestable landbase is managed.

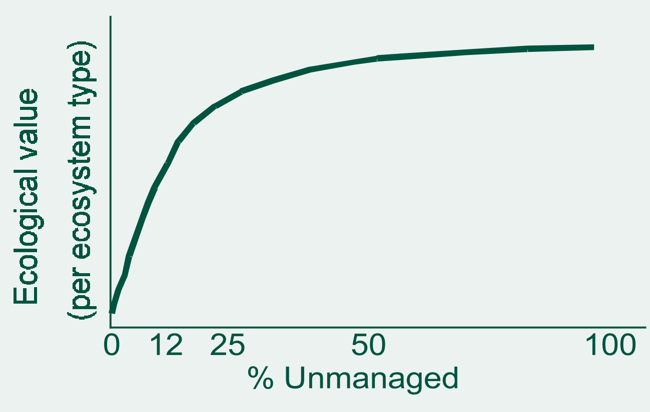
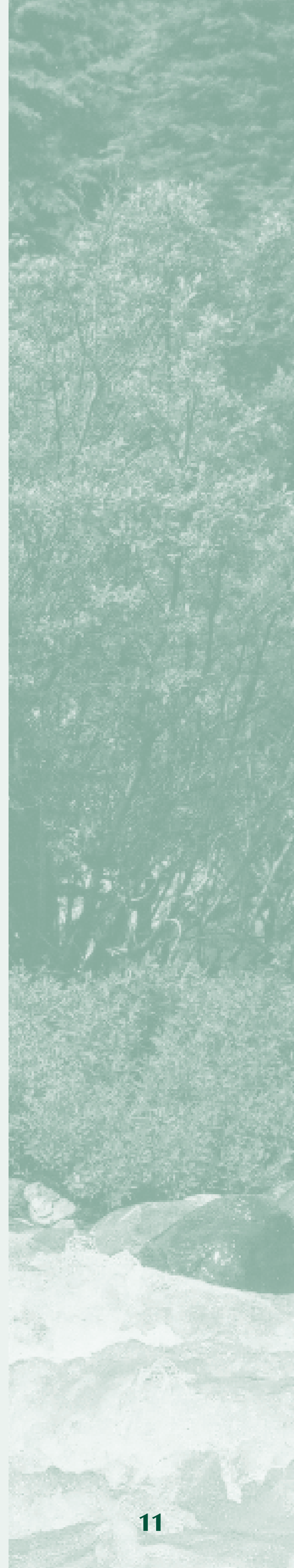
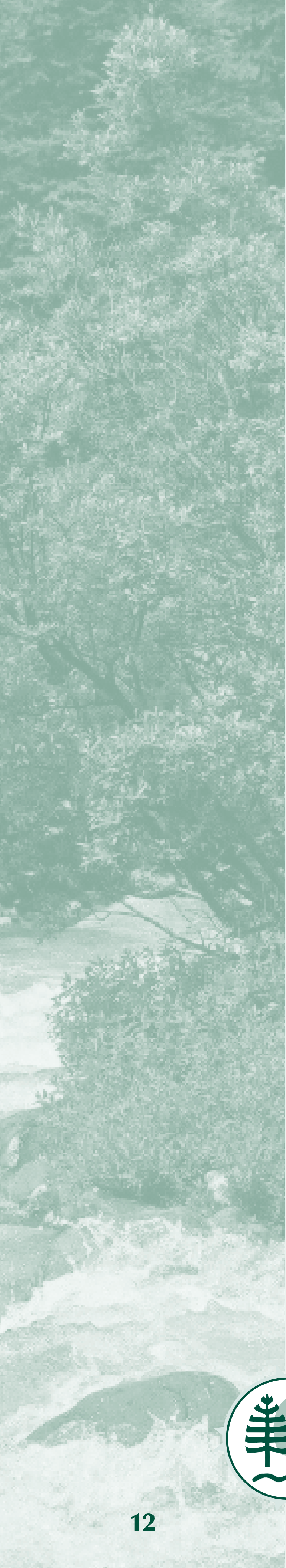


Fig. 1. Hypothetical example of marginal value curve.





Although there is a lack of extensive ecological knowledge needed to specify marginal value curves for the wide range of organisms that are required to represent "biodiversity", many ecologists have fairly consistent impressions about reasonable values for this curve. The amount of unmanaged area for a given ecosystem type will need to be based on further research within an adaptive management context and objectives for these attributes in managed landscapes based on values determined within regulatory and forest management frameworks. There are virtually no empirically derived targets for target amounts of unmanaged areas, and therefore none that can be justified with empirical data.

Worrying about nailing down targets, thresholds, shapes of marginal value curves or relationships with natural disturbance regimes can obscure the fact that, practically, there are obvious management implications from the results of a representation analysis. Mostly these are based on identifying and responding to obvious weak points in representation. For example, Weyerhaeuser's coastal BC tenure has about 2% non-harvestable area in the drier ecosystems of south-eastern Vancouver Island, and 60-80% non-harvestable in wet, northerly and high-elevation types - limited conservation and monitoring resources should clearly be focused on the drier ecosystems. Once people are familiar with the idea of accounting for the non-harvestable landbase, it is difficult to think how strategic decisions can be made without the information. Representation in unmanaged areas becomes the basic coarse-filter indicator of sustainable management (Lindenmayer et al. 2000).

Specific ways that representation analyses have applications to management include:

1. Amount and location of old forest reserves. In BC, reserves to maintain old forest in managed landscapes are designated by companies (e.g., Old Growth Stewardship Zones on 10% of Weyerhaeuser's tenure in coastal BC), or by government land-use plans (Old Growth Management Areas, or OGMA's). Other provinces have comparable programs, such as conservation land-use zones. Ecosystem representation is a key criterion in determining where these reserves should go. Official protected areas also, of course, require information on ecosystem representation, but parks designation is usually a different scale of process than planning reserves within managed landscapes, and is more influenced by many other factors.

2. Location of intermediate land-use zones and management within them. Most landscape zoning systems now include an intermediate zone that includes both ecological and economic objectives. One of the main functions of these

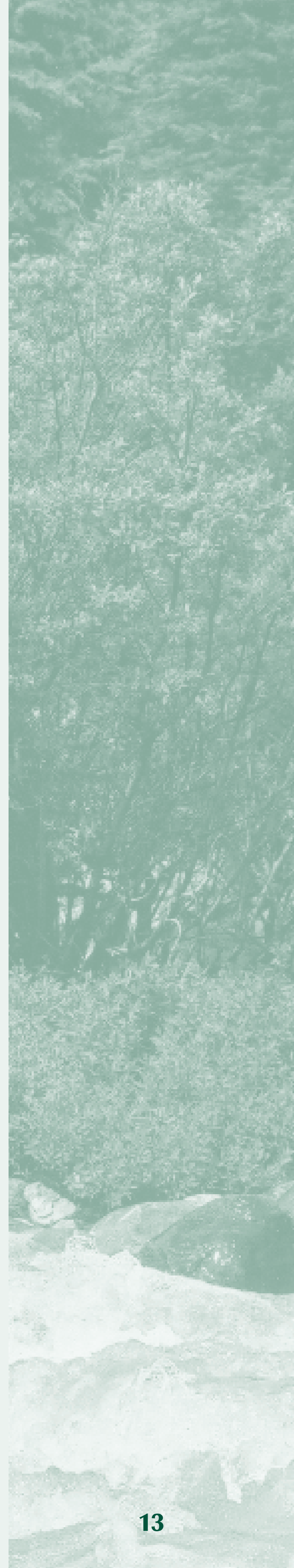
zones is to provide flexibility in meeting overall biodiversity objectives, while still maintaining timber flow. Ecosystem types with moderately weak non-harvestable representation can be locations for these intermediate zones, with an explicit management objective of conservative management of the more poorly represented types.

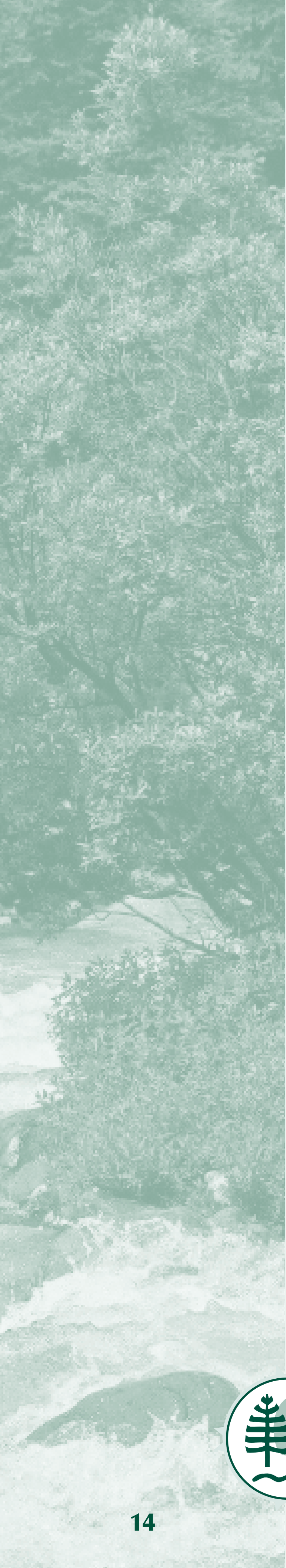
3. Evaluation of non-biodiversity reserves. Reserves for meeting specific objectives (such as featured species, watershed protection, connectivity, visual landscape quality, etc.) often have some flexibility in their locations. Adjusting these reserves to improve representation of poorly-represented ecosystem types can allow them to also help meet biodiversity objectives.

4. Retention patches and retention levels within managed stands. Patches of habitat retained within cutblocks can serve as representative unmanaged forest for many small organisms. Ecosystem types that are poorly-represented overall could serve as “biological control points” for locating some of the within-block reserves. Cutblock settings within poorly-represented ecosystem types could also be favoured for relatively high levels of retention. Monitoring representation at the large scale therefore helps with cutblock-level management decisions.

5. Landscape and cutblock planning to buffer non-harvestable areas. The non-harvestable landbase provides a “skeleton” that can be the basis for planning in the managed landbase and in adjacent managed stands, including using these stands to buffer edge effects into non-harvestable stands and to improve connectivity among non-harvestable stands.

6. Focusing finer-filter monitoring. Sound stand management is relied upon most heavily in ecosystem types where there is little non-harvestable area. These types should therefore be a prime focus for monitoring and adaptive management of practices. Well-represented ecosystem types can more safely be ignored in monitoring programs when funding is limited. Representation analysis also helps to identify representative larger unmanaged areas that could serve as benchmarks for long-term monitoring. Monitoring programs can also be directed to help test some of the assumptions in the coarse-filter representation approach including: 1) that definitions of ecosystem types correspond to organisms’ distributions, 2) the appropriate scale of geographic distribution of representative areas, 3) the extent of edge effects into non-harvestable areas, and any other patch-size or spatial effects,





4) the typicalness of non-harvestable areas in terms of habitat structures or organisms, to look for any unidentified biases in non-harvestable stands.

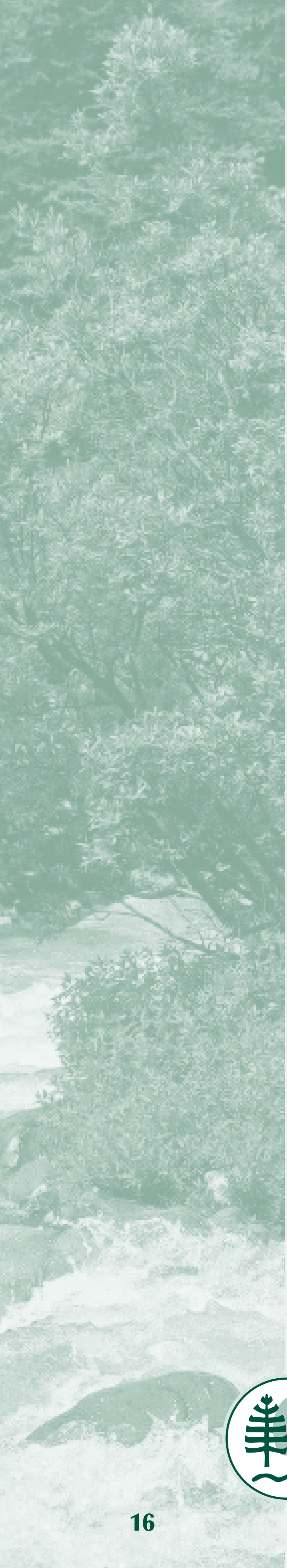
7. Valuing the non-harvestable landbase. Generally, analyzing the ecological contributions of the non-harvestable landbase helps to recognize its conservation value. This valuation can help prevent its loss to incremental development, which is often not cost-effective in these areas in any case. It can also prevent needless economic loss and conflict when harvest constraints are imposed in the harvestable landbase in areas where the broader view suggests that they are not needed.

Implementation Summary:

Developing an assessment & monitoring program for the non-harvestable landbase in managed landscapes

From the previous sections, the main points for monitoring the ecological representation of the non-harvestable landbase as a coarse-filter component of a biodiversity management strategy are:

1. Use or develop a system of mapping of ecosystems that correspond to distributions of a wide range of organisms, based on physical surrogates or sets of indicator organisms.
   - Add special ecosystem types not covered by the ecosystem classification system.
   - Distinguish different levels of stand productivity (e.g., through site index).
   - Use monitoring and research programs on organisms to test the ecosystem units.
2. Map regulatory or operational constraints that produce non-harvestable areas in (at least) 3 categories:
   i) Relatively permanent reserves established by regulations (e.g., parks, riparian reserves, ecologically sensitive sites, visual quality reserves, wildlife reserves, old growth management areas, etc.),
   ii) Inoperable areas, which may become harvestable with changes in technology or markets,
   iii) Commercially non-productive or "problem forest types", which may not represent the full range of organisms in that ecosystem type.
   - Also track forest with partial constraints on harvesting, which may provide the easiest opportunities for improving representation.
   - Representation analyses would ideally be done for entire ecological units, rather than within administrative boundaries. This requires the difficult task of co-ordinating information on harvesting constraints across multiple tenure-holders.
   - Make sure not to double-count areas that are constrained in 2 or more ways!
3. Consider proportional representation of ecosystem types in the non-harvestable landbase as the primary goal.
   - Modify this by over-representing types that are globally rare, poorly represented in protected areas overall, or of high responsibility in the monitoring region.
4. As secondary criteria, monitor:
   - Size distribution of non-harvestable patches (ideally: some large areas, and range of sizes),
   - Geographic distribution (ideally: widespread, for geographic components of diversity and for natural disturbances),
   - Edge/interior ratios of non-harvestable landbase (probably the spatial measure with the best-developed empirical support),
   - Current age distribution (for short-term adequacy – in the long-term, non-harvestable stands will age and ideally go through natural disturbances).
   - Other aspects of the spatial distribution of non-harvestable land are of uncertain relevance.
5. Monitor activities other than normal forest harvesting that can affect the assumed ecological contribution of non-harvestable areas:
   - Oil and mineral exploration
   - Salvage or "sanitation" logging
   - Effective fire suppression
   - Cattle grazing



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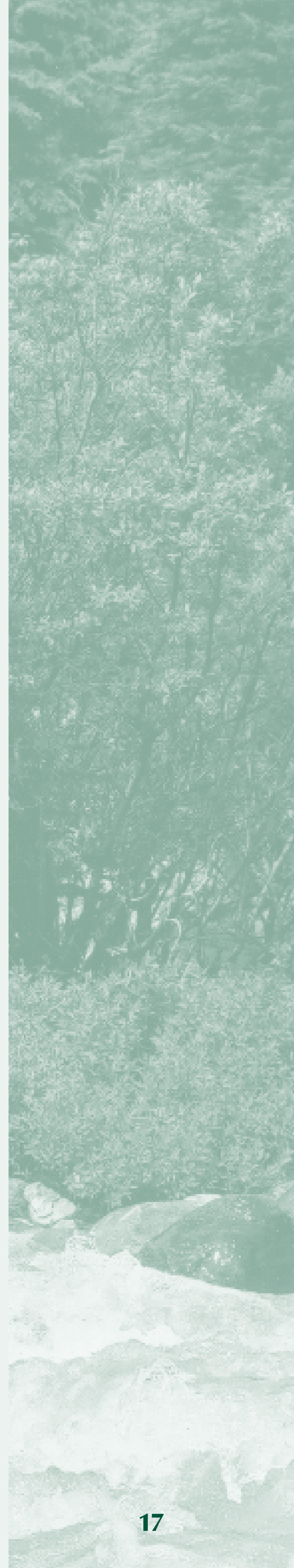

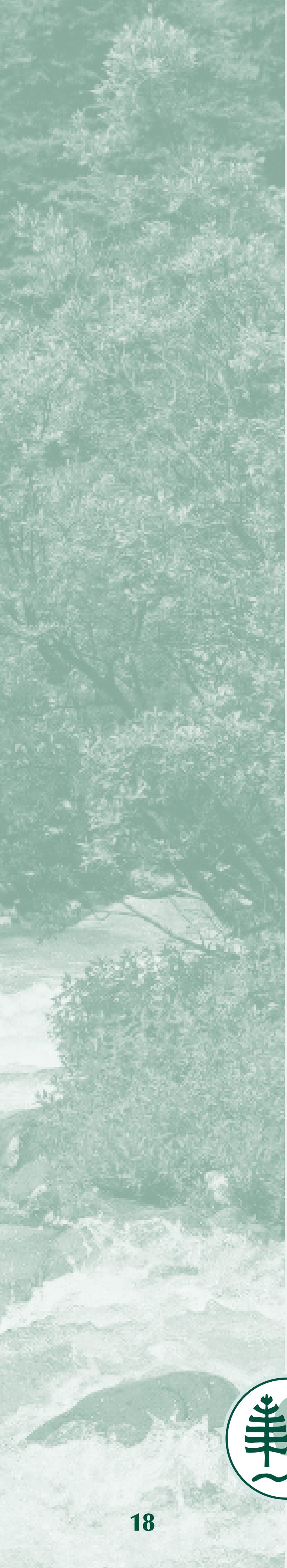

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Appendix 1

Case study 1
Ecological Representation in Weyerhaeuser's (Coastal BC) Non-timber Landbase (Huggard 2001)

Summary

Ecologically representative unmanaged areas are an important coarse-filter component of the adaptive management program to maintain biological diversity on Weyerhaeuser's coastal BC tenure. This report analyses ecological representation on the tenure, based on GIS overlays of BEC (ecosystem classifications) variants or site series, areas fully or partially constrained from timber harvesting for operational reasons, forest cover information, stewardship zones and other ecological land designations. The analyses determined:

- Priority BEC variants for Weyerhaeuser management, based on percent of the variant's extent that is within Weyerhaeuser's tenure and percent of the variant in official protected areas;
- Representation of BEC variants (tenure-wide) or site series (Block 2) in fully and partially constrained landbases;
- Representation of BEC variants in all forest versus commercially productive stands only;
- Representation in high site index stands;
- Edge-influenced versus interior non-harvestable forest;
- Age and patch size distribution of non-harvestable forest;
- Representativeness of stewardship zones, and the additional contribution of Old Growth zones to unmanaged forest;
- Representativeness of other ecological land designations, including areas of interest to ENGO's, high Biodiversity Emphasis Options and Special Resource Management Zones;
- Overlap of Weyerhaeuser's stewardship zones and these other ecological land designations.

Main results of the representation analysis include:

- Over the whole tenure (excluding Clayoquot Sound), 25.7% of the forested area is fully constrained from harvesting, with an additional 7.3% partially constrained (50-90% reduction in timber). 14.2% of the commercially productive (non-"scrub") forest is fully constrained.
- Priority variants for Weyerhaeuser include CWHwh2 (an example ecosystem class) and MHwh2 on the Queen Charlotte Islands, CWHmm1 and 2, CWHxm1 and 2, and CDF.
- Representation of site series within constrained areas in Block 2 approaches the best-case for a given percent unmanaged, with proportional representation of each type and some overrepresentation of the rarer types.
- Variant representation in fully constrained areas across the tenure is strongly skewed to wetter, more northerly and higher-elevation variants, with little representation of the driest subzones (CDF and CWHxm) and lower-elevation variants (CWHvh1 and vm1). Representation in commercially productive stands is lower overall, but shows a similar bias away from dry and low-elevation variants. The higher site index sites (>25m at 50 years) are relatively poorly represented overall.

Case study 1 continued

- Because many constrained areas are long and thin, or highly convoluted shapes, approximately 50% of non-harvestable forest is within 50m of the edge of the harvestable landbase, while almost all non-harvestable forest is within 200m of the edge.
- Patch size and age distributions of the harvestable and fully-constrained landbases are similar.
- Over the whole tenure, including Clayoquot Sound, 8.2% of forest is in Old Growth zones and 26.2% in Habitat zones (6.8% and 24.2% respectively for commercially productive forest only). These values are approaching the original targets, particularly as the results do not include recently created protected areas that used to be part of Weyerhaeuser's tenure. However, Old Growth stewardship zones also overrepresent wet, northerly and high-elevation sites. Habitat zones show a better ecological distribution, except for a lack in the driest subzones.
- A high percentage of Old Growth zones are operationally constrained from harvesting, because they were located mainly in current large patches of old forest. As a result, Old Growth zones make only a small additional contribution to representation in some variants.
- Areas of interest to ENGO's would complement existing representation of nonharvestable forests, while high BEO's and special RMZ's show very poor ecological representation. Old Growth stewardship zones do not encompass ENGO areas of interest very well, but Habitat zones include many of these areas. Stewardship zones do correspond more closely to the BEO and resource management zone designations, and so will help meet the ecological objectives of those land use planning processes.

Management suggestions from this work include:

- Focussing best VR practices and discretionary reserves (e.g., ungulate winter ranges, old-growth management areas) in poorly-represented priority ecosystem types: CWHxm1 and 2, CWHmm1, CWHvh1 and CDF.
- Planning within partially constrained areas and Habitat zones to improve representation of these ecosystem types and high site index stands where possible.
- Locating reserves within VR stands and high retention stands adjacent to non-harvestable areas to improve the amount of interior unmanaged area.
- Developing a strategy for improving the poor representation of dry variants, most of which are on private land, through old growth conservation or restoration and planning within Habitat zones.
- Using ENGO areas of interest as focuses for landscape planning, particularly within Habitat zones, to improve ecological representation.
- Mapping constrained areas on private land to allow recognition of their contribution to ecological representation.
- Orienting the adaptive management monitoring program to the poorly-represented priority ecosystem types where good stand-level management is most important, and establishing benchmark monitoring sites in "scrub" stands to assess their ecological contribution.

Completing TEM mapping across the tenure to allow a finer-level examination of ecosystem types, and participating in regional analyses to provide broader context for Weyerhaeuser's management.

Case study 2

Ecological Representation in the Arrow IFPA Non-harvestable Landbase (Huggard 2000)

Summary

Representing different ecosystem types in unmanaged areas is the basis of coarse-filter biodiversity management. This project assessed ecological representation in the fully- and partially-constrained landbases on crown land in the Arrow IFPA area. Ecosystem types were analysed at the level of biogeoclimatic (BEC) variant, groupings of BEC site series, and combinations of site series and slope/aspect modifiers. Constraint types from timber supply analyses were overlaid on PEM maps of the area in a sequential GIS analysis that identified the area of each ecosystem type in the fully constrained landbase (e.g., protected areas, inoperable, environmentally sensitive areas, riparian reserves, etc.), fully constrained areas with poor growing conditions (e.g., problem forest type, non-commercial brush), partially constrained areas (e.g., visual quality objectives retention and partial retention, caribou management), and lightly constrained or standard management areas. Analyses also measured the proportion of the fully constrained landbase more than 50m from partially constrained or standard management areas ("interior"), and assessed how important one changeable constraint type, inoperable areas, are as contributions to representation.

Overall 42.7% of the 4056.2km2 study area is fully constrained, with only a small part of that as poor sites. A further 25.4% is partially constrained. The unmanaged areas are well distributed across the 5 main variants, with >30% unmanaged in each, and the variants least represented in the fully constrained landbase have abundant partially constrained areas. Fine groupings of site series, which are presented as the most appropriate ecological unit available for biodiversity representation, are also represented fairly equitably in the fully constrained landbase. Though circum-mesic sites tended to be less represented than drier or wet sites, only 1 site series grouping had less than 30% representation. The finest ecosystem types analysed, combinations of PEM site series and slope/aspect modifiers, showed more variability in representation, with several units having <25% representation in the fully constrained landbase. The ecological importance of representing each of these units is uncertain, but increasing their representation where possible should be encouraged. If inoperable areas were eliminated, the total unmanaged area would decrease, but not greatly, because of other full constraints that overlap much of the inoperable. No particular ecosystem type would be particularly affected by changes in operability. A high percentage of edge area (40%) in the fully constrained landbase is a concern, casting some uncertainty on the ecological contribution of the non-harvestable landbase.

The high percentage of unmanaged area, and its relatively even distribution across ecosystem types provides a good coarse-filter for biodiversity conservation in the Arrow IFPA area. Using opportunities provided by the partially constrained landbase, reserves for other resource values and stand-level practices to increase representation of a few underrepresented ecosystem types and to buffer possible edge effects would further improve the contribution of the non-harvestable landbase. Detailed analysis of planning in the partially constrained landbase is probably not worthwhile for a coarse-filter evaluation, because of the complexity of overlapping and changeable constraint types, and the lack of strong reliance on the partially constrained areas for representation of any ecosystem types. Existing unmanaged areas may be meeting the coarse-filter goals of the Biodiversity Guidebook, suggesting that biodiversity management emphasis could be shifted to the stand-level provisions of the guidebook. Important future work for this project include validating the accuracy of PEM, especially for rarer ecosystem types, incorporating special ecosystem types not indicated by BEC units, and testing that unmanaged areas are truly representative of managed areas in the same ecosystem types at the level of habitat elements and specific organisms.

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